II
TECHNICAL
PROCEDURES

MATERIALS

BLACK

Dr. G. V. Black's Operating Room, Jacksonville, Illinois

Dr. Black began the practice of dentistry in Winchester, Illinois, in 1858. In 1861 he enlisted tor the Civil War and was appointed Captain of a small company of men on special duty. He was injured and hospitalized for several months in Louisville, Ky. He was discharged in 1862 on account of his physical condition. He opened an office in Jacksonville in 1864 where he practiced until 1897. He thereafter devoted his time to research, teaching and writing. He bought a home on East State Street in Jacksonville in 1865, and in about 1875 an addition was built to accommodate his offices. This operating room was used by him from that time until 1897. The desk at the right was used for most of his writing and microscopic work. A door beyond the desk (not shown in the illustration) led to his laboratory, where many of his researches were carried on. The foot driven dental engine was patented by Dr. Black in 1871. This was the first engine to have the shaft of the hand-piece directly driven by the cord from the driving wheel. The operating tray, the small work bench across the window and the stool at the back of the chair were made by Dr. Black. The typewriter was one of the first models of the "Caligraph." All of the furniture was made of walnut wood.

The illustration is a reproduction of a photograph of the replica of Dr. Black's office, which is a part of the G. V. Black Memorial rooms in Northwestern University Dental School. This room is built to proper measurements and the doors and part of the wood trim were removed from the Jacksonville office. The views from the windows are reproduced on canvas.

THE INLAND PRESS, INC., CHICAGO

G. V. BLACK'S WORK

ON

OPERATIVE DENTISTRY

with which his

SPECIAL DENTAL PATHOLOGY

IS COMBINED

PUBLISHED IN FOUR VOLUMES

VOLUME TWO

TECHNICAL PROCEDURES IN MAKING RESTORATIONS IN THE TEETH

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350 ILLUSTRATIONS

REVISION BY

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CONTENTS OF VOLUME II.

Technical Procedures in Making Restorations in the Teeth

Technical Procedures in Making Restorations in the Teeth

INTRODUCTION

THE material in this volume has been selected and arranged to cover the laboratory training which a student should have in preparation for the clinical treatment of dental caries.

The chapter on the materials used in Operative Dentistry by Prof. Eugene W. Skinner is devoted to the composition, metallography, chemical and physical properties of the materials used in making restorations. This includes studies of wax for patterns. investments for inlay castings and other accessories. The manipulation of all of these materials, to secure the best results, is also presented from the viewpoint of the physicist. So far as the materials used in operative procedures are concerned, this chapter should serve as a sufficient guide for their study as a part of a more general course in dental materials, until such time as more complete texts are available. Thereafter, it may be used for a brief review of the materials used in the operative field.

The remainder of this volume is adaptable for a course in operative technics. It is devoted to cavity nomenclature, the study of instruments, the principles of cavity preparation, the manipulation of various materials used in making restorations, also the accessory appliances.

In this volume the preparation of cavities and the manipulation of materials have been confined as closely as seemed practicable to the principles involved, rather than to give the complete detail of specific operations. Positions at the chair, finger positions, use of the dental engine, use of water and air, and the technic of keeping the field of operation dry, are given in greater detail, as these subjects are considered only incidentally elsewhere.

No attempt is made to set up a course in operative technics.

The teacher is left free to arrange the course as he may desire and to select cases from Volume III for the training of his classes in the more detailed technic.

This arrangement makes it possible to leave the manikin at the close of this Volume and consider the treatment of the human being in ways and by means applicable in actual practice in Volume III.

The new illustrations in this volume are, for the most part, line drawings made by the author. There is necessarily some duplication of these in Volume III. The formulae for the instruments are not given here for each illustration, as in Vol. III, for the reason that the principles of their use are presented here, rather than specific sizes, which vary according to conditions.

Materials Used in Operative Dentistry

By EUGENE W. SKINNER, Ph.D.

ILLUSTRATIONS: 241-256

DENTAL restorations and materials are as adaptable to scientific design and standardization on a small scale as are the larger engineering structures, and similar methods should be used as far as possible. That a scientific accumulation of knowledge of dental materials is important can be justified by the remarkable improvement in such materials during the last decade, principally due to the leadership of the research group at the National Bureau of Standards in Washington. Since this work will be so frequently referred to, a brief history will be given at this time.

In 1919, the Bureau of Standards was requested to select and grade dental amalgams for use in federal service, and a very excellent report was published in 1921. This research was done under the leadership of Dr. Wilmer Souder, in charge of the Dental Division of the Bureau. The information contained in this paper was so enthusiastically received by the profession, that studies of other materials were demanded.*

Although many helpful ideas as to the application of the basic sciences in gaining an understanding of the phenomena involved in the compounding and manipulation of dental materials have come from the work of the Dental Research Group, their main interest is setting up testing methods as bases for specifications. Fundamental research in the behavior of these materials, and their correct manipulation is extremely important. Such research must also be done in our dental schools and other research centers. Although marked improvement in the quality of commercial products has resulted from these studies, there remain many uninvestigated materials on the market, with others being constantly introduced with unwarranted claims as to their merits. These claims must be evaluated by careful research, if the dentist is to be protected. The

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* The Government could not, at that time, allocate funds for the proposed studies and the Weinstein Research Laboratories cooperated by supplying the services of Mr. Richard L. Coleman as a research associate at the Bureau. The study of materials used in casting was begun in 1922 and culminated in 1928 with the publication of the excellent *Research Bulletin No. 32.* In April 1928, the American Dental Association became the cooperator through its Research Commission. At the present time there are two research associates at the Bureau working under the direction of Dr. Souder. Nine tentative specifications for dental materials have been published, which include amalgams, impression compounds, inlay waxes, investments, cast gold inlays, wrought gold inlays, mercury and cementing media. Other materials are being studied.

wise dentist will refuse materials which do not bear the manufacturer's guarantee to meet the specifications of the American Dental Association.

Not only must the research program be carried out, but the data must be interpreted for the use of the dentist in practice. An understanding by the dentist of certain engineering and metallurgical nomenclature and principles becomes important, if he is to evaluate adequately for himself the manufacturer's claims, and manipulate correctly the materials supplied.

This discussion of the materials used in operative dentistry is for the purpose of presenting scientific criteria for judgment so necessary in this comparatively new field. The dentist should have the fullest possible knowledge of the materials with which he works. He should understand the sources and composition of the materials, as well as their manipulation. This calls for knowledge of the application of the basic sciences in so far as they affect the physical and chemical properties of the materials, in order that he may use them intelligently in practice. He must also have criteria for adequate evaluation of new products and processes on a rational and scientific basis, and an appreciation of research methods in this field which may be carried over into dental practice.

Physical Properties of Materials.

Two basic sciences — physics and chemistry — are involved in this study of dental materials, and it is necessary that the meaning of certain terms be clearly understood, if one is to profit by these studies.

A *force* is any push or pull upon matter, either external or internal to its structure.

A *stress* is an internal force induced by an external force or load, usually measured in terms of force per unit area. For example the masticating *forces* are the *loads* or *forces* exerted by the teeth on the food, whereas the *stresses* are the forces within the mouth tissues or restorations, which resist the external masticating action. Although they are numerically equal, they act in diametrically opposite directions. This is a very important distinction.

There are three types of stresses: *Tensile stresses,* which resist a pulling or stretching load; *compressive stresses,* which resist a compressing load; and *shearing stresses,* which resist a twisting motion.

A *strain* is any deformation of a structure caused by an external load. A stress is always accompanied by a strain. Hence strains may also be classified as tensile, compressive, and shearing.

Elastic deformation is the term applied when the deformation disappears when the load is released. The stresses and strains also disappear when the load is released, but in *inelastic* or *permanent*

deformation the structure remains permanently deformed after the load is released.

The *elastic limit* is the maximum stress to which a structure may be subjected without incurring a permanent deformation.

Under elastic stress, the stress is always directly proportional to the strain.* The maximum stress which may be applied to a structure, such that the stress is proportional to the strain is called the *proportional limit.* This is practically the same quantity as the elastic limit, and the terms will be treated synonymously hereafter.

In elastic deformation, if the stress be divided by the corresponding strain, a constant results, which is called the *modulus,* or measure, *of elasticity.* This term together with the proportional limit, gives considerable information about the *flexibility* of a material. The maximum flexibility is directly proportional to the proportional limit, and inversely proportional to the modulus of elasticity.

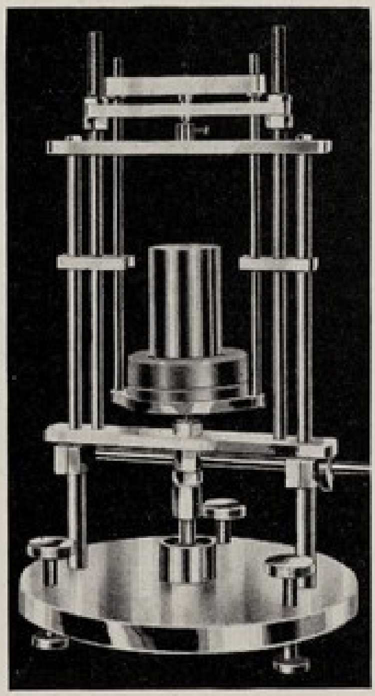

FIG. 241. Micro-Brinell Hardness Tester.

Resilience is the amount of energy stored up in a body when it is elastically deformed,† or its ability to resume its normal size and shape after deformation. Dentin is very resilient. Most masticating stresses are caused by impact forces, such as are produced by a blow. Such forces can be measured by their energies. Since the energy is in part transmitted to the mouth structures, the

* Hooke's law

† A discussion of resilience in inelastic deformation has been omitted for purposes of simplification.

energy which they absorb elastically is measured by their resilience. The resilience, when measured at the elastic limit of a unit volume of the material, is known as the *modulus of resilience.* It can be shown mathematically that this latter quantity is directly proportional to the square of the proportional limit, and inversely proportional to the modulus of elasticity.

Hardness is the property of a material to resist permanent deformation in the form of indentation, abrasion, etc. This property is usually measured in dental materials by means of a micro-Brinell hardness tester. See Figure 241. A one-sixteenth inch steel ball is impressed on the surface of the material under a static load of 12.6 kilograms. The *Brinell Hardness Number* (B.H.N.) is obtained by dividing the area of the impression into the load applied. In practice, the diameter of the impression is measured, and the B.H.N. is found in tables prepared for the purpose.

Tensile strength, or ultimate tensile strength, is the maximum tensile or stretching load which a material will withstand without rupture.

Crushing strength, or ultimate compressive strength, is the maximum load a material will withstand without fracturing under compression.

Ductility is the property of a material to be permanently deformed under tension without rupture; i. e., to be drawn into a wire. It is measured by the percentage increase in length of the material after rupture, as compared with its length before tension was applied, the quantity being called *percentage elongation,* or simply *elongation.* In standard testing, a two-inch gauge length is usually employed.

Malleability is the property of a material which allows it to be extended permanently in all directions without breaking, as in rolling sheet metal, or beating foil.

There are other properties which might be included, but only those are given which occur most frequently in the literature and which are most useful.

The importance of these properties should be quite clear. For example, a dentist would be very foolish to place an inlay in the occlusal surface of a tooth, using an extremely hard gold alloy which would wear more slowly than the tooth structure, and eventually cause movement of the teeth to accommodate the occlusion, or injure the supporting structures by subjecting them to abnormal stresses. Neither should he use too soft a metal. The B.H.N. gives the degree of hardness for the various alloys of gold. Furthermore, the alloy should have a sufficiently high proportional limit so that it may take up the shock of mastication without being permanently deformed. The B.H.N. is a very significant quantity, as it has been shown that, in dental gold alloys, it is directly proportional to the proportional limit and tensile strength.[3]

In other words, the material to be used in practice must be carefully selected according to its physical properties so that it may adequately accomplish the purpose for which it is intended.

Principles of Metallography.

Matter may be classified as liquids, solids, and gases. In some materials the distinction between the three types is not always entirely clear.

Solid materials are classified as either crystalline or amorphous. X-ray data have demonstrated that crystalline solids have a regular arrangement of atoms in a unit crystal, whereas amorphous materials more closely resemble liquids in their molecular arrangement. Metals are characteristically crystalline materials, and dental inlay waxes, for example, may be classified as amorphous solids.

A *space lattice* may be defined as the regular arrangement or pattern of the atoms in space within a single crystal. Figure 242 is a simple cubic space lattice—sodium chloride.

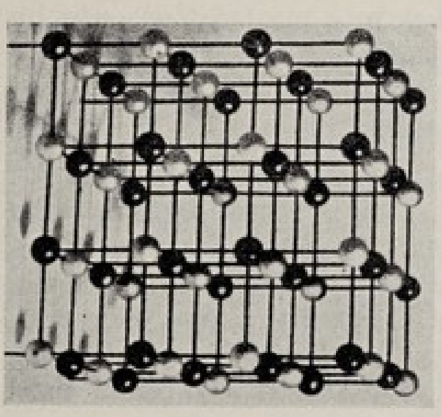

Fig. 242.

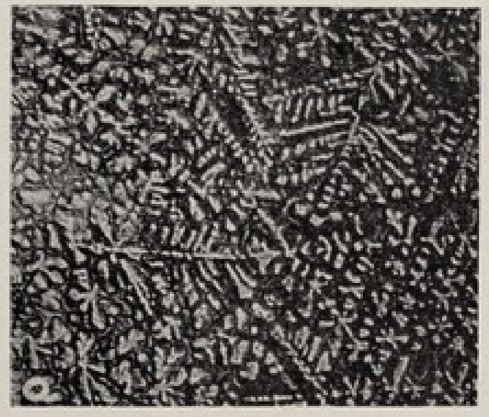

Fig. 243.

Fig. 242 Simple cubic space lattice; sodium chloride.

Fig. 243. Dendritic grain structure of a slowly cooled gold alloy.

The metals and alloys used in dentistry are made up of unit crystals or grains. Each grain may be assumed to be a perfect crystal with a definite space lattice, but the metal in its entirety must be conceived of as being made up of grains, each of which is differently oriented with respect to its neighbor as regards space lattice. The grains may be observed by means of a microscope, or occasionally with a naked eye, when the metal has been properly treated, but the space lattice is submicroscopic in character.

So far as this study is concerned, grains may be classified as being either *equiaxed* or *dendritic*. Dendritic grains are tree-like in structure, whereas equiaxed grains tend to approach a spherical form. Dendritic grains are characteristic of cast materials and

equiaxed grains are characteristic of metals which have been cold worked and annealed (wrought metals). Figure 243 shows the dendritic grain structure of a cast gold alloy.

METALS: A metal may be defined as any metallic element. Metals are characteristically crystalline, and show definite melting, freezing, and boiling points, all of which are characteristic of each individual metal.

Solidification and Fusion of Metals: If a metal has been heated and is allowed to cool from the molten state under temperature and time observation, it will be found that a point will be reached when the temperature no longer decreases with the time, i.e., the temperature remains stationary until the metal is solidified. This results from the fact that heat energy is given up by the atoms while changing from the liquid to the solid state. In the reverse process of fusing the metal, similar phenomena will take place, except that heat will be taken in by the metal when changing state. Since the amount of the heat involved in producing the change is different for and characteristic of each individual metal, in melting metal for casting more heat may be required to melt one metal than another, even though their fusion points may differ only by a comparatively small amount. Solidification usually takes place from certain centers or nuclei, and progresses in various directions, branching out to form the characteristic dendritic grain structure.

Alloys: An alloy is a mixture composed of two or more metals.* An amalgam may be defined as an alloy, one of whose constituents is mercury. Alloys may be classified according to the number of alloying elements: binary, tertiary, quaternary, etc., meaning two, three and four elements. Although dental casting alloys may contain more than two metals, only binary alloys will be considered, since their study gives sufficient knowledge for all practical purposes.

Alloys may be further classified as to structure. The types which are of importance in Operative Dentistry are as follows: solid solution alloys, eutectic alloys, intermetallic compounds, and mixed type alloys.

Solid Solution Alloys: The constituent metals in these alloys are soluble in each other, in both the liquid and solid states. Instead of freezing at a constant temperature, as do pure metals, they solidify over a range in temperature, the magnitude of the range being characteristic of the composition of the alloy.

In general, the physical properties of alloys cannot be predicted from the properties of the constituent metals. Binary solid solution alloys usually show a lower ductility and higher tensile strength than their constituents. Gold casting alloys show a density corresponding very closely to a value calculated from their

* Strictly speaking, the alloying element or elements need not necessarily be a metal. The above definition is sufficiently accurate within the scope of this work.

composition.[32] The melting ranges of the binary solid solution alloys may lie between the melting points of the higher and lower constituent, or in some cases, lower than that of either constituent. The gold-copper alloy is an example of the latter case; the introduction of copper with gold lowers the melting and solidification points of the alloys below that of either gold or copper, which is very significant from a dental standpoint.

Eutectic Alloys: The constituents of these alloys are soluble in the molten state, but insoluble in the solid state. Their melting ranges are always lower than the fusion temperatures of their constituents. Regardless of the composition, one constituent (providing it is not that of the eutectic) will freeze in a nearly pure condition, until a definite composition of the melt is acquired, when the mass will solidify at a definite temperature, this temperature being always the lowest melting point of the system.

The alloy having the composition corresponding to the lowest melting point, is called a *eutectic,* which means "lowest melting." This alloy is a mixture of the crystals of the constituents, and not a solution. Its cooling curve is similar to that of a pure metal, i.e., a constant solidification temperature.

The physical properties of these alloys are approximately what would be expected from their composition. Their use in operative dentistry is somewhat limited.

Intermetallic Compounds: The student is already familiar with the fact that metals form chemical compounds with non-metallic elements. According to present views, metals may also form compounds with each other. Although they combine in definite stoichiometric (combining weight) proportions, the laws of valence do not hold. One of the important intermetallic compounds found in dental amalgam alloys is Ag_3Sn, for example.

In general, these alloys are extremely brittle and hard, and not necessarily lacking in strength. Their melting points are sometimes higher than those of the constituent metals, and they solidify at a constant temperature.

Mixed Type Alloys are exactly what their name implies, — a combination of any of the above types. For example, two solid solutions might form a eutectic; an intermetallic compound might be a constituent of a solid solution, etc. Obviously the structure may become quite complicated, with no specific means of predicting the resulting properties.

Annealing of Metals and Alloys: If one should attempt to flatten out a piece of metal, such as a nail, by hammering, he would observe that a limit of permanent deformation is reached. If further deformation is attempted, the metal will crack or split. In other words the metal becomes hard and brittle.

Almost all metals will *strain harden* in this way when worked at room temperature. This is caused by a certain plastic deforma-

tion of the grains which reaches a limit, rendering the metal brittle. The complete theory of strain hardening is beyond the scope of this book.

Such a strain hardening can be removed by heating the metal to a certain temperature called the *recrystallization temperature,* when the deformed grains rearrange themselves into small equiaxed grains, completely relieving the strained condition. The metal again is soft and plastic as before, and the deformation can be resumed. This process of heating the metal to remove strain hardening is known as *annealing.*

DENTAL AMALGAM.

The importance of the study of dental amalgams for restorations cannot be over-emphasized. When the alloys are correctly compounded by the manufacturer, and the amalgam is correctly manipulated by the dentist, a serviceable restoration results. On the other hand, the most expert manipulation cannot result in a good restoration if an inferior amalgam is used. It is the most foolish economy for the dentist to use alloys which do not meet the specifications set up by the American Dental Association. With precise manipulation, dependable restorations may be made if good alloys are used.

Metallographically, the amalgam is defined as an alloy, one of the constituents of which is mercury. By the term *amalgam alloy* is meant the alloy, usually supplied as filings, which is mixed with the mercury to produce the amalgam.

HISTORICAL.

The exact date when amalgams were first used in filling teeth is not known. However, there is a possibility that its use may have been an outgrowth of the work of M. Regnart who, in 1818, attempted to produce a low fusing alloy containing mercury for filling teeth.

About 1833-35 a so-called "silver paste" appeared which was undoubtedly an amalgam of pure silver and mercury. This soon led to the mixing of shavings of silver coins with mercury. The mass would set very slowly, and show considerable expansion. These amalgams were introduced into the United States soon after their invention in England and fell into the hands of charlatans and itinerant dentists, who went from town to town leaving pain and misery in their wake.

In the face of such practices it is not to be wondered that the material fell into considerable disrepute. In fact the feeling for and against its use became so acute that in 1845 the first national organization of dentists, the American Society of Dental Surgeons, passed a resolution as follows:

"Resolved: That any member of this Society who shall here-

after refuse to sign a certificate pledging himself not to use any amalgam, and moreover, protesting against its use under any circumstances in dental practice, shall be expelled from this Society."

Some dentists believed the material had possibilities and the resolution precipitated the famous "amalgam war," which fairly tore the newly organized profession asunder. Although the resolution was rescinded in 1855, the Society soon ceased to exist.

The first important scientific studies of amalgam were by John Tomes of London in 1861. He packed seven different amalgams in cavities prepared in ivory, and observed the margins under a microscope. Six of them exhibited contraction, whereas the seventh, made of pure copper and mercury, showed no contraction.

The next plan, suggested by Thomas Fletcher of Warrington, England, was to pack amalgams in glass tubing, and observe the penetration of dye into the margins after setting. He reported shrinkage in most of the specimens tested.

The first quantitative measurement of dimensional changes was made by Charles Tomes, son of John Tomes, in 1861. He determined the specific gravity before and after set, and calculated the volume change. This latter test, although rather tedious, is quite practical. He found that the alloys shrank in varying magnitudes. The accuracy of his method was later confirmed by Dr. G. V. Black.

Mr. A. Kirby in 1871 attempted to measure the changes directly with a V-shaped trough and a micrometer screw. He found that amalgams expanded when made with pure silver.

Dr. Thomas B. Hitchcock of New York, in 1874, designed the first recording micrometer for determining dimensional changes. His instrument measured to within one thousandth of an inch. He used a one-inch steel trough in which the amalgam was placed. The trough was closed at one end, and the micrometer fastened at the other end. Even with the much longer specimen than was later used by Black and others, the instrument was not sufficiently accurate. Dr. Hitchcock died before completing his work.

Dr. G. V. Black, in 1895, began his fundamental work which finally resulted in the modern amalgam. The following account of his work is far too brief to stress its importance.

His first task was to construct a micrometer "which would measure accurately to 0.0001 inch, or possibly 1/1000 of a millimeter (one micron) if required."[5] Instead of a large specimen in a trough, he used a small hardened steel tube which enabled him to more nearly match dental conditions of experimentation.

Although the micrometer method, due to certain inherent inaccuracies, has been largely supplanted by the interferometer at the present date, most of Dr. Black's conclusions are fundamental and sound.

After making a survey of the existing amalgams on the market to no avail, he decided to compound his own alloys. He states:

"I mixed chemically pure precipitated silver and chemically pure precipitated tin in varying proportions cold and made amalgams, and recorded their behavior. They expanded badly. Then I melted these together, . . . in the same proportions in which the cold mixtures had been used. . . . These shrunk badly."

These data led him to conclude that the secret of making amalgams was not related to the metals individually, but rather to their condition in the alloyed state.

He then discovered the principle of annealing. He found that filings from an alloy of 65% silver and 35% tin, when melted in a closed electric crucible in the presence of hydrogen (a method still employed by some manufacturers), would neither expand nor contract when amalgamated the same day, but if the filings were left on the shelf for a month, the amalgam would shrink. He further found that in the latter case, less mercury was required and a slower setting time resulted.

By placing the freshly cut filings in a test tube in boiling water for fifteen minutes, he demonstrated that the change noted in a month under the previous test took place in fifteen minutes. He rightly concluded that he was simply annealing the filings. The phenomenon observed with the freshly cut filings was evidently due to their strain hardened condition, brought about by the cutting process. The reason for this change in the physical properties of the amalgam due to annealing the filings, has eluded all investigators up to the present time.

He then made a systematic investigation of the effects of varying composition of tin and silver upon the physical properites of the amalgams. The experiments were so splendidly done and the information so fundamental that the text is quoted verbatim.

G. V. Black's Investigations

"Experiments with silver-tin alloys. The next problem was to find whether or not a silver-tin alloy could be found that would neither shrink nor expand in setting when annealed to the normal state of the metal at ordinary room temperatures. This was done as follows: A silver-tin alloy was made of 30 of silver and 70 of tin; another of 35 of silver and 65 of tin; another of 40 of silver and 60 of tin; and this progression was continued to 80 of silver and 20 of tin. These alloys were made with all possible care and tested, both freshly cut and fully annealed, as to working property, amount of mercury required to make an amalgam, the time required in setting, shrinkage or expansion in setting, strength under crushing stress, and flow under continued pressure, and every fact recorded for each. All of them were made of one batch of the metals as obtained from the refiner, for it had been learned that these would vary from about 97 to 100 per cent fine, sufficient to effect seriously the results. Also double redistilled mercury was used, discarding the first and last of the distillate to

insure its perfect purity. This line of work revealed the fact that annealed alloys of 70 per cent or less of silver and 30 per cent or more of tin all gave amalgams that shrank, while all containing more than 75 per cent of silver would expand when fully annealed.

"From this point another short series of alloys only one-half per cent apart was necessary to find the exact balance which would produce an alloy that would not change bulk while hardening. When this was found, it was a good formula for that batch of metals but not for another batch, for the purity might be different, and the formula for each new batch of metals had to be found. *Therefore, no fixed formula could be good for general use.*

"If it were possible to use chemically pure metals, a fixed formula would be possible, but such metals would be too expensive for use in dentistry.

EXHIBIT OF UNMODIFIED SILVER-TIN ALLOYS

Formulæ		How Prepared	Per cent of Mercury	Shrinkage	Expansion	Flow	Crushing Stress
Silver	Tin						
40	60	Fresh-cut..........	45.78	6	7	40.15	178
40	60	Annealed...........	34.14	9	3	44.60	186
45	55	Fresh-cut...........	49.52	4	8	25.46	188
45	55	Annealed...........	32.13	7–11	1	28.57	222
50	50	Fresh-cut...........	51.18	2	2–4	22.16	232
50	50	Annealed..........	37.58	10–17	0–1	21.03	245
55	45	Fresh-cut...........	51.62	0–2	0–2	19.66	245
55	45	Annealed...........	40.11	10–18	0	17.53	276
60	40	Fresh-cut...........	52.00	1–3	0	9.06	239
60	40	Annealed...........	39.80	10–17	0	14.10	297
65	35	Fresh-cut...........	52.00	0	1–5	3.67	290
65	35	Annealed...........	33.00	6–10	0	5.00	335
70	30	Fresh-cut...........	55.00	0	14–20	3.45	316
70	30	Annealed...........	40.00	5–7	0	4.67	375
72.5	27.5	Fresh-cut...........	55.00	0	28–42	3.92	275–350
72.5	27.5	Annealed...........	45.00	0–3	0–4	3.76	362–450
75	25	Fresh-cut...........	55.00	0	40–60	5.64	258
75	25	Annealed...........	50.00	0	6–8	5.40	300

"The above exhibit is in the main a copy of that published in the *Dental Cosmos* for December, 1896, but has been amended by introducing variations justified by notes of alloys made since, and of tests, using the closed electric crucible filled with hydrogen in melting and alloying. These gave constant differences (though not large) from alloys made in the open crucible. Many questions may be answered by a study of this exhibit. It is a matter of much interest to note that the alloys containing 45 per cent silver and 55 per cent tin, and up to 60 per cent silver and 40 per cent tin, which were about the range of alloys then in use, lay in the center of the range of greatest shrinkage. Note particularly also the

double movement—expansion, then shrinkage—of the alloys from 40 silver and 60 tin on to those containing equal parts of the metals.*

"No attempt was made, when this table was first published, to represent the variation of shrinkage that might occur from different samples of alloy made from the same formula. Variations must be expected. The amendment made is on account of the constant variation (which is not the same in each sample of metals obtained from the dealer) of alloys made in hydrogen gas in the closed electric crucible, an arrangement that gives the greatest facility in accurate alloy making.

"Will alloys prepared for use by annealing to the normal for room temperature maintain these properties permanently? (1) as to shrinkage or expansion; (2) as to working properties; (3) as to amount of mercury required. These questions required time for their full determination, but something could be learned at once.

"(1.) Annealing longer continued at the temperature of boiling water did not effect further changes in shrinkage or expansion. This gave the presumption that time would not.

"(2.) Additional annealing does continue to affect the working properties in such a way as to render the amalgamation easier, reduce the amount of mercury required, and it also slows the setting. This is not very great, but it is quite marked.

"Tubes of alloy were put up for time tests, some of which yet remain after twelve years, and frequent tests have been made. Shrinkage and expansion remain unaffected. The amount of mercury required diminishes, the amalgamation becomes easier, the setting becomes slower, and the strength of the amalgam is gradually reduced. An alloy that makes a crisp amalgam which sets quickly, such as should always be used in practice, will, if kept two to three years at ordinary room temperatures, come to make rather a sloppy, slow-setting mass. If the alloy is exposed to the heat of the sun or otherwise to unusually high temperatures, these changes will be rapid in proportion. If the alloy is much of the time exposed to cold, as in cold rooms in winter in northern localities, these changes will be slower."

The shrinkage together with the later expansion found are given in 0.0001 inch. The flow and crushing strength values were made on cubes 0.085 inch on a side, both observed five days after mixing.

The flow was determined by placing the block under a load of 60 pounds (8300 lbs./sq. in.) for one hour. To obtain the

* Note.—In the expansions recorded, which occurred at the beginning of the setting, the amalgam, being firmly held by the walls of the steel tube, was caused to flow upward in the tube. Therefore, the expansion recorded represents more nearly the cubical expansion. All of the shrinkages recorded, however, represent purely lineal contraction. The record of shrinkage recorded is that below the measurement at the beginning of the experiment.

crushing strength in pounds per square inch, the values in the table must be multiplied by the factor 139. The crushing strength values quoted range from a minimum of 25,000 lbs./sq. in. to a maximum of 62,000 lbs./sq. in. Gray [8] has shown that crushing strength values obtained on specimens of too short a length give higher values, due to the restraining action of the crushing jaws. In consideration of this factor, the values are approximately 25% too high. Nevertheless some of the higher values are undoubtedly comparable to the crushing strengths of modern amalgams.

Composition and Metallography of Amalgam Alloys.

The average composition of modern amalgams may be approximated at least by inspection of the composition specified by the revised American Dental Association Specification No. 1:

Silver	65% minimum
Copper	6% maximum
Zinc	2% maximum
Tin	25% minimum

When the alloy is mixed with the mercury, silver is generally considered to be the expanding element, and tin the contracting element. Black found this to be true, as well as Gayler.[9] However, Dr. Gayler does not agree with Black in the magnitude of the change. The higher silver content alloys also show considerably less flow and higher crushing strength.

The tin content of the alloy is very critical, other factors being equal. In the opinion of Gayler [9] the tin content is the composition factor which determines whether or not an amalgam is suitable for use as a filling material. She places the desirable tin content, irrespective of the silver and copper content (within limits), at not less than 25% and not greater than 26.8% by weight.

Tin is probably a deleterious element so far as physical properties go. Its chief advantage for use is its strong affinity for mercury, and its ability to decrease the amalgamation time in combination with silver. It reduces the setting expansion and crushing strength, and increases flow.

Copper may be used to replace the silver content in small amounts. It increases the expansion of the amalgam in setting, decreases the flow, and increases the crushing strength. However, it must be used sparingly, as it is very effective as an expanding element when it replaces silver.[9]

Historically, copper was undoubtedly introduced as a stabilizer as it was formerly thought that it formed a non-expanding and non-contracting amalgam with mercury. Modern research has shown that copper amalgams contract under all conditions so far investigated.

The function of zinc as an element of the alloy is rather obscure. Black [10] found that, when present in an alloy of composition; silver 61.75%, tin 33.25%, zinc 5%, it decreased the flow and increased both crushing strength and expansion. He noted that the wet mass of the amalgam exhibited adhesion to the cavity walls during condensation.

However, he further noted a strong objection to its use, viz., its slow setting properties. In the sixth edition of his book (p. 308), he states: "Experiment in watching fillings for five years shows that one-half of 1% of zinc is inadvisable for the reason that the amalgam will continue to change bulk very slowly for that

Fig. 244. Modern amalgam flow tester.

time and perhaps much longer. Though this change is not large (not more than one to one and one-half points* per year with one per cent of zinc), it will finally destroy the usefulness of the filling."

More scientific research is needed along this line, and its use is still questionable. Certainly any operator, when using a zinc and a good non-zinc amalgam in succession, will not be able to determine any important differences in their working properties.

Manufacture of Amalgam Alloy.

The first requisite of a good product is purity of the elements and second, correct annealing, once the correct formula is arrived at.

The metals are alloyed carefully in the absence of oxygen and cast into ingots, which are comminuted into filings or shavings. They are then annealed much in the same manner as described by Black. If the comminution process is carried out on a lathe, an

* 0.0001 — 0.00015 inches.

oxide film forms on the shavings, due to the heat generated. This may be removed by washing in hydrochloric acid, which leaves the surface bright and silverlike. This process merely removes the surface impurities and insures nothing as to the internal purity of the filings.

If the alloy is not properly balanced as to composition, an over-annealed alloy will, in general, produce a shrinking amalgam with a large flow, whereas under-annealing produces an abnormally large expansion with considerable flow. An ideal amalgam alloy is one which cannot be over-annealed. In cases where the annealing

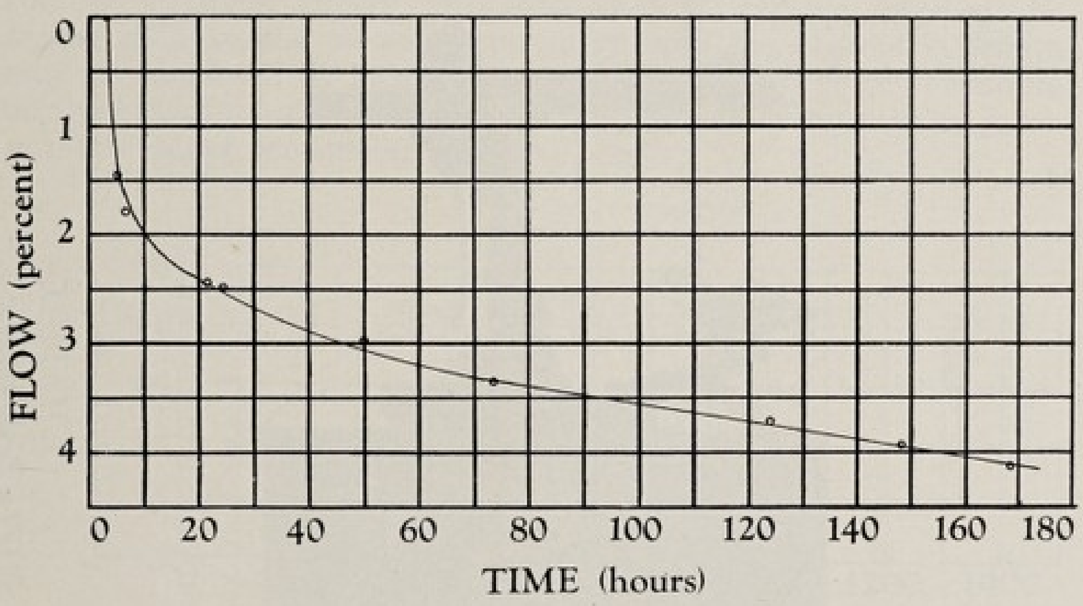

FIG. 245. Typical flow curve for a modern amalgam. Note the regularity of rate of flow after seventy-four hours.

is not carried to completion, it will continue slowly for a number of weeks. In this way, an amalgam alloy may be satisfactory at the factory, but by the time it is amalgamated by the dentist, its physical properties may be considerably changed. In other words, it exhibits a shelf life.

Too much credit cannot be given to the few manufacturers who are quietly and ethically providing the dentist with a reliable product.

PHYSICAL PROPERTIES OF AMALGAMS.

Crushing strength of modern amalgams has not been studied as much as it should be, since its testing has been deleted from the American Dental Association Specification No. 1. However, most modern amalgams are probably of ample strength for use in the mouth.

Flow is observed by noting the shortening in length of a cylinder of the material, four millimeters in diameter and eight

millimeters long, under a static load of 250 kg./sq. cm. for twenty-four hours. The test is started three hours from the time its trituration was begun. During this period, the flow must not be greater than four per cent shortening in length. Figure 244 illustrates a modern flow tester.

If the rate of flow is plotted it may be considerable at first, gradually becoming less as the twenty-four hour period is approached. Figure 245 is a typical flow curve. If the test is extended for a greater period, the flow continues as long as one

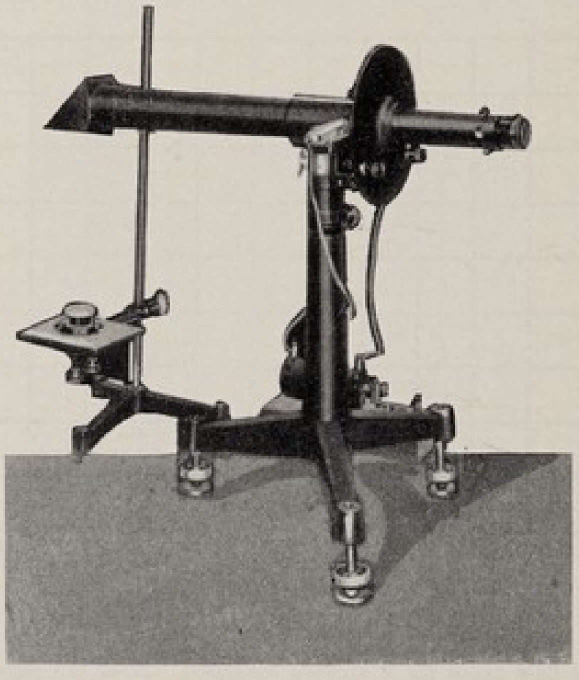

FIG. 246. The dental interferometer and viewing device.

continues to make observations, which probably indicates the material does not completely strain harden. Present indications are that the recrystallization point of the amalgam is below room temperature, which is a rather alarming conclusion so far as the durability of the amalgam restoration is concerned.

Flow is exhibited clinically by gingival overhangs on two surface restorations after considerable use. In occlusal restorations, amalgam is likely to flow up over the margins and break off, leaving a leaking margin which invites decay.

Dimensional changes are best observed by means of an interferometer, which is by far the most accurate instrument yet designed for this purpose. See Figure 246. It consists of two optical glass plates, placed one above the other, with air between. If they are placed at a small angle with each other, a collimated monochromatic light beam striking the top plate perpendicularly, is partially reflected from the top of the bottom plate. The reflected

wave meets the primary (or original) beam on the bottom surface of the top plate. If the beams meet in phase, a fringe of light is seen. If they meet out of phase, they annul each other, as shown by a dark band or fringe. The number of alternate light and dark fringes in a unit length depends upon the angle between the plates. If one side of the top plate is supported by two pins or screws, whose height remains constant, an amalgam specimen may be placed at the vertex of an equilateral triangle, the corners of whose base are formed by the constant set screws. As the amalgam shrinks or expands, the angle between the plates is changed, thus altering the number of fringes. The number of fringes may be counted between known reference lines at various intervals by means of a special viewing apparatus, and the change in length may be computed by means of a mathematical formula depending on the constants of the instrument, the change being usually given in microns per centimeter.

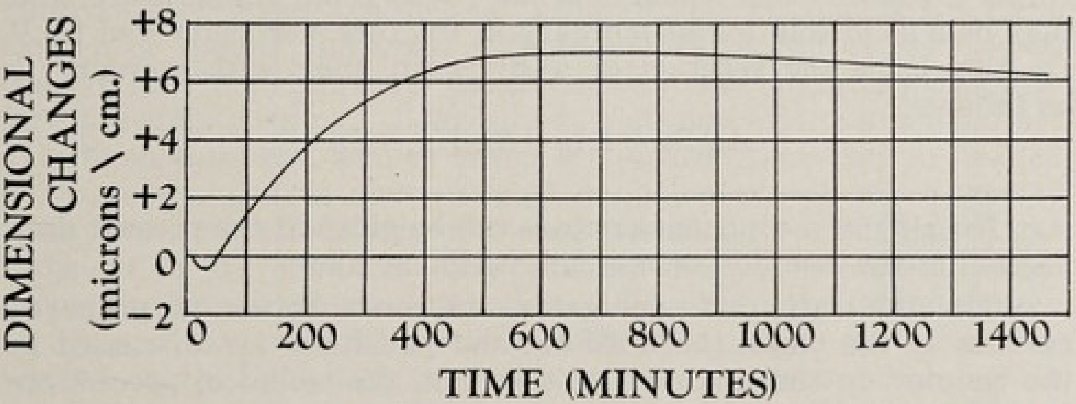

FIG. 247. A typical dimensional change curve over a period of twenty-four hours for a high silver content silver amalgam.

The accuracy of the instrument is in the neighborhood of 0.00001 inch. It is not subject to lever disturbances which are likely to be quite prevalent in other forms of measuring equipment. A typical curve for a good amalgam, showing the variation of dimensional changes over a period of twenty-four hours, is given in Figure 247. There is a short contraction followed by an expansion to a maximum, then a second slight contraction.

A contracting amalgam shows a similar curve, except that the initial contraction is longer in duration and of greater magnitude, any subsequent expansion not being great enough to bring the dimensions back to the original.

A consideration of differential thermal expansions between tooth structure and an amalgam restoration indicates that a slight setting expansion is desirable. Amalgam shows a greater linear

thermal coefficient of expansion than does tooth structure, and it is desirable that it expand while setting to overcome such an effect, the slight expansion being compensated for by the elasticity of dentin. Souder [13] places the figure for optimum expansion at eight microns per centimeter.

Various theories are advanced to account for these variations in volume during setting. Gayler [9] suggests that the expansion is due to the presence of an intermetallic compound Ag_3Sn in the alloy, together with a second silver-tin compound called "β constituent". The more β constituent present with Ag_3Sn, the greater will be the expansion, assuming a Ag-Sn-Cu ternary alloy. If tin is present in amount greater than 26 per cent by weight, the Ag-Sn alloy appears to be imbedded in a tin matrix without the β constituent, and the alloy shrinks.

Possibly one of the products of the amalgamation is an intermetallic compound Ag_3Hg_4. It is not entirely clear just what happens to the tin-mercury combination. A simple tin amalgam forms a plastic mass which does not set at room temperature, and may be a solid solution of mercury in tin (one per cent) and tin.[14] On this basis the reaction of a silver-tin alloy with mercury is as follows [15]:

$$Ag_3Sn+4Hg=Ag_3Hg_4+Sn$$

Nothing of a conclusive nature can be given at the present date regarding the reaction of mercury with the alloy.

The trituration of amalgams, its condensation in prepared cavities in the teeth, the finishing and polishing, are discussed in the chapter on the instruments used and the technical procedures in making amalgam restorations.

GOLD FOIL

There can be no doubt but that the gold foil restoration heads the list of materials for efficient and permanent preservation of tooth structure. As will be shown, its physical properties are adequate for the purpose intended. Its disadvantages are its color, high thermal conductivity and difficulty of manipulation.

Gold is one of the most noble of metals. It does not tarnish or corrode under ordinary conditions. It is the most ductile of metals, thus providing ample burnishing ability. It ranks third among the metals in thermal conductivity.[20] It is a soft metal with 27 B.H.N.[2] Its tensile strength is quite low (36,000 lbs./sq. in.[21]), and its elasticity is correspondingly small. It is also the most malleable of metals. Its melting point is 1945.4° F. (1063° C.).[29]

In the form of foil, its reflected color is yellow, but by transmitted light it has a green color. The making of foil is an art in itself.

Annealing Gold.

Gold foil exhibits the remarkable property of welding at room temperature, providing the surface is clean and free from adsorbed gases. There are two types of gold foil—cohesive and non-cohesive. The cohesive foil welds at room temperature, whereas the non-cohesive foil does not.

The following paragraphs are from the writings of G. V. Black on the welding properties of gold:

"Gold prepared in the form of foil or crystals welds perfectly in the cold state when clean surfaces are pressed into contact. It is the only metal which has this property in a high degree. In order that the welding property may be successfully used, the surfaces of the gold must be clean. As this property of gold is readily lost by improper care, it is well to know intimately the conditions of the development of it, and the loss of it.

"All metals, except those known as the noble metals, oxidize quite readily when exposed to the air; that is, they attract the oxygen of the air and unite with it to form a film of oxide upon the surface. This prevents the contact of clean surfaces and therefore prevents welding. Gold, silver, platinum and mercury do not oxidize in this way, and it is for this reason that they are called noble metals. Silver and platinum do, however, attract oxygen to their surfaces in the form of a transparent film of condensed gas sufficient to prevent their surfaces from coming in contact, which prevents them from welding cold. Gold does not attract oxygen or nitrogen to its surface, and it is for this reason that it can be welded cold. Gold does, however, attract to its surface certain gases that are often present in our atmosphere. These are often condensed upon it in such quantities as to prevent its surfaces from coming in contact and destroy, temporarily or permanently, its welding property. These, however, do not unite with the gold to form any compound. They do not affect its purity. Some of these gases are such as will be removed from the surface of the gold by volatilization when heat is applied (by annealing), rendering the surface again clean, with restoration of welding property. Other gases, notably those of the sulphur and phosphorus groups, condense upon the surface of gold and refuse to volatilize by heat, and thus the welding property of the gold is permanently destroyed. In these cases it seems probable that compounds in the form of fixed salts — non-evaporable — are formed on the surface of the gold. A salt that may be completely volatilized by heat may destroy the welding property temporarily. By annealing, such a salt is removed and the welding property is restored.

"These general facts with regard to gold may readily be illustrated by a few simple experiments, which any one with a reasonable familiarity with inorganic chemistry can perform. Ammonia

is strongly attracted to gold. Place a small quantity of spirits of ammonia, or of aqua ammonia, in a large glass jar. The ammoniacal gas from this will fill the space above the liquid. Now take a rope of gold, which has been annealed and the welding property of which is perfect, and swing it by a cotton thread above the liquid in the jar and replace the cork. In fifteen minutes remove the gold and try its welding property. It will not weld any more than so much tissue paper. Another rope of gold is swung above strong chlorine water; the welding property will be completely destroyed in two minutes. Now reanneal these ropes of gold; the welding property is completely restored.

"How are we to know that this effect is produced by a condensation of gas on the surface of the gold? Place a rope of gold, first in chlorine gas for ten minutes, and then transfer it to ammonia for an equal time. As these two gases unite to form a volatile salt —ammonium chloride—which readily crystallizes upon any cold substance, place the gold thus treated in a long test tube and heat it quickly over a Bunsen burner. Immediately white fumes begin to leave the gold, and these crystallize in a white ring on the colder portion of the test tube. Chemical examination of these crystals shows them to be ammonium chloride. This should occur only by the condensation of the gases on the gold, and the amount formed shows this condensation to be in very considerable quantity.

"In this experiment, the salt formed is volatile, and the gold is readily cleaned by heat. But suppose the salt formed were a fixed salt that does not volatilize at the annealing temperature? Then the welding property of the gold is permanently destroyed. This is what often occurs when the gold is not well protected. One of the principal reasons why the crystalline forms of gold are more difficult to keep in good condition than foil is the fact that the crystals form a sponge which more readily takes up and holds gases.

"By careful experiment it has been found that acid gases are most likely to permanently obscure the welding property of gold; hence, if the gold be kept in an atmosphere containing a liberal per cent of ammonia, ammonium salts will be formed on the gold. These salts are readily volatile; hence gold so kept will always be readily cleaned by annealing and its welding property restored.

"We may use gold foil, non-cohesive or cohesive, as we choose, from the same book, or the same sheet, by keeping it in a drawer containing a small bottle in which a bit of sponge, punk or cotton is placed, and occasionally saturated with spirits of ammonia. Used without annealing, this will be perfectly non-cohesive, or, when annealed, will be perfectly cohesive. This should be taken advantage of in keeping gold foil in good condition for use in either form."

Gold foil may be corrugated by placing it between sheets of paper, which are ignited in the absence of air. This form of gold

foil is of historical interest, since its discovery was an outcome of the great Chicago Fire of 1871. A dental depot had some books of gold foil in a safe. After the fire the safe was rescued and opened, and it was found that the paper had been charred, but the gold leaf itself was unharmed, except that it had become corrugated due to the shrivelling of the paper from the heat in the air-tight safe. After removing the carbon, it was found that the gold exhibited a superior welding property.*

Other forms in which gold may be supplied for foil work are electro-deposited crystals and "sponge gold", the latter of which is probably made by amalgamating gold with mercury and driving off the latter with heat.

Platinum foil may be covered with gold and used in place of pure gold. Black[22] reported that fillings made with this material were superior to pure gold foil in strength and abrasive resistance. Platinum is recognized as a good strengthener of gold in the alloyed condition.

Condensation of Cohesive Gold Foil.

The foil is condensed or welded with a condensing instrument and mallet. Each piece is welded to the whole by driving it against the mass already incorporated. This procedure strain hardens the metal, making it much harder than ordinary twenty-four carat cast gold.

The specific gravity of pure cast gold at 68° F. is given as 19.3 grams per cubic centimeter.[86] If the foil is properly condensed, its density should approach this value. Black[23] reports a density of 19.4 grams per cubic centimeter, for a gold foil hammered into a matrix. The accompanying table gives Coleman's results upon testing the hardness and density of gold foils in comparison with other golds used for restorations.

TABLE [2] 1

PROPERTIES OF FOIL FILLINGS AND SOFT INLAY GOLD.

Material	*Density* (g/cc.)	B.H.N.
Gold foil filling, sample No. 1	17.0	**36
" " " " No. 2	17.3	50
" " " " No. 3	14.2	† 18
" " " " No. 4	16.8	51
" " " " No. 5	18.2	61
" " " " No. 6	19.0	60
24 carat gold, cast.	19.3	27
22 carat gold alloy (0.5 per cent copper), cast.		32
22 carat gold alloy (3.7 per cent copper), cast.		54

* Chicago Branch of the S. S. White Dental Mfg. Co.

** B.H.N. in different spots varied from 22 to 46.

† B.H.N. in different spots varied from 13 to 26.

The gold foil specimens were made by six representative dentists in the United States. The foil used was a well known brand, the same brand being used in all cases. They were condensed in split steel molds.

It should be noted that the hardness of the better foils excels that of a twenty-two carat inlay gold, even though the density in each case is not as great as the twenty-four carat gold. Also the general trend of the data shows that the denser the filling, the greater its hardness. Since the Brinell hardness number is a measure of the resistance to abrasion, this factor is very significant. Black [25] made similar studies, determining the density, but not the hardness. Instead he subjected the filling to large loads and determined the per cent of shortening. His results show also wide variance between different operators.

Density and hardness alone are insufficient to insure permanent restorations. In addition, adaptation must be secured by the proper direction of force, in order to take advantage of elasticity of the dentin. The dentinal walls of the cavity must be slightly distended by the condensation process to give a tight retention and perfect adaptation.

It may be readily recognized that these considerations involve a study of both the magnitude and the direction of force applied. Inasmuch as the condensation process is done by malleting, the force is an impact blow and exists for a very short time. The physics of impact forces is quite involved, and only a limited treatment is within the scope of this work.

The force exerted during impact is proportional to the product of the force exerted and the square of the velocity with which it is applied. In the case of the mallet, the weight of the mallet is the exerting force and the velocity will be determined by the operator. In the study of physics it is easier to discuss the *mass* of a body rather than its weight. The mass of the mallet may be computed by dividing its weight in pounds by the acceleration of gravity, which has the approximate value of 32 feet per second per second.

Since the force of the impact exists for so short a time, it cannot be computed directly; yet some very interesting facts can be discovered about it, if the energy involved is considered. The physicist recognizes two forms of energy; kinetic and potential. Kinetic energy is energy of motion, and potential energy is energy by virtue of position. It is very evident that we are dealing with energy of motion in this case. It can be shown [27] that the kinetic energy is proportional to the product of the mass of a body and the square of its velocity. In fact this may be expressed by a very

simple mathematical equation, and the energy of the blow delivered by the mallet on the condenser may be computed:

Let W = weight of the mallet
32 ft./sec./sec. = Acceleration of gravity
V = velocity of the mallet at the instant it strikes the plugger.

Then the kinetic energy at the instant of impact $= \frac{W}{32} \times \frac{V^2}{2} = \frac{WV^2}{64}$

The law of conservation of energy states that energy cannot be created or destroyed, hence the energy of the blow must be dissipated, or rather transferred in some manner. Undoubtedly some of it is lost (not destroyed) in the form of heat, but this will be very small and may be neglected.

The major portion, then, will be received by the condensing instrument, the foil, the tooth and other mouth tissues. In other words the *resilience* of these structures absorbs or "takes up" this energy. Therefore all of the energy is not transmitted to the foil itself. If the mouth tissues are not permanently deformed, the impact is elastic; that is, the structures are elastically deformed and spring back to their original position after the blow has been delivered. The foil, on the other hand, is inelastically deformed, and this is, so far as the operator is concerned, the useful part of the energy.

As to how efficient the blow will be in welding the foil will depend upon the other structures involved in the system. If the shank of the condenser is very small, it will bend elastically under the blow, and this resilience will dissipate considerable of the energy before it reaches the foil. A thick peridental membrane will take up more energy or "shock" than will a thin membrane. Also the larger the tooth and the other structures, the stronger the blows may be without pain. Hence the possible strength of the blow and, as a consequence, the degree of condensation, will vary with the patient, and will not always be under control of the operator. Although at first thought such elastic resilience might seem to decrease the efficiency of the operation, yet on the contrary it is very necessary, otherwise the tooth and other structures might be injured by a blow of sufficient strength for welding purposes.

The action of the mouth structures as shock absorbers, and its effect upon gold foil condensation, may be illustrated by some scientific observations of Dr. Black.[25, 26] He discovered that much denser restorations could be made in steel dies when they were placed on a steel block, than if they were placed on a cushion, the latter supposedly being comparable to the peridental membrane in its action.

By a very ingenious experiment, Dr. Black arrived at an approximate value for the magnitude of the impact force.[28] A

weight of known magnitude, with a point similar to the face of a gold condenser, was allowed to fall from a definite height on a piece of cardboard laid on a boxwood block. The height of the fall was varied until the pasteboard was driven into the block exactly flush with the surface of the wood. Then another block of the same wood was placed under a static load, and the force was obtained which would press the cardboard into the wood, to the same degree as with the impact force. The latter force was, to all practical purposes, equal to the impact force in magnitude.

If a thin sheet of cork was used as a shock absorber by placing it under the boxwood block, it was found that the weighted condenser point must be raised possibly twice as far as before to obtain the same impact force.

By further experimentation it was found that not less than fifteen pounds of impact force on a condenser one millimeter in diameter is necessary to properly condense gold foil. For most men this is too much pressure to be exerted by the hand alone, and hence malleting is necessary. Furthermore, the suddenness of the blow is probably more effective in strain hardening the material than a static force by hand pressure of equal magnitude, even though the latter may be equally effective in welding the gold.

The area of the condensing point is an important factor. It requires four times as much force to produce the same effect with a point two millimeters in diameter as with a point of one millimeter diameter, as the two millimeter point has four times the area.

However, there is another factor which must be considered where an impact force is used. For example, if one hammers a piece of drill rod, which has a broad smooth end, on to the surface of a block of iron, little or no impression will be made. Yet if the drill rod is given a pointed end, it will indent the iron block even though both blows are of the same magnitude. Similarly, if the condensing point is too small in placing gold foil, the blow may drive it completely into the foil, thus chopping rather than condensing it. Considering all facts together, the diameters of points which should be used are limited. If the point is too large, the necessary force required for welding the gold will be greater than the patient can endure. If the diameter is too small, it will be driven into the foil. Dr. Black stated that the desirable limit of point diameter may vary between 0.5 millimeter and a little more than 1 millimeter.

It should be evident that the force of the blow is not the only factor in condensing the gold to a dense mass. To summarize the effect of the blow, the following statements may be made:[26]

To make a very dense filling does not require very heavy malletting, but does require that the gold be used in thin pieces, carefully and evenly laid, and that the malleting be complete over the surface of each piece.

To make a hard filling does require reasonably heavy malleting in addition to care in the laying of the gold, if the filling is to show great density, as well as hardness.

INLAY CASTING GOLD ALLOYS.

So far as can be ascertained, B. F. Philbrook of Iowa was the first to cast the gold inlay. He read a paper describing his methods in 1897 before the Iowa State Dental Society.[88] For some reason his work failed to receive any wide recognition.

Dr. W. H. Taggart is generally given the credit for first introducing the cast gold inlay to the dental profession in 1907, although Philbrook antedated him by ten years.

The use of twenty-four carat gold for casting inlays has been discontinued. The pure gold is too soft and weak for such a purpose; gold alloys are much preferable.

In the alloyed condition, the physical properties can be varied within wide limits according to the purpose for which the alloys are intended.

Composition and Metallography.

The metallography of the casting gold alloys is for the most part rather complicated. In number of elements, they may vary from two to five or more. Any detailed discussion of the constitution of the more complex alloys is very nearly impossible. However, a consideration of each metal itself, and binary alloys of the important metals, will give considerable information concerning the more complex structures.

The composition of the softer inlay gold alloys is generally gold, silver and copper. The hard inlay gold alloys contain, in addition to the three metals mentioned, platinum or palladium, or both. Zinc, and occasionally tin, may be present, as well as nickel in rare instances.

At higher temperatures below the melting range, all of these combined metals exist as solid solutions in binary combinations except the silver-copper alloy, which is eutectic.[31] At lower temperatures, in many cases solid-solid transformations take place in the form of Au-Cu, Pt-Cu, and Pd-Cu intermetallic compounds. Some of them are rather soft, which is not characteristic of such alloys. Nevertheless, their formation may be controlled by heat so as to considerably increase the strength, elasticity, and hardness of the alloy. The technic and theory of such heat treatment will be dealt with later.

Although the physical properties of an alloy cannot be exactly predicted from the elements contained in it, experience has shown that each metal does contribute certain general properties by its presence.

Gold, silver, palladium and platinum, in general, raise the melting point of the alloy,[32] providing that the original alloy to which the metal is added has a lower melting point than that of the metal itself. Although palladium has a lower melting point than platinum, it is more effective in raising the fusion point of the alloy than is the latter. Copper and zinc lower the melting point in the quantities ordinarily used in dental alloys. It should be noted that the melting point of copper (1083° C. or 1981° F.) is higher than that of gold or silver.

Gold contributes to the ductility and specific gravity of the alloy and, when alloyed with platinum, palladium or copper, or all three, a strong alloy results, although gold itself is comparatively weak. Platinum is the best strengthener of gold in the softened or solid solution condition, but upon tempering, the copper is the most important factor, due to its reaction with the other elements. Copper is a good hardener of gold.

When platinum and palladium are introduced in proper quantities, the alloy may be made practically fool proof as regards heating and cooling.[31] Both metals also reduce the grain size of the metal, platinum being most effective in this regard.

Resistance to corrosion and discoloration in the mouth is a very important consideration in dental alloys, but unfortunately not much is known about it at the present time. A test has been devised for it,[13] which may be of considerable help. Tamman has shown[33] that alloys of gold and copper, containing less than 50 atomic per cent (70.8 per cent by weight) gold, show little resistance to chemical reagents. If the platinum* content be included with the gold,[34] this means that the alloy should contain at least 70.8 per cent (by weight) of these metals to be resistant to tarnish in the mouth. However, combinations have been noted[32] which seem to be exceptions to this rule. At the present time, no chemical test has been devised which is absolutely conclusive.

Color is affected by all of the alloying elements. Gold contributes its color. Platinum and palladium whiten the gold, especially the latter. Under certain conditions, as little as 5 to 6 per cent of palladium will make the alloy totally white.[32] Silver is also a whitener, but rather weak in this respect. Nickel is used in white gold jewelry, but if it is used in the dental alloys for this purpose, their nobility is likely to be impaired.

Heat Treatment.

If a dental gold casting be heated and allowed to cool slowly, it will be harder, stronger and more resilient than if heated to a dull red color and quenched in water or pickling solution, but in

* There is some doubt as to whether palladium should be included because of its reaction with hydrochloric acid. Silver should never be included.

many cases its ductility will be so much reduced that it will be too brittle for use. The first manipulation is known as a *hardening heat treatment* or *tempering*. The term *tempering* is carried over from the science of steel treating and since the two processes are not analogous, it is a misnomer. Nevertheless, the term seems to be understood as used in the literature. The second manipulation is called a softening heat treatment or annealing.

SOFTENING HEAT TREATMENT: As noted above, the alloy is mainly in the solid solution condition after this treatment.

For practical work, the treatment consists of holding the casting in the Bunsen flame for two to three minutes at a temperature of 700° C. (1290° F.) — cherry red heat — and then immediately quenching it. In testing work, the material is annealed at this temperature for ten minutes in an electric furnace before quenching.

The alloy is in its softest condition, with its greatest ductility, when quenched from red heat. Hence all cold work, such as contouring, swaging, burnishing and polishing, should be carried out with the alloy in this condition.

HARDENING HEAT TREATMENT: This procedure may be carried out by either of two methods: (a) heating to 450° C. (840° F.) and cooling over a period of time to 250° C. (480° F.) and then quenching (oven-cooling process), or (b) heating at a definite temperature for a definite length of time and quenching (aging process).

In either case the object is to control the formation of the intermetallic compounds to give the maximum strength values with the least decrease in ductility. This treatment results, in many cases, in a radical increase in proportional limit, modulus of elasticity, hardness, and tensile strength, but the percentage elongation values are always decreased, sometimes alarmingly.

For testing purposes, the oven-cooling process, with a time interval of thirty minutes, is usually specified.

Due to the many different alloy compositions the manufacturer must specify the method of heat treatment for his gold.

In order for a gold alloy to take a hardening heat treatment, the copper content must be of the certain value. The general value lies between 8 and 17 per cent by weight,[32] depending upon the other constituent metals.

Because of the fact that the hardness of the hardened alloy is likely to be greater than that of the tooth structure, an inlay treated in this manner will not be abraded as fast in mastication as the tooth enamel. Hence, some authorities[3] feel that it is better to use inlay golds in the softened condition only, and to control the strength and other properties as needed by proper selection of materials.

Classification of Inlay Casting Gold Alloys as to Physical Properties.

In making a survey of the physical properties and composition of inlay casting gold alloys on the market,[3] it was found that they might be classified according to their Brinell hardness numbers into soft, medium, and hard inlay golds,* designated as types A, B, and C, respectively. The Brinell numbers were found to be proportional to the tensile strength and proportional limit, hence these golds are progressively stronger and more resilient.

Type A, Soft inlay gold alloys:

These alloys are from 20 to 22 carat, with a Brinell number** ranging from 40 to 75. They show high per cent elongation values, which indicates that they may be readily burnished. They seldom contain platinum or palladium, being generally composed of gold, silver and copper. As a rule, they cannot be hardened by heat treatment.

Their use is indicated for simpler inlays such as for small class 1, 3 and 5 cavities. If the expected stress is not large, they may serve also for class 2 and 4 inlays.

Type B, Medium inlay gold alloys:

The Brinell numbers of these alloys range from 70 to 100. They are stronger and harder than the preceding group. They also have less ductility and can be burnished with difficulty. When burnished, the margins are apt to be brittle, due to the strain hardening involved.

These alloys may contain platinum and palladium, in addition to the gold, silver and copper. Most of them can be hardened by heat treatment, but in practice it is not advised.

They may be used successfully in any type of inlay, and should be quite popular as they are not of a hardness which might cause trauma by reason of unequal abrasion during mastication.

Type C, Hard inlay golds:

The alloys with Brinell numbers 90 to 140 fall in this class. They are very strong and hard, with comparatively small ductility values. They cannot be burnished. They usually contain larger amounts of platinum and palladium in comparison with other types, and can be considerably hardened by proper heat treatment with a further loss in ductility.

Their use as inlays is limited only to conditions requiring great stress, such as bridge abutments and large three surface restorations in the mouths of the few patients who can exert abnormally large forces in mastication.

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* Alloys with a B.H.N. of less than 40 were ruled out as being too soft for practical use.

** All Brinell numbers given are for the quenched condition.

In dividing the alloys into types, it must not be thought that the division is either arbitrary or sharp, as the alloys vary almost continually in hardness from the softest alloy of type A to the hardest of type C. Therefore, it is proper to speak of a "medium hard type B alloy," "a hard type A alloy," etc. The dentist has a very large variety of alloys to choose from, so far as physical properties are concerned. In fact he has a choice of alloys with a wider range of properties than that available to almost any other user of structural material.[32]

The manufacturers should specify the physical properties of their alloys to the dentist, who in turn should be able to interpret the data in terms of his practice and select his alloys accordingly.

Shrinkage of cast gold alloys.

Unfortunately gold alloys shrink when cooling from the molten state to room temperature. Obviously, this is a very important consideration for the dentist, since the casting will be smaller than the cavity preparation after this shrinkage has taken place.

There are three stages of the shrinkage: (a) the thermal contraction of the liquid metal to the point where solidification begins; (b) the shrinkage of the plastic mass while solidifying, and (c) the thermal shrinkage of the completely solid alloy to room temperature.

The first is of little practical consideration, since any contraction of this nature will be compensated for by more liquid pouring in from the crucible.

The second contraction was found to have a linear value of 1.64 per cent (for pure gold).[35] Dr. Price[35] gave 2.2 per cent as the third value, but Coleman[2] found that the composition of the material affected this value somewhat. He also differed from Price in the value for pure gold. Coleman used much longer specimens, thus having less experimental error of measurement. He gives the linear thermal contraction of pure gold as 1.76 per cent, when cooling from near the fusing temperature to the solid state.

Coleman also determined the linear thermal contractions of several gold-copper alloys in the solid state. The lowest value found was 1.62 per cent for an alloy of 90 parts gold and 10 parts copper. In four different materials the figures ranged from this lowest value to 2.03 per cent as the highest value (10 per cent silver and 90 per cent gold).

He further determined the total shrinkage of the gold from molten state to room temperature by a method analogous to the casting procedure used in dentistry. The original paper[2] gives a description of the apparatus. He established the average value of total linear contraction from the molten condition to room temperature as being 1.25 per cent. This constant varies neither with the temperature of casting nor the composition of the gold alloy.

Obviously, this value is less than the lowest linear shrinkage of the alloys from the solidification point to room temperature. This discrepancy may be accounted for by two possible explanations:[24]

"(1) There may be sufficient friction or interlocking between the casting and the walls of the mold to hold and stretch the casting while it is cooling through that range of temperature within which the metal is very soft or weak, thus preventing the full normal shrinkage, and (2) the compensation of part of the total shrinkage of the solid metal may be dependent upon a difference in the rates of cooling of different parts of the casting. If part of the metal in the mold solidifies and cools to some temperature below the melting point before the metal in the sprue freezes, the shrinkage due to cooling of this solid metal may be compensated by the addition of metal from the crucible."

This work has been confirmed[36] recently at the National Bureau of Standards by W. T. Sweeney, using different shapes of castings, investments, and gold alloys. The total shrinkage of gold alloys is concluded to be 1.25 per cent with an experimental error of 0.1 per cent. The volume shrinkage is approximately three times the linear shrinkage.

Inlay Casting Wax.

Inlay casting wax is used for obtaining wax patterns for later reproduction in the form of a gold casting. In use it is made plastic by heat, and then forced into the cavity preparation under pressure and held until rigid. It is then burnished and carved to the anatomy of the tooth; removed from the cavity and invested.

In consideration of both the method of preparation of these patterns and the limited possibilities of production of suitable wax formulae, the American Dental Association Research Associates at the National Bureau of Standards have indicated the following characteristics as being desirable for inlay casting waxes:[4] "1. The waxes should soften without becoming flaky or laminated. 2. They should be sufficiently plastic at temperatures slightly above mouth temperature to permit forcing them into all the details of the cavity walls. 3. They should harden sufficiently at mouth temperature to permit withdrawal from the cavity without distortion. 4. They should carve without chipping or flaking. 5. The color should be such that it facilitates the carving of the pattern in the mouth through contrast with the hard and soft tissues of the mouth. 6. The thermal expansion characteristics should be known to insure the correct use of the material in any technic requiring wax expansion." Two other requirements might be added: 7. The waxes should be cohesive but not adhesive. 8. They should vaporize at temperatures compatible with normal casting practice without leaving any residue other than carbon.

The exact composition of these materials is a secret closely

guarded by the manufacturers. Some of their ingredients may be as follows: Paraffin, beeswax, carnauba, ceresin, dammar resin (gum dammar) and stearin. Coleman[2] gives a formula for a satisfactory inlay wax as follows: Carnauba, 25 per cent, paraffin, 60 per cent, ceresin, 10 per cent, beeswax, 5 per cent, and a small amount of coloring matter.

Paraffin is usually the basic ingredient, with other materials added to raise the melting and softening point, notably carnauba.

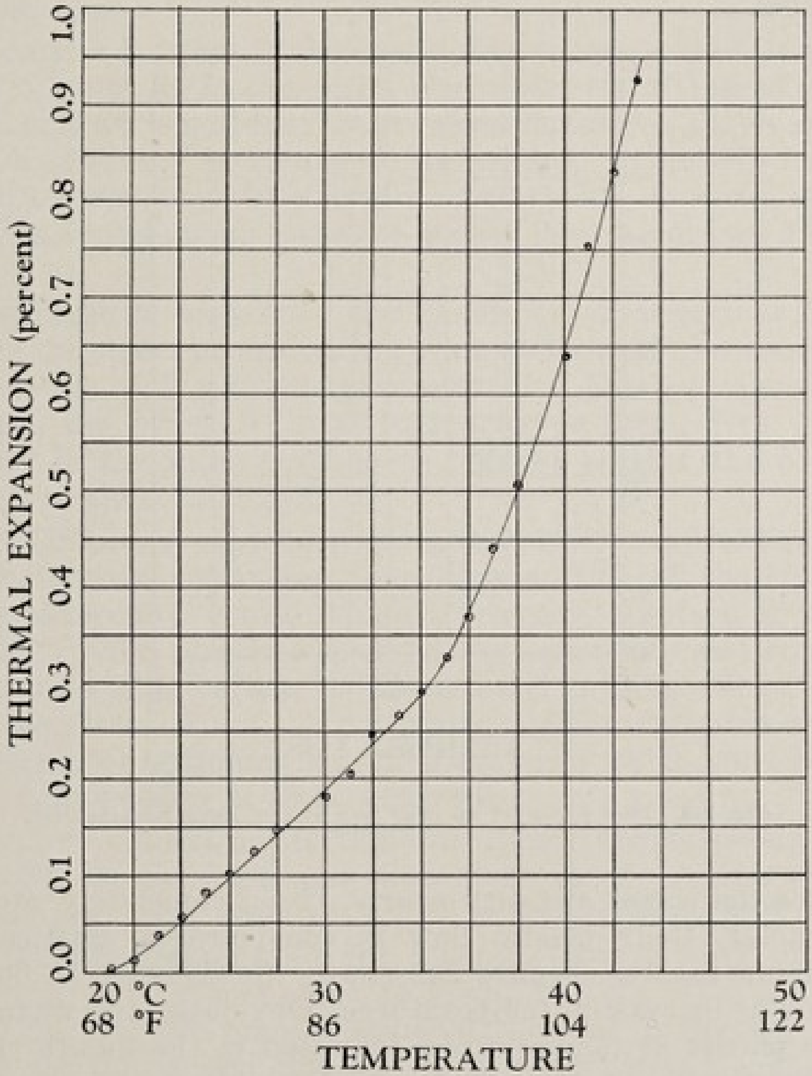

FIG. 248. Typical linear thermal expansion curve for a dental inlay wax.

The commercial varieties of modern inlay waxes start to smoke at an approximate temperature of 240—290° F., and have a flash point approximately 150° F. higher. Their thermal properties are quite striking, especially as regards thermal expansion, which is generally very large.

In Figure 248 a typical linear thermal expansion curve for an inlay wax is shown. The non-uniformity of the curve should be

noted. It is obvious that no general constant can be given for computing the expansion of the wax for the total temperature range. The reason for this non-uniformity is due to the varying thermal expansions of the ingredients; carnauba wax for example shows larger thermal dimensional changes in comparison to the others.

For casting purposes, the thermal expansion should be kept as low as possible up to body temperature, so that the contraction of the pattern from mouth to room temperature shall be as small as possible.

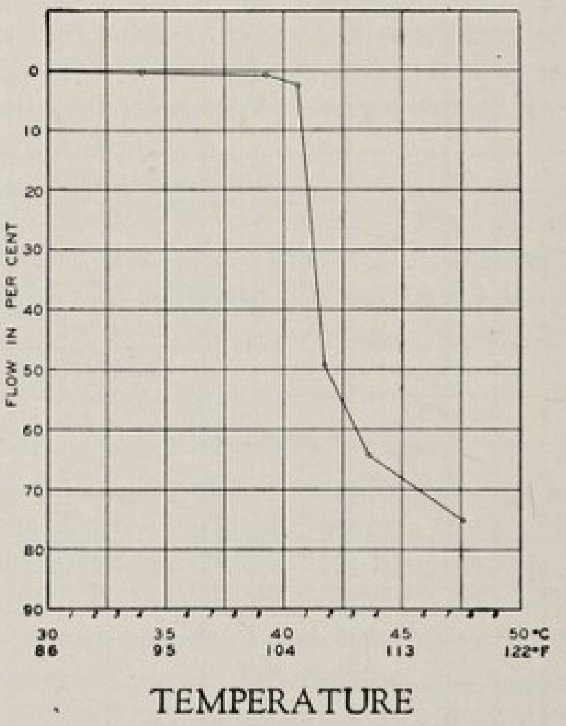

Fig. 249. Flow curve for an inlay wax at increasing temperatures.

Since the waxes are very nearly, if not completely, amorphous in character, their plastic flow is considerable, particularly at higher temperatures. Figure 249 shows the increase in flow of an inlay wax at increasing temperatures. Obviously, the waxes should be quite plastic at temperatures tolerated to the mouth tissues in order that they may be molded into the cavity, yet at mouth temperature they must be sufficiently rigid that they will not be distorted when the pattern is withdrawn.

Amorphous materials are considered to be supercooled liquids, that is—liquids which have solidified with their molecular configuration intact, a condition which is distinctly different from the freezing of a crystalline material, where a rearrangement from the liquid molecular configuration to a definite crystalline arrangement takes place.

Being principally amorphous materials, inlay waxes exhibit

characteristics of both the liquid and solid states. Liquids exhibit viscosity—the molecules can slide over one another so that the liquid always settles to the lowest point in a container. If a stick of wax is bent suddenly, between the fingers at room temperature, it breaks much like a glass rod; yet if it is supported between blocks, placed at each end, the stick will gradually flow of its own weight, even though the temperature is the same as before. At higher temperatures, the waxes are more nearly liquids than solids, but at room temperatures they show a preponderance of solid properties.

As long as it is solid, even at higher temperatures, it exhibits elasticity,* which is in general a characteristic of the solid state. If a stick of wax is softened, bent into a horseshoe shape and then released, a tendency to return to its original shape will be noted. The stick of wax may be placed under tension at room temperature, and a stress-strain curve of a sort may be drawn from the data.

In amorphous materials, the molecular arrangement is probably quite random in nature, yet it may be assumed that a preferred average molecular distance exists. If this average distance is changed, the molecules tend to rearrange themselves (but not necessarily in the same position as before) so that the preferred distance is again established.

For example: A stick of wax, cooled under compression, shows a greater thermal expansion than does a stick of the same wax and same dimension cooled without pressure. In fact, if the wax is stretched while plastic, cooled in that position, and cut to the same dimensions as before, it will actually contract when its temperature is raised. All of these examples demonstrate the existence of a preferred or optimum molecular distance which must be maintained if homogeneity is to be realized.

It follows, therefore, if the wax is not homogeneous, it will change with temperature and time more in one region than another, thus providing an effect which is termed *distortion*.

From a practical standpoint, such a theory is very important in explaining what may happen to a wax pattern after it has been carved. Consider the manipulation of the wax if certain precautions are not taken, and compare them with the above examples: The wax is forced into the preparation under pressure and chilled. Some regions are compressed more than others. The wax is carved, which tends to displace molecules and to introduce strains. Perhaps it is short at the gingival and more wax is added, and allowed to cool without pressure. It is removed from the cavity and held in

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* By elasticity is meant the attraction between molecules tending to restore a body to its original shape, at a constant temperature (see Glossary, Vol. 1). The term, as used by Price[38] and others in connection with wax, must not be confused with the present meaning.

the hand, involving a temperature change from that of the mouth to the room, and then to that of the hand. A hot sprue pin is inserted in it, and then it is carried to another room of a different temperature, and invested in cold water, or, what is worse, it may stand uninvested for three hours to three days or longer. One who has thoroughly mastered the theory involved will readily understand why the final casting does not fit. These phenomena have been known[35, 38] for a considerable time, but they have not received the attention which they deserve.

These distortions cannot be entirely avoided, but they can be reduced greatly by proper manipulation of the wax.

To summarize: An expansion is an enlargement in volume per unit volume *equal* in all directions and parts, whereas a distortion is a *change* in volume, but *not* equal in all directions and parts. So far as waxes are concerned, it may be stated that a wax thermal *expansion* takes place only if the wax is homogeneous (i.e. of equal density) throughout, otherwise distortion occurs. The same reasoning may be applied to the thermal contraction. If the contraction is not uniform in all portions of the wax during a given temperature change, a distortion occurs.

Inlay Casting Investments.

After the pattern has been made it is placed in an investment for the purpose of forming a casting mold.

Dental investments are essentially plaster of Paris and quartz. In order to be efficient in modern practice of dentistry, an investment should have the following properties: (1) The constituents should segregate neither while in the container nor during manipulation. (2) The investment should mix together with the water so as to give a smooth consistency, and (3) it should set neither too rapidly nor too slowly. (4) It should have a fineness of particles and a composition such that the surface smoothness of the casting will not be impaired. (5) It should contain no ingredients which are injurious to the casting metal. (6) It should neither crack nor give off offensive odors when heated. (7) It should have sufficient setting or thermal expansion or both for casting and wax shrinkage compensation. (8) The temperature of maximum thermal expansion (i.e., casting temperature) should not be critical, and such a temperature should be within the range of normal dental practice. (9) It should have a reasonably high crushing strength. (10) It should have sufficient porosity to vent the air from the mold during casting.

The plaster of Paris acts as a binder, and provides the setting expansion of the investment. It also affects the crushing strength; in general, the higher the plaster content, the greater will be the crushing strength.

The setting expansion probably is caused by a change in crystal space lattice of the plaster after the initial set.* The wax pattern is expanded along with the investment during this expansion. However, if the investment is confined by bulky three surface patterns for example, only part of the setting expansion is effective. The pattern is not stretched or distended by the investment, but rather undergoes a thermal expansion at the same time that the setting expansion is taking place, the heat being furnished by the heat of reaction between the plaster and water and the heat evolved during the crystalline change.[39]

The setting expansion is very easily reduced or even restrained completely if the investment is confined on three or more sides. It

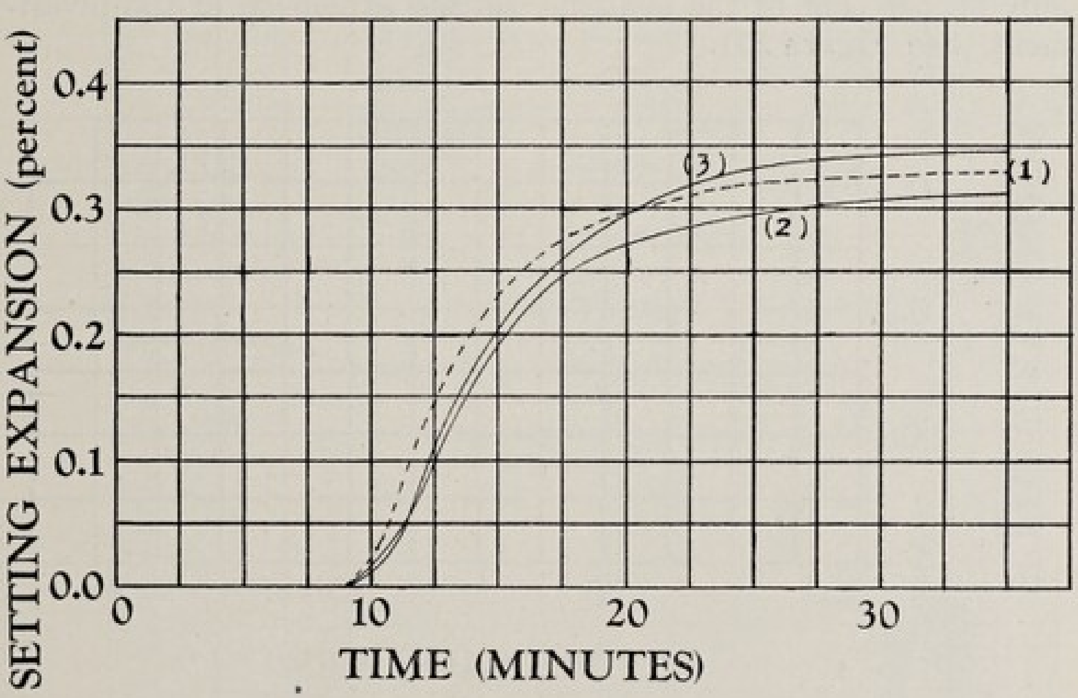


FIG. 250. Free and effective setting expansion for an investment of approximate composition: Plaster of Paris, 45 per cent and quartz, 55 per cent. Curve (1) free. Curve (2) confined in hard inlay wax, thickness 0.8 mm. Curve (3) confined in hard inlay wax, thickness 2 mm.

may be readily seen that a three surface wax pattern provides such confinement, unless it expands at the same rate and time that the investment does. If the change in temperature brought about during set is not great enough to expand the pattern *thermally* to the same extent that the investment expands in setting, obviously all of the investment setting expansion will not be effective so far as the increase in dimension of the pattern is concerned. *Free setting expansion* of an investment is that expansion which takes place in setting when the investment is free to expand unimpeded in all

* This explanation seems to be the most plausible at the present time, but the exact cause of the setting expansion of plaster of Paris is debatable.

directions, whereas *effective setting expansion* is the amount of expansion which the wax pattern takes on during set, regardless of the free setting expansion and may be counted as effective in compensating for shrinkage as explained later on. Of course such a theory precludes any wax flow. If the heat received by the pattern is sufficient to soften it, a serious distortion will result.

Since the heat is furnished by the plaster, the greater the plaster content, the closer the effective setting expansion will approach the expansion exhibited when the investment is free. For example, it has been shown that the effective setting expansion is exactly the same as the free setting expansion for an investment containing 45 per cent plaster of Paris. See Figure 250. In another investment containing 25 per cent plaster, the pattern expanded only 52 per cent of the available setting expansion of the investment. See Figure 251.

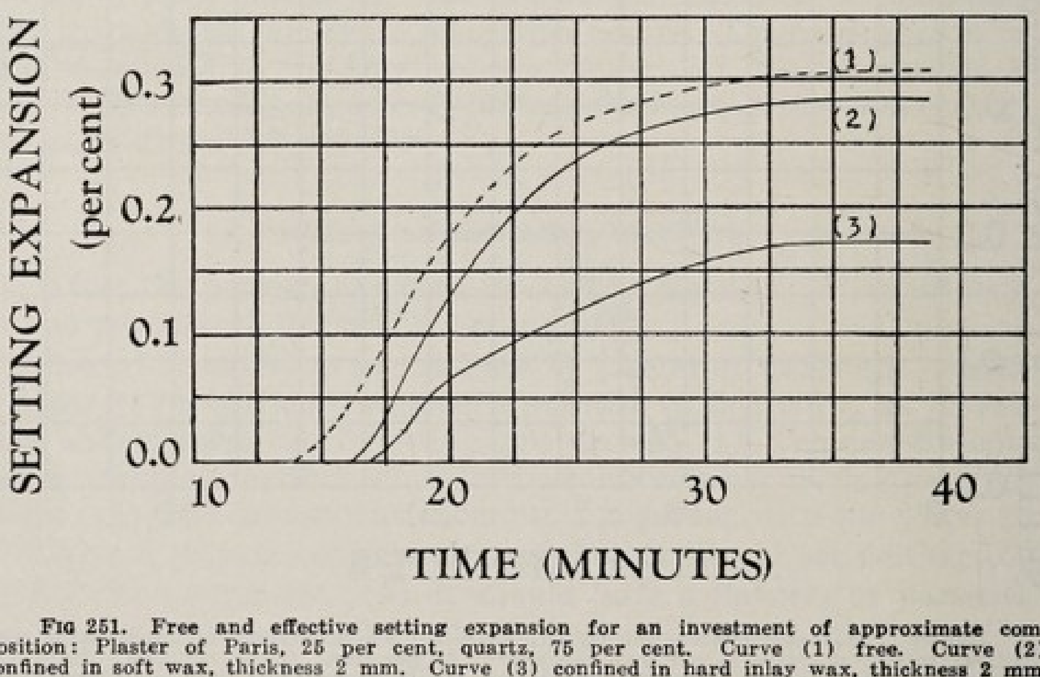


FIG 251. Free and effective setting expansion for an investment of approximate composition: Plaster of Paris, 25 per cent, quartz, 75 per cent. Curve (1) free. Curve (2) confined in soft wax, thickness 2 mm. Curve (3) confined in hard inlay wax, thickness 2 mm. In setting, the investment generated enough heat to cause the soft wax to flow, thus practically realizing the entire expansion. The hard wax did not flow, and did not expand thermally enough to allow the normal setting expansion to take place.

The thermal expansion of plaster of Paris is very poor in relation to the treatment to which the plaster is subjected in casting. At high temperatures, it is very weak and shows a marked thermal contraction, which prohibits its use alone as a mold forming material. As noted elsewhere, the gold alloy shrinks 1.25 per cent during solidification, and plaster alone might increase the error as much again.

Figure** 252 shows the thermal changes which take place when

**This graph and Figures 253, 255 and 256, are taken from a paper by Drs. Paffenbarger and Volland, printed in the Journal of the American Dental Association.[40]

plaster of Paris is heated. Note that a small expansion occurs up to a temperature slightly above the boiling point of water, which is followed by a marked contraction as the temperature rises further. Had the temperature been raised to a higher value than is shown in the graph, a slight expansion might have been noted following the contraction.

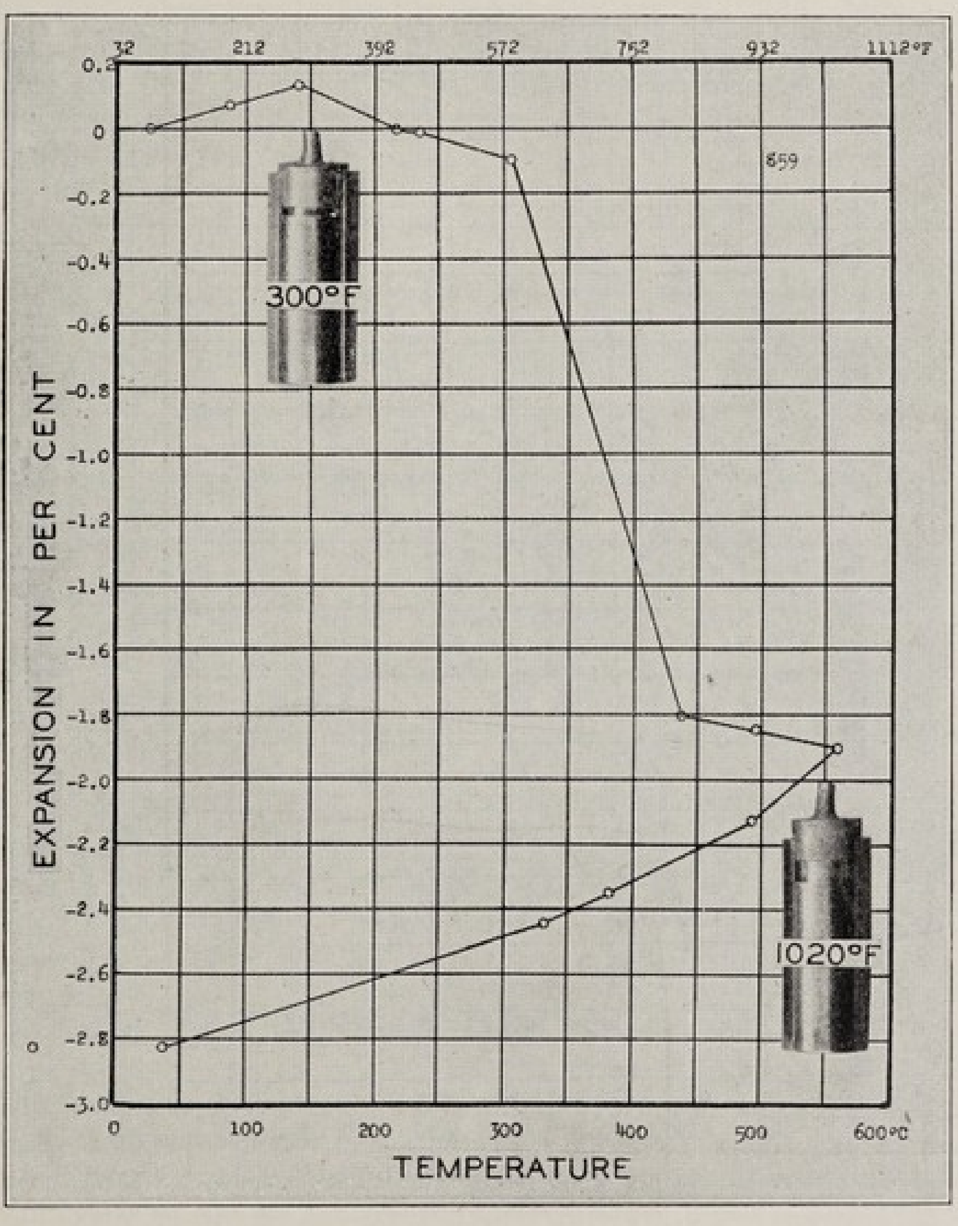
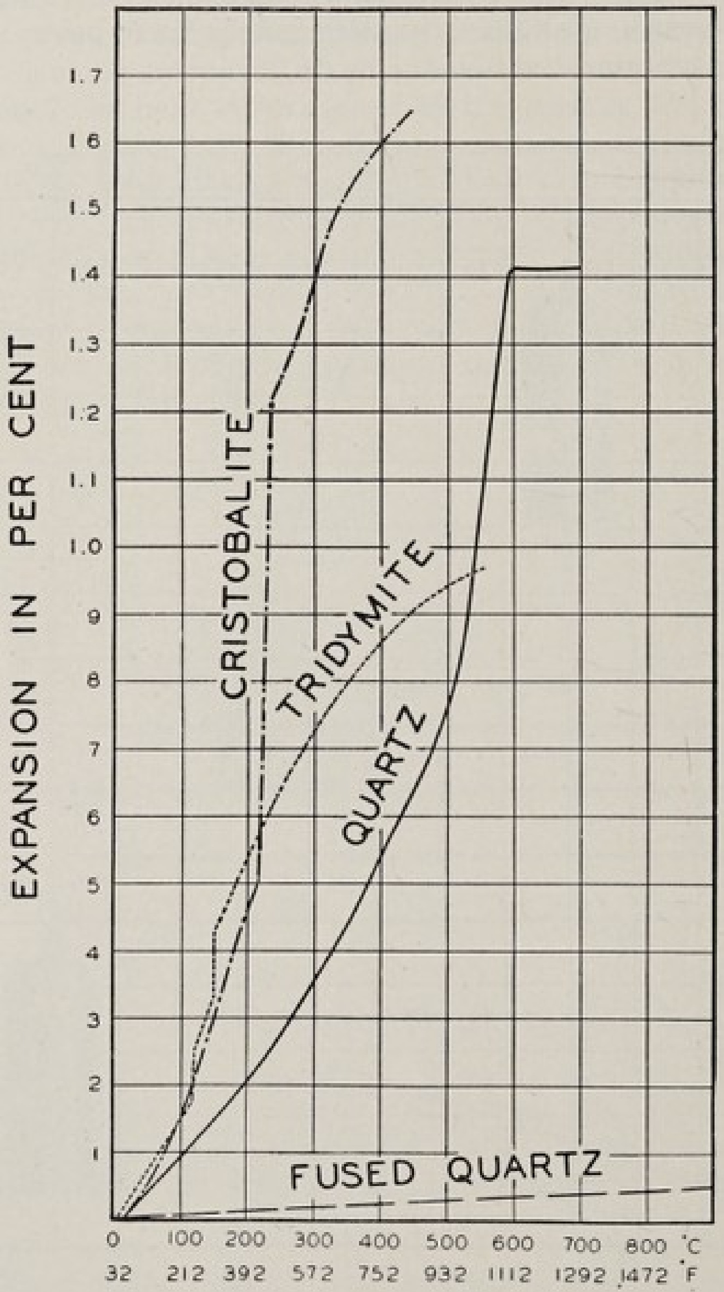


FIG. 252. Thermal expansion curve of plaster of Paris. (Courtesy Journal Amer. Den. Assn.)

Quartz is added to the investment as a filler, both to make it more refractory and to give it the property of thermal expansion. There are four allotropic forms of quartz or silica which are of interest: (1) Fused quartz which is amorphous in character and

has little application in this connection; (2) quartz; (3) tridymite; and (4) cristobalite. All of these materials have the same chemical formula, but are physically different.



Cristobalite (Braesco) Tridymite (Braesco). Quartz (Braesco). Fused silica (Souder and Hidnert)

FIG. 253. Thermal expansion curves of four forms of silica. (Courtesy Journal Amer. Den. Assn.)

Figure 253 shows their respective thermal expansions. Fused quartz has a very low but regular thermal expansion. The other three show fairly regular expansions until a certain temperature is reached, when their expansion rates show a sudden increase. This is caused by an allotropic change or inversion in the crystal-

line structure to a new lattice which is stable only at the higher temperatures. Comparing these curves with that for the thermal dimensional changes of plaster of Paris, Figure 252, the advantage of combining these materials with plaster becomes apparent at once.

The thermal expansion gradually increases with decrease in the plaster content as might be predicted. The fit of the castings on the dies varies according to the expansion realized. Not until the gold shrinkage value (1.25 per cent) is approached, do the castings fit. The temperature at which the casting was made is printed through the die, and the fit may be compared directly with the curve below it.

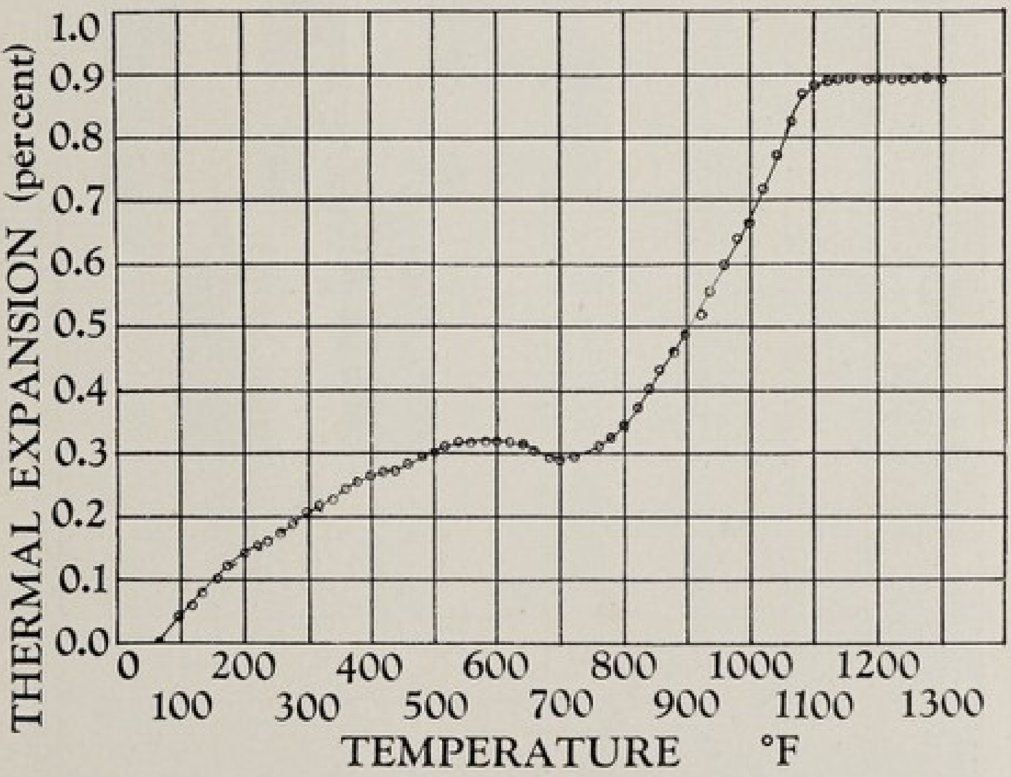


FIG. 254. Thermal expansion curve for an investment of approximate composition: Plaster of Paris, 45 per cent; quartz, 54.2 per cent; sodium chloride, 0.8 per cent.

The amount of quartz which may be introduced is limited by the fact that the crushing strength decreases with decrease in plaster content, until the investment becomes dangerously weak. The formula of 25 per cent plaster and 75 per cent quartz is approximately the limiting value in this respect. It has been found that the addition of certain chemicals such as boric acid, or sodium chloride,* tend to eliminate the investment contraction which usually occurs before the allotropic change of the quartz, thus very materially increasing expansion. Figure 254 shows the thermal expansion curve for an investment of the approximate composition:

* Sodium chloride is the most efficient.[41]

45 per cent plaster of Paris, 54.2 per cent quartz, and 0.8 per cent sodium chloride.

Cristobalite occurs only rarely in nature. It is manufactured by heating quartz (sand) of different varieties above a temperature of 1450° C. (2642° F.) when the quartz is changed to cristobalite. The change is rarely complete, and the commercial variety used in investments undoubtedly contains a certain amount of tridymite and quartz. It is used in combination with plaster in

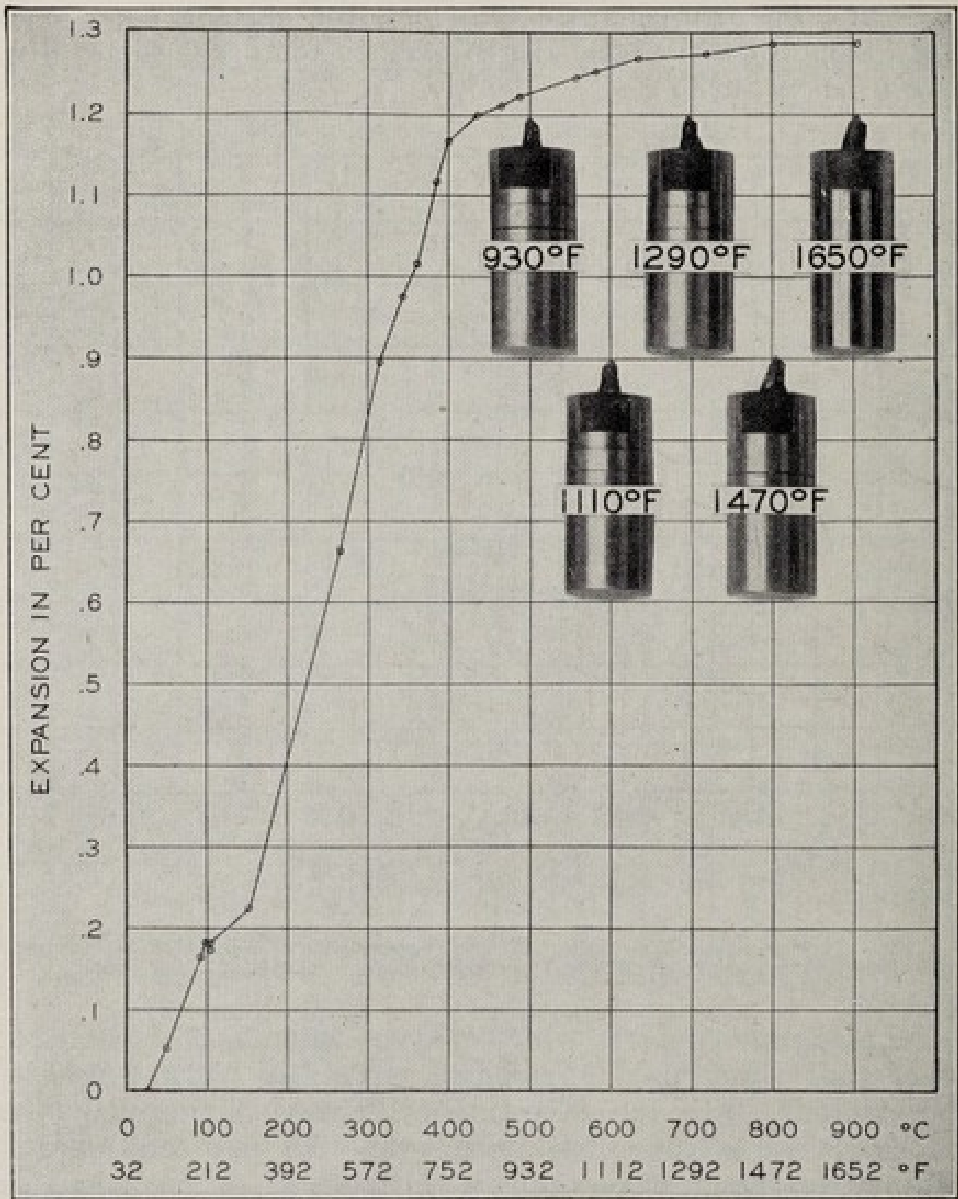


FIG. 255. Thermal expansion curve: Cristobalite investment. (Courtesy Journal Amer. Den. Assn.)

the investment in the same manner as quartz.[47] It has at least two advantages when used in the investment in place of quartz: It expands more during its inversion from low cristobalite to high

cristobalite and also its inversion occurs at a lower temperature. See Figure 255.

The inversion temperature of quartz occurs at 1065° F. (575° C.) whereas that of cristobalite takes place at 390° to 525° F. (199° to 274° C). Thus greater thermal expansion can be realized with the cristobalite investment at a lower temperature. However, there are certain difficulties with this type of investment which are not as yet understood, although in the hands of many dentists it is proving very satisfactory.

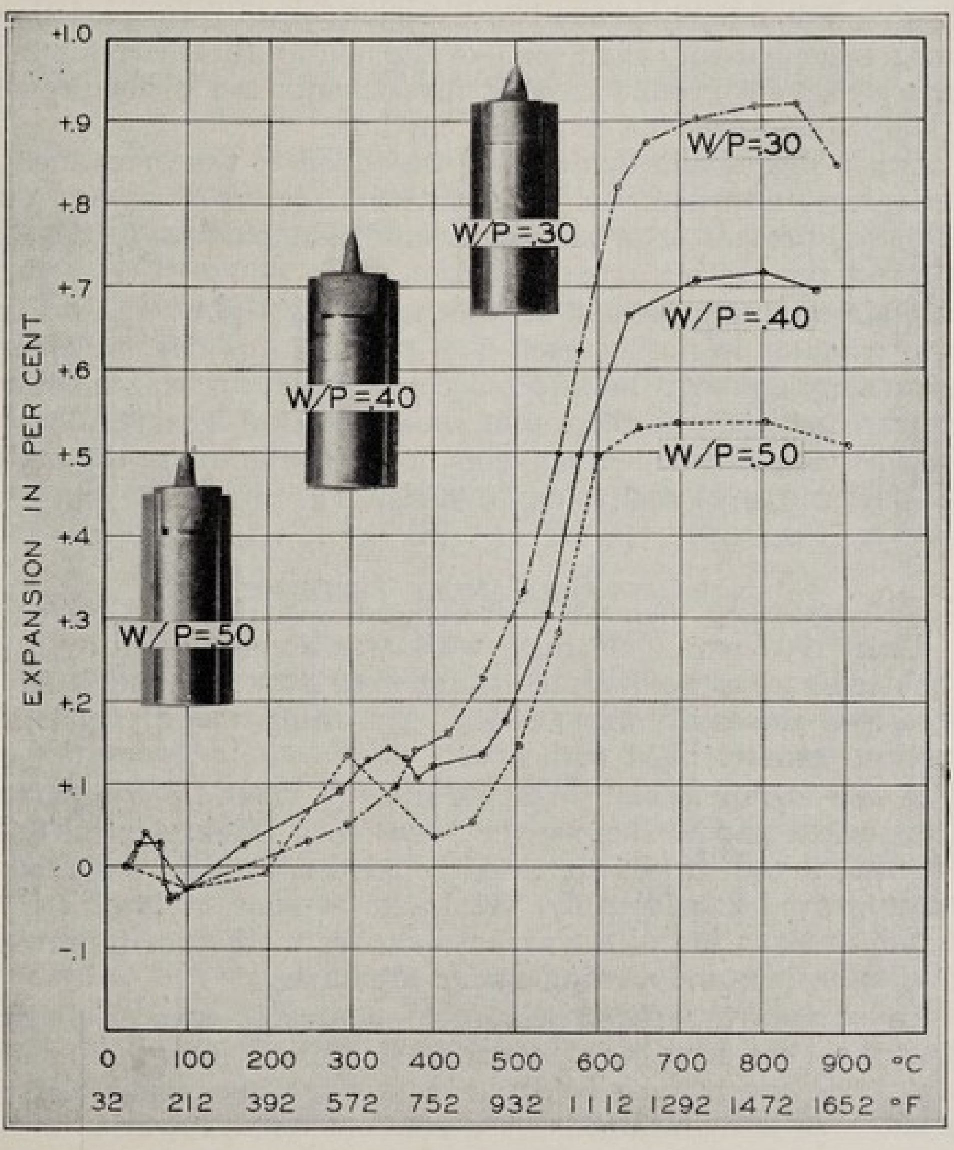


FIG. 256. Thermal expansion curve of 20 per cent plaster of Paris. (Courtesy Journal Amer. Den. Assn.)

Figure 256 shows the influence of various investment water ratios upon the thermal expansion of the investment. It should be noted that the expansion decreases with increase of water content in the mix. This is also true for the setting expansion. It is

evident that the proportions of investment and water must be measured with accuracy, if the expansions are to be controlled. The student should notice this fact carefully, as manufacturers sometimes claim otherwise. This is a scientific fact, and *is true for all types of investments.*

The porosity of an investment is an important factor. The air must escape from the mold ahead of the molten gold. In general, the porosity decreases as the plaster content increases,[2] and also as the proportion of water used decreases. The fineness is not necessarily a factor in porosity, but rather the uniformity of particle size. Some finely ground investments of uniform particle size, show greater porosity than some of the non-uniform coarser investments.[42] Finely ground casting investments are to be preferred, as they help to produce smoother castings.

Other ingredients which may be added to the investment are accelerators, retarders, coloring matter, asbestos fiber, and fluxes. If a flux is present, it is usually carbon. The purpose of the flux is to protect the casting from oxidation.

The investment should be kept in an air tight container at all times, when it is not in use. The plaster of Paris is somewhat hygroscopic, and will be affected considerably by the moisture in the air. Furthermore, the top of the can should be carefully wiped off each time before opening, so as not to contaminate the material with dust particles and other impurities.

Cast Gold Inlay Technic.

Until 1907 most gold inlay work was accomplished by casting or soldering to a gold or platinum matrix which had been burnished over the cavity preparation. The result was a poorly fitting structure, usually filled with pits.

A new era in dentistry started in 1907, when Dr. Taggart read his historical paper[43] before the New York Odontological Society on casting inlays in one piece. Although Dr. Taggart's method has been improved considerably, yet in its essence, it is still in use, viz., the preparation of a wax pattern, the method of its investing and elimination, and casting under pressure.

Dr. Taggart realized that gold contracts when solidifying. After the gold has been melted and forced into the mold, he states:[43] "While it (the gold) is in this freshly molded condition the pressure is maintained for a few moments, in order to allow the molten gold to thoroughly congeal; either this continued pressure prevents the gold from contracting, or the amount of expansion in the hot mold is equal to it; at any rate the filling fits."

As the profession became more critical of this new invention, it became apparent that the inlays did not fit, and the reasons for the discrepancies were ardently sought.

In a paper by Dr. Price[35] read at the National Dental Asso-

ciation Meeting at Denver, July 20, 1910, twelve variables were noted, all of which he recognized as contributing to faulty casting; he further recognized the necessity for controlling them to offset gold contraction and other errors. Quoting from his paper, the variables are as follows:

"(1) Change in the dimensions of the impression or the pattern by the cooling when removing.

"(2) Change in the dimensions of this impression or pattern material by change in temperature when investing.

"(3) Change in the shape of the pattern due to the elasticity of the wax.

"(4) Change in the dimensions of this investing medium in its process of setting.

"(5) Change in dimensions of this investing medium in the process of heating, or heating and cooling.

"(6) Effects of the wax or pattern material on the investing medium.

"(7) Change in the investment dimensions from the pressure of the gold when casting.

"(8) Action of the molten gold on the investing medium.

"(9) Change in dimensions of the gold with its change of state from liquid to solid.

"(10) Change in dimensions of the cooling gold.

"(11) Distortion of the mold in the investing medium by the cooling gold.

"(12) Stretching of the gold if held when cooling."

No better summary of the variables involved can be given at the present date. The paper was considerably ahead of its time, since the materials available could not possibly have overcome these variables. Hence it was lost sight of and many of the variables have been rediscovered within the last few years.

Dr. Van Horn appears to have presented the first paper[44] in which was outlined a casting technic which would successfully compensate for the shrinkage of gold and wax. This paper was read before the Susquehanna Dental Association at its annual meeting on May 24th, 1910. Dr. Van Horn recognized the most important of Dr. Price's twelve variables, although working independently.

The Dental Group at the National Bureau of Standards, together with the Cooperative Research Group, under the auspices of the Dental Research Commission of the American Dental Association, have made outstanding as well as fundamental contributions to this field.

Due to the standardization and improvement of materials, the casting technic has reached a precision unheard of a few years ago. However, there are still many refinements to be made.

General introduction to the casting technic.

The object of the casting procedure is to cast an inlay which is in form an exact duplicate of the missing tooth structure. If the inlay is to function permanently in place of the lost portion of the tooth, it should fit the cavity with absolute exactness.

It is a physical law that lowering the temperature of a body causes it to contract, and conversely, if heat is applied, it expands. As already noted, the gold alloys contract 1.25 per cent when cooling from the fused state. However, there are other contractions involved, the principal one being the wax contraction. Room temperature is usually lower than mouth temperature. Therefore when the pattern is taken in the mouth, it contracts an average amount of 0.4 per cent from mouth to a room temperature of 68° F. If the temperature be higher than this, it will contract less. Whatever the contraction, it must be added to that of the gold.

As in balancing a ledger, the shrinkage must be balanced by certain compensation methods, if the inlay is to fit in the mouth. Obviously, if a contraction is to be overcome, it must be done by a counteracting expansion. In the case cited above, the wax pattern at room temperature will be too small by an amount equal to its thermal contraction (0.4 per cent) plus the gold contraction (1.25 per cent), thus making a total contraction of 1.65 per cent. Therefore, in order for the casting to fit the tooth, the mold must be made 1.65 per cent larger at the time of casting than the pattern at room temperature. The accomplishment of this is known as *compensation.*

There is a casting technic available which uses a type of setting expansion alone. This method was discovered and developed by Dr. C. H. Scheu.[45] He found that when certain investments were placed in water at the time of initial set, they expanded to an extent as high as 2.2 per cent. The reason for this phenomenon is not known at the present time. This type of expansion is known as "hygroscopic expansion", to distinguish it from the ordinary setting expansion due to the normal allotropic change in crystalline form of plaster of Paris.

The hygroscopic expansion may be controlled so as to give a very accurate means of compensation. It is unfortunate that the method has not been adopted more widely by the profession than it has at the present time.

As yet no investment is available to the profession which will give the total compensation required by means of thermal expansion alone. This can be done, and it is a refinement in method which should be made. The setting expansion introduces some as yet uncontrollable errors which seriously impair the accuracy of the work in many types of castings [46] due to the hygroscopic expansion as a secondary effect.

Inlays made by the most perfect technic yet developed always

show widely exposed margins under the microscope, whereas the openings should be submicroscopic. The greatest single uncontrolled factor is wax distortion, which cannot be entirely avoided under any conditions. For this reason, the inlay is inferior as a seal to the tooth structure in comparison to a correctly placed gold foil restoration, for example. Other uncontrollable errors, so far as the operator is concerned, are lack of standardization of materials by the manufacturer, and room humidity and temperature changes.

PREPARATION OF THE WAX PATTERN. The most generally employed methods of preparing a wax pattern are the *direct*, the *indirect* and the *impression* methods. The direct method, as the name signifies, consists of taking the pattern directly in the mouth, doing all contouring and polishing before removing it from the cavity. When the indirect method is used, an impression is taken of the cavity preparation, using impression compound in a matrix band. A model is made in the impression and the pattern is secured from the model. These methods are discussed elsewhere.

The contraction of the impression compound from mouth to room temperature averages approximately 0.3 per cent. The unknown factor is the change in dimension of the model materials.

The materials which are usually used for models when the indirect method is used, are: Quick-setting stone, silver amalgam, copper amalgam, and silicate cement. All of these show unpredictable setting changes, which introduce unknown errors.

After attaching the sprue former, the pattern should be placed on the sprue base and invested immediately.

INVESTING THE PATTERN. It is at this stage that care must be taken to insure a smooth casting. There are probably six causes [42] of surface roughness on castings: (1) Coarse investment; (2) too high a proportion of water used in the mix; (3) excessive vibration of the pattern during the investing process causing water to collect on the surface of the pattern; (4) unclean patterns; (5) air bubbles in the investment; and (6) too rapid rate of wax elimination.

It may be noted that all the points except the last one can be eliminated while investing. To summarize: Assuming a fine investment, surface roughness in dental castings is due to water and air bubbles collecting on the pattern during the investing process.

Localized shrinkage must also be given consideration. As previously noted when the gold freezes it clings to the walls of the mold during a certain stage of the process. At this stage the metal tends to shrink toward the periphery, leaving voids at the center of the casting. If the sprue freezes before the casting itself, no more molten metal can pour in to fill up these voids, hence a porous casting results.

It is obvious that either a sprue former of fairly large diameter must be used, or else a reservoir provided.

The latter may be accomplished by placing a ball of wax on the sprue former, *close* to the pattern. By *close* is meant one-sixteenth of an inch or less. Even at this small distance, the connection between the wax ball and the casting should be enlarged with wax, if a small sprue former is used. The size of the wax ball should be *at least* as large as the thickest portion of the pattern. After elimination, the space occupied by the wax ball, and its vent to the casting is to serve as a reservoir as described above, so that the molten gold will pour into the voids left by the gold freezing at the casting periphery. In other words, this portion should be the *last to solidify*. Only plenty of bulk of the molten metal at this point will insure this.

The sprue former should be placed on the sprue base so that the highest portion of the pattern (the portion most remote from the sprue base) reaches to within one-third of the distance from the open end of the flask. This will insure proper venting of the mold for the escape of air.

The casting flask should be lined with asbestos to provide for setting and thermal expansion of the investment during elimination.

The pattern may be washed with a solution of equal parts of tincture of green soap and hydrogen peroxide to remove any blood or saliva sticking to it, then syringed with room temperature water.

In painting the pattern there are several obstacles to be overcome, which cannot be balanced. If considerable care is taken to prevent water and air bubbles from forming on the pattern, it means that time must be spent in investing. Under ordinary conditions of temperature and humidity, the water in the investment is evaporating, which cools the patterns considerably, with a resulting shrinkage and distortion. By actual experiment this shrinkage has been found to be as great as 0.3 per cent in four minutes after the painting was begun. This is a point which has been overlooked by many dentists, and is well worth considering. Obviously, the pattern will return to room temperature after it is placed in the filled flask, but nevertheless the resulting distortion is likely to be considerable.

The air bubbles may be largely removed by proper mixing as hereinafter outlined, but the water bubbles are not easily avoided.

If a stick of inlay wax be dipped into water, it will be observed that the water clings to it in droplets. The water does not "wet" the wax, i. e., there is very little cohesion between the water molecules and those of the wax. Since water has considerable surface tension, it "balls up." If this surface tension can be reduced it will spread evenly and smoothly over the surface of the wax, thus avoiding drop formation. The following procedure is recommended for the beginner at least, as a means of insuring a smooth casting. However, it must be admitted that the smoothness may be obtained somewhat at the expense of wax distortion.

A small mix of investment and water, about the consistency of cream, is made in a small dish. This is painted thoroughly over the pattern with a brush, and blown off. If the wax shows through at any point, the procedure is repeated until a smooth *thin* coating of investment is formed over the entire pattern surface. The coat is so thin that it will not prevent the expansion of the pattern during the setting of the investment, yet when hardened it will be sufficient to prevent the collection of water on the surface during subsequent manipulations. The theory is that the plaster in the investment dissolves in the water, lowering the surface tension of the latter so that it will spread. After setting, the investment is quite insoluble, and will stay in position.

The main investment mix is now made in the proper proportions with a mechanical mixer. The investment and water mixture should be vibrated before and after the mixing. The pattern is covered with the new mix and placed in the flask, which is also filled. If the "investment wash" is used as described above, vibration may be used while investing. If the wash is not used, the vibration should be limited, as it may cause bubbles to collect on the pattern.

The investment should be allowed to set for at least thirty minutes before starting to eliminate the wax.

Heating the mold. The sprue base and sprue former are removed, and the flask is placed in the elimination furnace. The flask should be heated gradually until the boiling point of water is reached to dry out the investment. Failure to do this may result in an explosion due to entrapped steam. Electric eliminators are much preferable to gas for this purpose.

After the excess water has been driven off, the case may be brought up to red heat (1290° F.) in thirty to forty minutes. This heating must not be hurried, as it must be remembered that the investment is a poor thermal conductor. As an illustration, consider what happens if water is heated in a thick glass tumbler over a Bunsen burner. The glass is a poor thermal conductor. The portion next to the flame becomes hot before the inside does. The outside portion expands thermally, whereas the inside does not. Because of the unequal forces the glass cracks.

In a similar manner, if the case is heated too rapidly the outside of the investment starts to expand before the inside does and a crack forms. The flask should be heated slowly enough so that the temperature gradient between the outside and inside may remain nearly equal. This is particularly necessary when using cristobalite investment.

The wax will burn out as the temperature increases, leaving a carbon residue. The latter will combine with the oxygen in the air and go off as carbon monoxide and dioxide gases. When the

mold has reached a cherry red color as seen through the sprue, the case is ready to be cast. The color should be noted with the flask in a shaded position. In bright light, what appears to be a cherry red color may actually be a bright cherry red or even orange under correct conditions of observation. Such a temperature is too high. The casting should be made immediately.

CASTING THE GOLD. To insure against the cooling of the mold after the flask has been removed from the furnace, and the consequent loss of thermal compensation, the casting should be made within one minute.

The gold may be first melted on a charcoal block before the flask is removed from the furnace. Such a procedure not only reduces the casting time, but also removes any occluded gases, which are another factor causing internal porosity.

The choice of a casting machine is a personal one. Any device which will force the gold into the mold with the correct amount of pressure is satisfactory.

The flask is quickly placed in position, the gold is placed in the crucible, and a reducing flame is applied. The gold may be fluxed if necessary. It should be thoroughly melted and carried to an orange color.

It is not enough simply to melt the gold, but it should be carried approximately 200° F. beyond its melting point to give it sufficient fluidity so as to insure casting detail. It must be understood that it is not impossible to overheat the gold. However with students, at least, using a gas-air blow torch, the tendency is to underheat rather than overheat. Underheating of gold is one of the causes of discontinuity between the button and the casting proper, as well as failure to fill the mold completely.[87] Other causes are insufficient casting pressure and insufficient amount of metal.

The fluidity of the gold may be tested by moving the flame slightly. If the molten ball tends to move with the flame, and has a clean orange colored surface, the machine may be released.

The casting should be quenched as soon as the button (the portion of the gold remaining in the crucible) turns black. This not only softens the gold, but also helps to free it from investment, by the explosive action of the water when it penetrates the hot mold.

The casting may be pickled in a 30-40 per cent solution of sulphuric acid.

DENTAL CEMENTS

Cements are used in operative dentistry both as a lute for inlays and for restorations. They may be classified as zinc phosphate cements (sometimes erroneously called zinc oxyphosphate), copper cements, and silicate cements. All types have much in common as to content, chemical reaction and manipulation. They

all consist of a basic powder which is mixed with a liquid which is mainly orthophosphoric acid, the two reacting to form a hard mass.

It should be stated at the outset that much that is written at the present date may become somewhat obsolete in a short time due to the work now in progress by the dental research group at the Bureau of Standards. Already a specification* has been made for the zinc phosphate cements which demands a much superior product than was available only a few years ago. At the present time another specification is in process of assembly for the silicate cements.

An ideal cement, whether used as a cementing medium or a restoration, should have the following properties:

1. It should be strong and hard, yet not excessively brittle. The hardness should be comparable with that of the tooth structure.

2. It should be cohesive and adhesive. It should show adhesion, both before and after set, to any substance in the mouth with which it is brought in contact while soft.

3. It should be insoluble, particularly in the mouth fluids.

4. At no time should it have any detrimental corrosive, or other harmful pathological action, upon the mouth tissues with which it comes in contact.

5. It should not contract during set, but rather it should show a slight expansion. Subsequently, during use, it should never contract under any normal conditions, nor should it expand sufficiently to harm the restoration in any way.

6. It should have a coefficient of thermal expansion, similar to that of the tooth structure, and it should exhibit a low thermal conductivity.

7. It should be easy to manipulate, both in and out of the mouth.

8. It should be able to take and retain a high polish.

9. It should be absolutely non-porous in nature, and should be free from bubbles of any sort.

10. Its physical and chemical form should not be impaired by moderate changes in temperature and humidity.

11. Its color and general appearance should harmonize with that of the tooth structure, if the cement is to be used in a position where it will be exposed to view.

There is no cement at the present time which even approximately meets these requirements. Some of the properties noted are under control of the dentist, and the others must be met by the manufacturer. Considerable improvement is needed from both quarters, which can be gained only by diligent research and study

* Specification No. 8

Zinc phosphate cements.

The composition of the powders of sixteen zinc phosphate cements as analyzed at the National Bureau of Standards [48] is shown in Table 2. These are all commercial dental brands, bought in the open market by the American Dental Association Research Commission.

Table [48] 2

Composition of Zinc Phosphate Cement Powders
(Percentage by Weight)

Sample	*ZnO*	*MgO*	*SiO_2*	*R_2O_3*	*Bi_2O_3*	*Miscellaneous*
A	100.0	...	0.05	0.05	...	
B	99.7	...	0.1	0.1	...	CaO, 0.1
C	98.0	...	...	...	1.9	
D	99.4	...	0.6	0.1	0.04	
E	92.4	7.5	0.1	0.06	...	CuO, 0.1
F	90.3	8.2	1.4	0.1	...	
G	90.2	9.4	0.4	0.07	...	
H	89.9	9.1	0.4	0.5	...	
I	89.5	9.4	0.3	...	...	$BaCrO_4$, 0.8
J	89.3	9.4	0.3	0.1	...	CuO, 0.02; $BaCrO_4$, 1.0
K	88.0	9.4	0.8	...	1.8	
L	89.1	4.0	1.8	0.5	4.5	
M	82.2	9.0	3.0	0.9	4.1	CuO, 0.8
N	83.1	7.2	0.1	0.04	...	$BaSO_4$, 8.2; BaO, 1.3
O	84.0	7.2	4.9	1.0	...	CaF_2, 2.7
P	74.9	13.0	1.3	2.6	...	BaO, 2.2; B_2O_3, 5.1

It will be noted that the cements are of three types as regards composition.

The first four cements, except for the coloring material, may be said to be pure zinc oxide (ZnO) powders, the rest of the ingredients probably being accidental.

The next seven, again excluding coloring matter and impurities, may be called ZnO-MgO cements, the powder having been modified by the addition of magnesium oxide in approximate ratio of ten parts of ZnO to one of MgO.

The last five powders, although mainly zinc oxide, have been modified further by the addition of silica and bismuth trioxide in addition to the magnesium oxide.

It is very difficult to penetrate the trade secrecy surrounding these materials, to determine just what part the modifiers play in the cements. Judging from the meager information available, the modifiers are supposed to make the cement stronger and more insoluble. The results of one investigation [49] seem to indicate that bismuth trioxide contributes to the smoothness of working properties while mixing.

In manufacturing the powder, the ingredients are sintered into a cake at temperatures between 1000° and 1400° C. (1832-2552° F.).[50] The cake is ground and sifted to the powder form.

The chemical analysis of the liquids supplied to use with the

powders given in Table 2 are shown in Table 3. The letters designate the same brands of cement as before. It may be noted that the principal constituent is orthophosphoric acid (H_3PO_4), the principal modifiers being aluminum and zinc hydroxide. In the table, the first four columns, after the identifying letters, give the chemical analyses, whereas the last four give the composition as calculated from the analyses. It was assumed that all of the neutralizing elements, or basic modifiers, combined to form a neutral salt whose amount is given in the ninth column. The total amount of orthophosphoric acid in the liquid, before buffering, is shown in the eighth column. The original liquid undoubtedly contained water in addition. The calculated free H_3PO_4, and combined H_3PO_4, are shown in the sixth and seventh columns respectively. The eighth column is obviously the sum of the sixth and seventh columns.

TABLE[48] 3

COMPOSITION OF ZINC PHOSPHATE CEMENT LIQUIDS
(Percentage by Weight)

	Analysis				Calculations			
Sample	*PO_4*	*Al*	*Zn*	*Mg*	*Free H_3PO_4*	*Combined H_3PO_4*	*Total H_3PO_4*	*Phosphate*
A	57.4	1.8	10.0	...	42.8	16.6	59.4	27.8
B	55.2	3.4	3.1	...	41.6	15.5	57.1	21.5
C	64.3	2.7	...	...	56.8	9.8	66.6	12.2
D	57.3	2.1	10.0	...	41.7	17.6	59.3	29.2
E	64.6	2.7	1.6	...	55.5	11.4	66.9	15.4
F	52.6	2.5	7.1	...	38.2	16.2	54.4	25.3
G	59.9	2.9	2.0	...	49.4	12.6	62.0	17.0
H	59.7	2.1	4.1	...	50.1	11.7	61.8	17.6
I	57.9	2.8	...	0.3	48.9	11.0	59.9	13.7
J	61.1	2.8	...	...	53.1	10.2	63.3	12.7
K	64.0	3.2	...	...	54.7	11.6	66.3	14.5
L	64.2	2.7	0.9	...	55.8	10.7	66.5	14.0
M	67.2	3.0	...	...	58.7	10.9	69.6	13.6
N	64.9	2.9	...	...	56.6	10.6	67.2	13.1
O	54.6	2.3	10.3	...	37.8	18.7	56.5	30.7
P	53.4	2.7	...	...	45.5	9.8	55.3	12.2

When the ZnO powder is mixed with orthophosphoric acid to form a solid as a result of their chemical combination, two solid phases may be present in the set cement,[50] secondary and tertiary hydrated zinc orthophosphates ($ZnHPO_4.3H_2O$; $Zn_3(PO_4)_3.4H_2O$). However, the formation of the tertiary salt to any noticeable extent, is questionable. Hence the set cement probably consists of the acid phosphate salt. Ray[51] gives the following chemical reaction:

$$ZnO + H_3PO_4 + 2H_2O \rightarrow ZnHPO_4.3H_2O$$

Note that the water is essential to the reaction.

The hydrated acid phosphate is relatively insoluble in water, and the tertiary salt is even more insoluble.

The dentist must picture the reaction as being first a chemical

change forming the zinc acid phosphate which deposits as crystals only as it becomes supersaturated in solution; thus, although interdependent, there are two distinct phenomena involved. The formation of the crystalline phase must not be interfered with by prolonged mixing, if a strong cement is to be obtained.

Not all of the powder combines with the liquid, and the final set mass consists of uncombined particles in suspension in a matrix of hydrated zinc acid phosphate crystals.* Considerable heat evolution occurs, and in general the materials shrink while setting.

If ordinary commercial zinc oxide is used for combining with an unmodified orthophosphoric acid solution, the reaction is very rapid with considerable evolution of heat; the setting time is altogether too short for dental use, and the resulting product is porous and friable. Hence the rate of set must be retarded.

There are various methods of bringing this about, such as:

1. Decreasing the surface of the powder in contact with the liquid.
2. Varying the concentration of the liquid.
3. Adding retarders to the powder.
4. Buffering or partially neutralizing the acid liquid with a base.
5. Reducing the temperature of mixing slab.
6. Reducing the rate of addition of the powder to the liquid.
7. Reducing the amount of powder used in ratio to the liquid.

The time of set is obviously very important to the dentist since he must have ample time for manipulation, yet have the cement harden quickly after the inlay is seated or the celluloid matrix applied.

Items 1, 2, 3 and 4 are obviously under the control of the manufacturer. The surface of the powder is controlled by sintering and grinding as described.

The manufacturer gives the correct concentration to the liquid. The maintaining of this concentration is the task of the dentist, and it is accomplished by keeping the container tightly stoppered at all times. Failure to do this will usually result in loss of water from the liquid, a condition which prolongs the set. If water is added, as by using a damp mixing slab for example, the set will be hastened.

Very likely some of the modifiers in the powder may act as retarders, but the simplest method is to partially neutralize the liquid. As may be noted from Table 3 the base generally used for this purpose is aluminum hydroxide. Another effect often observed when a bottle of liquid is left unstoppered, is the deposition of crystals on the walls of the bottle due to the reaction between the modifiers and the acid.

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* Compare with the setting of amalgams.

Copper cements.

The copper cements are generally zinc phosphate cements with a copper compound added to the powder, although in exceptional cases the powders may contain 100 per cent CuO.[52]

The copper compound used may be identified by the color of the powder. Cupric oxide (CuO) gives a black colored cement, cuprous oxide (Cu_2O) — red, cuprous iodide (Cu_2I_2) — white, and the silicate of copper ($CuSiO_3$) — green. The main object in adding the copper is to render the cements germicidal in the mouth. Silver salts have also been used for this purpose in the same manner.

In all probability, the chemistry for these cements is similar to that of the zinc phosphate cements, since the liquids used are very similar. However, few data are available. They gradually wash out in the mouth, as do the other cements, but maintain a polished surface, which enhances their value and popularity, in cases where cement is indicated in the posterior teeth.

Silicate cements.

The exact composition of the powders used in modern silicate cements is a closely guarded secret. It is to be hoped that analyses will soon be available in the forthcoming report of the Dental Research Group at the Bureau of Standards.

The only available hints as to composition are given by Crowell:[50]

"Silicate cements differ from zinc phosphate cements chiefly in the composition of the powder. The liquids are solutions of phosphoric acid partially neutralized with zinc oxide and alumina, differing from zinc cement liquids only in the amount of water used.

"The powders are complex acid-soluble glasses. Their constitution is unknown. When acted upon by acids, silicic acid is liberated, but the base to which it was attached in the glass is difficult to determine. In our opinion, it is alumina. When a large amount of alumina is present, the powder is quick setting. Reducing the quantity retards the set.

"The powders are made by melting together silica, alumina, and fluxes, and heating until fusion is complete. A high temperature, about 1400° C,* is required. The resulting glass is crushed and ground to a fine powder.

"Several compounds have been used as fluxes. The earlier cements, made in Germany, used beryllium silicate. Most of the cements manufactured in the United States use calcium fluoride. Calcium silicate, calcium borate, and soda-lime glass have also been used, but the resulting cements have been deficient in translucence."

In contrast with the zinc phosphate cements, the problem involved in controlling the setting time is one of acceleration rather

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* 2552° F.

than retardation. As mentioned above, the aluminum oxide (Al_2O_3) speeds up the reaction, but at the same time it tends to reduce the translucency [50] if the content is unduly increased. Other than this the speed of reaction is very likely controlled by taking advantage of the variables noted for controlling the set of zinc phosphate cements.

The powder is usually ground very fine. The set may be delayed by the use of a cool mixing slab, but is speeded up when the cement comes in contact with the warm tooth. The activity of the liquid is controlled much in the same way as for the zinc phosphate cements.

The process of setting is rather complicated. The water present seems to hasten the reaction. The liquid reacts with the powder to produce certain bases and silicic acid. When the acidity drops to a certain value, silicic acid gel forms in a network of phosphate crystals, together with powder particles which are not attacked. The reaction probably continues slowly for some days, the final product being hard and translucent.

At no time must the gel be disturbed, once it starts to form. If it is broken, it cannot be rejoined. This is a very important point, and is undoubtedly the cause of many failures when this cement is used as a material for restorations.

The silicic acid gel must be kept moist at all times. Failure to do this causes dehydration of the gel, which is accompanied by a serious contraction.[54] A chalky layer results which is lacking in translucence. Rehydration occurs to some extent, but the surface layer is permanently ruined. It is for this reason that silicate restorations are not indicated for mouth breathers. The effect is particularly bad if the water is removed during set. For this reason, Crowell[50] states that the cavity should not be drastically dehydrated before inserting the filling. As with all cements, water must not be allowed to come in contact with the cement while it is getting its initial set. To prevent the silicate cement from losing water while this occurs, the surface should be initially covered with a water impervious material.

The solubility of these cements is generally conceded to be less than that of zinc phosphate cements, although they do "wash out." When testing their solubility in one per cent lactic acid solution, Voelker[55] found it approximately twice as great as for distilled water only. He considers such data as very important in explaining the solubility of the cement in the mouth. At any rate, the solubility of these cements must be counted as a great factor against them for their use as permanent restorations.

Their thermal properties are excellent. All the cements have a low thermal conductivity. The silicate cements have a coefficient of thermal expansion more nearly equal to that of the tooth structure itself than probably any other filling material.[1]

Recent studies by Dr. Edgar W. Swanson* in which the silicate cement particles in samples purchased on the market have been separated according to size into small, medium and large, and separately studied, suggest possible improvements in this material. He states that the larger particles delay the setting time, increase the shrinkage, show greater liquid permeability and reduce the crushing strength, while the fine particles speed the setting time and show the least shrinkage. The medium particles give the best results as to crushing strength. The combination of all three sizes is the most translucent, which property is decreased as the particle size becomes smaller in specimens made from the separated powders of different fineness.

PHYSICAL PROPERTIES OF CEMENTS.

There appears to be no cement at the present time which is "hydraulic",[64] notwithstanding much advertising propaganda to the contrary. The term hydraulic infers that the product will harden under water, and remain impervious to water. All cements must be kept dry until the initial set occurs, otherwise the orthophosphoric acid and other products will be leached out.

ADHESION. It is generally conceded that zinc phosphate cements are adhesive, whereas the silicate cements are not. This opinion is probably based on the fact that the former are extremely "sticky" while mixing, whereas the latter are only moderately so. If the physical definition of adhesion, as being the attraction between unlike molecules, be strictly adhered to, there is no adhesion between the set cements and the structures involved.[64]

If the term adhesion be used in a broader sense, i. e., the interlocking of surfaces due to surface irregularities, there may be considerable basis for such an opinion. This is brought out in the discussion of a paper written by Dr. Vogt.[65] The point is made that even glue is not adhesive when hard, — it may be easily stripped from the surface of smooth glass in this condition. However, if there are small surface irregularities or pores into which it may be forced while plastic, its retention is very great. In a similar manner, cements hold inlays in place. They are difficult to remove after cementation because of the shearing stresses involved. In other words, their degree of retention depends upon the nature of the surface irregularities in the inlay and cavity walls.

Tests have shown that the thinner the film of cementing medium, the stronger will be the union of the substances cemented together. Obviously, the thinnest possible film thickness depends largely upon the size of the powder particles.

Another reason for paying attention to film thickness is to allow the correct seating of carefully made inlays. In the past, some dentists have objected to accurately fitting inlays because "there was no room left for the cement." This objection is not

*Master's Thesis, Northwestern University Dental School.

valid if a good quality cement is used. No inlay can be cast accurately enough that a cement film cannot form between the inlay and the walls of the prepared cavity. Assuming that the wax pattern can reproduce all the microscopic undercuts and scratches in the cavity preparation caused by the burs and cutting instruments (very likely an impossible assumption), the markings would be smoothed out when the pattern is removed, otherwise removal would be impossible. Therefore, assuming an accuracy of 100 per cent in reproducing the pattern in a casting, there would still be ample room for a cement film, assuming the cement meets the American Dental Association Specification No. 8.

SETTING TIME. The factors influencing the setting time, which are under control of the manufacturer, have already been mentioned. The factors under control of the dentist are the following (unless otherwise stated, it may be assumed that the statements apply to all types of cements as far as can be determined from the literature):

1. Powder: liquid ratio — thick mixes set faster than thin ones.

2. The faster the powder is added to the liquid, the quicker is the set.

3. Within limits, prolonged mixing lengthens the setting time.

4. In general, the higher the temperature of the mixing slab, the quicker is the set, provided the cement is allowed to react on the slab, but when it is transferred to the mouth, the slab temperature seems to be of little importance in this respect. However, a cool slab gives a smoother mix because of the retardation of set while mixing. The humidity seems to have little effect upon the setting time.[48]

5. Diluting the liquid hastens the set, whereas evaporation of water retards it.

CRUSHING STRENGTH. The crushing strength of cements is important both in their use for setting inlays and in making restorations. Studies [48] on the zinc phosphate cements as to crushing strength demonstrate some interesting facts.

The samples were prepared from sixteen different brands of zinc phosphate cements (composition given in Tables II and III), and one silicate cement. Seven samples of each were stored in distilled water for twenty-four hours, and crushed. The lowest crushing strength observed was 3,500 lbs./sq. in., and the highest 12,000 lbs./sq. in. Twenty more specimens were prepared of each brand. Ten were immersed in distilled water for six months at 99° F. The other ten were placed in liquid petrolatum for a like period of time. The latter liquid was assumed to be inert so far as the cements were concerned, and served as a control to compare the action of the water as related to crushing strength.

Some of the cements showed an alarming decrease in crushing strength in the distilled water in comparison to the specimens kept in the liquid petrolatum. All but four showed less crushing strength in this respect.

The crushing strength increases as the powder:liquid ratio is increased up to a certain value, after which stiffer mixes do not alter it appreciably.

According to Ray [54] the crushing strengths of silicate cements vary from 5,650 to 8,450 lb./sq. in. in the specimens tested. He found that the crushing strengths were independent of the temperature of the mixing slab, and nearly independent of the consistency of the mix, — the thin mixes showed slightly greater strengths than the thick ones. Furthermore the crushing strength was independent of the liquid concentration in two trials made.

DIMENSIONAL CHANGES. Provided the change is not excessively great, the dimensional changes for zinc phosphate cements, used primarily for cementing inlays, are perhaps not as important as for those of copper and silicate cements which are used as materials for restorations. There are no quantitative data available for the copper cements, but very likely their dimensional changes are similar to those of the zinc phosphate cements described below.

Using the dental interferometer, as described for use in testing amalgams, the setting changes have been measured for both the zinc phosphate cements[48] and the silicate cements.[54]

The zinc phosphate cements shrink under water 0.05-2.0 per cent. In no case was a permanent expansion noted. The shrinkage took place within 2 - 3 hours, after which they remained fairly constant in dimension. One specimen was allowed to stand in air, and showed an enormous shrinkage. In water its total shrinkage was approximately 0.05 per cent, whereas in air the shrinkage was in the neighborhood of 3.0 per cent. Obviously, the cements must not be allowed to dry out.

The magnitude of the shrinkage of the silicate cements, when tested under water, is quite comparable with that of the zinc phosphate cements.[54] It was found that the water content of the liquid was a large factor in the contraction of the former. Apparently the more water present the greater is the contraction. When ten per cent of the water was evaporated from the liquid, an expansion as high as 0.12 per cent was realized. However, in the latter case the mix sets very slowly. Undoubtedly a superior silicate cement might be realized if a slight expansion could be incorporated with a normal setting time.

When the contraction of a silicate cement was measured in air it was large, although the specimen expanded again after being placed in water, but did not regain its original size. As noted the silicate cements are partially, at least, irreversible colloids, which leads one to speculate as to the possibility of warpage on partial

recovery of volume. At any rate, the materials are not indicated for use in the teeth of mouth breathers. Furthermore, while operating, all silicate restorations in the patient's mouth must be kept moist at all times.

DENSITY OF THE POWDER. In the case of zinc phosphate cements at least, the density of the powder has just the opposite effect upon the physical properties than one would be apt to predict. It has been thought that a dense powder would produce a stronger cement, with greater resistance to disintegration in the saliva.

According to the data of Paffenbarger, Sweeney, and Isaacs,[64] the cements having the denser powders were distinctly inferior. They had low crushing strengths and were slow in setting.

MANIPULATION OF CEMENTS.

Any discussion of manipulation of cements to improve their properties is handicapped at the outset. The greatest disadvantage of the cements is their solubility in the mouth fluids. This factor is not in the control of the dentist, and can not be improved greatly by any reasonable method of manipulation so far as is known. The cements all shrink in spite of anything the operator can do to prevent it. At present the very best cement is far from being a satisfactory material. None of the cements can truthfully be called permanent in any sense. They must be radically improved. The above detailed discussion has been given in order that their present qualities may be understood, in the hope that members of the profession will be more critical, and demand better products.

To secure the best results there are certain details of manipulation which must be strictly adhered to. In selecting cements, the dentist should demand products which are guaranteed to meet the specifications of the American Dental Association. This, of course, applies to all materials as well as cements. When the brand of cement has been selected, the directions given by the manufacturer should be strictly adhered to.

One of the precautionary measures to observe in handling cements is to keep the bottle of liquid tightly closed at all times. The dropper should either be kept in the liquid, or thoroughly cleaned and dried after use. Under no circumstances should the smallest drop of water or other impurity be allowed to get into the liquid. The liquid has been carefully made up and buffered by the manufacturer, and its concentration or purity must not be changed.

The powder must be carefully protected from dust or other contamination. The slab and other utensils must be kept spotlessly clean. Such precautions must be diligently observed, if the color and other properties are to be preserved.

In mixing the cement, it should be remembered that the aim in mixing zinc phosphate cements is to prolong the setting time.

The powder should be incorporated in small portions, and the spatulation may be carried on somewhat longer than in the case of the silicate cements. In mixing the latter, the general tendency should be to shorten the setting time, hence the powder should be incorporated at a faster rate than in the previous case.

Under no conditions should the mixing be prolonged until the reaction products begin to form, thus breaking them up. This is particularly true of the silicate cements, which are somewhat more critical in manipulation. In any case, a uniform mass must result with no voids of unmixed powder or liquid. Such a condition will cause a weakness in structure. The mix must be plastic, and not too stiff. As noted previously, a stiff mix shows no superiority in strength to a thinner one of medium consistency.

The mixing is preferably done on a cool slab (65 – 75° F.), provided the temperature is not below the dew point of the air in the room, when moisture will collect on the slab. This provides for a smooth mix which will not set too quickly before inserting in the cavity.

The cement should be used immediately after mixing and remain undisturbed until set. Particularly silicate cements should be inserted promptly and held in place with a celluloid strip. They must not be disturbed until the first set has taken place; the silicic acid gel, once broken does not grow together again. Finishing must be delayed for at least twenty-four hours.

All of the cements must be kept absolutely dry until they have hardened. In the case of the silicates, a coat of varnish or cocoa butter should be applied to the exposed surfaces. After hardening, the cements should be kept moist.

The color of the silicate cements should be selected to match the natural tooth. Their color is always lighter when first mixed, but as the cement hardens it increases in translucency and the color deepens.[50] For this reason the color should be selected from a shade guide, and not from the mixed cement.

DENTAL PORCELAIN

It is somewhat difficult to treat the question of ceramics from a purely scientific standpoint. During the past centuries, the ceramic industry has been operated on a purely empirical basis. Only fairly recently has the specialized science of ceramic chemistry come into being, and its problems have by no means been solved. Even now certain divisions of ceramic industry are using many of the methods and formulae of ancient times, with but few changes.

Even less is known concerning dental ceramics than that of the making of industrial porcelainware. The manufacturers keep the composition and treatment of their products a secret. The majority of writers on dental ceramics treat their subject as an

art, rather than from a scientific viewpoint. The dental literature is filled with statements concerning the properties of dental porcelain, and facts concerning its manipulation, almost entirely unsubstantiated by scientific data or quoted authority.

Undoubtedly the porcelain inlay is the best restoration available at the present time from the standpoint of esthetics, and ranks high in desirable physical properties. It is unfortunate that its construction has not been subjected to more scientific scrutiny, as has that of the gold inlay for example.

A general technic for the construction of a porcelain inlay is somewhat as follows: An impression is taken of the prepared cavity, from which a model is made. A thin sheet of platinum (called the matrix) is burnished into the cavity model. The porcelain of the desired shade is mixed with water, and condensed into the matrix lined cavity. The porcelain is then fired in the electric furnace. During firing, the porcelain shrinks noticeably, sometimes as much or more than forty per cent by volume. Unfortunately the amount of this volume shrinkage cannot be accurately predicted as in the case of gold shrinkage, hence its complete compensation cannot be accomplished by expansion. This is one of the disadvantages of the porcelain inlay; it is likely to be too small, and show a "cement line" around its margins, due to the solubility of the cement with which it is luted into the cavity. Since these inlays are used in general only in the anterior teeth, the cement line is likely to be quite serious esthetically.

The main theses of this discussion will be the control of shrinkage, translucency, color and strength of porcelain.

Composition and Manufacture.

As mentioned previously, the composition of dental porcelains is kept secret. Many formulae were published in the first half of the nineteenth century when the dentist had to compound his own material. They are all very similar to a formula[67] accredited to Dr. Wildman for tooth body:

Kaolin 1 oz.
Silex 3 oz.
Feldspar 18 oz.
Titanium oxide 65 grs.

The following formula for a high fusing porcelain body is given by Dr. Felcher:[68]

Kaolin 4½ parts
Flint 15 parts
Orthoclase Feldspar 85½ parts

Three other formulae are given by Searle.[69] Table 4 shows their chemical composition by analysis, and Table 5 the materials used in compounding them.

TABLE 4.

CHEMICAL COMPOSITION OF DENTAL PORCELAIN.

Porcelain	Silica	Alumina	Ferric Oxide	Potash	Soda	Lime	Titanium Oxide	Borax	Loss
A	68.2	16.7	trace	10.1	2.3	...	0.23	...	2.5
B	68.1	2.2	....	6.9	10.1	0.8	trace	10.6	1.2
C	69.6	11.3	0.3	11.8	1.7	2.4	0.2	0.3	...

TABLE 5.

MIXTURES USED.

Porcelain	Kaolin	Feldspar	Flint	Na_2CO_3	Borax	$CaCO_3$	K_2CO_3
A	4	81	15	...	...	...	...
B	...	61	29	2	1	5	2
C	...	12	60	8	11	1	8

The chemical composition of porcelain is not the most important factor. The firing of the material is the principal criterion determining the final nature of the product. For example, in the industry two identical formulae may be used for either earthenware or fine porcelain, depending upon the firing procedure. The firing of both dental and industrial porcelain is a matter of control of pyrochemical reactions. In other words, the reactions are arrested at certain stages to give the desired product.

CLASSIFICATION. In general, dental porcelains may be classified according to their fusion temperatures as:

High fusing, 2400-2500 deg. F.
Medium fusing, 2200-2340 deg. F.
Low fusing, 1700-2000 deg. F.

The fusion temperatures may be lowered by adding fluxes such as sodium and potassium carbonate, borax, etc. It is generally conceded that the lower fusing porcelains are less stable in the mouth than the higher fusing variety. The medium fusing porcelains are generally used for inlays.

Little or nothing is known as to the constitution of the final product after firing, particularly in the case of dental porcelain. Searle, in referring to the industrial material, states:[76] "An ideal porcelain should consist of a mixture corresponding to the formula $Al_2O_3.SiO_2$ (sillimanite) and a fusible glass which binds the other particles firmly together."

Under the microscope, a glazed dental porcelain body appears to consist of a vesicular structure mixed with pores and blebs. Often the center shows more porosity than nearer the periphery. The entire mass is amorphous in character, and appears to be made up of amorphous aggregates suspended in a glassy matrix.

If the surface is properly glazed, it is absolutely impervious to fluids. The pores cannot be burnished over by polishing as in the case of gold. This is shown by the "red ink test" borrowed from the ceramic industry: A drop of red ink is placed on the surface to be tested; if it can be rubbed off completely, the surface is said to be impervious.

Shrinkage of porcelain.

As previously stated, dental porcelain always shrinks to a more or less degree while firing. The shrinkage may be controlled to some extent by the method of condensation. The magnitude of control by this means is usually exaggerated by many experimenters, who measure linear shrinkage rather than volume shrinkage. For example, let it be assumed that a five millimeter cube is condensed and measured. Assume that it shrinks ten per cent at the high biscuit temperature, when it is usually conceded that the major portion of the shrinkage has taken place. This means that the cube should measure 4.5 millimeters at this stage. However, due to the high flux content, porcelain tends to become spherical or warps to a slight extent, even under the most controlled conditions. Due to this effect, the dimension measured will always be larger than it should be in comparison to the volume; 0.1 millimeter difference in this respect would give a calculated shrinkage of eight per cent, instead of ten per cent in the above example. Since this could amount to a surface bulge of 0.05 millimeter on both ends measured, it will hardly be discernible to the eye, yet it would be registered on the micrometer.

The first shrinkage which takes place is the "air shrinkage," or simply the shrinkage that occurs in air due to the evaporation of the water during condensation and low firing temperatures. The size and shape of the particles govern this shrinkage, as well as the degree of condensation. Clark[72] states that the major portion of the total shrinkage is due to lack of condensation. He found the shrinkage to be negligible when dry porcelain was condensed under a 150 ton load.

Other shrinkages are due to ignition loss of binders and other organic material and the effect of surface tension by the fluxes during firing. Clark places the average minimum linear shrinkage not under control of the operator by the normal methods of condensation available in dental practice, at 10 per cent.

Although some methods appear to give less shrinkage than others upon firing, it should be noted that all of them have one thing in common — the removal of as much excess water as possible. Theoretically the vibration method is probably the best method of condensation due to the reorientation of the particles during vibration, in addition to the other phenomena described. However, the method is not always practicable, hence a combination of the spatulation and vibration methods are largely employed.[73]

Firing of dental porcelain.

As in heating investments, it must be kept constantly in mind that the porcelain body is a very poor thermal conductor, and therefore too rapid heating is to be avoided. Failure to observe this precaution will result in case hardening, i.e., a fusion on the

outside, with a less fused mass in the center portions. Also stresses may be introduced which will slow up after firing.

The temperature must be under control at all times, particularly during the pyrochemical reactions, and must be raised at a constant rate of time, determined largely by experiment, in order to keep all factors under control. Failure to do this will likely result in overfusing which is characterized by balling, loss of color, and a glassy mass.

Gill[79] is most extreme in the length of the firing time which he advocates. For example, using a popular high fusing porcelain, ten minutes is taken to bring the work up to 1400° F. so as to allow ample time for the gases to be expelled; ten minutes more is allowed to carry the temperature to 1900° F., then five minutes to raise the temperature to 2250° F., at which temperature the work is held for five minutes to allow a slow diffusion of the molten mass through the interstices; then five more minutes are allowed to bring the work to a temperature of 2400° F., where the case is soaked for five minutes, thus making a total time of forty minutes necessary for the bake. All authorities advocate slow cooling to avoid crazing and strains.

Other writers advocate a shorter firing time. For example, Clark[72] advocates bringing the work up to the beginning of the chemical stage in a short time, and then is begun the timing. He states that a rise in temperature of 50° F. per minute to the final temperature is sufficiently slow. Undoubtedly, soaking the work at a lower temperature is preferable to carrying it continuously to a higher temperature.

The lower fusing porcelains are fired in an analogous manner, the main difference being their lower firing temperatures due to the low fusing fluxes present in their composition.

Physical properties of dental porcelains.

Each advocate of various condensation techniques claims superiority in strength, density, translucency, etc., for his particular method. It is very difficult to evaluate these properties quantitatively, and much of the research along these lines has been subject to error and questionable procedure. As previously mentioned, the influence of chemical composition of the material is secondary to the methods of condensation and firing.

Table 6 shows Sayre's results on baked specimens of high fusing porcelain. It is very evident that the vibration method is the best from the standpoint of volume shrinkage. However, the differences between shrinkages of various methods is surprisingly small. This is somewhat in contradiction to various reported linear shrinkage values for different condensation techniques. Sayre determined the volume shrinkage by determining the volume of water displaced by weighing in water and air and comparing with

the original volume. Such a method is not dependent on localized differences in surface irregularity.

TABLE 6.

INFLUENCE OF CONDENSATION IN A MATRIX ON PHYSICAL PROPERTIES OF DENTAL PORCELAIN (SAYRE[81])

Method of Condensation	*Volume Shrinkage* (%)	*Apparent Density* (g./cc.)	*Mod. of. Rupture* (lbs./sq. in.)
Vibration	38.1	2.350	6960
Spatulation	38.4	2.338	7160
Brush Application	40.5	2.363	5290
No Condensation	41.5	2.386	4900

LIGHT PHENOMENA. To appreciate adequately the phenomena of light, as applied to dental porcelains and tooth structure, would require a vast knowledge of applied geometrical and physical optics. Only a rudimentary idea can be given here.

If the body is opaque, the light waves will not penetrate it, but will be reflected or absorbed, or both, depending on the nature of the body.

If the body is transparent, as window glass for example, the light will be regularly transmitted, although it will be bent in accordance with the law of refraction.

If the body transmits light diffusely so that the objects cannot be seen through it, the material is said to be *translucent*. Translucency may be caused by a number of factors, such as constituents in the material with different indices of refraction, different orientations, etc.

The dentin may be regarded as an opaque material for all practical purposes, while the enamel may be optically considered as a coating formed by a bundle of translucent prisms.

As has already been noted, dental porcelain may be considered as "solid particles of 'aggregate' united by a glassy bond."[73] The material is amorphous in character, and not crystalline as is the enamel. The optical properties then resolve themselves into a scattering of light due to different indices of refraction and transmission coefficients caused by different "aggregates", bond, blebs, etc. It may be seen at once that the optical structure does not resemble that of the enamel in the least. The porcelain inlay may match the tooth structure from the front, yet a side view will show it to have a different texture and color due to difference in optical property from this direction. It will diffuse light differently than the enamel under different illuminants. Fortunately the difference is not great, and is apparent only to a discerning eye.

Since the material is translucent, obviously the cement used in seating the inlay will have its effect. A silicate cement is best because of its translucency. However, if the cement washes out at the margins, the familiar "cement line" appears, due, not to the

cement, but to its absence, changing the optical property at that point.

Although the tooth structure cannot be faithfully reproduced, its color can be copied if care is exerted by the dentist in matching the tooth color with his shade guide, and has developed ability in the selection of the several shades which may be required for a single restoration.

The porcelains may be had in a wide variety of colors, the pigments being introduced in the form of metallic oxides which turn to the desired color upon fusing. Also stains of a similar nature may be used.

GUTTA-PERCHA.

The chief source of gutta percha is the Malay Archipelago, where it is extracted from trees of the family *Sapotaceae*, other varieties of the same family being sources of caoutchouc (rubber).

It is extracted from the tree much in the same way as rubber latex — as an exudate of a juice or latex from slits made in the cambium layer. The latex is a colloidal suspension, which is coagulated by boiling.

Chemically, the essential constituent is *gutta*, a hydrocarbon of the empirical formula C_5H_8, which is isomeric with the rubber molecule. At least two resinous materials — albanes and fluavils — are found in the crude product. Gutta-percha dissolves in much the same solvents as caoutchouc.

Physically, it is unlike rubber in many respects. It is inelastic at any temperature. It softens at a temperature of 65-66° C. (149-152° F.) and becomes quite plastic, and can be molded readily. Upon cooling it again hardens, retaining its molded form, the hardening being accompanied by a contraction.

It is not affected by alkaline solutions or by dilute acids. Strong sulphuric acid and nitric acid attack it by oxidation. It is readily soluble in chloroform and carbon disulphide, and is somewhat less soluble in oils, such as eucalyptol or oil of cajuput.

When exposed to air, gutta-percha deteriorates to a hard brittle resinous material, very likely due to an absorption of oxygen with a resulting oxidation. It is insoluble in water.

It is not extremely hard when cool, but is quite tenacious and tough. The raw product varies in color from a grayish to a pink. It has a low coefficient of thermal conductivity and has a specific gravity of 0.96-1.00.

As used in dentistry, it is adulterated with much the same fillers as is rubber, which are used in the case of the latter to increase the wearing qualities. The fillers may be Burgundy pitch, zinc oxide, chalk, carbon, etc., together with coloring and flavoring materials.

Gutta-percha is used in filling root canals; as a seal for medicaments placed in cavities of decay, in pulp chambers or in root

canals; also for temporary restorations in treatment of hypersensitiveness of the dentin or thermal sensitiveness of the pulp; and occasionally in cavities in buccal surfaces which extend beyond the cemental line.

In making a restoration with gutta-percha, the walls of the cavity should be coated thinly with eucalyptol or oil of cajuput to insure adhesion by the gutta percha. The material is heated cautiously, preferably on a tray, and molded into the cavity, piece by piece. It is too often abused in heating. Too much heating will cause it to become sticky and oxidize, or even burn, after which it exhibits very inferior physical qualities. Furthermore, the use of too much oil will render it permanently soft.

There are a number of substitutes for gutta-percha, generally called temporary stoppings, most of which are distinctly inferior, probably containing wax and fatty acids.

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CAVITY NOMENCLATURE

ILLUSTRATIONS: FIGURES 273-284.

NOMENCLATURE treats of systems of naming things. Dental nomenclature treats of the terms, or names, used in dentistry. The subject is of first importance, for, if we do not know the names by which things are called, we will be unable to understand each other in speaking of them. Every profession, business or trade, has its special system of naming things pertaining to it, and this nomenclature must be understood before the student can become proficient. In operative dentistry this system of nomenclature is very simple and comprises but few words. However, these words are used in a fairly wide range of combinations that will be very perplexing to the student who has not a good knowledge of them. He should understand them when spoken by others and be able to use them freely and correctly in his ordinary speech. Otherwise he will be unable to understand his professors or fellow students as accurately as he should. and thus find his studies more difficult than they otherwise would be.

For the most part, the words are the same as those used in Dental Anatomy, with which the student and every dentist already should be familiar. But they are applied differently and to different subjects. This new use now becomes a subject of study as applied in cavity preparation and cavity nomenclature.

Cavity preparation includes all those operations required in the removal of carious material from cavities formed in the teeth by decay, and forming the cavities for restorations, with such extensions and preparations as will most likely prevent a recurrence of decay.

Cavity nomenclature includes the names of cavities, and of groups of cavities, also the names of the internal parts of cavities, including the several walls and their lines and points of junction.

RULE: *Cavities in the teeth take the names of the surfaces of the teeth in which they occur.*

We group cavities together according as the decayed surfaces are similarly situated. A further grouping may also be made into classes, each class including those cavities that require similar treatment.

Cavities occuring in the occlusal surfaces of the teeth are called occlusal cavities. They occur in the molars and bicuspids, constituting a group.

Cavities occurring in the buccal surfaces of the bicuspids and molars are called buccal cavities, and constitute a group.

Cavities occurring in the lingual surfaces of the bicuspids and molars are called lingual cavities. They are not frequent.

Cavities occurring in the proximal surfaces of the teeth are called proximal cavities. These are divided into two groups: those occurring in the bicuspids and molars forming one group, bicuspid and molar proximal cavities; and those occurring in the incisors and cuspids forming a separate group, incisor proximal cavities. The forms of the proximal surfaces of these two groups of teeth are so different as to require differences in consideration and treatment. Each of these groups is again subdivided into mesial cavities and distal cavities. Mesial cavities are those that are in surfaces of the teeth toward the median line, following the curve of the arch. The median line is the central line of the face, the head, or of the whole body, from before backward, perpendicularly. Distal cavities are those that are in the surfaces of the teeth farthest from the median line, following the curve of the arch.

Cavities occurring in the lingual surfaces of the upper incisors are considered as a separate group, incisor lingual cavities.

Cavities occurring in the labial surfaces of the incisors and cuspids are called labial cavities.

When a cavity involves two or more surfaces of a tooth, either by the extension of decay or by cutting in its preparation, a complex cavity is formed. Complex cavities are named by combining the names of the surfaces of the tooth involved by the cavity: as mesio-occlusal cavity; mesio-occluso-distal cavity, etc.

In each of these groups the individual cavity name is rendered specific by adding the name of the tooth in which it occurs, as: Occlusal cavity in the left upper first molar, mesial cavity in the right upper central incisor, etc. The word proximal is used only as a general term, while mesial or distal is used when speaking of a particular proximal cavity.

In addition to these terms, all cavities which occur in the axial surfaces of the teeth are called axial surface cavities. An axial surface of a tooth is one, the general plane of which is parallel with the long axis of the tooth. These include all buccal, or labial, lingual and proximal cavities.

In each of these localities decay has peculiarities in its mode of attack, or there are differences of approach and of instrumentation in the preparation of the cavity for insertion of restorations, that render differences in their consideration necessary.

Cavities are also divided into two groups; pit and fissure cavities forming one group, and smooth-surface cavities forming a second group. This constitutes a most important division of cavities, calling for a radical distinction in consideration and treatment.

PIT AND FISSURE CAVITIES have their beginning in minute faults in the enamel of the teeth. Pits are formed where three or more lobes of the teeth join, because of imperfect closure of the enamel plates, as upon occlusal surfaces of the bicuspids and molars and the lingual surfaces of the incisors, or at the endings of grooves, as upon the buccal surfaces of the molars. Fissure cavities occur where there is imperfect closure of the enamel plates along the lines of the grooves. These latter may occur along the lines of the grooves of any of the teeth, but are seen mostly in the occlusal surfaces of the bicuspids and molars.

SMOOTH-SURFACE CAVITIES are those formed by decay beginning in surfaces of the teeth that are without pits, fissures, or faults of the enamel, i. e., in perfectly smooth surfaces. These positions are all on the axial surfaces and in such positions that the surfaces are habitually unclean, either because of the position in relation to the movements of food in chewing or the proximation of the surfaces of other teeth, as upon the proximal surfaces. Decay is the result of fermentation in these positions with the formation of an acid which dissolves the calcium salts of the teeth.

Among the groups of cavities, all of the occlusal cavities in the bicuspids and molars are, in their beginning, pit or fissure cavities. A part of the buccal cavities in the molars are pit or fissure cavities occurring in the buccal pits or fissured grooves, and part are smooth-surface cavities, occurring in the smooth portion of the enamel of this surface to the gingival of the pit, or in the gingival third of the buccal surface. All buccal cavities in the bicuspids are smooth-surface cavities. All labial cavities in the incisors and cuspids are smooth-surface cavities. All lingual cavities in the upper incisors are pit or fissure cavities. A few fissure cavities occur in the occlusal half of the lingual surfaces of the molars. All proximal, or mesial and distal cavities, whether in the molars, bicuspids or incisors, are smooth-surface cavities. Lingual cavities in the gingival half of the molars are also smooth-surface cavities.

Pit and fissure cavities occur in surfaces of the teeth that are habitually clean, except as the imperfections of the enamel—pits and fissures—afford places for the lodgment and fermentation of debris, which causes the beginning of decay. Therefore, in their preparation, they require a sufficient opening of the cavity to completely uncover the carious area and to find margins sufficiently level and smooth, i. e., free from grooves, to allow of a good finish of the margins of the restoration to be made.

Smooth-surface cavities occur in positions in which the surface of the enamel is habitually unclean, and usually begin in the central portion of the unclean area. The injury to the enamel surface tends to spread superficially from the central area of first beginning toward the margins of the unclean area. Therefore, such

cavities require such extension in their preparation for restoration as will include the habitually unclean area within their outline in order to prevent the recurrence of caries.

Classification of Cavities into Artificial Groups.

In a classification of cavities, it is the intention to group together in classes cavities of decay that require a similar line of treatment, in order that these may be more closely associated.

Class 1. Cavities beginning in structural defects in the teeth; pits and fissures. These are located in the occlusal surfaces of the bicuspids and molars, in the occlusal two-thirds of the buccal surfaces of the molars, in the lingual surfaces of the upper incisors, and occasionally in the lingual surfaces of the upper molars.

Class 2. Cavities in the proximal surfaces of the bicuspids and molars.

Class 3. Cavities in the proximal surfaces of the incisors and cuspids which do not involve the removal and restoration of the incisal angle.

Class 4. Cavities in the proximal surfaces of the incisors and cuspids which do require the removal and restoration of the incisal angle.

Class 5. Cavities in the gingival third — not pit cavities — of the labial, buccal or lingual surfaces of the teeth.

Classes 2, 3, 4 and 5 are all smooth-surface cavities. They all occur in positions in which the surfaces of the teeth are habitually unclean.

With respect to manipulative procedures, each of these classes has its especial peculiarities. For instance, Class 5, which includes all buccal, labial and lingual cavities, requires, in most cases, the use of the Hatch clamp on the incisors and bicuspids, and the special clamps on the molars to extend the rubber dam sufficiently to the gingival, and the method of the instrumentation in their preparation is peculiar to them. Classes 2, 3 and 4 all agree in requiring the use of the separator to give room for finishing, because all are proximal cavities, but each of these classes presents especial peculiarities in manipulative procedure, which will receive attention later.

Nomenclature of the Internal Parts of Cavities.

In giving the nomenclature of the internal parts of cavities, the rules and illustrations of each rule will be given. Students should not burden themselves with memorizing these illustrations, or lists, for, if they know the rules and their application, they can make complete lists at any time. This should be practiced until the walls and angles of any cavity can be named at sight without hesitation.

WALLS OF CAVITIES.

RULE: *The surrounding walls of a prepared cavity take the names of those surfaces of the teeth adjoining the surface decayed, toward which they are placed.*

Illustration: Occlusal prepared cavities, Figures 273, 274, have—

A mesial wall, M. W.
A buccal wall, B. W.
A distal wall, D. W.
A lingual wall, L. W.

And —

A fifth wall, which is called the pulpal wall, P. W.

FIG. 273.

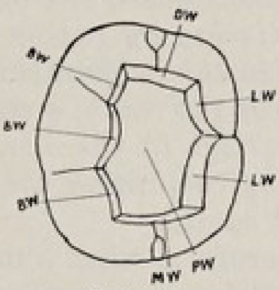

FIG. 274.

FIG. 273. This prepared cavity in a lower first molar is much larger and more box-like than occlusal cavities should be prepared. This was done purposely in this case to present more clearly the nomenclature of the walls.

FIG. 274. Diagram for explanation and naming of cavity walls in Figure 1. M W. Mesial wall. B W. B W. B W. Buccal wall. D W. Distal wall. L W. L W. Lingual wall. P W. Pulpal wall. If the contour of a wall is broken by the cutting out of grooves or other necessary deviation of form, as occurs in the buccal wall in this case, the wall is named as a whole, the same as if the form were regular.

RULE: *That wall of a prepared cavity which is to the occlusal of the pulp, and in a plane at right angles to the long axis of the tooth, is called the pulpal wall. In case the pulp of the tooth is removed, and the cavity thus extended to the floor of the pulp chamber, it is called the sub-pulpal wall.*

Illustration: Buccal and lingual prepared cavities have —

A mesial wall,
An occlusal wall,
A distal wall,
A gingival wall,

And —

A fifth wall, called the axial wall.

RULE: *That wall of a prepared cavity in an axial surface of a tooth in a plane paralled with the surface in which the cavity is prepared and nearer to that surface than to the opposite axial surface of the tooth, is called the axial wall. The axial wall usually covers or approximates the pulp. If this wall is nearer the opposite axial surface, (the pulp having been removed) it takes the name of the opposite axial surface.*

Simple mesial or distal prepared cavities (proximal cavities), in the bicuspids and molars, have—

A lingual wall,
A buccal wall,
A gingival wall,
An occlusal wall,

And —

An axial wall.

But mesial and distal cavities, as usually prepared in bicuspids and molars, become mesio-occlusal or disto-occlusal cavities (complex cavities); the occlusal wall is missing and a step is cut in the occlusal surface.

RULE: *When one of the surrounding walls of a prepared cavity is missing by reason of extension of decay, or by extension by cutting in the preparation for restoration, so as to involve another surface of the tooth, a complex cavity is formed and the remaining walls extend to the new surface involved. A complex cavity is named by combining the names of the surfaces involved, as mesio-occlusal cavity.*

Therefore, when a mesial or a distal prepared cavity in a bicuspid or molar has involved the occlusal surface, the buccal and the lingual walls will terminate at the occlusal enamel margin. The axial wall will also extend to the occlusal enamel margin, if no step has been formed, and the occlusal wall will be missing. When a step has been formed, its walls will be named as in a simple occlusal cavity, except that that wall toward the cavity from which the step is formed will be missing.

Therefore, mesio-occlusal (or disto-occlusal) prepared cavities, Figure 275, also Figures 278 and 279, in the bicuspids and molars have—

In the proximal portion:

A gingival wall, G. W.
A buccal wall, B. W.
A lingual wall, L. W.

And —

An axial wall, A. W.

In the step portion:

A distal (or mesial) wall, D. W.
A buccal wall, B. W.
A lingual wall, L. W.

And —

A pulpal wall, P. W.

It should be noted that in mesial cavities, the mesial wall of the step portion will be missing, and in distal cavities the distal wall of the step portion will be missing.

In a mesio- or disto-occlusal prepared cavity in a bicuspid or molar in which the pulp is removed, the pulpal and axial walls are

removed. The floor of the pulp chamber becomes the sub-pulpal wall of the cavity. This is usually distinct from the gingival wall, because it is on a different level. Therefore, a mesio- or disto-occlusal cavity in a molar or bicuspid with pulp removed, has—

A buccal wall,
A lingual wall,
A gingival wall,
A distal (or mesial) wall,
And —
A sub-pulpal wall.

Also some portions of the mesial (or distal) wall of the pulp chamber will remain next to the gingival wall as a mesial (or distal) wall. In a bicuspid or molar with a single broad pulp canal, there is no sub-pulpal wall.

Proximal prepared cavities in the incisors and cuspids, on account of the wedgelike or triangular form of these surfaces, have but three surrounding walls:

A labial wall,
A lingual wall,
A gingival wall,
And —
An axial wall.

When, in incisor or cuspid proximal prepared cavities, the incisal angle becomes involved so that its removal is required, a complex cavity may be formed by cutting an incisal step. There is in this case no change in the naming of the walls of the proximal portion of the cavity, as no one of the walls named has been completely removed. Such a cavity will have—

In the proximal portion:
A lingual wall,
A labial wall,
A gingival wall,
And —
An axial wall.

In the step portion:
A labial wall,
A lingual wall,
A mesial (or distal) wall,
And —
A pulpal wall.

Labial and lingual cavities in the incisors and cuspids have—

A mesial wall,
A distal wall,
A gingival wall,
An incisal wall,
And —
An axial wall.

ANGLES OF CAVITIES.

In naming walls and angles of prepared cavities, the typical idea of the cavity is that of a cuboid space, or the form of a box. No matter how irregular the actual form of the cavity, its walls and angles are named as if the form were regular.

Each simple cavity has two sets of line angles and one set of point angles.

RULE: *All line angles are formed by the junction of two walls along a line, and are named by combining the names of the walls joining to form the angle. They are, therefore, named in two terms.*

RULE: *All point angles are formed by the junction of three walls at a point, and are named by joining the names of the walls forming the angle. They are, therefore, named in three terms.*

In simple prepared cavities one set of line angles is formed by the junction of the four surrounding walls with each other, forming lines which run from the enamel margin to the pulpal wall in occlusal cavities, or to the axial wall in axial cavities. A second set of line angles is formed by the junction of the surrounding walls with the pulpal wall in occlusal cavities, or with the axial wall in cavities in the axial surfaces of the teeth.

The point angles are formed where the line angles of one set meet the other set at the angles of the cavity. The broader rule for naming angles, to which there is but a single exception, is:

RULE: *All angles of prepared cavities are named by combining the names of the walls joining to form the angle. The particular order in which these are named is not important. Linguo-distal angle and disto-lingual angle mean the same thing.*

Illustrations: (Each angle named is formed by the junction of the walls, the names of which enter into the name of the angle.)

Occlusal prepared cavities have—

- First set of line angles:
  - A mesio-buccal angle,
  - A mesio-lingual angle,
  - A disto-buccal angle,
  - A disto-lingual angle.
- Second set of line angles:
  - A bucco-pulpal angle,
  - A linguo-pulpal angle,
  - A mesio-pulpal angle,
  - A disto-pulpal angle.
- Point angles:
  - A mesio-bucco-pulpal angle,
  - A disto-bucco-pulpal angle,
  - A mesio-linguo-pulpal angle,
  - A disto-linguo-pulpal angle.

In case the pulp is removed, the pulpal wall is removed and the floor of the pulp chamber becomes the sub-pulpal wall of the cavity, and the pulpal angles become sub-pulpal angles.

A buccal or a lingual prepared cavity in a bicuspid or molar has —

First set of line angles:
- A mesio-gingival angle,
- A disto-gingival angle,
- A mesio-occlusal angle,
- A disto-occlusal angle.

Second set of line angles:
- An axio-gingival angle,
- An axio-mesial angle,
- An axio-occlusal angle,
- An axio-distal angle.

Point angles:
- An axio-mesio-gingival angle,
- An axio-mesio-occlusal angle,
- An axio-disto-occlusal angle,
- An axio-disto-gingival angle.

A simple mesial or distal prepared cavity in a bicuspid or molar has —

First set of line angles:
- A linguo-gingival angle,
- A bucco-gingival angle,
- A linguo-occlusal angle,
- A bucco-occlusal angle.

Second set of line angles:
- An axio-lingual angle,
- An axio-occlusal angle,
- An axio-buccal angle,
- An axio-gingival angle.

Point angles:
- An axio-linguo-gingival angle,
- An axio-bucco-gingival angle,
- An axio-linguo-occlusal angle,
- An axio-bucco-occlusal angle.

But in mesial and distal prepared cavities in the bicuspids and molars, the occlusal wall is generally cut away and a step formed in the occlusal surface, forming a complex cavity. In this case, the occlusal wall is missing and all of the angles formed by the junction of this wall with others are also missing. Then the step in the occlusal surface has its angles the same as in a simple occlusal cavity, except that the angles pertaining to the missing wall, mesial or distal, are also missing. This is a universal rule with complex cavities. Line angles are shown in Figure 276. Point angles are shown in Figure 277. See also Figures 278, 279.

Hence a mesio- or disto-occlusal prepared cavity has —

In the mesial or distal portion:

First set of line angles:
- A bucco-gingival angle, B. G.

A linguo-gingival angle, L. G.

Second set of line angles:

A bucco-axial angle, B. A.

A linguo-axial angle, L. A.

A gingivo-axial angle, G. A.

Point angles:

A gingivo-bucco-axial angle, G. B. A.

A gingivo-linguo-axial angle, G. L. A.

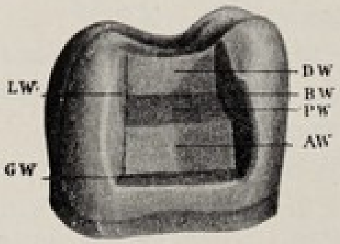

FIG. 275.

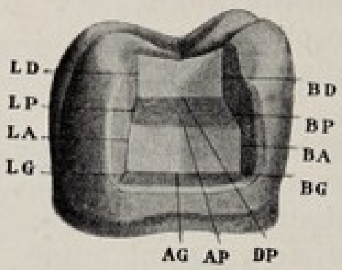

FIG. 276.

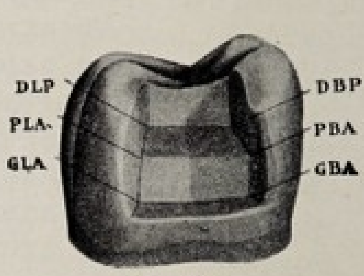

FIG. 277.

FIG. 275, 276, 277. These cavities are all larger than would usually be prepared. This was purposely done to give a clear view of the several walls.

FIG. 275. Illustration of the naming of the walls in proximo-occlusal cavities; a mesio-occlusal cavity. L W. Lingual wall. G W. Gingival wall. D W. Distal wall. B W. **Buccal wall.** P W. **Pulpal wall.** A W. **Axial wall. In the text these walls are given separately for the proximal** portion and for the occlusal, or step portion. With this division, the buccal wall and the lingual wall are each given twice, because these walls belong to both portions of the cavity.

FIG. 276. Line angles of a mesio-occlusal cavity. See rules for naming cavity angles. L D. Linguo-distal angle. L P. Linguo-pulpal angle. L A. Linguo-axial angle. L G. Linguo-gingival angle. B D. Bucco-distal angle. B P. Bucco-pulpal angle. B A. Bucco-axial angle. B G. Bucco-gingival angle. A G. Axio-gingival angle. A P. Axio-pulpal angle. D P. Disto-pulpal angle. In the text the line angles are divided into the first and second sets for the proximal portion and the first and second sets for the occlusal, or step portion; in each case the line angles which run from the enamel margin to the pulpal wall or to the axial wall constitute the first set, and those which form the boundaries of the pulpal wall or of the axial wall constitute the second set.

FIG. 277. Point angles of a mesio-occlusal cavity. D L P. Disto-linguo-pulpal angle. P L A. Pulpo-linguo-axial angle. G L A. Gingivo-linguo-axial angle. D B P. Disto-bucco-pulpal angle. P B A. Pulpo-bucco-axial angle. G B A. Gingivo-bucco-axial angle. In the text the point angles are given separately for the proximal portion and the step portion of the cavity.

In the step portion:

First set of line angles:

A bucco-distal (or mesial) angle, B. D.

A linguo-distal (or mesial) angle, L. D.

Second set of line angles:

A disto- (or mesio-) pulpal angle, D. P.

A linguo-pulpal angle, L. P.

A bucco-pulpal angle, B. P.

Point angles:

A disto- (or mesio-) bucco-pulpal angle, D. B. P.

A disto- (or mesio-) linguo-pulpal angle, D. L. P.

And a line angle formed by the junction of the axial and pulpal walls.

An axio-pulpal angle, A. P.

And two point angles, formed by the junction of the pulpal

and axial walls with the lingual wall and with the buccal wall.

A pulpo-linguo-axial angle, P. L. A.
A pulpo-bucco-axial angle, P. B. A.

The rule illustrated in the above is universal. A buccal prepared cavity with an occlusal step, or united with an occlusal cavity, would also have its pulpo-axial angle. The angles belonging to the occlusal wall of the buccal cavity would be missing, and the angles belonging to the buccal wall of the occlusal cavity would also be missing. This, however, makes no difference whatever with the naming of the remaining angles. If, however, the pulp of the tooth is removed, removing the axial and pulpal walls, the angles formed by the junction of these walls with the other walls are also removed, and the angles of the pulp chamber (sub-pulpal angles) substituted.

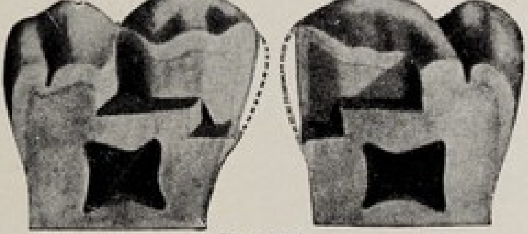

FIG. 278.

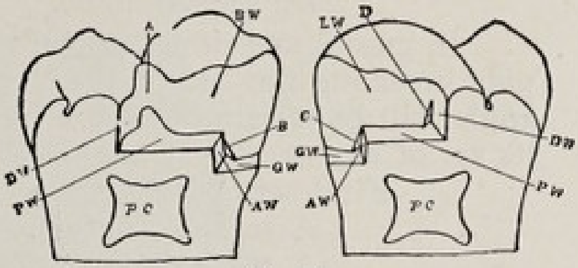

FIG. 279.

FIG. 278. An upper first molar with a prepared mesio-occlusal cavity, split mesio-distally, displaying the cavity form. The buccal half is on the left and the lingual half on the right side. The mesial surfaces of the two halves are next each other. The dotted lines rounding from these show the form of the mesial surface of the restoration if it were placed. Both the pulpal and gingival walls of this cavity are cut much deeper than they would ordinarily be cut in practice.

FIG. 279. An outline view of the cavity shown in Figure 278 for a further study of the internal parts. D W. Distal wall. P W. Pulpal wall. G W. Gingival wall. A W. Axial wall. B W. Buccal wall. L W. Lingual wall. P C. Pulp chamber. A. Acute angle formed by cutting out the buccal grove. D. Starting point cut in the disto-linguo-pulpal angle. B. Starting point cut in the bucco-axio-gingival angle. C. Starting point cut in the linguo-axio-gingival angle.

Labial or lingual prepared cavities in the incisors and cuspids have —

First set of line angles:
- A mesio-gingival angle,
- A disto-gingival angle,
- A mesio-incisal angle,
- A disto-incisal angle.

Second set of line angles:
- An axio-gingival angle,
- An axio-mesial angle,
- An axio-distal angle,
- An axio-incisal angle.

Point angles:
- An axio-mesio-gingival angle,
- An axio-disto-gingival angle,
- An axio-mesio-incisal angle,
- An axio-disto-incisal angle.

Mesial and distal prepared cavities in the incisors and cuspids have, on account of their triangular form, but three angles instead of four. They have —

First set of line angles:
- A labio-gingival angle,
- A linguo-gingival angle,
- *An incisal angle.

Second set of line angles:
- An axio-labial angle,
- An axio-lingual angle,
- An axio-gingival angle.

Point angles:
- An axio-labio-gingival angle,
- An axio-linguo-gingival angle,
- *An incisal angle.

In mesial and distal prepared cavities in the incisors and cuspids involving the loss of the incisal angle of the tooth, the incisal angle will be missing and the incisal step when formed will have its set of angles. These are —

First set of line angles:
- A mesio- (or disto-) labial angle,
- A mesio- (or disto-) lingual angle.

Second set of line angles:
- A pulpo-distal (or mesial) angle.
- A pulpo-lingual angle,
- A pulpo-labial angle,
- A pulpo-axial angle.

Point angles:
- A mesio- (or disto-) labio-pulpal angle.
- A mesio- (or disto-) linguo-pulpal angle.

And a line angle formed by the junction of the axial and pulpal walls:

An axio-pulpal angle.

And two point angles, formed by the junction of the pulpal and axial walls with the lingual wall and the labial wall:

- A pulpo-linguo-axial angle.
- A pulpo-labio-axial angle.

While all angles are theoretically and actually present as named and according to the rules given and illustrated, these incisal steps are so narrow that it would rarely be desirable to name the point angles in any directions for cavity preparation or in cavity description.

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* Note.—The incisal angle given here is the one exception to the rule of naming cavity angles. If the rule were followed strictly, it would be the labio-lingual line angle, for it is formed by the junction of the labial and lingual walls. In like manner the incisal point angle would be the axio-labio-lingual angle. This latter is formed by the junction of the labial, lingual and axial walls, but is never called by the compound name formed by these words. The name, incisal angle, is distinctive and gives rise to no confusion.

These lists of cavity angles may seem long and tedious, but it must be remembered that in any directions for the preparation of cavities, or in cavity descriptions, very few of them need to be mentioned. However, the student should be able to understand just what is meant when any one of them is mentioned, or be able to name any of them in any cavity. This he will not do by memorizing lists that are given, but by so learning the application of the rules as to be able to correctly apply a name to any angle of any prepared cavity.

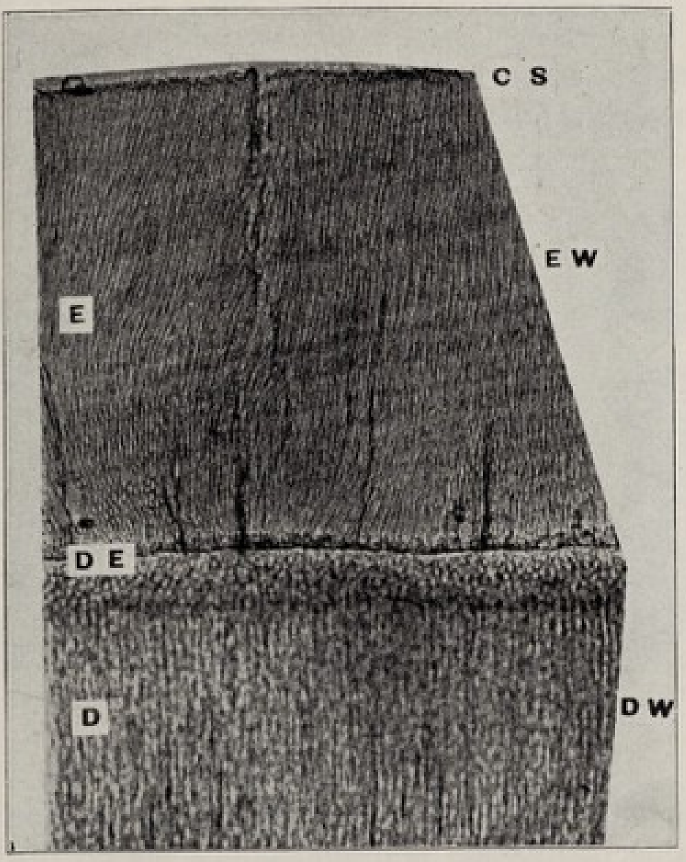


FIG. 280. A portion cut from a photomicrograph of a section of a tooth showing: E. Enamel. D. Dentin. D E. Dento-enamel junction. D W. Dentin wall. E W. Enamel wall. C S. Cavo-surface angle. A dentin wall and an enamel wall may be continuous on the same plane as the cut on the left-hand side of the figure; or, the dentin wall and the enamel may be cut on different planes as on the right-hand side of the figure.

PARTS OF A WALL OF A PREPARED CAVITY.

THE CAVO-SURFACE ANGLE of a prepared cavity, or of the enamel, is the angle formed by the junction of the wall of the cavity with the surface of the tooth. Figure 280, C. S. The cavo-surface angle of a cavity will ordinarily be of enamel; under some unusual conditions it may be of dentin; or, in cavities that extend beyond the cemental line, the cavo-surface angle will be of cementum. The term cavo-surface angle is used especially when it is desired to indicate the form to be given this angle in any particular portion of the enamel margin, or outline of a cavity; as, the buccal cavo-surface angle is to be beveled.

The enamel margin includes the whole outline of the prepared cavity and is equivalent to the marginal lines of the cavity. In this sense the enamel margin marks the outlines of the prepared cavity.

THE DENTO-ENAMEL JUNCTION is the line of junction of the dentin and enamel as it appears in the walls of prepared cavities. Figure 280, D. E.

THE ENAMEL WALL is that portion of the wall of a prepared cavity which consists of enamel. E. W. It includes the thickness of the enamel from the dento-enamel junction to the cavo-surface angle.

THE DENTIN WALL is that portion of the wall of a prepared cavity which consists of dentin. D. W.

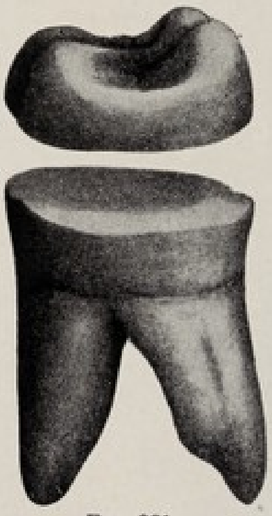


FIG. 281.

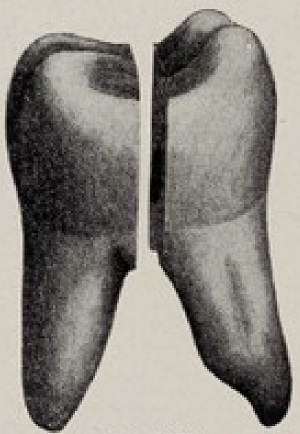


FIG. 282.

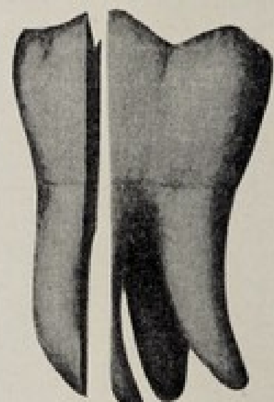


FIG. 283.

The dentin wall of a prepared cavity and the enamel wall may be on the same inclination and continuous, as on the left side of Figure 280, supposing that to be the wall of a prepared cavity. Or the dentin wall may be on one inclination and the enamel wall on another, as shown by D. W. for the dentin wall and E. W. for the enamel wall, supposing these to constitute the prepared cavity wall.

THE PLANES OF THE TEETH AND THE INCLINATION OF WALLS OF PREPARED CAVITIES.

The teeth have three planes which may frequently be used to advantage in descriptions of cavity preparations, and especially in speaking of the inclination of cavity walls.

THE HORIZONTAL PLANE, Figure 281, is at right angles to the long axis of the tooth and may be supposed to cut through the crown at any point in its length.

THE AXIO-MESIO-DISTAL PLANE, or the mesio-distal plane, Figure 282, passes through the tooth mesio-distally parallel with its long axis.

THE AXIO-BUCCO-LINGUAL PLANE, or the bucco-lingual plane, Figure 283, passes through the tooth bucco-lingually parallel with its long axis. In the incisors and cuspids this is the labio-lingual plane.

The inclination at which walls of prepared cavities are cut, or of the dentin wall and the enamel wall, when each is specifically mentioned, is reckoned from these planes of the teeth. When great accuracy of statement is desired, the inclination may be given in centigrades. More generally the term, outward inclination, or inclined outward, is used, with some word expressing degree, as slightly, strongly, etc. In this use of words the wall of the prepared cavity mentioned is always inclined away from the plane of the tooth in passing from within outward. The enamel wall and

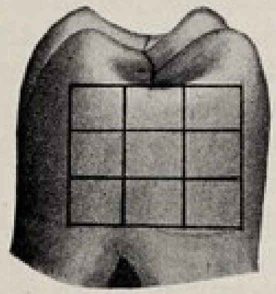


FIG. 284.

the dentin wall of any given part of a prepared cavity may be on different inclinations; for instance, the lingual dentin wall of a mesial cavity in a first molar tooth may be cut in the mesio-distal plane and the enamel wall inclined outward five or six centigrades, as shown in Figure 280. This will make a slight angle at the dento-enamel junction.

The bevel of the cavo-surface angle is always reckoned from the plane of the enamel wall.

THE USE OF DIVISIONS OF THE SURFACES OF THE TEETH IN CAVITY DESCRIPTION.

Whenever it is desired to indicate the portion of a surface of a tooth involved in decay, or the extent of a cavity, it may conveniently be done by an imaginary division of the surface into thirds, fourths or fifths. This division may be mesio-distally upon a buccal, lingual, or occlusal surface, or occluso-gingivally upon a buccal, lingual, mesial or distal surface, or it may be bucco-lingually upon an occlusal, mesial or distal surface. In other words, the divisions may be made upon any one of the planes of the tooth. Figure 284 shows the mesial surface of a molar divided into thirds

in both the bucco-lingual and the occluso-gingival directions.

For instance, a cavity in a buccal surface may be said to involve the middle third mesio-distally of the gingival third occluso-gingivally. Or, if the cavity is broader, it may involve the middle three-fifths bucco-lingually of the second fourth of the surface occluso-gingivally.

In this use of words, it must be borne in mind that when the adverbial form is used, it indicates direction. Mesio-distally means from mesial to the distal. Bucco-lingually means from the cheek toward the tongue, etc. This use of words is so simple that it should only require mention to be perfectly understood. Surgeons continually use this plan in speaking of the location of fractures of the bones. As, for instance, the humerus was broken at the junction of the middle and upper thirds, or the radius was broken in the middle of the lower third, etc. There is no need of any specific rules for this use of words in dividing the surfaces of the teeth in cavity descriptions, as any divisions intelligently made will be readily understood, and the portions of the surface involved quite accurately described. If it is said that a cavity in the mesial surface of a first lower molar extends from the occlusal surface to the junction of the gingival and middle thirds, and bucco-lingually from the mesio-buccal angle to the junction of the middle and lingual thirds, it should be understood. The same conception of the cavity should be obtained if it is said that it occupies the buccal two-thirds bucco-lingually, or that it occupies the buccal and middle thirds. There is scarcely any limit to the use that may be made in cavity descriptions of these divisions of the surfaces of the teeth.

CUTTING INSTRUMENTS

ILLUSTRATIONS: FIGURES 285-292.

IN the past the want of some recognized scheme of nomenclature and classification of dental operating instruments which would individualize the instruments of the several orders and classes was a great bar to progress in teaching instrumentation. This was felt by all who labored for exactness in their operations, or endeavored to express the manner of their performance in writing, or to speak of the instruments used. A teacher had no means of telling his students just what particular instrument he would use in performing a specific act in excavating a given cavity. So long as the writer or speaker was without this means of communication, students in school, dentists in societies, or readers of the literature, were unable to know just what was meant, and any description of cavity preparation was confusing and without the force of exactness. It was therefore necessary to develop a strict classification of the useful forms of excavators, condensers, etc., and a nomenclature by which each individual form could be designated.

Students need in the beginning of school work a close drill in the appreciation of the forms, particularly of cutting instruments, which will enable them to discover the peculiarities of each with exactness, as to width, length and angle of blade and the proportions of the several parts. If this be coupled with observation of the capabilities of each of the several classes of forms, and experience in their use, an impression will be made upon the mind and a skill acquired by the hand that will be a great aid in the development of manipulative ability. Such a nomenclature has now had sufficient trial and is found adapted to the naming of all manner of cutting instruments and condensers.

INSTRUMENT NOMENCLATURE.

NAMES OF INSTRUMENTS. Each of the names applied to instruments has a meaning. There are four classes of names. First, those which denote the purpose, as excavator, condenser, scaler, separator, clamp; second, those which denote position or manner of use, as hand condenser, hand mallet, automatic mallet, push scaler; third, those which describe the form of point, as hatchet, chisel, margin trimmer, spoon; and fourth, those which describe the part which forms the angle of the blade in relation to the handle.

These names are often combined for more complete descriptions of the instruments named, thus: Monangle excavator, or,

monangle hatchet excavator, binangle spoon excavator, contra-angled enamel hatchet, etc. In these combinations each name is descriptive of some part of the instrument or of its use.

NAMES OF PARTS. Each excavator is composed of a shaft, which is used as a handle, a shank and a blade. Usually the shaft is perfectly straight and without variation in size. The *shank* begins with the first turned portion and connects the shaft with the blade or working point. It usually tapers from its connection with the shaft to where the blade begins. The *blade* is the part bearing a cutting edge. It begins at the angle which terminates the shank — the last one, if there are two or more — and terminates in a cutting edge.

Condensers have no cutting edge. The part corresponding with the blade in excavators terminates in a blunt point called the *nib,* or simply the point. The end of this nib is called the *face* of the condenser, and is usually finely serrated or roughened to prevent slipping. The face itself may be flat or convex. The form of the face may be round, square, or a parallelogram.

NAMES OF ANGLES. The angles of the blades of instruments in relation to their shafts are varied to give proper access in different positions in the mouth and different surfaces of the teeth, also to maintain the best balance of the instrument in the hand when force is applied and to give the operator the best view of the field of operation.

Instrument blades may be continuous in the direction of the shaft, or the shank may have one, two or three angles; they are called straight, monangle, binangle or triple angle instruments. See Figure 292.

EXCAVATORS AND THEIR USES.

Instruments in the forms of chisels, hatchets and hoes are used for two principal purposes: (a) to cleave or split enamel which has been undermined by decay in the dentin or by cutting the dentin away with a bur (b) to cut the dentin walls to proper form. In the descriptions of cavity preparations in this work, the chisel and hoe forms are all placed in a single group and designated as chisels, while the instruments heretofore listed as enamel hatchets (in pairs with right and left bevels), and the bibeveled hatchets are placed in a single group of hatchets. It will be noted later that the formulas, which give the width, length and angles of the blades make it possible to indicate any of these instruments as either a *chisel* or a *hatchet,* without further designation than the formula. The formulas for the bibevel hatchets in the new set are in every case different from the right and left bevel hatchets, and the formulas for the chisels and hoes are in a definite series.

CHISEL. Straight blade with cutting edge formed by beveling from one side. The blade is usually straight, but may be slightly curved.

MONANGLE CHISEL. Same as straight chisel, except the blade is placed at an angle with the shaft. This instrument has heretofore been classified as a hoe.

BINANGLE CHISEL. A chisel blade placed at a slight angle with the shaft in the hoe form; the cutting edge is on the distal side of the blade. Other chisels of the same form have the cutting edge on the mesial of the blade. These are called reverse bevel chisels. As the name indicates, there are two angles between the shaft and the blade of all binangle chisels.

HATCHET. The shank has one or more angles or curves, the last length forming the blade, the flat sides of which are in the plane of the angle or angles, or, if the blade were at a right angle with the shaft, the cutting edge would be parallel with the shaft. Hatchets may be bibeveled, as is an ordinary hatchet, or they may have a chisel blade placed with the cutting edge at right angles as compared with that of the chisel. These are always in pairs, one with a left and one with a right bevel.

SPOONS. The spoons are always made in pairs. They are first made in the form of hatchets and then the blade of the one is curved to the right and the blade of the other is curved to the left. The cutting edge is ground to a semi-circle and sharpened to a thin edge. The direction of the curve of the blades makes the instruments true rights and lefts, i. e., lateral cutting instruments. Spoons are used to remove decayed dentin.

MARGIN TRIMMERS AND ANGLE FORMERS. These instruments are like spoons both as to the curves of the blades and the dimensions, while the cutting edge is like that of a single bevel hatchet, but at an angle to the length of the blade. There are always two pairs of these instruments, constituting a set of four in a given size. Each pair has a right and a left beveled instrument. The cutting edges of one pair make an acute angle with the edge of the blade farther from the handle; the cutting edges of the other pair make an acute angle with the edge of the blade nearer the handle. As will be explained later, these instruments are convenient for trimming margins of various walls of cavities and also for forming sharp angles in the internal parts of cavities. They will be generally referred to as *margin trimmers*.

DISCOID. (Disc-like, circular). The blade is circular in form, having a cutting edge extending around the whole periphery, except that portion by which it is joined to the shank. This circular blade is placed at more or less of an angle with the shaft. The discoid is used for the same purpose as a spoon — to remove carious dentin.

CLEOID. (Claw-like, in the form of a claw). Sharp pointed blades in the form of a claw, with cutting edges on two sides of the blade. The cleoid is used particularly to remove any portion of dentin that might overhang a horn of a pulp, after the pulp chamber has been otherwise fully opened.

SIDE BEVEL ON BLADES. The chisels and hatchets of the larger sizes are beveled on both edges of the same surface of the blade as the bevel of the cutting edge. The angle of the side bevels is the same as that of the bevel of the cutting edge at the end of the instrument. This enables the operator to cut in either direction with the sides of the blade, as occasion presents. In several positions, this side bevel permits the instrument to be used more effectively in cutting with the end of the blade. For example, in preparing the buccal and lingual walls of the proximal portion of proximo-occlusal cavities in the bicuspids and molars, the thin edge of the blade, which is in contact with the proximal tooth, permits the blade to be so placed that it will project farther into a very narrow embrasure than would be possible without the edge bevel, and gives the cutting edge at the end of the instrument a better "bite."

FORMULA NAMES

Formula names have been adopted for the cutting instruments which describe each individual instrument so accurately that each one may be known when its class and formula is spoken or written. This is necessary in order that a teacher or writer may be understood when speaking of the use of particular instruments, and that students and dentists may speak intelligently of these matters to each other.

These formula names are formed upon the same principle as that used by the carpenter in naming his chisels or augers, as half-inch chisel, one-inch chisel, three-quarter-inch auger, etc. But to sufficiently describe the point of an excavator so that the particular instrument will be known at sight, it is necessary to give three measurements. In all of this, the metric system of measurement is used and there are three distinct units: One for width of blade, the tenth of a millimeter; one for length of blade, the millimeter; one for the angle of blade, the centigrade. The name which indicates the working point, as hatchet, hoe, spoon, etc., is mentioned first, and then the formula of the point or working part. This formula consists of the measurement, first, of the width of the blade in tenths of a millimeter used as the unit; second, of the length of the blade in millimeters; third, the angle of the blade in relation to its shaft or handle, in centigrades, or hundredths of a circle. It should be noted that the width and length indicate the size of the blade. Also, in order that the individual instruments may be easily learned and remembered, the set is confined to a regular range of sizes and range of angles of blades that will give an orderly set for practical use and a sufficient variety of forms. In this way, unnecessary multiplication of forms is avoided.

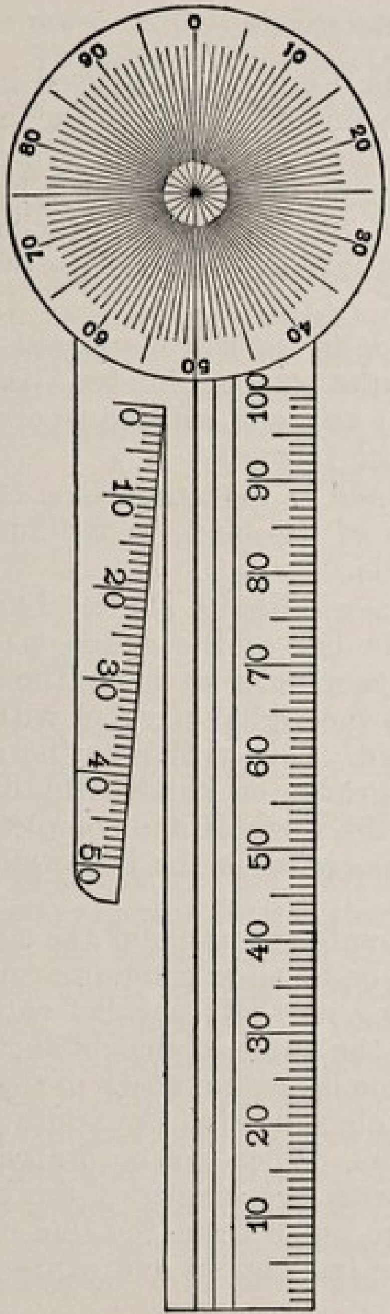


FIG. 285. The dental instrument gauge.

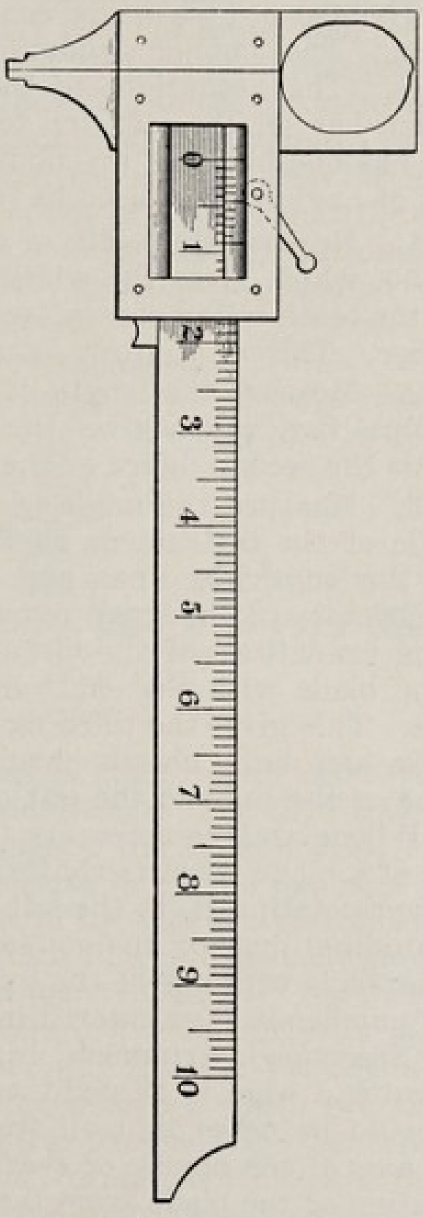


FIG. 286. The Boley gauge.

THE METRIC SYSTEM OF MEASUREMENT.

There is but one practical way of learning any system of measurement and that is by using it. The denominations of the system may, however, be learned from books. In the metric system these denominations, so far as our uses in dentistry require are:

Meter	39	inches	approximately.
Decimeter, tenth of a meter...........	4	"	"
Centimeter, hundredth of a meter.....	$\frac{2}{5}$	"	"
Millimeter, thousandth of a meter.....	$\frac{1}{25}$	"	"
Tenths of a millimeter.			

DENTAL INSTRUMENT GAUGE.

This gauge for dental instruments, Figure 285, is used in the measurement of excavators, condensers and burs. It is in the metric system. The smaller gradations on the principal bar are millimeters. The gradations of the width of the slot formed by the smaller bar on the left are tenths of millimeters. The circular head has one hundred divisions — centigrades — for the measurement of angles. It is used as follows:

1. Measure the width of the blade in the slot numbered from 0 to 50, which gives the width in tenths of a millimeter. In this case the tenth millimeter is used as the unit and entered as a whole number. This is the first figure in the formula.

2. Measure the length of the blade in the gradations on the principal bar, which gives the length of the blade in millimeters. This is the second figure of the formula.

3. Measure the angle of the blade with its shaft. Lay the handle of the instrument on the main bar of the gauge, parallel with the lengthwise lines, and, while keeping it so, bring the blade (turned toward the small numbers to the right) parallel with one of the gradations of the circular head. This will give the angle of the blade with the shaft in centigrades or hundredths of the circle. This gives the third figure of the formula and completes it. The reverse bevel chisels should be placed with the blade parallel to one of the lines to the left of zero.

Whenever it is necessary to designate the angle of the cutting edge of a blade with its shaft, it is done by sliding the instrument, without rotating it, to the left, keeping its shaft parallel with the longitudinal lines on the gauge, until the angle of the cutting edge corresponds with one of the lines of the larger numbers to the left. This number is then entered in brackets following the width number. See margin trimmers, Figure 292. When not so designated, the cutting edge is at right angles with the length of the blade. It should be noted that all angles are made from the line of the long axis of the handle or shaft of the instrument and express the deviation of the blade from that line.

These formulas are stamped on the handles of the excavators. Condenser points and other instruments may be measured and designated in a similar manner.

The diameters of burs and drills, and the dimensions of condenser points may be obtained by measurement in the slot. The measurement of angles may be done as well on the illustration of the instrument here published; other measurements can also be made, but less perfectly. The Boley gauge described later, though less convenient, will answer for all instrument measurements except the measurement of angles.

THE CENTIGRADE CIRCLE, Figure 285, was adopted for the measurement of the angles of instrument blades with shafts or handles

after much inquiry and trial of the divisions of the circle in general use. The astronomical divisions of the circle (360 degrees) would be very cumbersome because of its excessive number. The division of the mariner's compass (32 points) was not found well suited to this work. After much measurement and study of the angles of instruments in the market, and especially of the favorite instruments in dentists' cases, the centigrade circle was adopted as being best suited for the purpose. It has proven very easy of mental grasp as compared with the other scales or divisions of the circle. To convert centigrades into degrees, multiply 360 by the number of centigrades and divide by 100. The following is a comparison of the centigrade angles used, with degrees:

6	centigrades	=	21.6	degrees.
12	"	=	43.2	"
18	"	=	64.8	"
23	"	=	82.8	"
28	"	=	100.8	"
80	"	=	288.0	"
95	"	=	342.0	"

The two last are angles of the cutting edges of the margin trimmers. See Figure 292.

THE BOLEY GAUGE.

In dentistry, the metric system is much better suited to the necessary measurements than feet and inches. For all of this work, except the measurement of instruments, the Boley gauge, Figure 286, is much the best device. It should be in the hands of every student and dentist. It is widely used by watchmakers and scientific men, and is not expensive. With it, one can make measurements to one-tenth millimeter without difficulty. As there are approximately twenty-five millimeters to the inch, this is one-two hundred and fiftieth of an inch. In doing this the Vernier is used. This is the short scale on the sliding piece by which the jaws of the instrument are opened. Notice particularly that the ten divisions of this short scale — the Vernier — are equal to nine divisions of the principal scale on the instrument bar. When, in reading a measurement, it is found not to coincide with a division of the instrument bar, but is plus a part of a division, the division of the Vernier to the right that is opposite a division of the bar, gives the tenths plus of the true measurement, completing the reading. Besides the measurement of instrument blades, condenser points, burs, drills, etc., there are hundreds of uses for it in dentistry, and its use contributes to accuracy of observation.

There is no other one item in manual training that does more for the acquirement of appreciation of form than that of making many accurate measurements. In the human mouth it is rather rare that the central incisors differ so much in width as to be noticed by the ordinary observer, yet, with the Boley gauge, modi-

fied by grinding the ends of the straight points moderately thin so that they will go deeply into the embrasures between the teeth, it will be found that these two important teeth are generally not exactly the same in width. The instrument should be used much for measurements in building out broken angles of teeth and in the selection and adaptation of artificial substitutes for lost teeth. The man who makes much use of delicate measurements acquires a much finer appreciation of size and form by the eye alone than the man who does not make such measurements.

Instrument Construction.

Dentists should be familiar with the principal points in the construction of instrument forms that render them adapted to the particular uses designed. The reduction in the sizes of instrument points used by dentists that has steadily been going on for the last hundred years is quite as remarkable as the differences in form. The general tendency noticed is toward smaller and smaller working points in all cutting instruments and condensers. This has reference to those instruments in greatest use by dentists, decade after decade. With this difference in size has also come a difference in instrument grasps, and in the method of handling instruments in dentistry. All of the older instrument forms were based on the developments in fine carving and engraving. Carving was highly developed in very ancient times. The instruments for all of the more delicate work were adapted to manipulations in which the object being cut could be turned to suit the hand and the instrument grasp. In all of the books on dentistry more than one hundred years old, the instrument handles were designed to be grasped in the same way as instruments were grasped by persons doing fine carving. The handles were large, the points were large and rigid and they were used with the palm grasp or palm-and-thumb grasp. The dentist operating on the natural teeth could not turn the tooth about to accommodate his hand. And as the conception of the delicacy needed in this work grew in his appreciation, a change very gradually took place in the forms of instrument handles, making them suitable for the more delicate pen grasp with its larger variety of applications, and reduced the size of the working points in proportion to the reduction of power in the form of grasp. This is clearly a case of the survival of the fittest, or those forms and methods of use of instruments best adapted to the objects designed. Enamel and dentin are hard substances to cut, and in order to cut them effectively, the force that can be exerted by the hand with the grasp used must be concentrated upon a very short length of blade. It is a mistake to use a broad blade, of a chisel for instance, where much enamel is to be cut away. The length of the cutting edge is too great for the power of the hand to do effective work. Narrower blades and more careful direction by the hand contribute to speed, because the whole force of the hand is concentrated on

the smaller area and becomes that much more effective. The dentist should never lose sight of this fact.

Many alloys have been introduced as substitutes for steel in the manufacture of cutting instruments, in order that they may be sterilized by boiling without injury to the fine finish so essential for dental instruments. Many of these have been tried, but none were sufficiently hard to maintain a satisfactory cutting edge.

FORMING THE ANGLES. Considering the small diameter of the handles of present day instruments, it is a rule that the cutting edge must be within three millimeters of the central axis of the shaft to maintain the proper balance of the instrument. If the cutting edge is a greater distance from the line of the central axis of the shaft, the instrument is liable to turn in the hand when pressure is applied. Such an instrument is unsteady and ineffective. See Figure 287.

MONANGLE. Instruments having one angle must have fairly short blades or the angle of the blade with the shaft must be slight. Obviously, a blade set at 23 centigrades (almost a right angle) to the shaft, may not be more than 3 mm. in length. The monangles therefore constitute the large majority of the small instruments. See instruments number 216 to 260 in Figure 292.

CONTRA-ANGLE. Instruments with moderately long blades to be placed at an angle with the shaft would have their cutting edges outside the three millimeter limit, if but a single bend or angle should be made in the shank. In order to bring the cutting edges more nearly in line with the central axis, two and for some instruments three angles are made.

BINANGLE CONTRA-ANGLE. In an instrument of the angle of 12 centigrades or less, the binangle contra-angle will bring the cutting edge sufficiently near the central line of the shaft, and at the same time carry the shank sufficiently out of the way to permit the use of the full length of the blade. In forming a binangle contra-angle the shank of the instrument is first bent backward (from the direction of the cutting edge), and nearer the cutting edge another bend is made forward — this length forming the blade, the object being to form a long blade, the edge of which will be near the central line of the shaft, as shown in Figure 288E.

TRIPLE-ANGLE CONTRA-ANGLE. In instruments of a greater angle than 12 centigrades a binangle will not bring the cutting edge sufficiently near the central line of the shaft, therefore a triple-angle contra-angle must be made. This is done by first bending the shank backward, as in the binangle contra-angle, and then forming another angle which will bring the remainder of the shank parallel with the shaft; then passing forward a space of more or less length as may be required, another bend is made forward by which the blade is formed. In this way the cutting edge of a long blade is brought sufficiently near the central line of the shaft for

effective work and the shank carried sufficiently out of the way to permit the full use of the length of the blade.

This is an important factor in instrument construction that has been much ignored by persons designing instrument forms. For this reason, persons selecting instruments should examine carefully to see that the working point is sufficiently near the line of the central axis of the shaft for the instrument to be fairly balanced in the hand when pressure is made with its cutting edge. This will be better appreciated by trying such an instrument as any of those illustrated in Figure 287, which have been incorrectly contra-angled. At every effort to cut with such an instrument, there is felt a tendency to turn in the fingers, and, unless this is closely guarded in every considerable effort, it may do damage. Under any conditions such an instrument will be found lacking in usefulness as compared with a similar length of blade properly contra-

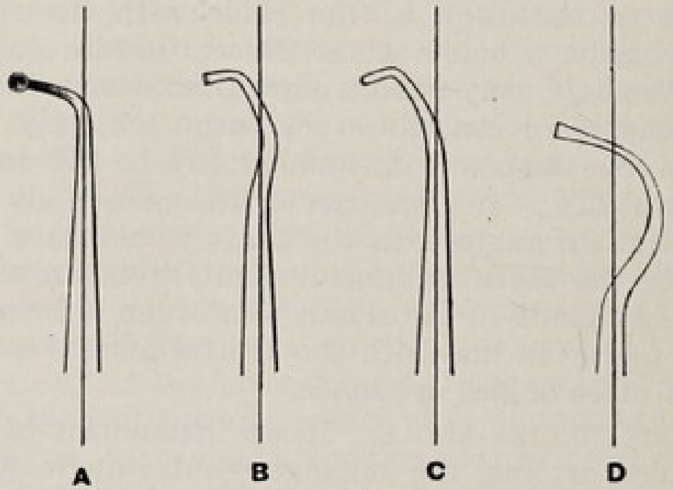


FIG. 287. Instruments wrongly contra-angled. Their points are so far from the line of the central axis of the shaft, as shown by the line, that they incline to twist, or turn, in the fingers when the effort is made to cut with them. They are out of balance.

angled as shown in Figure 288. The object of the contra-angle is to enable one to use a long blade effectively.

In Figures 287, 288, a line has been drawn over the handle and instrument point to show the relation of the point to the long axis of the instrument handle. It will be noticed that those in Figure 287 have the point far to one side of the central line of the shaft, while those in Figure 288 have the contra-angle so made that the working point is close to the line of the central axis of the shaft. These latter will reach into a deep cavity just as well as the former, and will be steady under pressure in cutting. In using those made as in Figure 287, the hand will always be struggling to prevent the instrument from tipping or turning. This will not be felt in the use of those made as shown in Figure 288.

The cutting edge of each contra-angled instrument should be so near the central line of the handle that, when the instrument is

laid edge downward upon a plane surface (as the top of a table), the edge should be close to, but not actually rest upon the surface.

RIGHTS AND LEFTS. While the greater number of cutting instruments are *direct* cutting, there is a distinct division of *lateral* cutting instruments better known as "rights and lefts." The instrument which is used to cut in the direction from right to left is designated as the right, the one which cuts from left to right as the left instrument of the pair. These are all *double plane* instruments. If an instrument with two or more curves or angles in the shank is laid on a table, it will generally be found that all of the curves are in a single plane, which may be made to coincide with the plane of the table top. Or, if held before the eye, or between the eye and a window, in a certain position in relation to its curves, it forms a straight line. This is a *single plane* instrument because all of its angles and curves are on one plane. All of

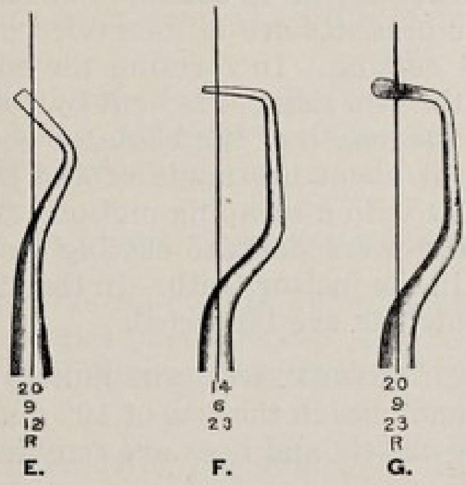


FIG. 288. Instruments correctly contra-angled. Their points are brought close enough to the line of the central axis so that they will not be inclined to twist, or turn, in the fingers when the effort is made to cut with them. They are well balanced.

the lateral cutting instruments have an angle or curve in a plane at right angles to this principal plane. This will be seen by holding any of the spoons or gingival margin trimmers before the eye. The curve of the blade is in the opposite plane to the angles. It is this that makes it a lateral cutting instrument. They are therefore *double plane* instruments. Angles that are in any other direction than in one of these planes are inadmissible. It often appears that an angle in a different direction would enable one to do certain things easier and many instruments have been so made. None of them have remained long in use because of their unfitness. There seems to be some undefined sense of antagonism to the muscular sense or the appreciation of motion that causes all such instrument forms to become awkward and objectionable.

BEVELED RIGHTS AND LEFTS. Beveled rights and lefts are direct cutting instruments made into rights and lefts by placing a

bevel on one side of the blade of one, and on the other side of the blade of another, forming a pair. The instrument having a bevel on the right side of the blade as it is held with the cutting edge down and pointing away from the observer, is designated as the right instrument of the pair. These are single plane instruments and are designed primarily for direct cutting, yet may be used for lateral cutting with a scraping motion; one is suited for shaving down one wall of a cavity and the other suitable for the opposite wall. See hatchets 18-9-12, Figure 292. The larger sizes are made heavier and stronger in their shanks and blades than others, for the heaviest usage in chipping enamel and shaving enamel or dentin walls.

The smaller sizes are more delicate instruments primarily for use in the anterior teeth, although they are useful in many positions in the bicuspids and molars.

BIBEVELED INSTRUMENTS. In the set of 102 and also in the set of 48 instruments, the hatchets are all bibeveled cutting instruments, intended for direct cutting. In forming the edges, the blades are equally beveled on the two sides. They cut by being pushed forward in the direction of the length of the blade, or shave a wall by being inclined toward it at about the angle of the bevel, or again they may be used laterally with a scraping motion. This form of instrument is used for the more delicate cutting in the preparation of cavities, especially in the incisor teeth. In the 1935 set of 46 instruments, only four hatchets are bibeveled.

SINGLE BEVELED INSTRUMENTS, NOT RIGHTS AND LEFTS. These include the chisels and hoes in the sets of 102 and of 48 instruments. In the 1935 set, the chisels and hoes are combined into a single set of chisels.

They are regularly beveled on the distal side of the blade like a carpenter's chisel. Instruments of this type with a slight angle, may be beveled on the mesial side. These have been called *reverse bevel chisels*. Straight chisels and those with blades at angles of 12 centigrades are generally used with a push motion, although they are also effective in cutting with a scraping motion. The blades at angles of 23 centigrades are essentially pull motion instruments.

CUTTING INSTRUMENTS ARRANGED IN SETS.

A secondary object in classifying instruments according to their use and in developing formulae by which the blades may be accurately described was to make possible the arrangement of sets consisting of a sufficient variety of widths, lengths and angles of blades of each type to meet all requirements in the preparation of cavities. In order to give wide range of choice a set of 102 instruments was originally designed. No dentist would care to have

so many instruments. This large set permitted each operator to select a set to meet his individual needs and to add others as he might desire. The plan has also been used in designing other sets which contain few, if any, duplicates of the set of 102. Certain instruments are more popular than others in special localities, because outstanding operators have designed them and taught their use. The important consideration is that each set shall have ample range to enable the operator to prepare cavities in the best form with the least discomfort to the patient, and not be burdened with unnecessary instruments. Most operators develop favoritism for certain instruments and use them to the best advantage. Others will prepare similar cavities quite as well with other instruments.

It has always been the objective to select, particularly for the student lists in dental colleges, the smallest number of instruments that will answer for satisfactory training. After graduation, a few additional instruments are usually added to the college set. For most operators, from forty to fifty instruments should be sufficient.

From the original set of 102, the University set of 48 was selected in 1907 as being sufficient for teaching purposes, as well as to meet the needs of most operators.

NEW SET OF FORTY-SIX INSTRUMENTS.

A new set of 46 was selected in 1935, after consultation with a number of teachers and practitioners who have used the set of 48 for many years. See Figure 292. It differs in several respects from the set of 48.

The following table gives the number of instruments of each type in each of the three sets:

	Set of 102	Set of 48	Set of 46
Chisels	6	6	14
Hoes	24	9	
Enamel Hatchets	6	6	16
Hatchets	24	9	
Special Hatchets	2	2	2
Spoons	18	6	4
Margin Trimmers	8	8	8
Discoids	3	1	1
Cleoids	2	1	1
Others	8		

The set of 48, with slight modifications, has been used in a considerable number of dental schools for more than a quarter of a century. However, the selection of a new set appeared to be desirable in order that certain new forms, suggested by various teachers, might be included. The new forms consist of reverse bevel chisels — with the bevel on the mesial side of the blade, and

an extension of the series of right and left beveled hatchets into smaller sizes. These two modifications added six instruments to the set. In order to avoid an increase in the total number, new sizes were introduced by which two instruments of certain classes would replace three. Several other minor changes were made. In this study attention was given to the fact that the chisels and hoes were so nearly alike that they might be placed in one group. Likewise the changes in the hatchets made it practicable to combine the enamel hatchets and the bibeveled hatchets into one group. This grouping enhances easy comprehension of the adaptability of these instruments to the box form of cavity.

If one thinks of a simple occlusal cavity in a lower left molar tooth, cut in the form of a box, it has four surrounding walls — mesial, distal, buccal and lingual. The chisels, beveled with the cutting edge on the distal side are adapted for cutting the mesial wall; the reverse chisels, beveled with the cutting edge on the mesial side, are adapted for the distal wall; the left beveled hatchet for the buccal wall and the right beveled hatchet for the lingual wall. These two groups, chisels and hatchets, are the only instruments in the set which are used to make the major preparation of cavities to the generally required forms in the bicuspid and molar teeth.

The other instruments may be considered as accessories. The spoons are used to remove carious dentin, oftentimes after the general cavity form is attained, and have no real part in forming the box-like cavity. The margin trimmers are used to trim margins smooth at proper angles, also to "sharpen" line angles in bicuspid and molar cavities.

The same principles apply to the forms of prepared cavities in the incisors, except that those in the proximal surfaces are triangular in form. The only change of consequence in the new set is that the hatchets with blades at angles of 6 and 12 centigrades are in pairs with right and left bevels, instead of bibeveled. Operators who have used the new instruments are agreed that they are more useful than the bibeveled instrument. Their use will be mentioned in presenting the detail of preparation of various cavities.

COMPARISON OF SETS OF 48 AND 46 INSTRUMENTS.

The University Set of 48 instruments and the 1935 set of 46 instruments are arranged in parallel columns on the following page, with the same or closely similar instruments of the two sets in corresponding positions in the two columns. This arrangement permits easy comparison and also serves as a guide in selecting instruments of the two sets which would be used for the same purpose.

UNIVERSITY SET *48 Instruments*	1935 SET OF *46 Instruments*
CHISELS	CHISELS
20 straight	18 straight
15 "	12 "
10 "	
20-9-6 binangle	18-9-6 binangle
15-8-6 "	12-6-6 "
10-6-6 "	18-9-94 "
	12-6-94 "
HOES	
12-5-6	
12-5-12	12-6-12 binangle
12-5-23	12-6-23 triple angle
8-3-6	9-3-6 monangle
8-3-12	9-3-12 "
8-3-23	9-3-23 "
6-2-6	6-2-6 "
6-2-12	6-2-12 "
6-2-23	6-2-23 "
ENAMEL HATCHETS	HATCHETS
20-9-12 R & L bevel	18-9-12 R & L bevel
15-8-12 R & L "	12-6-12 R & L "
10-6-12 R & L "	
ORDINARY HATCHETS	
12-5-6 bibeveled	12-6-6 R & L "
12-5-12 "	
12-5-23 "	
8-3-6 bibeveled	9-3-6 R & L bevel
8-3-12 "	9-3-12 R & L "
8-3-23 "	9-3-23 bibeveled
6-2-6 bibeveled	6-2-6 R & L bevel
6-2-12 "	6-2-12 R & L "
6-2-23 "	6-2-23 bibeveled
SPECIAL HATCHETS	
5-3-28 bibeveled	
3-2-28 "	3-2-28 bibeveled
	3-1-28 "
SPOONS	
20-9-12 R & L	
15-8-12 R & L	15-8-12 R & L
10-6-12 R & L	10-6-12 R & L
DISCOID	DISCOID
20-2-12	20-2-12
CLEOID	CLEOID
20	20
GINGIVAL MARGIN TRIMMERS	MARGIN TRIMMERS
20(95)-9-12 R & L	
20(80)-9-12 R & L	
15(95)-8-12 R & L	15(95)-8-12 R & L
15(80)-8-12 R & L	15(80)-8-12 R & L
	10(95)-6-12 R & L
	10(80)-6-12 R & L

IDENTIFICATION OF INSTRUMENTS. In 1912, Dr. E. M. S. Fernandez* suggested the simple method of cutting a ring around the handle of each instrument in a group for the purpose of assuring their proper replacement in the operating case. In a particular group, the first ring was cut near to the end of the handle, the second a little farther away, the third still farther, and so on through the series.

A somewhat similar plan is here proposed for quick identification of rights and lefts of all instruments made in pairs, to distinguish the reverse or mesial bevel chisels from the same sizes and forms with the regular distal bevel, also to tell a small chisel from a hatchet. Rings are cut in the shank ends of the handles so that they may be readily seen in the drawer of the cabinet. The rings are described in detail in connection with the illustration, Figure 292.

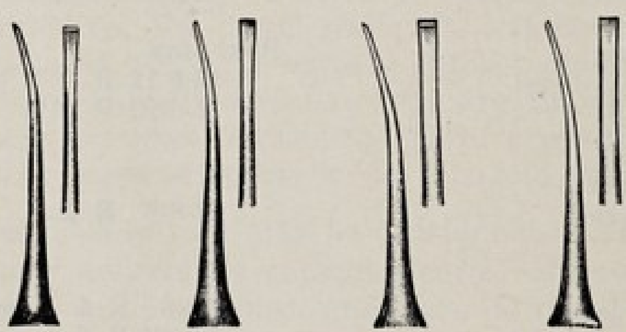


FIG. 289. Chisels designed by Dr. E. K. Wedelstaedt.

Credit is here accorded to the late Dr. E. K. Wedelstaedt for suggesting the Wedelstaedt chisels, illustrated in Figure 289, also for his splendid work in the organization of many dental clubs for the study of the technical procedures in cavity preparation and gold foil restorations.

The set of angle-forming instruments designed by Dr. C. E. Woodbury, who has been an outstanding teacher and study club worker in this field for many years, are illustrated in Figure 290. These are hoes, modified by grinding the bevel so that the cutting edge will be at an angle of 85 centigrades to the length of the blade, thus forming an acute angle with the long side of the blade. This acute angle is used to cut the line angles more sharply than may be conveniently done otherwise. There are two pairs of these instruments, 6(85)-2-6, right and left, and 12(85)-2-6, right and left.

More recently, Dr. Leroy Hartman suggested a similar change in the right and left beveled hatchets (enamel hatchets) to make both margin trimmers and angle formers of these instru-

* Dental Brief, 1912, Vol. 26, p. 810.

ments. This change seems not to impair their use in cleaving enamel. See Figure 291.

Attention will be called to the uses of these several instruments, which have special merit, but are not included in the set of 46, in the descriptions of the preparations of cavities.

ARRANGEMENT OF INSTRUMENTS IN THE OPERATING CASE.

A very satisfactory arrangement of the instruments of the new set of 46 in the operating case is presented herewith.

When the instruments are placed in the operating case for use they should be arranged in a definite form and always kept so. It is not important what form is used so that the form selected suits the convenience of the operator. The arrangement illustrated in Figure 292 is preferred as it has the instruments generally used for cavities in the anterior teeth in one group and those for the posterior teeth in another group. The spoons, discoid, cleoid and

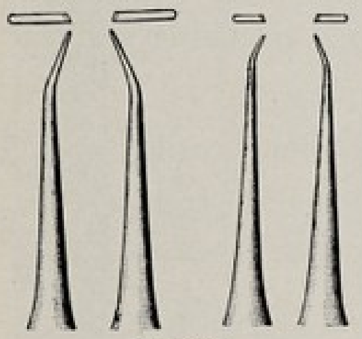


FIG. 290.

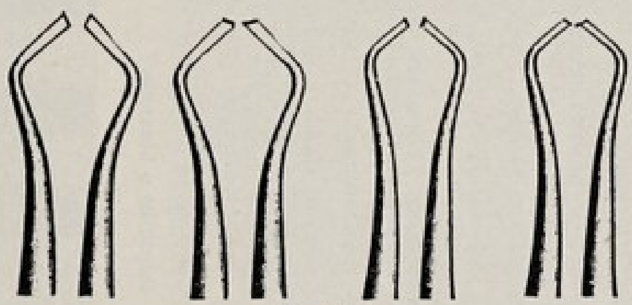


FIG. 291.

FIG. 290. Angle forming instruments designed by Dr. C. E. Woodbury. Formulae; 12(85)-5-6, right and left; 6(85)-2-6, rights and lefts.

FIG. 291. Angle forming instruments designed by Dr. Leroy Hartman. The blades are the same as the larger hatchets, while the cutting edges are the same as the margin trimmers. They are combinations of the two. Formulae; 15(95)-8-12, 15(80)-9-12, 10(95)-6-12, 10(80)-6-12, in pairs, rights and lefts.

margin trimmers are placed in a third group. These are considered accessory instruments, as they are used after the general form of the cavity has been made. With such an arrangement, one should quickly learn to select the desired instrument for a particular purpose.

The instruments of each group are arranged progressively from the largest to the smallest sizes. The dentist who knows the instrument points at sight and is able to think and speak in their formulas, should be able to do one-third more excavating in a given time and do it more accurately than one who does not know them. The dentist who has not learned to think in terms of instrument forms and their adaptation of these to his needs, wastes much time in searching for, and in making changes, to find instruments with which to do certain things. This time will be much more than saved by the orderly method of procedure. A definite arrangement, such as is possible on the formula plan, enables one

Fig. 292 Set of Forty-Six Cutting Instruments; Arrangement in Operating Case

This arrangement of the set of instruments in the operating case is suggested as the most practical. They are divided into **three groups:**

The first group, in the upper row, consists of the smaller sizes of **chisels** and **hatchets**, which will generally be the only instruments required for preparing cavities in the incisors and cuspids.

The second group, in the middle row, consists of the larger sizes of **chisels** and hatchets, which will generally be the only instruments required in obtaining outline resistance and retention forms in cavities in the bicuspids and molars.

The third group, in the lower row, consists of the spoons, discoid, cleoid and margin trimmers, which may be considered as accessory to the instruments of the first and second groups, although generally used in the preparation of cavities in the bicuspids and molars.

The formula is given for each instrument, also the manufacturers stock number.

Special Markings on Instrument Handles as an Aid in Quick Identification. There are certain instruments in the set, which may not be easily distinguished from others; the two pairs of binangle chisels are exactly alike, **except for** the bevels of their blades; the smaller chisels and hatchets have the same formulae and look much alike, as do the right and left hatchets of each pair. From one to four rings, in two widths, are cut in the handles of selected instruments to assist the operator in identifying them. These rings are cut on the shank ends of the handles, so that they are in view when a drawer is only partly open.

Chisels. The pair of 94 angle chisels have four narrow rings; the two straight chisels have no rings; other chisels have three rings. There are wider cuts for instruments with blades of 9 width and 3 length. This last provision is to avoid confusion with chisels having blades of 6 width and 2 length.

Hatchets. All pairs have two rings on the left instrument and one ring on the right instrument. These rings are wider on the instruments with blades of 9 width and 3 length, to enable the operator easily to distinguish them from the blades of 6 width and 2 length. The bibeveled hatchets have **no rings.**

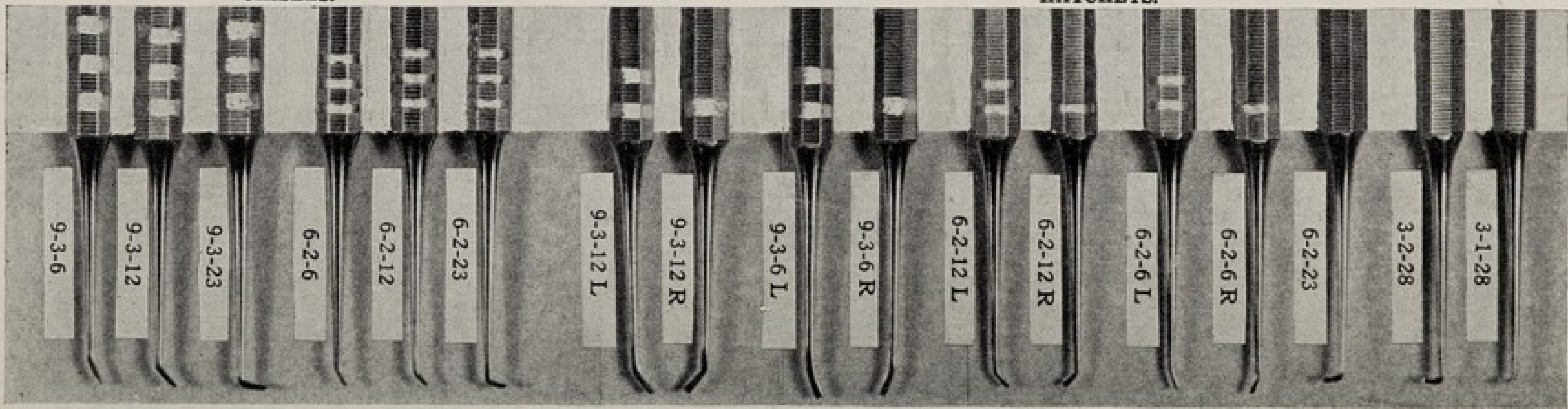
Spoons and Margin Trimmers. The left instrument of each pair has two narrow rings, the right instrument one narrow ring.

Cleoid and Discoid. These instruments have no rings.

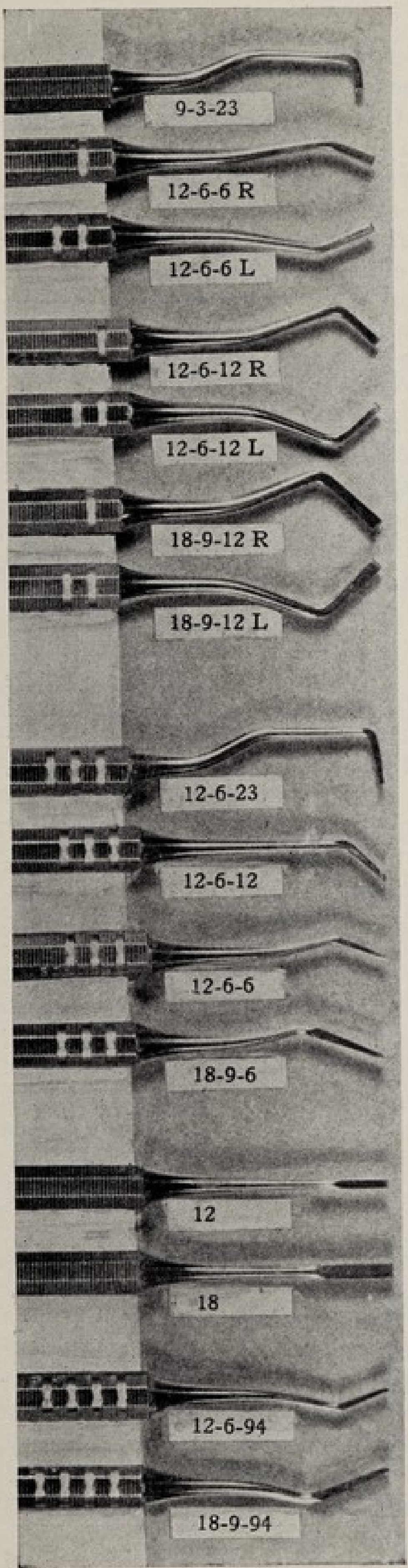
The blades of all chisels and hatchets that are 12 or 18 tenths mm. wide, are beveled at both sides at the same angle as the end bevel. The side bevels are not shown **in these illustrations.**

Note: The chisel 12-6-12 is illustrated as a monangle instrument. **It should be a binangle.**

CHISELS. HATCHETS.



216. 217. 218. 221. 222. 223. 240. 241. 242. 243. 244. 245. 246. 247. 256. 259. 260.

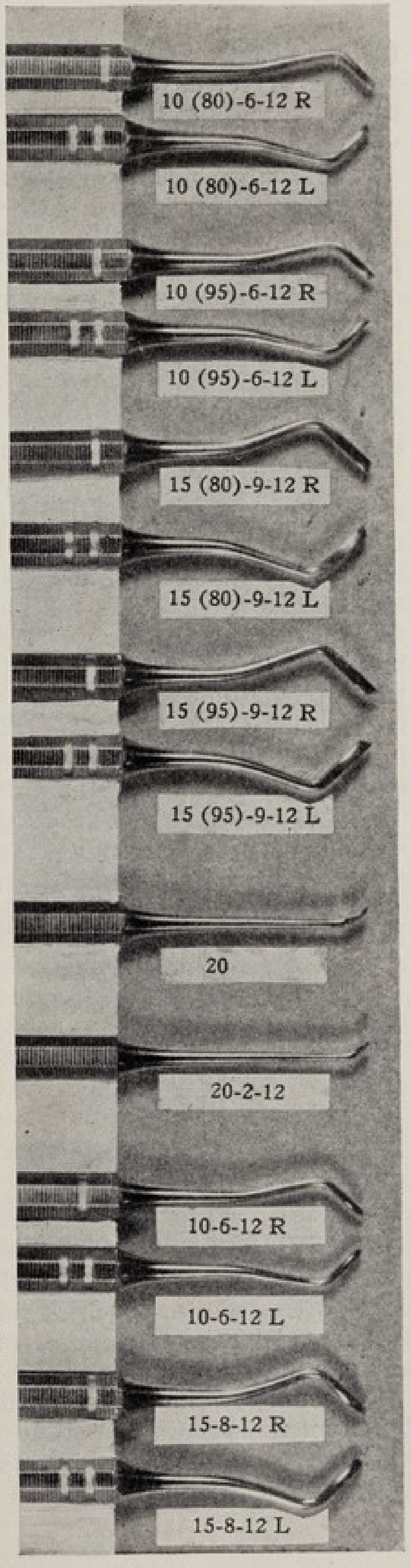


HATCHETS.

253. 237. 236. 235. 234. 233. 232.

CHISELS.

213. 212. 211. 210. 207. 206. 203. 202.



MARGIN TRIMMERS.

289. 288. 287. 286. 285. 284. 283. 282.

CLEOID.

279.

DISCOID.

276.

SPOONS.

275. 274. 273. 272.

to think easily in several ranges of forms and to adapt a greater variety of forms to the varying needs. This contributes both to the accuracy and the speed in operating, and is worth many times what it costs in effort to accomplish it.

The suggested arrangement gives a good idea of the ranges of sizes and of angles of blades for a single cavity. It also indicates that the operator usually selects instruments for a particular cavity from a rather small group, thus eliminating something of the confusion which a large number of instruments suggests. The situation is further simplified by the fact that one has a choice of sizes, depending upon the size of the cavity. For a cavity presenting no unusual complications, a few well selected instruments will usually be sufficient. One may be judged a good operator by noting the small number of instruments used in preparing a cavity.

THE STUDY OF INSTRUMENT FORMS AND POINTS. Every dentist should learn to read the instrument points and to know each instrument at a glance. The spoons, margin trimmers, discoid and cleoid are easily recognized and not likely to be confused with the chisels and hatchets. Likewise the hatchets are easily distinguished from the chisels because their cutting edges are at a right angle to the line on which the shank is bent at its junction with the blade, while the cutting edges of the chisels are parallel to the line of the bend in the shank. The principal difficulty is to distinguish particular instruments of the chisel group, and likewise especially the rights and lefts in the smaller hatchets.

One may quickly familiarize himself with the instruments of either group by arranging the instruments in several ways. The chisel group may be used as an example:

First they are arranged as to widths of blades.

18 straight	9-3-6
18-9-6	9-3-12
18-9-94	9-3-23
12 straight	6-2-6
12-6-6	6-2-12
12-6-94	6-2-23
12-6-12	
12-6-23	

It will be noted that there are three of 18 width; one straight and two of 9 length with angles 6 and 94; one with a distal, the other with a mesial bevel. There are five of 12 width; one straight, two of 6 length with angles of 6 and 94, one of 6 length and 12 angle, and one of 6 length and 23 angle.

Second, it should be noted that in the first arrangement, the instruments were incidentally also arranged according to lengths of blades. This view emphasizes the point that the widths and lengths correspond throughout the range of these instruments.

Third, these instruments may be arranged according to the angles of the blades.

18 straight	12-6-12
12 straight	9-3-12
18-9-94	6-2-12
12-6-94	
18-9-6	
12-6-6	12-6-23
9-3-6	9-3-23
6-2-6	6-2-23

There are two straight chisels of 18 and 12 widths of blade. There are two with angle 94, in widths 18 and 12; also four with angle 6, in widths 18, 12, 9 and 6, and in lengths 9, 6, 3 and 2. There are three with the angle 12; one is 12 wide and 6 long, one is 9 wide and 3 long, one is 6 wide and 2 long. There are three with the angle 23; one is 12 wide and 6 long, one is 9 wide and 3 long, one is 6 wide and 2 long.

A similar study should be made of the hatchets, then one should note the rights and lefts among the spoons, margin trimmers and hatchets. For the margin trimmers, it is also necessary to note the angles of the cutting edges in relation to the blades. The right and left hatchets are distinguished by the bevels of the blades.

USE OF THE DENTAL ENGINE

ILLUSTRATIONS: FIGURES 299-304

There have been many refinements in design of the dental engine within recent years. These include variations in speed, both forward and reverse, reduced noise, and improvements in hand-pieces. The contra-angled hand-piece enables one to use a bur or drill conveniently in locations inaccessible to the straight hand-piece. More recently greater precision has been attained in the hand pieces through new designs and finer workmanship. The improvement is especially noticeable and advantageous in the contra-angle.

The engine is used for certain parts of the excavation of cavities, for trimming restorations to form after they have been inserted, and for much of the polishing of restorations. For these several purposes, engines should be equipped with certain sizes and forms of excavating burs, a few sizes and forms of finishing burs, stones for grinding and sandpaper disks of different grades of fineness, rubber disks and brushes for carrying polishing powders, etc. In excavating, the bur is indispensable, and yet but a small part of the excavating should be done with burs. The forms of bur most useful are the round bur, the inverted cone bur and the fissure bur. Carborundum points, gold finishing burs, bibeveled drills, burnishers, disks, etc., are also used in the dental engine.

The selection of burs of proper size in each case is very important, as is the speed with which they revolve. Size, speed of revolution and sharpness are all related to the generation of heat, which usually means pain to the patient. The sharp bur, the slow movement and the small bur all make for less heat and less pain. Time is also related to pain. If a given amount of cutting is done with a series of cuts, with a very slight interval between, the pain is less because it requires the least bit of time for the bur and the tooth to become heated; the interval between cuts allows both to cool a little. Sharpness makes for exactness in cutting, and therefore better operating.

Burs are made both right and left cutting. Those in general use are right cutting; they revolve clockwise. Most burs have blades on the ends and sides. The end blades cut when pressure is made in the line of the shaft of the bur. For efficient cutting with the side blades of the bur the shaft should be moved clockwise along the wall that is being cut in order that the sidewise motion will aid each blade in "taking hold." One may demonstrate the difference by moving the shaft in the opposite direction. The difference will be more apparent if one endeavors to trim away a considerable thickness of a fairly hard gold. Therefore the place of beginning and the direction of movement are of importance when the cutting is to be done with the side blades.

As a rule, enamel should not be cut with a bur. There are two exceptions; when a pit is so slightly decayed that it is necessary to use a bur to effect the initial penetration of the enamel; also, when it is desirable, in cases of proximal decay in bicuspids and molars, that enamel of the occlusal surface be penetrated in preparing the step, or anchorage. This applies also to the lingual surface of the incisors. The opening is made in the position of a pit, where there is usually a larger percentage of comparatively soft cementing substance in relation to rods, and the cut can be made without pain if too much heat is not generated by the friction of the bur.

Figure 299 shows an assortment of burs which should be sufficient for most purposes. There are two sizes of round burs, with diameters of 10 and 20 tenths millimeters; six sizes of inverted cone burs, ranging from 6 to 16 tenths millimeters; and five sizes of fissure burs, ranging from 8 to 14 tenths millimeters. All sizes of fissure burs are also made with cross-cut blades, and both types are made in the tapered form. One straight cross-cut, or dentate, fissure bur is illustrated, also one tapered fissure bur.

One should familiarize himself with the various sizes by measuring them with the printed instrument gauge, Figure 285, so that a mental picture of each will be formed when its diameter is mentioned.

THE ROUND BUR. The round bur is used only for the opening of pit cavities in which decay has made little progress. For this pur-

pose round burs, from about one millimeter to one and a half millimeters in diameter, should be used by placing them in the pit while in motion and swaying the hand-piece to and fro so as to rotate the bur laterally while it is turning upon its axis. This lateral motion of the hand-piece will cause the bur to cut much more rapidly than when it is held in one position. The smaller size should generally be used first, and when it has entered the pit, may be followed with the larger size, if desired. Then the round bur should be laid aside and the cavity should be finished with other instruments. There is no other use for a round bur in excavating cavities, and many operators do not use them at all, but prefer an inverted cone bur or a bibeveled drill to open pit cavities.

THE INVERTED CONE BUR. There are three important uses for the inverted cone bur: The first is to extend the outline form of pit and fissure cavities after an initial opening has been made through to the dentin, either by caries or by a round bur. In either

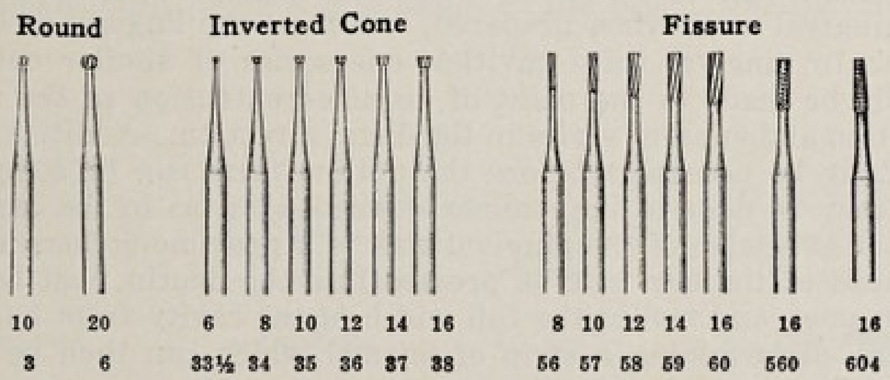


FIG. 299. An assortment of Burs. The first row of figures gives the diameter of each bur in tenths of millimeters, the second row gives the stock numbers.

case, the inverted cone bur should be carried slightly into the dentin, then laterally, undermining a little of the enamel, and withdrawn to break away the undermined enamel. To whatever extent the decay has already undermined the enamel, this cutting may usually be done painlessly. When sound dentin must be cut, it will usually be painful unless anesthesia is secured. The cuts are repeated along each groove until the rules of extension are satisfied. See Figure 300A.

The same use of the inverted cone bur is made, sometimes in reverse order, in securing outline form for the occlusal portion of proximo-occlusal cavities. The outline of the occlusal step may be secured on the plan just mentioned by beginning in a pit and extending along the several grooves. In so doing the cutting to the mesial or distal will lead to and connect with the proximal decay. Or, the cutting may begin in the decayed area and a series of cuts, undermining and breaking through the enamel, will fol-

low along a groove to the pit, reversing the order of beginning in the pit.

The same method of cutting with the inverted cone bur is employed to secure outline form in the smooth surfaces of the teeth. Although the access is different, the procedure is the same for all cavities of this type, which include proximal and gingival third cavities in all of the teeth. Usually some enamel in all directions from the position in which the decay has penetrated is first removed with a chisel or hatchet. As a rule all, or nearly all, of the enamel undermined by decay can be cut or chipped away. If it is desirable that the outline form in the particular surface be extended, an inverted cone bur is used in much the same manner as described for pits and fissures, except that there are no grooves, or developmental lines, to follow. The series of cuts are made in the dentin to undermine the enamel, which is broken out with the bur or may be removed with a hand excavator. In preparing proximal cavities, the cutting should preferably be in the gingivo-lingual and gingivo-labial, or buccal directions, to the points where the gingival wall, when prepared, will meet the lingual, or buccal, walls. In gingival third cavities, one series of similar cuts will usually be made to the point of required extension in the mesial direction and another series in the distal direction. Additional cutting may be necessary before the outline form can be completed. This may be done in the manner described, or, as in the case of a further extension of the gingival wall of a proximo-occlusal cavity, the head of the bur may be pressed into the dentin, just beneath the enamel, and moved the full width of the cavity from buccal to lingual, undermining a strip of enamel which can then be easily trimmed away with a hand excavator.

In making these extensions it is important that the bur be kept very close to the enamel, as there is no reason for deeper cutting, which would unnecessarily weaken the tooth and endanger the pulp, either through subsequent thermal shock, or by actual exposure.

The second use of the inverted cone bur is to prepare resistance and retention form in all classes of cavities, although there are certain limitations to the use of the bur for this purpose in incisor cavities, which will be pointed out in discussing their preparation. This cutting is entirely in the dentin. In most cases this cutting is painful unless the tooth has been anesthetised. The objective is to develop the boxlike form by making a flat pulpal wall, with right angles of junction with four surrounding walls in occlusal cavities; a flat gingival wall with right angles of junction with axial, lingual and labial, or buccal walls in all proximal cavities; and a flat axial wall, with right angles of junction with four surrounding walls in gingival third cavities. In each case, if access permits, the end of the bur is held in the plane of the wall which constitutes the floor of the cavity, and is carried along the line-

angles of junction of that floor with each of the surrounding walls. See Figure 300B. It is obvious that the step portion of proximo-occlusal cavities would be treated the same as an occlusal cavity. It is often necessary to broaden some portions of the occlusal step of a proximo-occlusal cavity beyond the requirement of a simple occlusal cavity, to secure better anchorage for the restoration. This may be done by carrying the bur laterally in the dentin, in a line parallel to the cavity wall, undermining a narrow strip of enamel.

In many instances a hand excavator is preferable to a bur in the cutting of resistance and retention form, as will be mentioned in the preparation of the various cavities.

The third use of the inverted cone bur is to make starting points for gold foil restorations. The smallest sizes of burs are used for this purpose. Starting points for gold foil are made in all cavities, except those that are so small that the gold may be easily wedged between opposing walls. Two starting points are made in most cavities, so located that gold may be started in one and quickly built along a line angle to the other, thus anchoring

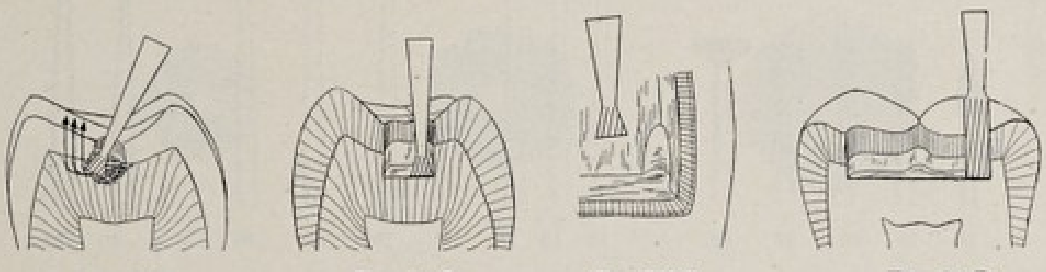


FIG. 300A. FIG. 300B. FIG. 300C. FIG. 300D.

the mass of gold between the two points. These starting points are naturally placed in positions of easy access; at either extremity of the disto-pulpal line angle in occlusal cavities; at either end of the axio-pulpal line angle in proximal cavities; and usually at either end of the axio-distal and possibly also the axio-mesial line angle in gingival third cavities.

The technic of making a starting point is illustrated in Figure 300C. The end of the bur is first placed against, for example, the pulpal wall of an occlusal cavity, in the disto-linguo-pulpal point angle. As the bur revolves, pressure is made laterally only, in the direction of the disto-lingual line angle. The bur should cut into the wall a little more than half of the diameter of the end of the bur; it should then be slowly withdrawn in the occlusal direction with the lateral pressure maintained but gradually lessened, making a slight groove leading away from the depression first formed. As a rule, the base or floor of the starting point should be on the same level and a continuation of the pulpal wall. Occasionally it seems desirable to cut the starting point slightly deeper than the pulpal wall.

THE FISSURE BUR. The fissure bur may be used instead of the inverted cone bur, in making extensions of cavity walls to obtain outline form, and more especially in preparing resistance and retention form in occlusal or proximal positions in molars in cases in which the cavities are deep. See Figure 300D. The end of the bur may be placed against the pulpal, or gingival, wall with the long axis of the bur held parallel with the axis of the tooth. As this bur follows the line angles of the pulpal wall with the surrounding walls, the end blades of the bur will cut the pulpal wall at right angles to the surrounding walls, while the side blades cut each axial wall in its full length from pulpal wall to the cavo-surface angle, parallel with the long axis of the tooth. In using a fissure bur in this way, attention should be paid to the danger of generating heat and causing pain. The cutting surface in contact with the tooth is several times as great as with an inverted cone bur of the same diameter. This should be compensated for by slower motion or less pressure or both.

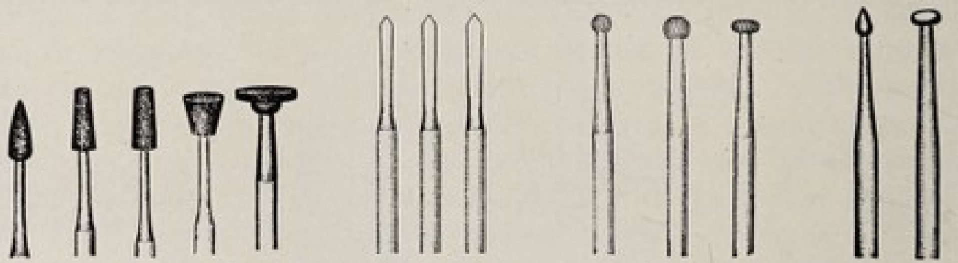


FIG. 301.

Fissure burs may be used in cases in which pulps of bicuspids and molars, particularly, have been removed and it becomes necessary to trim all of the surrounding walls in planes parallel or nearly parallel with the long axis of the tooth.

A variety of carborundum stones, drills, finishing burs and burnishers are illustrated in Figure 301. The several shapes of carborundum stones vary in size from 20 to 60 tenths millimeters. Three gold finishing burs are shown, two are round, with diameters of 20 and 30 tenths, one is oval, 30 tenths. Three bibeveled drills are 10, 15 and 20 tenths. Two burnishers are 20 and 30 tenths millimeters.

CARBORUNDUM STONES of fine grits are used for trimming cavity walls and particularly the enamel walls. They smooth enamel very effectively and are preferred by some operators for finishing enamel walls. They should be used at high speed and with very slight pressure, and should be kept wet with water from a syringe. The full depth of the surrounding walls of a cavity, both enamel and dentin, may be smoothed at one operation.

FINISHING BURS. These burs are made with the blades closer together and less deeply cut than the burs for excavating cavities. They are used for trimming the surface of amalgam, cast gold and gold foil restorations. Grooves may be deepened and margins may be trimmed. In trimming margins the blades should cut from the surface of the restoration toward the surface of the tooth.

The two burnishers illustrated were selected for the particular purpose of burnishing areas of erosion to relieve the sensitiveness.

THE BIBEVELED DRILL. The use of drills should be confined to certain especial purposes. These should be used when for any reason it becomes necessary to cut into the pulp chamber of a sound tooth, or make an opening through a restoration. This necessity occurs because of hyperemia or death of the pulp after a restoration has been made, or from death of the pulp from a blow or some unknown cause. It is often necessary to cut from the surface of the tooth to the pulp chamber, either through a restoration or through the enamel and dentin. The bur is not suitable for this work. The flat drill, bibeveled to a point, is the proper instrument; or the drill, followed by a round bur to enlarge the opening. In doing this where considerable tissue is to be cut through, it is best to use a small drill first, and when this has penetrated some distance, enlarge the opening with a larger drill or a round bur, then penetrate farther with the small drill and again enlarge. Proceed in this way until the pulp chamber is reached. In the attempt to drill deeply with a small flat drill, the instrument does not clear itself of chips readily and is apt to heat; also, it is likely to be broken by any movement of the patient.

FIG. 302.

DISKS. Three sizes of polishing disks are illustrated in Figure 302. The ½ inch and ⅝ inch should be most generally used in the coarser grits, the ⅝ inch and ¾ inch in the finer grits. The principal use of disks is in the polishing of gold foil and amalgam restorations, also for the final smoothing and polishing of the margins of gold inlays, on occlusal and proximal surfaces. In doing this, care must be exercised to avoid thermal shock. The smallest convenient size of the coarser grits should be used and the engine should be operated at slow speed. Larger sizes of the finer grits may be used, although the motion must be fast to give the finest

polish. The dentist should form the habit of applying disks intermittently, to permit the restoration to cool slightly during brief periods while the disk is held away. If a very little vaseline or cocoa-butter is applied to the disk, it will generate less heat.

Accurate trimming of gold foil and amalgam restorations with hand instruments, and wet polishing with wood points, rubber disks, etc., should reduce the use of disks to the minimum.

THE CONTRA-ANGLE HAND-PIECE is often useful in connection with the preparation of cavities, particularly in the lower molars. With it the proper position of the bur may be obtained in places that are not accessible to the straight hand-piece. The right-angle hand-piece has been used much in the past for this purpose, but it is a very awkward instrument, for the reason that the working

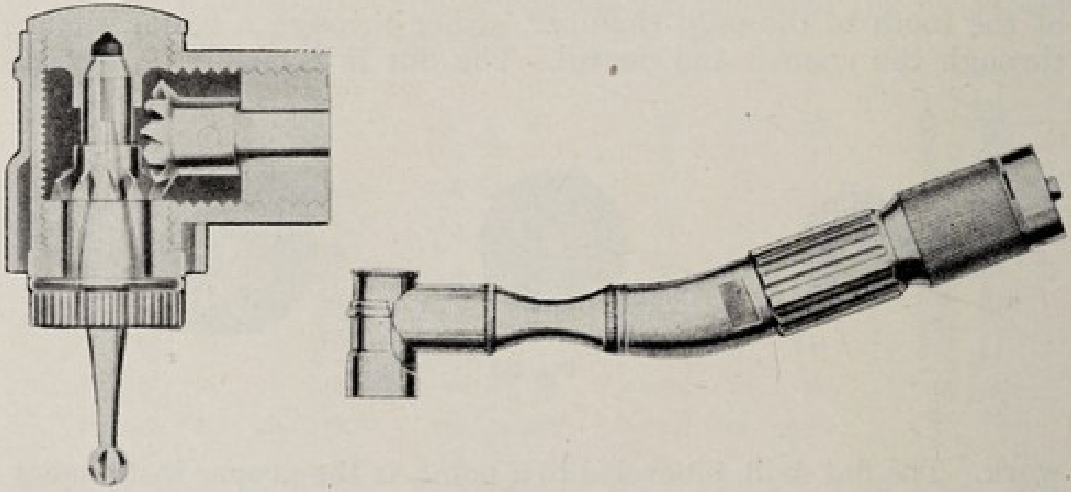


FIG. 303.

end of the bur is far out of the line of the axis of the hand-piece. This renders it ineffective. The contra-angle hand-piece remedies this defect. The instrument illustrated in Figure 303 is a recent development and a real precision mechanism; the bur revolves without vibration and this makes for accuracy and exactness in cutting. The mechanism is shown in the sectional view. Special burs, drills, etc., are required, but these are available through dental supply houses.

A HAND DRILL FOR DENTAL INSTRUMENTS. A dentist occasionally is called to a patient's home in an emergency or to care for a person who is ill in bed or confined to the house and is handicapped for lack of an engine. The hand drill illustrated in Figure 304 is very convenient under such conditions. It may be used as a straight hand-piece, or a contra-angled hand-piece may be attached to it. It operates on either direct or alternating current, revolves clockwise only and is controlled by pressure on a button with a finger,

or may also be operated by a foot control. It is convenient for many purposes in the laboratory.

SHARPENING INSTRUMENTS

Nothing in the technical procedures of dental practice is more important than the care of the cutting edges of instruments. No man has ever yet become a good and efficient dentist until after he had learned to keep his cutting instruments sharp. It is impossible effectively to prepare cavities for restorations without sharp instruments. The student who can not, or will not, learn this should abandon the study of dentistry.

Fig. 304.

A good Arkansas stone is a necessity and is one of the best pieces of property in the outfit of a dentist. If properly cared for, it will serve for many years. It is therefore well worth while to be careful in its selection and to pay a price that will command a stone of the best quality. It is of first importance that the stone be very hard. Dental instruments are very small, and if the attempt is made to use a soft stone, the point will catch and ruin both the edge of the instrument and the surface of the stone. The quickness of cutting, or the so-called "sharpness" of the stone is certainly a very desirable quality, but should be held as secondary to hardness; for, if the surface of the stone easily becomes roughened or uneven, it becomes ineffective. A very hard stone that will cut with only medium quickness is much more desirable than a quicker cutting stone that is continually losing the evenness of its surface. Dental

instruments do not need much grinding but do need accurate grinding.

The size of the stone should not be less than two by five inches. A little larger stone is better, but a dentist should not use a smaller one. The stone should be cared for methodically and carefully. It should be kept in a light but strong case or box that will protect it from breakage in any ordinary fall. The stone should be thoroughly soaked in oil and then wiped off as dry as possible. It may then be used with oil or used dry, but however used the surface should be cleaned after using with a woolen cloth and oil. In grinding steel, the steel cuttings fill up the "teeth of the stone" and soon the stone becomes dulled and will not cut well. The oil on the woolen cloth removes these cuttings and serves to keep the face of the stone sharp and otherwise in good condition. It is well to keep such a cloth in the box with the stone and always clean the stone after using, before it is put away. In operating at the chair, the stone should always be conveniently at hand for correcting the edge of any instrument that is not just right. If, in time, the surface of the stone becomes in any way marred or is worn unevenly, it may be refaced by rubbing it on a sheet of emery paper laid flat on a smooth table or level board. The facing should be finished on the finest grade of emery paper.

In grinding the cutting edges of excavators, the correct bevel should be carefully maintained. The most desirable bevel for each class of instruments should have careful study. When the blade has been placed in proper position in relation to the stone, it should be moved back and forth slowly in strokes which include the major portion of the length of the stone. Light pressure should be made, usually during one direction of the stroke. If the motion is too fast or the pressure too great, sufficient heat may be generated to draw the temper of the instrument, and it will thereafter be less effective unless it is retempered.

The bibeveled hatchets should be ground to a thin edge equally beveled on the two sides and the degree of bevel should be the same at each grinding. The motion in grinding should include the length of the stone at each stroke, with a finger resting on the face of the stone, or of its box, which should slide with the stroke in order to maintain the particular angle of the blade to the stone throughout the length of each stroke.

The chisels have only one bevel, which should be at an angle of from ten to twelve centigrades. In grinding those which have the blades at twelve centigrades angle with the shaft, the shaft should stand almost perpendicular to the surface of the stone in order to obtain this bevel. If the edge is turned from the operator, the grinding should be done mostly with the pull motion. On the push movement, the instrument is likely to chatter if pressure is used. Those with twenty-three centigrades angle of blade should be placed on the stone with the edge down and the shaft inclined

toward the operator sufficiently to give the correct bevel of the blade, and in the movement back and forth the principal pressure should be applied on the push motion. It is not difficult, with a little careful attention, to keep the edge straight and square with the blade. The instruments of six centigrades angle must also have their particular position on the stone to give their blades the proper bevel. They should be held with the beveled side downward, with the point toward the distant end of the stone. Then the handle should be raised until the blade is at the proper angle with the surface of the stone to give the correct bevel in grinding. The straight chisels should be held with the handle toward the operator at a lesser angle with the stone than the instrument of the angle six centigrades. The reverse bevel instruments, the blades of which are at a 94 centigrade angle, must be held with the handle more nearly parallel with the stone than the straight chisels.

The single-bevel hatchets, used for chipping enamel and trimming enamel walls, should have a short bevel. In sharpening these, the stone should be laid crosswise to the length of the arm in grinding the right-hand instrument. The instrument shaft should be held between the third and fourth fingers, with the point between the thumb and forefinger. When the position that will give the correct bevel is determined, the movement back and forward should be from the elbow. In this grasp, the end of the second finger may slide on the stone as a rest. The ordinary pen grasp, with the hand turned until the thumb nearly touches the stone, should be used for the left hand instrument. The third finger may be used as a rest on the stone.

In the new set of forty-six instruments, the blades of all chisels and hatchets of 18 and 12 widths have bevels on both edges as well as the ends. To sharpen these side edge bevels, the instrument should be held in such position that the entire bevel will be in contact with the stone, and the principal pressure should be made during the movement in which the edge to be sharpened is in advance of the blade.

The spoons, discoid and cleoid may be sharpened with fine emery disks. The instrument should be held in the left hand and the rotating disk so placed that its motion is from the edge. By carrying the disk regularly around the circumference, the edge may be given the proper curve. After a few efforts a particular way of holding the instrument for obtaining accuracy of bevel in all parts of the circumference of the edge will be readily found. In sharpening a pair of spoons, the disk should revolve to the right for one, to the left for the other. The emery disk will not make as fine an edge, however, as a good Arkansas stone.

These instruments may be sharpened by so placing them on the stone that the motion in grinding will be parallel with the length of the circular edge. During each stroke from end to end

of the stone the shaft of the spoon should be rotated in its length on its point in the line of the length of the stroke so as to bring every point in the circular edge on the stone. In this movement, the point of the instrument is first toward the near end of the stone, and with the progress of the stroke the angle is progressively changed so that in the center of the stone the shaft is perpendicular to the stone, and at the end of the stroke the point will be toward the distant end of the stone. In the progress of each stroke, the circular edge is ground at the proper bevel in every part of its length. When this stroke is once learned, it is easily and rapidly done and these circular edges may be very accurately ground. The edge of the blade describes a figure eight on the stone.

The margin trimmers should be held in such position in relation to the stone as to maintain the bevel of the edge and the correct angle of the edge with the shaft of the instrument. They should be very sharp, but the bevel should be rather short.

It will be seen that each class of point has its particular position on the stone for each angle of blade. The size of the blade does not affect its relation to the stone. For each instrument, the best relation to the stone for that form should have careful attention. It is to be done in the same way day after day and correct habits of grasp and movement should be formed for each instrument.

In every case, just previous to using an instrument, the edge should be tested to learn the degree of sharpness. The trials should be made on the thumb or finger nails. The blade should be held in touch with the surface of the nail in about the same relation as in cutting a tooth and should catch with the slightest pressure. If any part of the edge slips on the nail instead of taking hold, it is not fully sharp. This test on the nails is a very accurate one and if delicately used will not mar the nails and will very certainly reveal any lack of perfection in the edge of the instrument.

Sharpness of burs is of special importance. While it is important that every cutting instrument have a perfectly sharp edge, actual injury to the tooth and the infliction of unnecessary pain often results from the use of a bur that is not sharp. As compared with the hand-cutting instrument, the bur moves with great speed in its contact with the tooth, even when the engine is running at its slowest, and the friction of dull blades generates heat rapidly, often causing a marked hyperemia of the pulp. A new bur, used for cutting enamel, should not be again used until it has been resharpened, because sound enamel will dull the blades. A bur may be used a number of times in cutting dentin and remain sharp. For accurate cutting, and to avoid both pain and injury to the pulp, a dull bur should never be used. The best plan is to place all burs in a jar after they have been used and when a few

dozen have accumulated, examine the blades with a magnifying glass to determine their condition. A few will be found sharp and may be used again; others will have dull blades and should be sent to an instrument maker to be resharpened; still others will be much worn or have one or more broken blades and should be discarded.

Finishing files are sharpened with knife-edged slips of Arkansas stone. These may be obtained from the jeweler's supply houses. A very hard stone is essential. The stone is used as in delicate filing and is held against a blade of the file. The edges of the stone should be flooded with oil. When the edge of the stone has become dulled or rounded by use, it is ground to correct form on a strip of fine emery cloth on a flat board. Every blade of the file should be made sharp and the work should be so regularly done that the edges of the different blades will be of equal height. This may be done by the dentist himself, or he may have the instrument maker do it for him. The files may be reground many times and still do good work. There is perhaps no instrument more seriously impaired by becoming dulled than the finishing files. Therefore, frequent sharpening is very essential to their usefulness.

Time for Sharpening Instruments.

The instruments to be used for each operation should all be sharp before the operation is begun, in order that there may be no unnecessary delay. This requires the establishment of a definite habit in procedure — the habit of resharpening all instruments before they are replaced in the operating case. In practice, one should have two sets of cutting instruments or, at least, duplicates of those instruments which are most frequently used, and thus oftentimes avoid delay during a busy day.

Instruments with keen edges are among the best preventives for pain, contribute much to preciseness in cavity preparation and very appreciably reduce the time required. A dull instrument, scraping along the dentin walls of a cavity without accomplishing much, causes infinitely more pain than a very sharp instrument which, under considerable pressure, cuts a wall to smoothness and proper form at a single stroke.

THE USE OF WATER AND AIR

ILLUSTRATION: FIGURE 305.

WATER, both warm and cold, should be constantly ready for use at the operating chair for washing the teeth and gums of patients. For use in the mouth, water should be generally heated to about 105 degrees Fahrenheit, or just a little warmer than blood temperature. In the large majority of cases, this temperature will be found most grateful to patients. If, however, cases occur, as they will, in which some of the teeth are very sensitive

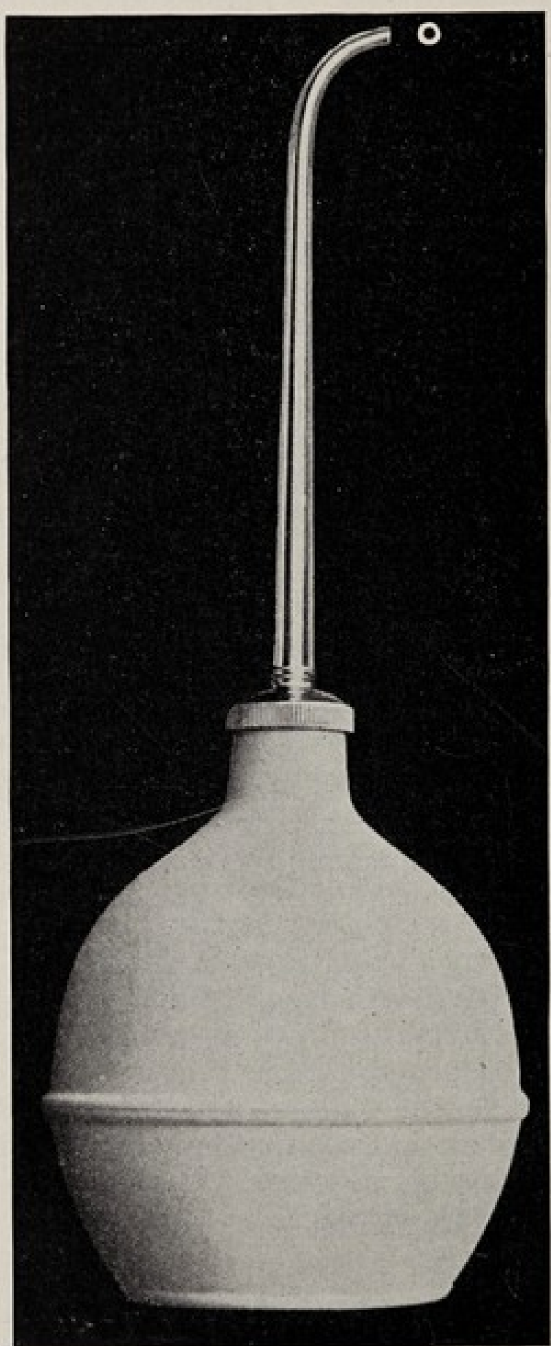


FIG. 305. The large rubber bulb syringe, used for rinsing the mouth. Illustration actual size. This syringe holds two ounces. The hole in the end of the nozzle should be 1.5 mm. inside measurement. In the preparation of cavities it is important to have plenty of water to remove most of the saliva and mucus from the mouth; and in scaling operations to thoroughly cleanse the mouth of mucus, blood and debris.

to thermal changes, the temperature of 105 degrees will cause considerable pain, and in such cases the temperature should be carefully reduced to blood temperature.

Preferably there should be more than a single glass of warm water available, such as is usually the case with the electric heating unit designed for the purpose, for the reason that the water will vary too much in temperature in accordance with the quantity in the glass. A larger container or two separate heating units of the present type would be a great improvement. The best arrangement is a small tank, electrically heated and thermostatically controlled. An ordinary bath shower mixing valve will permit one to have a constantly running small stream of water of the desired temperature.

The uses of water at the operating chair are:

For cleaning the teeth preparatory to operating.

For keeping the teeth and mouth free from blood and debris while removing calculus, or in doing any operations upon diseased gums, or while treating diseases of the peridental membranes.

For washing cavities during any portion of their preparation that may be done before placing the rubber dam.

For cleaning the necks of the teeth before applying the rubber dam.

For treating the gums after removing the rubber dam.

For removing debris and polishing powders during any portion of the polishing of restorations that may be done without the rubber dam.

For the prevention of pain and hyperemia of the pulp by keeping the tooth cool while using a stone or other instrument in the engine which might develop heat.

For any and all of these uses a good rubber bulb water syringe, which will hold about two ounces, is necessary. A syringe should be used with which the mouth can be flooded with water, or a strong, continuous stream thrown for several seconds. Such a syringe is illustrated in Figure 305.

For cleaning the teeth preparatory to operating, warm water should be used in almost every case, even though the teeth are apparently in a cleanly condition. In the best conditions there is usually more or less gummy material, containing many microorganisms about the necks of the teeth, or about cavities, especially proximal, buccal and labial cavities, which should be loosened with scalers and removed with a strong stream of water. In all cases the field of operation should be made clean as the first procedure.

The use of water while removing calculus is imperative. The field of operation requires to be repeatedly washed with strong jets of water. This is necessary in order to remove particles of loosened calculus from about the necks of the teeth, and to remove

blood and debris that the next step of the operation may be seen, also to impart a sense of cleanliness and comfort to the patient.

In excavating cavities, water should be used freely in any portion of the operation that is done before placing the rubber dam. In many cases it is desirable to open cavities and do much of the excavating before the dam is applied. During such part of the operation, the cavity should be frequently washed with strong jets of water at the proper temperature, for the purpose of removing all debris from the cavity and from the mouth of the patient. It is especially important that the accumulated saliva and mucus be frequently removed to maintain the best view of the internal parts of the cavity.

Before placing the rubber dam, water should be used to free the necks of the teeth from microörganisms, even in the most cleanly mouths. A thin scaler should be passed around all of the surfaces, loosening up any gummy substance adhering to them, and this should be washed away with a strong jet of warm water. If the case is not especially cleanly, there is greater necessity for this proceeding. The object is especially to prevent pushing a mass of microörganisms and debris under the free margin of the gum by the rubber and the ligature. Often the gums are more or less bruised by this procedure, and if at the same time a mass of debris containing many active microörganisms is crowded into the soft tissue and held there for a considerable time, the microörganisms will take hold of this injured tissue, and cause very inconvenient soreness, or actual suppuration.

After removing the rubber dam the gums should be treated with a thorough douching with warm water while kneading them thoroughly with the fingers of the other hand. This is especially important to the comfort of the patient. If the rubber dam has been in place for a considerable time and the gums have been compressed by the rubber or other appliances for securing it in place, the circulation of the blood through this part has been impeded. The douching, together with the kneading, causes the blood to return to these tissues, starts it into active circulation again, and removes any injurious material that may have been forced into the gingival space by the rubber. It imparts a feeling of comfort to the parts and causes at once the most complete feeling of rest from the operation that it is possible for the operator to give.

The washing away of powdered stone and debris during and after polishing restorations, should be thorough and complete, and the patient dismissed with a clean mouth.

In preparing cavities, fine carborundum points may be used with very little pain to the patient if the tooth is kept flooded with cold water. There is not the same accuracy of vision, as in cutting with a bur in a dry cavity. Stones may be used with water to the best advantage in smoothing the surrounding walls of occlusal and

proximo-occlusal cavities, which require that the hand-piece be held in approximately the same relation to the long axis of the tooth while the cutting is in progress.

USE OF AIR.

The use of air is of much importance in operations on the teeth in removing tooth debris from cavities in process of preparation with the rubber dam in place; as an adjunct to other means of keeping limited areas dry for brief periods of time; also for clearing the interproximal spaces and other areas of saliva to facilitate visual examination.

Compressed air is available from a pressure tank which may supply an entire building, or the dentist may have a small compresser for his own use. Oftentimes the outside supply is under too heavy pressure for use at the chair and must be controlled by a reducing valve. For most uses at the chair, light pressure, in the neighborhood of five pounds, is preferable. An electric heating unit is desirable in order that the air may be the right temperature to avoid pain. It is just as important in many cases to have the air at exactly the right temperature as the water, if it is to be blown into a cavity of a sensitive tooth. It becomes a question of regulation of pressure in relation to the heating unit to secure the desired result.

The rubber bulb air syringe in the hand of a well trained assistant has certain advantages over compressed air and the heating unit. The pressure may be more easily adapted to the particular tooth, and no more need be used than is necessary to clear the field of debris. If one uses a syringe with a four ounce bulb, the amount of air will be sufficient to permit reasonably accurate temperature regulation by heating the nozzle of the syringe in the gas flame and then draw the air in slowly by relaxing the grip on the bulb. The temperature should be tested by blowing a little of the air against the cheek. Oftentimes a quick light puff from the hand syringe will be quite effective without discomfort to the patient.

Air is used to frequently remove the debris in the preparation of cavities with the rubber dam on, or when the early preparation is done with absorbents in the mouth to withhold saliva from the field for a short period at a time. In this, room temperature air is usually not painful, if it is not applied with too much force. However, if the tooth is sensitive, the temperature of the air should be regulated so that it will not cause pain.

Air is helpful in maintaining dryness of a cavity while a temporary restoration is placed, the immediate area being packed with rolls of gauze or cotton. It may be similarly used when inlays are cemented to place, although the operator must recognize the definite hazard to the eventual success of the operation from the

admission of the least bit of moisture. Notwithstanding the fact that many cements are advertised as requiring a little moisture for a proper set, recent investigations indicate that no dental cement is hydraulic.

In making mouth examinations, compressed air may be used to advantage to clear away saliva and possibly some debris not previously removed with the water syringe. Etched enamel of buccal, labial and proximal surfaces may be disclosed by thorough drying, which might not be found with the exploring tine. After the use of the air blast, flakes of serumal calculus may occasionally be seen on the teeth under the free gingivae, which otherwise would not be noticed.

Histological Structure of the Teeth in Relation to Cavity Preparation

THE ENAMEL.

ILLUSTRATIONS: FIGURES 306-311.

THE structure of the enamel is of such importance in its relation to the preparation of cavities for restorations that it requires special study. It is difficult to so prepare specimens of the enamel that they show its structure well. The ordinary book page, does not permit the reproduction of photomicrographs sufficiently amplified to show the enamel rods well and at the same time show a sufficient amount of the tooth form to give their relations. The best way to study these effectively is under the microscope itself. However the microscopic study makes possible the effective use of diagrammatic illustrations.

Enamel is composed of rods cemented together by an intervening cement substance. The rods and the cement substance have very nearly the same density or quality of refracting light, so that when examined in the perfect state, the enamel seems to be almost homogeneous, or without special structure. In the most perfect specimens of enamel, only a striation suggesting structure can be seen. However, the cement substance between the rods, by which they are united, dissolves more readily in acids than the rods themselves. The rods may be partially isolated by solution of the cement substance with very dilute acid, and they are thus brought into view.

The enamel rods are stronger than the cement substance that unites them together, so that in any attempt to cut the enamel, it is inclined to split along the length of the rods. Since the enamel is very hard and difficult to cut, a knowledge of the direction of the rods becomes of first importance in preparing cavities in teeth. The rods, while hard to cut, are, when they are parallel, very easy to split apart. Indeed, much of human enamel will split almost as easily as straight-grained pine, if the force is applied in just the right direction to the margin of any opening that has been previously made. See Figure 306A. This is because the substance that cements the rods together is much weaker than the rods themselves. In other specimens of enamel, the rods, instead of lying parallel with each other, are very much interwoven and twisted together, as shown in Figure 306B; so much so, indeed, as to prevent them being readily split apart. This enamel, instead of splitting like straight-grained pine, is more like the pine knot,

which is very difficult to split or cut as compared with the straight-grained wood. Formerly it was supposed that this difference in the enamel to cutting instruments was due to a greater amount of calcium salts. However, this is not the case. The one contains no greater proportion of lime salts than the other and will not resist decay any better. But the difference is due wholly to the difference in the relative interlacing of the enamel rods.

Fig. 306A.

Fig. 306B.

This interlacing or twisted form of enamel is usually confined to the inner half or two-thirds of its thickness. While in the outer portion of the enamel, the rods are parallel and will split apart readily, as shown in Figure 306B. Therefore, when a chisel is applied for the purpose of splitting it off, it will, if

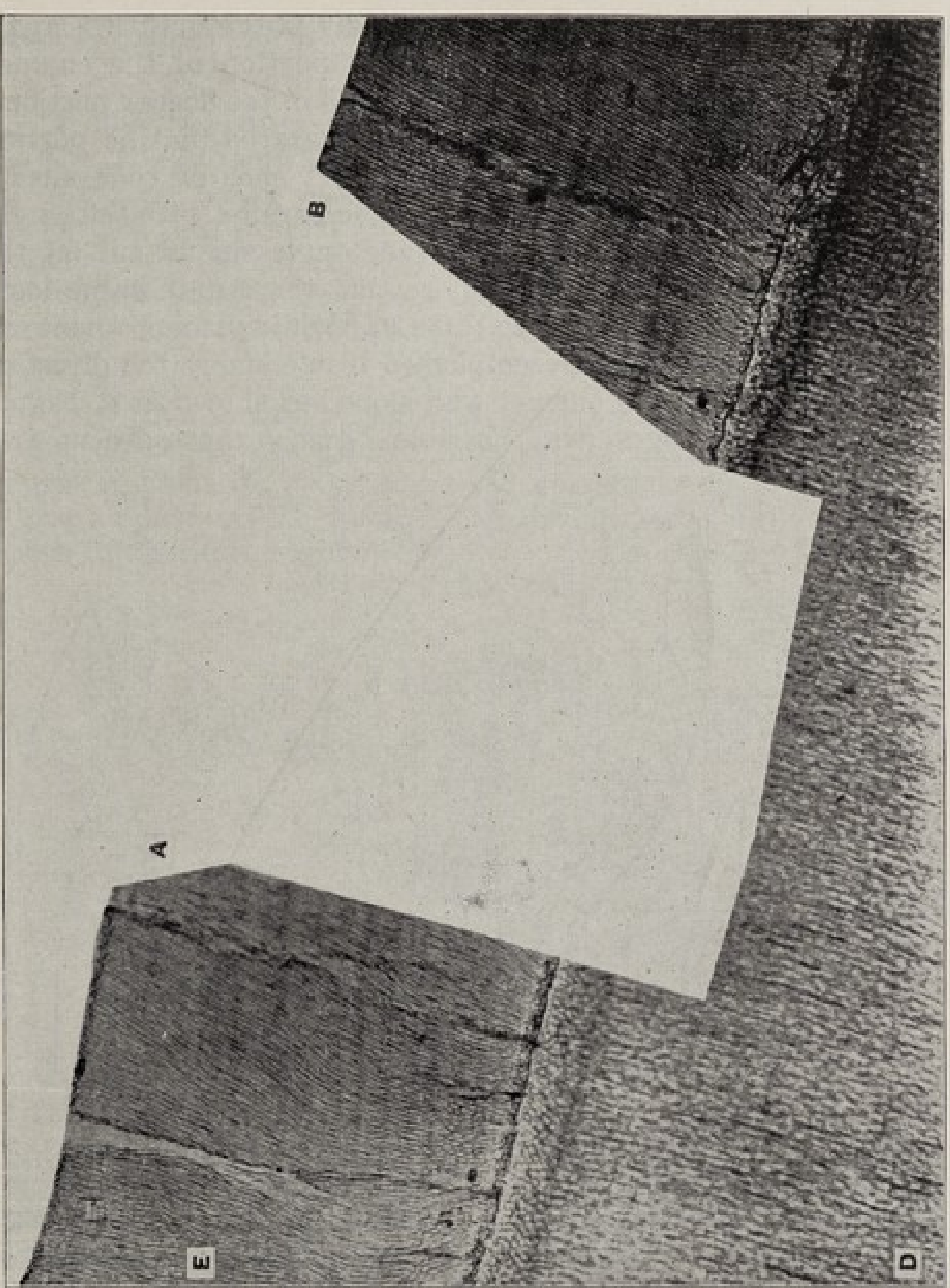


FIG. 307.

supported by sound dentin, split but part way and the remaining part of the thickness can be removed with great difficulty. It is then almost a necessity that this portion be undermined by cutting away the dentin from beneath it, after which it will break down quite readily.

The enamel rods are almost always parallel with each other in the outer part or near the surface of the enamel. This is of the utmost importance in the preparation of the cavo-surface

angles of cavities. All that has been said of the splitting apart of the enamel rods, applies to this outer portion of the enamel, no matter how much the rods may be twisted in the deeper portions, and for this reason cavities should be so prepared that no portion of the cavo-surface angle will present short ends or rods unsupported; that is, if the enamel wall should be parallel with the length of the rods, a bevel of the cavo-surface angle should cut off the ends, as shown at A in Figure 307, so that there may be no loose ends of rods upon the surface to fall away while placing a restoration. This may readily be accomplished if one knows the direction of the enamel rods. An enamel wall sloped as shown at B, Figure 307, makes the strongest wall possible, because there are no free

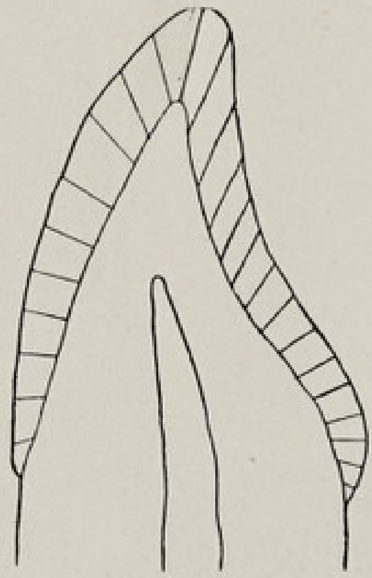


FIG. 308A.

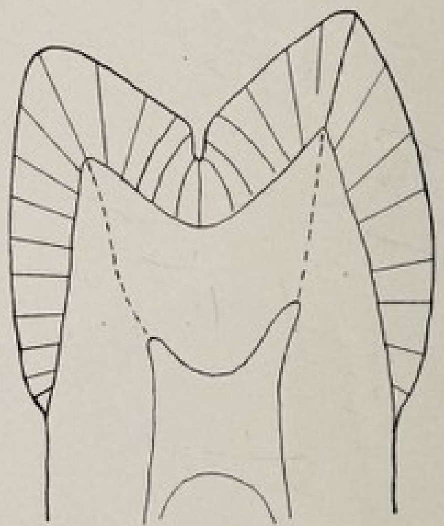


FIG. 308B.

ends of enamel rods in any part of its surface. In this case, the slope or inclination of the enamel wall relates especially to its deviation from the direction of the enamel rods.

The direction of the rods may be known, first, by obtaining a good general knowledge of their course by the study of prepared sections of enamel; second, by observing the direction of cleavage during the preparation of cavities. By the term "cleavage" is meant the tendency of a substance to split or separate in given directions. The direction of cleavage is the direction in which it splits most readily, which is along the length of the enamel rods. Therefore, for our purpose, the terms "cleavage" and "splitting" are practically synonymous.

THE DIRECTIONS OF THE ENAMEL RODS IN DIFFERENT PARTS OF THE CROWNS OF THE TEETH.

It may be stated, as a general rule, that the direction of the enamel rods is from the center of the crown of the tooth toward the surface. Everywhere on the crown of the tooth the ends of the enamel rods present to the surface. Over the greater portion of the crown, the direction of the enamel rods is perpendicular to the surface, but in every tooth there are certain portions in which the enamel rods approach the surface at a more or less considerable inclination.

(1.) In a central perpendicular section labio-lingually through an incisor tooth, the enamel rods will be cut parallel with their length in all of its parts, but they will not all be at right angles to the surface of the tooth. The deviations in this respect are shown in diagram, Figure 308A.

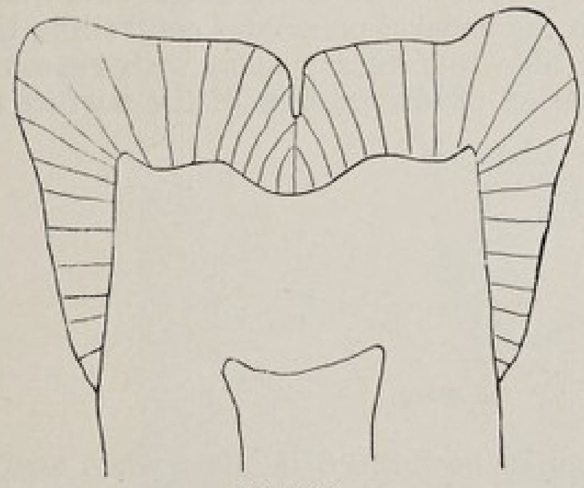


FIG. 309A.

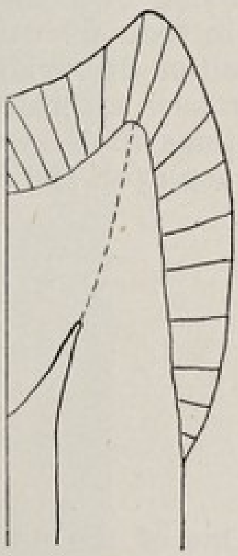


FIG. 309B.

(2.) In a central perpendicular section bucco-lingually through a bicuspid tooth, the enamel rods will be cut parallel with their length in all of its parts, but the enamel rods will not all stand at right angles to the surface of the tooth. The deviations in this respect are shown in diagram, Figure 308B.

(3.) In a central perpendicular section mesio-distally through a lower molar tooth, the enamel rods will be cut parallel with their length on the mesial and distal surfaces and over the marginal ridges onto the occlusal surface, but will be cut irregularly diagonally across in parts of the occlusal surface, depending upon the relation of the section to the developmental grooves and pits. This is illustrated in diagram, Figure 309A.

(4.) In a perpendicular section from a point in the occlusal surface of a molar tooth in a line passing directly over the point

of any cusp and along the axial line angle to the cemental line, the enamel rods will be cut parallel with their length in all of its parts. But the rods will not all stand at right angles with the surface of the tooth. The deviations in this respect are shown in diagram, Figure 309B.

(5.) In a section perpendicular to the surface of a tooth cut across any deeply grooved developmental groove or pit, the enamel rods will be inclined toward the groove or pit from both sides. The deeper the opening of the groove or pit, the greater will be the inclination of the rods toward it and the larger the area of the enamel affected. Figure 309C.

With the necessities for the formation of good enamel walls in view, a careful study of these diagrams in their relations to the surfaces of the teeth, the variations of the inclination of the enamel rods from a right angle to the surface in approaching and in passing over the cusps and the marginal ridges, the disturbance in their direction by deep grooves, fissures or pits, and their disposition over ridges and angles of the teeth, one should quickly obtain such an insight into the general principles controlling these deviations that he will be able to forecast them with reasonable accuracy upon the examination of any portion of the surface of a tooth.

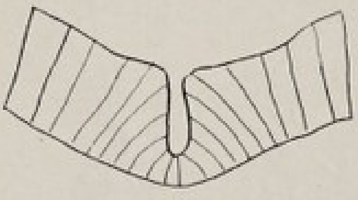


FIG. 309C.

One of the first things to be noticed is that, when sections are cut parallel with the long axis and perpendicular to the axial surfaces of the teeth, the enamel rods are cut parallel with their length in every position from the cemental line to, and over, the marginal ridges and cusps of the occlusal surface of the bicuspids and molars, and the cutting edges of the incisors. Therefore, in the direction of these sections, the enamel rods are at right angles to the surface of the tooth at all points. The normal and regular deviations from the right angle to the surface are all in the direction of the length of the tooth so far as the axial surfaces are concerned. These are confined to the approach to the cemental line at the one extreme and the approach to the marginal ridges, cusps and cutting edges at the other. These variations are shown in the five diagrams. While this is true as the statement of a general fact of normalcy that may be taken as a working basis in the preparation of cavities, it must not be forgotten that there are frequent variations from the normal direction of these rods which must be found by noting the direction of cleavage as hereafter described.

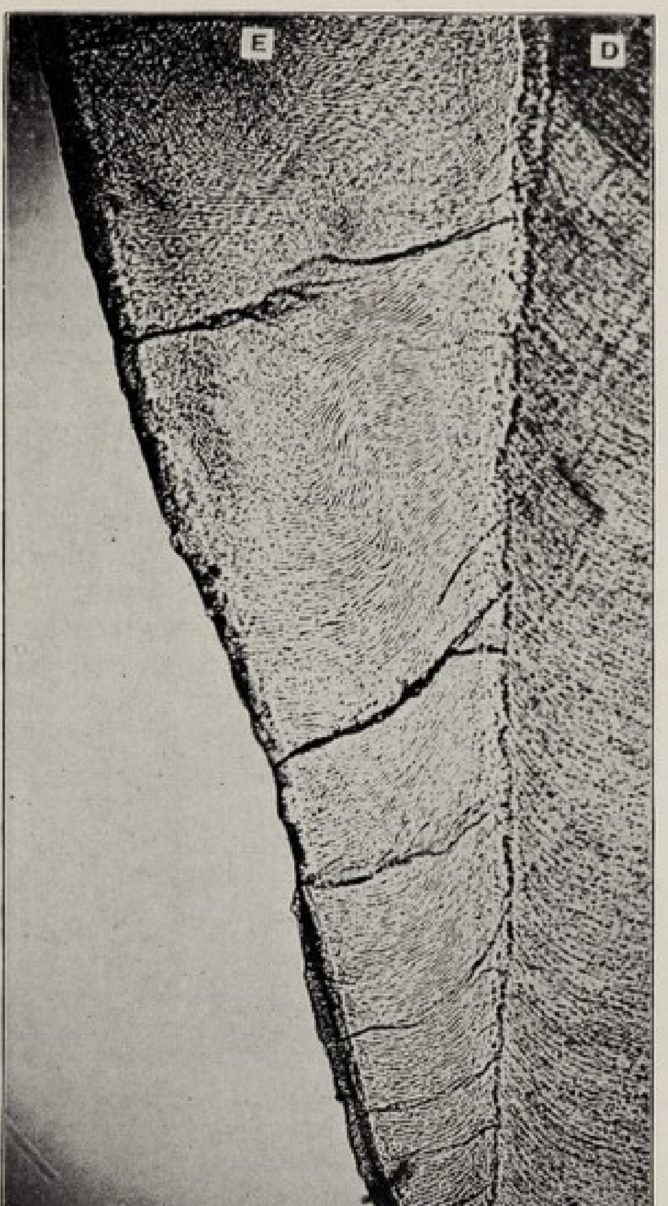


FIG. 310A.

If the attempt be made to prepare a cavity upon an axial surface of one of these teeth and this cavity approaches a cusp or a marginal ridge, the enamel wall must be inclined outward (or toward the occlusal) very greatly, or else short ends of enamel rods will be left at the surface. And if inclined enough to prevent this, the margin of the restoration will be so thin that it will not have sufficient strength. These facts forbid the laying of enamel mar-

gins near the occlusal margins of the axial surfaces of the teeth. Figures 308A, 308B and 309A.

On the occlusal surfaces of the bicuspids and molars, the direction of the enamel rods is such that perpendicular and parallel cavity walls of cavities occurring in pits, will, except in very large cavities, have particularly strong enamel walls, because the inclinations of the enamel rods are all toward the center of the area in which restorations are made. It is only in the approach to the marginal ridges and apices of the cusps that especial care must be taken regarding the directions of the rods. In very large occlusal cavities this is always to be reckoned with, and the enamel walls must be sloped outward to agree with the outward inclination of the rods.

In the incisors and cuspids, the general directions of the enamel rods are as shown in the diagrams. On the distal surfaces, where the distal angle is much rounded, the deviation of the enamel rods from the right angle to the surface begins farther from the incisal angle than upon the mesial surface and is often much more

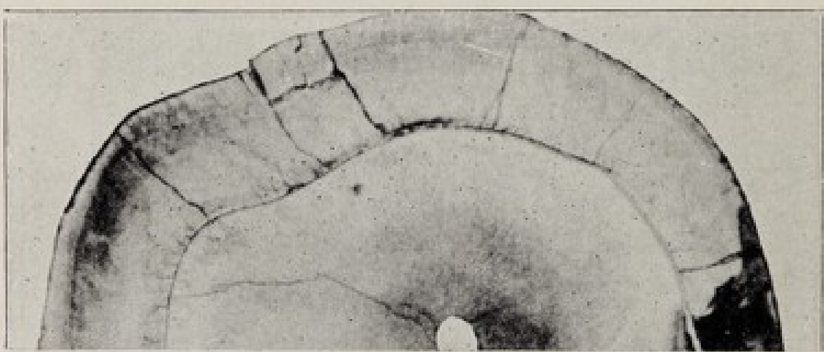


Fig. 310B.

considerable before reaching close to the angle. The enamel wall at this point requires special care. The greatest difference occurs in the distal surface of the upper lateral incisor, which has the most rounded incisal angle. On the mesial surface, where the angle is acute, the change of direction occurs very suddenly at the incisal angle, and the considerable inclination that would seriously interfere with the formation of the cavity wall is most generally so close to the angle as to be out of the way. Cavities in the mesial surfaces of the upper incisors can therefore approach the incisal angle more closely with safety and afford opportunity for a good margin for a restoration without too thin an edge than can cavities in the distal surfaces of these teeth.

The inclination of the enamel rods around the incisors and cuspids in the circumferential direction is generally perpendicular to the surface at the junction of the middle and gingival third of the length of the crown. A notable exception to this, is the approach to and over the mesio- and disto-lingual marginal ridges.

Here the enamel rods incline somewhat toward the marginal ridges, but, in passing over these ridges, their direction or inclination changes very suddenly and often very irregularly. For this reason this becomes rather a dangerous point in the preparation of proximal cavities in the incisors. When the marginal lines of these proximal cavities reach to the lingual marginal ridge, it is rarely safe to leave any of the ridge remaining, because of the very uncertain direction of the enamel rods. Especially is this true of lateral incisors in which the curve of the ridge is often very abrupt. While this ridge is very strong in the perfect tooth, it becomes very frail when its support on either side has been destroyed, and the only safe course seems to be to cut it away sufficiently to be certain of the direction of the enamel rods upon the margin formed. The rounding of the labio-mesial or labio-distal angles is not so abrupt, and the enamel rods usually hold closely to a direction perpendicular to the surface, so that good margins can be made at any point by observing carefully the form of the tooth and the enamel cleavage.

There are considerable variations from normal in the inclination of the enamel rods as the gingival line is approached on buccal and labial surfaces on many teeth. The photomicrograph, Figure 310A, is an example from the gingival third of the labial surface of an incisor in which the course of the rods is very irregular, showing many twists and turns. The checks in it show the easier cleavage lines that would be found in chipping with a chisel. The ragged character of the breaks would be noted by an experienced operator as indicating the irregular course of the rods. Similar irregularities will be found frequently in any parts of the enamel. These are shown by the several checks in the buccal surface of the bicuspid, which is cut in cross section. See Figure 310B. A much greater irregularity in the direction of the rods may be noted in Figure 171, a photomicrograph showing a segment of a cross section of carious enamel. Such examples show that the normal directions shown by the diagrams can not be too implicitly depended upon in preparing cavity walls. These must be verified by the chisel and corrected.

THE TEMPORARY TEETH.

There is one striking difference in the direction of the enamel rods of the temporary teeth, as compared with the permanent teeth. In the enamel of the permanent teeth the rods on the axial surfaces are inclined gingivally from within outward as the cemental line is approached. In the temporary teeth, there is no inclination of the rods gingivally in any position. All of the rods of the enamel in all axial surfaces are inclined occlusally. See Figure 311A, a central perpendicular section labio-lingually through a temporary upper central incisor, and Figure 311B, a central per-

pendicular section mesio-distally through a temporary lower second molar.

In preparing the gingival walls of cavities in the temporary teeth, if the wall is prepared in the horizontal plane, there will be no advantage in bevelling the cavo surface angle, as in the horizontal preparation there are no short ends of rods at the surface. However, in the permanent teeth the gingival wall must be inclined gingivally, and it must also be beveled.

HOW TO STUDY THE DIRECTIONS AND INCLINATIONS OF THE ENAMEL RODS.

The first studies of the enamel rods should be made of ground sections, which have been etched before mounting, so that the rods may be seen well. When a fairly good idea of the structure has been obtained in this way, one should continue the study by using the chisel in splitting off the enamel, which is the easiest way of removing frail margins, and noting carefully the cleavage of the enamel while operating at the chair. In preparing cavities, the

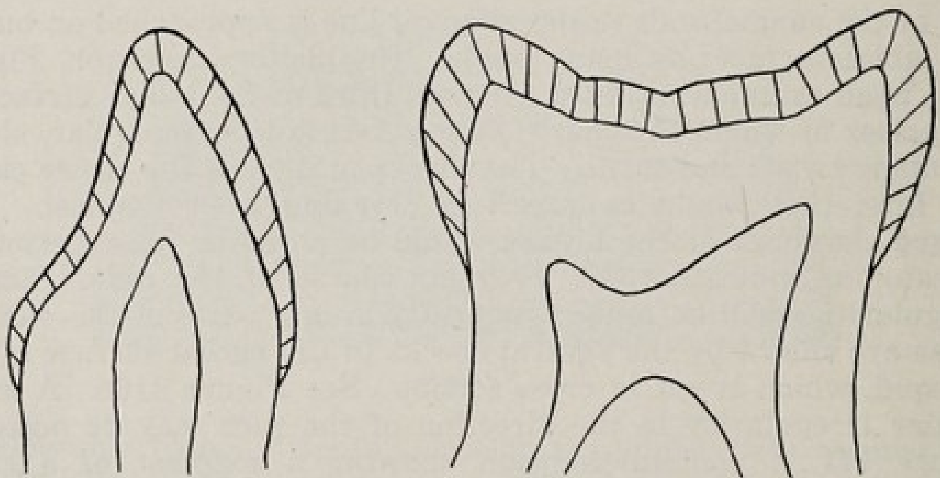


FIG. 311A. FIG. 311B.

direction of the cleavage should be carefully noted, and, knowing that this cleavage follows the length of the enamel rods, one may be continuously studying their direction in different positions upon any and all of the teeth. Such a study enables an operator to so place his instruments as to split off the enamel easily in opening cavities, which is of immense advantage, as it can be done easier and quicker than by any other method. Irregularities in the course of the rods, which occur frequently, will be detected and the enamel wall may be inclined more or less to avoid leaving short ends of rods at any point. This knowledge can be obtained only by the use of hand-cutting instruments. They enable one to make the most perfect preparation of the enamel walls and cavo-surface angles. One soon learns to feel the direction of the enamel rods with cutting instruments in preparing cavities and to take advan-

tage of the irregularities of the cleavage in cutting the enamel, and knows when the enamel margin is firm and strong.

The shaving or planing of the enamel in finishing the enamel wall should be looked to with great care. Those points at which the enamel rods are more or less broken apart will generally appear a little whitish and, in pushing a sharp edge lightly along them, the loosened rods are easily dislodged in what appears as a fine powder. This whitened appearance may be due to caries of the enamel. In this case, all of the whitened part must be cut away. If the enamel is sound, by continuing the shaving motion it will become clear and have a firm, vitreous appearance. This condition of the enamel wall should always be obtained in finishing the preparation of the cavity.

Rarely there are white spots in the enamel because of imperfect development that may be included in the area of the cavity or appear on the line upon which the enamel margin should be found. See Figures 106 and 107. In the latter case it will become a question whether to cut them out or leave them. When these are covered in with a good glazed surface, it is perfectly safe to leave them, provided a good restoration can be made without breaking the margin. Generally this may be done. These white spots must be distinguished sharply from caries of enamel which also may show as white spots. Both cut more easily than normal enamel. Generally the white spots due to faulty development have a glazed surface; carious spots do not. Often caries of the enamel occurs as a considerable area of whitening on several teeth, particularly on buccal surfaces in which the enamel rods have been separated to a considerable depth, as shown in Figure 310B. This is often spoken of as chalky enamel. The condition has been produced by caries.

In the study of the enamel in sections, it has been seen that the lines of the grooves are weak lines on account of the imperfect fusion of the enamel plates in coming together during development. This is true even in those grooves that are most perfectly closed. But in very many cases they are imperfectly closed, so that along these lines the enamel has no strength. Also when cutting near to a groove, the enamel rods incline toward the groove, increasing the danger of leaving short ends of rods at the cavo-surface angle.

RULE: *When in the preparation of a cavity, the line of the cavity margin must approach near a groove, one should cut past the groove.*

This rule should be regarded as applying in all positions upon the teeth if the cavity margin is parallel, or very nearly parallel, with the groove. For instance, in preparing large cavities in the distal surfaces of upper molars, the lingual portion of the disto-lingual groove is often approached. In such cases, the enamel

should be cut away, including the groove, to and over the ridge onto the lingual surface, where its direction is more to the mesial.

If the mesio-buccal angle of a molar is so decayed as to make the removal of a considerable part of it necessary, the wall should be carried a little beyond the buccal groove, for if this is not done the intervening portion of the enamel is very likely to break away. The same rule applies to the triangular grooves of the bicuspids that pass over to the buccal surfaces to the mesial and distal of the buccal cusps. If, in any case, the enamel of the angles of these teeth is so undermined by decay that the cavity lines should approach near these grooves, the margins should be placed beyond the grooves.

In any case in which the angle of an incisor must be removed, and conditions require that the enamel be cut away near to the line of either labial groove, the margin should be placed beyond the groove. This is for the reason that the lines of the grooves are weak and the enamel likely to break along them.

THE DENTIN.

In preparing the retention and resistance forms of cavities, also in removing carious dentin or doing any cutting whatsoever in the dentin, one should have in mind constantly the question of the conservation of the pulp. This involves two principal problems; the possibility of the death of the pulp from thermal shock, and the danger of exposure of the pulp. Usually the pulp will recover promptly from thermal shock caused by heat, generated in the use of a bur; the real danger is from too near approach to the pulp, followed by the placing of a metallic restoration, which may cause thermal shock every time hot or cold foods or drinks are taken into the mouth. In operating for young persons, it should always be presumed that the pulp chamber in the particular tooth is the maximum, rather than the average size that it might be for the age of the patient. It should be the rule to cut no deeper than is absolutely required in any case.

RECESSIONAL LINES OF THE PULPAL HORNS.

These are the lines along which the pulp has receded during the growth of the dentin. They are also the lines in which unusually long horns are found and often exposed when these lines are cut. In its early growth, the full size of the occlusal surface of the tooth is represented when the first joining of the enamel plates of the several lobes of the tooth has occurred. At this time but a very thin layer of dentin has been formed on the inner surface of the enamel cap. The whole, practically, of the dentin of the crown of the tooth is represented in pulp tissue. The dentin grows from the dento-enamel junction inward. The pulp recedes and becomes smaller as the dentin is formed. This

is rapid, comparatively, during the childhood period, but under normal conditions gradually slows down until the person is forty years old or past. Under abnormal conditions of irritation from very slowly progressive caries, erosion, abrasion, etc., this is much hurried, and may go on to the complete obliteration of the pulp chamber. In this normal and abnormal recession of the pulp, the pulpal horns become shorter and shorter. The lines of this recession of the horns of the pulp have been named the recessional lines of the pulpal horns. It not infrequently happens that a horn of a pulp will persist as a slender thread of pulp tissue reaching far toward the point of a cusp to or past middle age, even when the pulp chamber has become quite small.

Careful observation shows that fully ninety per cent of the accidental exposures of the pulp in the preparation of cavities of medium and moderately deep decays occurring in either occlusal pits or proximal surfaces in molar teeth, are exposures of the horns of the pulp. These exposures are all made by cutting across the recessional lines of the pulpal horns. These lines are, therefore, especially dangerous.

The recessional lines lead from the axio-occlusal margin or crest of the pulp on one of its angles, towards the point of each of the cusps of the teeth. This line is usually nearly straight, but a little bent in the form of the concavity of the occlusal surface of the tooth. In Figure 308B, the recessional lines of the pulpal horns are indicated by dotted lines. The anatomy and histology of the tooth in respect to these lines should be very closely studied for the advantage it will give in avoiding these lines in the excavation of cavities.

While the mesio-buccal horn of the pulp is the most dangerous of the horns of the pulp in the molar teeth in regard to exposure, counting very much the larger number of accidents, the mesio-lingual horn of the lower molar is also very dangerous. Indeed, all horns of the pulp have their recessional lines, and all of these are to be shown due respect in cavity preparation.

The recessional lines of the crests of pulps may also be traced in histological specimens. While these are much lower than the horns, they are responsible for a minority of the exposures by accident in the preparation of cavities in the proximal surfaces of the molar teeth. In proximal cavities the crest of the pulp is a frequent point of exposure by decay.

In the preparation of cavities, the rule should be to avoid cutting any of the recessional lines of the pulpal horns whenever the extension of decay will allow of its complete removal without so doing. In the preparation of proximo-occlusal cavities there is usually room to occupy one-third of the bucco-lingual breadth of the tooth in a step without interfering with the pulpal horns, provided the step is not cut too deep, i. e., deeper than necessary

for substantial strength. In mesial cavities in upper molars, the occlusal step may be somewhat broader than in distal cavities in upper molars, or in mesial or distal cavities in lower molars, because the lingual horn of the pulp in the upper molars is placed farther to the distal, giving more room in the neighborhood of the mesial surface. In all of the molar teeth there is more danger from cutting these recessional lines in the mesial than in the distal areas because the pulpal horns are longer, giving less room between the occlusal surface of the tooth and the probable ends of the pulpal horns.

Temporary teeth. The dentin of the temporary teeth is formed in the same general manner as in the permanent teeth. The pulp chambers are considerably larger in proportion to the size of the crowns, so that caries may expose the pulp within a comparatively short time. This is one reason why the teeth of the temporary dentition should be examined three or four times each year.

The recessional lines of the pulpal horns are more generally fully closed in the temporary than in the permanent teeth, and it is uncommon for secondary dentin to be formed.

Principles of Cavity Preparation

ILLUSTRATIONS: FIGURES 312-372.

DEFINITION. The term *cavity preparation* is applied to that mechanical treatment of dental caries and other diseases and injuries of the hard tissues of the teeth, as will best fit the remaining part of the tooth to receive a restoration to its original form, give it strength, and prevent recurrence of decay in the same surface. To prepare cavities in the best form requires a good knowledge of the pathology of dental caries, as a basis for further study by observation and practice.

The procedures in cavity preparation are not different in the temporary teeth from those in the permanent teeth, except for the fact that they are in young children and usually may not be so thoroughly done; also the requirements of extension for prevention may be less strictly observed, particularly when smooth surface decays occur late in the life period of these teeth. In addition the gradual movement apart of the incisors and cuspids simplifies the treatment of proximal decays in those teeth.

In the following pages, the principles involved and the technical program employed in the preparation of the several classes of cavities are presented. Later, the treatment of a variety of decays of all classes will be described and illustrated. This will include methods of immunization, the technic of cavity preparation, and of the making of restorations, with consideration of many variations in conditions which call for modifications in treatment.

ORDER OF PROCEDURE IN CAVITY PREPARATION

GENERAL PRINCIPLES. There are certain fundamental principles that are general to orderly procedure in the excavation of carious cavities in the teeth, the observance of which will simplify and facilitate these operations, which may be expressed as follows:

First, obtain the required outline form.

Second, obtain the required retention and resistance form.

Third, obtain the required convenience form.

Fourth, remove any remaining carious dentin.

Fifth, finish the enamel wall.

Sixth, make the toilet of the cavity.

In certain conditions, which will be given in detail later, the fourth of these should be placed as the second. These will be found to be exceptions to the general rule.

In addition, the avoidance of pain should be a matter of study in every step of the preparation of each cavity.

The careful observance of this order of procedure will greatly facilitate operations and will be helpful in the selection of appropriate instruments and the promotion of better system throughout each operation.

OUTLINE FORM is the form of the area of the tooth surface to be included within the outline or enamel margins of the finished cavity; the laying out of and cutting to these lines should be the first thing considered and accomplished.

In all pit cavities the outline of the cavity will be found by cutting away all enamel overhanging the decayed area, completely uncovering it, and following out any fissures connecting with the cavity to such points as will enable a perfect finish to be given to the margins. The cutting out of fissures which are decayed eliminates the opportunity of food lodgements and the entire surface becomes self cleansing when a restoration is placed, which has perfectly smooth margins at all points. This is extension for prevention of recurrence of decay. This should always be done before there is an attempt made to remove the decay from the deeper parts of the cavity.

The outline form for cavities of this type is controlled: (1) by the extent to which the enamel has been involved by direct penetration of acid; (2) by the lateral spread of decay along the dento-enamel junction; (3) by extensions that must be made along fissures to secure smooth margins.

In smooth-surface cavities, that is, in proximal cavities and in buccal and labial gingival third cavities, which occur in the central portion of an area of uncleanliness that is habitual, in which the superficial injury to the enamel tends to spread, the laying out of the outline form of cavities is done upon a different principle. In these it is not simply cutting away overhanging enamel for the exposure of the dentin already decayed, but the object should be to include within the outline of the cavity such portions of the surface as are especially liable to decay in the future. As decay is liable to occur only upon the unclean areas, the entire unclean area should be included within the outline of the cavity. This requires a careful study of the conditions surrounding each smooth-surface cavity and the extension of the cavity outlines to include the area of the surface that may have suffered superficial injury, or is in danger of decay in the future. This will often require that a little of sound enamel and dentin be cut away to obtain the correct outline form, and this additional cutting, beyond that required for removing the actual decay is known as extension for prevention of the recurrence of the decay. The study of each case should be made, the outline determined upon and the cavity cut to the outline form required as the first procedure.

The outline form for proximal cavities is controlled by the following conditions, so long as the lateral decay in the dentin has not undermined enamel beyond the limits of growth of colonies of micro-organisms on the surface of the enamel: (1) In the gingival direction, by the position of the crest of the healthy gingiva, which should cover the entire length of the gingival margin of the restoration. Consideration should be given to the probability of future recession, depending on the age of the patient. (2) In the buccal, or labial, and lingual directions, by the dentist's estimate of the extent of the area of liability to surface extension of decay near the line of the margin of the gingivae. This is determined in part (a) by the opening or flare of the embrasures in either direction from the contact point, (b) by the opportunity to make the embrasures wider by disking the teeth, or by separating the teeth and making a restoration of greater convexity than that of the tooth, (c) by the occlusion and force used in mastication, (d) by the mouth hygiene of the patient, (e) by the estimate of susceptibility of the patient in relation to the age, (3) in the occlusal, or incisal, direction, by the contact point.

In cases in which the lateral decay in dentin has undermined enamel beyond the position where the outline would otherwise be placed, the decay in the dentin becomes the controlling factor and requires that all of the undermined enamel be removed.

The outline of the occlusal step is largely controlled by the rules for placing the margins of occlusal cavities, plus the fact that a dovetail for good anchorage may require extensions along grooves which are not fissured.

The outline form for gingival third cavities in buccal and labial surfaces is controlled; (1) In the gingival direction, by the position of the margin of the healthy gingiva, which should cover the entire length of the gingival margin of the restoration. Here, also, the probability of future recession of the gingivae should be considered. (2) In the mesial and distal directions, by the dentist's estimate of the extent of the area of liability to surface extension of decay, which depends upon (a) the force used in mastication, (b) by the occluso-gingival inclination of the surface as related to the cleansing of the gingival area in mastication, (c) by the mouth hygiene of the patient. Of these, the cleaning by the patient is of the greatest importance. (3) In the occlusal direction, by placing the margin where it will certainly be cleaned in mastication.

RETENTION FORM AND RESISTANCE FORM. Cavities should have such retention form that the restorations will be firmly held in place. In all positions in which the stress of mastication is to be brought upon the restoration, the cavity should also have such resistance form that the restoration will withstand the stress without being dislodged. *Retention* and *resistance* are two distinct

requirements, both of which are met by the same operations in preparing the cavity. They may therefore be considered together. The importance of resistance form is in direct relation to the degree of exposure of the restoration to the occlusion and to the force used in mastication. This force is, on the average for young adults, about 175 pounds in the first molar region, although many persons can exert more than 300 pounds. The best combination of retention and resistance form is necessary for occlusal and proximo-occlusal restorations in the bicuspids and molars. This calls for the box-form of cavities, with pulpal and gingival walls in the horizontal plane and surrounding walls as nearly at right angles as is practicable. It is to give sufficient retention form that the dovetail occlusal step is a standard part of the preparation of proximo-occlusal cavities. Cavities in the proximal surfaces of the anterior teeth, which involve the incisal angle, also require special attention to resistance form. Incisor proximal cavities which do not involve the angle, but extend lingually to or beyond the lingual marginal ridge require secure resistance form.

As a matter of convenience in teaching, the term *retention form* may be used, with the understanding that retention form always includes resistance form; or the term *retention-resistance form* may be used.

STARTING POINTS for gold foil restorations should be included under the heading of retention form. These consist of slight undercuts, situated at angles or other parts of the cavity, which enable the operator to quickly anchor the first few pieces of foil, previous to the time when foil is condensed into the true retention form of the cavity. Starting points are usually placed in two of the most convenient point angles.

CONVENIENCE FORM is secondary to other points in the preparation of cavities. When the general form of the cavity has been developed, modifications are to be made that will render the form more convenient for placing the restoration. This applies more particularly to preparations for gold foil. Often by cutting a wall away to a certain inclination, the condenser point will reach some portion of the cavity better or at a more available angle, enabling the operator to condense gold more securely and avoid the necessity of using hand pressure. This is particularly important in preparing the mesial walls of occlusal cavities and more especially the mesial and buccal walls as they approach the mesiobuccal angle.

In preparing cavities for inlay restorations, a slight modification of the inclination of a wall may simplify the preparation of the wax pattern. Occasionally, the cavity outline may be extended or the walls inclined, or both, as a matter of convenience in securing access to the pulp chamber and root canals.

REMOVAL OF REMAINING CARIOUS DENTIN. Generally when

the cavity has been cut to form, no carious dentin will remain. But in the deeper decays it will often be a question whether or not the pulp will be exposed when all decayed dentin overlying it is removed. There should be no cutting toward the pulp until the cavity is otherwise well prepared, for the reason that if a pulp exposure is found, the cavity will be fully cleaned and ready for the immediate treatment of the pulp in any way indicated. Then when this stage in cavity preparation has been reached, the remaining softened dentin is carefully and completely removed with the broadest spoon excavators that may conveniently be used.

FINISH OF ENAMEL WALL. Finishing the enamel wall and beveling the cavo-surface angle is the last cutting done in the preparation of a cavity. This should always be done with the rubber dam in place and with all provisions made for the immediate placing of gold foil or amalgam restorations. The rubber dam should also be in place for the final inspection of enamel walls before making a pattern or taking an impression for an inlay. This is a necessary precaution against the possibility that a partial penetration of enamel by caries has been overlooked, such as a secondary extension of caries to the gingival of a proximal decay. Such an area will appear as a white spot when the enamel is thoroughly dry. When the inlay is ready to be cemented, the enamel walls should be gone over with very sharp instruments and extremely light pressure, to remove any particles which may be attached to the walls, without cutting the enamel. This is of special importance if a varnish has been used in the treatment of sensitive dentin.

The cavo-surface angle of the cavity in every part of its outline should receive attention. The plane of this enamel wall should be as nearly as practicable in the line of the length of the enamel rods, or such as will certainly cut more from the outer than the inner ends of the rods, and should be perfectly smooth. When this has been satisfactorily accomplished, the cavo-surface angle of the enamel should, if necessary, be cut to a sufficient bevel outward. The depth of this bevel should generally not include more than one-fourth the thickness of the enamel wall, although in some cases, as occlusal cavities, the entire wall may be cut at such an angle in relation to the direction of the rods as to fully meet the requirement. The angle of the bevel should be from six to ten centigrades from the plane of the enamel wall for gold foil restorations, but should be less for all others. The object is, first, to cut away any loose ends of enamel rods that might afterward fall away and render the margin imperfect; and, second, to strengthen the cavo-surface angle of the enamel as a safeguard against possible checking in the condensation of gold.

The cavo-surface angle of the enamel is friable and readily broken by violence, and beveling will materially lessen this liability. But the marginal angle of the material used for the restora-

tion, which covers the bevel, must not be made too thin by too great a bevel of the cavo-surface angle of the enamel. If so, it will have no strength and will tend to roughen, and in this way render the margin imperfect. Therefore, the bevel of the cavo-surface angle of the enamel must not be too great.

TOILET OF CAVITY. This is the final step in cavity preparation and consists in freeing all surfaces from chips and dust that have accumulated during the excavation. The bulk of this is done, of course, with water or the air syringe during the progress of the excavating. But there will remain some fine dust upon the walls and margins that should be removed. It is not well to wash this with any known liquid, for, even with the use of pure alcohol (*which is definitely not recommended*), and after drying with the air syringe, something will be left coating the walls. The best way is by thorough wiping of all parts of the cavity with absorbent cotton held in the pliers. This should be well done and the cavity is then ready.

RULE: *No moisture of any kind whatever should enter a cavity after the last of the cutting is done, and if, by any accident, a portion of the cavity should become wet, it should be dried thoroughly and then the portion that has been damp should be freed of any particles which might be attached to the walls, by using very sharp instruments with light pressure and without cutting the enamel.*

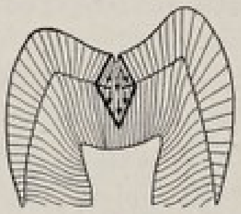


FIG. 312A.

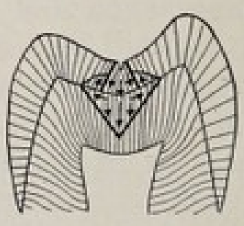


FIG. 312B.

PIT AND FISSURE CAVITIES.

In caries of enamel, the acid dissolves the cementing substance first, and the penetration of the enamel follows the direction of the rods. Therefore, since the enamel rods surrounding all pits are inclined inward, converging as they approach the surface, the area affected takes the form of a cone with its base at the dento-enamel junction. In section, the area appears as a triangle, as shown in Figure 312A.

When the acid involves the dentin, it penetrates the tubules directly toward the pulp, and also spreads laterally in all directions along the dento-enamel junction. The rapidity of this lateral decay depends upon the extent to which there are free anastomoses between the outer ends of the tubules. However, as the ends of additional tubules are involved, direct penetration towards the

pulp begins in each tubule. The penetration is naturally deepest in the tubules first involved and less deep in surrounding tubules. Therefore a conical area of decay occurs in the dentin with its base at the dento-enamel junction and its apex toward the pulp. The width of the base in relation to depth of penetration varies in accordance with the opportunity that the acid has to spread laterally, and it follows that the size of the base of the cone in the dentin may be the same or very much broader than the base of the cone in the enamel. In Figure 312A, the two bases are the same; in Figure 312B, the base of the dentin cone is much broader, but without deeper penetration.

Outline form. The principles involved in the preparation of outline form are illustrated in Figures 313, 314, 315 and 316. In each of the four cases presented, there are what appear to be

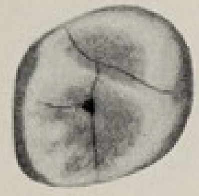


Fig. 313A.

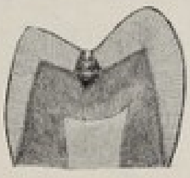


Fig. 313B.

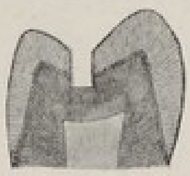


Fig. 313C.

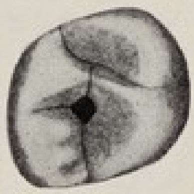


Fig. 313D.

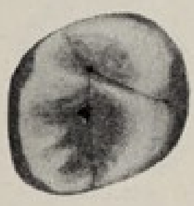


Fig. 314A.

Fig. 314B.

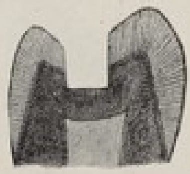


Fig. 314C.

Fig. 314D.

identical cavities in the central pit of the occlusal surface, as shown in Figures 313A, 314A, 315A and 316A. In the cross section, Figure 313B, it will be noted that the area of dentin involved is practically the same as the enamel decay at the dento-enamel junction. Therefore the outline form is no wider than the enamel involvement. A section through the prepared cavity is shown in Figure 313C, and the restoration in Figure 313D.

In Figure 314B, lateral decay in the dentin has undermined enamel not involved by direct penetration, and this decay in the dentin controls the outline form, as shown in Figure 314C, and the restoration in 314D. In this case there was also a decay in the distal pit, similar to that in 313B, and this pit has a very small restoration.

In Figure 315B, the lateral decay in the dentin is about the same as in 314B, but more time has elapsed and there has occurred

much backward decay of the enamel, beginning at the dento-enamel junction. Since the penetration of the enamel follows the direction of the rods, the area of enamel involved by backward decay can never be as large, and is usually considerably smaller, than the lateral decay in the dentin. Therefore the prepared cavity would be the same as Figure 314C, except for the fact that there are fissures along the lines of all the grooves, which will not permit of the placing of a restoration with all of its margins smooth and flush with the surface of the enamel. Figure 315C illustrates a fairly deep, undecayed fissure. These fissures require that the outline be extended until smooth margins can be made, and the finished restoration is shown in Figure 315D.

There were no fissures in the teeth illustrated in Figures 313A and 314A, therefore no extensions were made. Oftentimes

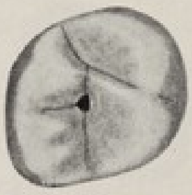


Fig. 315A.

Fig. 315B.

Fig. 315C.

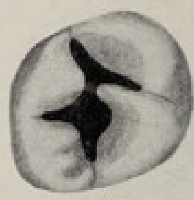


Fig. 315D.

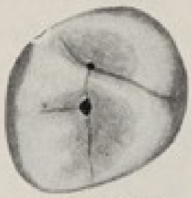


Fig. 316A.

Fig. 316B.

Fig. 316C.

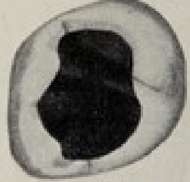


Fig. 316D.

there are fissures extending from both central and distal pits, without the distal groove, which connects these two pits, being fissured through the disto-buccal triangular ridge, in which case the extensions should not include it. It is in every case only a question of cutting far enough to secure a smooth margin.

In Figure 316A, there are decays in both pits, but no fissures. On surface inspection, it appears the same as 314A, but this case has been long neglected, as shown by the bucco-lingual section in Figure 316B and the mesio-distal section in Figure 316C. The lateral decay in the dentin controls the outline form and the restoration includes most of the occlusal surface. See Figure 316D.

Outline form in all cavities of this class is obtained by very simple procedures and with few instruments. In cavities similar to that shown in Figure 313B, an 8 tenths mm. inverted cone bur should be used to make the initial opening through the enamel. The opening should be enlarged with the same bur cutting the

enamel mostly from within outward, to include the full area of involved enamel, when the outline form would be completed. For the cavity illustrated in 314B, there is already an opening through the enamel and some undermining by decay in the dentin. This undermined enamel may be split off with a chisel of appropriate size and angle. If the access is good, a straight chisel or one with the blade at a 6 centigrade angle should be the only instrument required. A chisel may generally be used in two ways in breaking down enamel; with a push motion in the direction of the length of the blade, as illustrated in Figure 317, and with pressure at right angles to the length of the blade, as in Figure 318.

In preparing a cavity for a restoration similar to that in Figure 315D, it would be necessary to cut out undecayed fissures. After the enamel undermined by decay has been removed, an inverted cone bur should be used to open the fissures. This is done by placing the bur in the cavity, with the head of the bur only partly in the dentin, and cutting first laterally about 1 mm. along the line of the fissure, then drawing the bur occlusally through the enamel that has been undermined. This should be repeated as many times

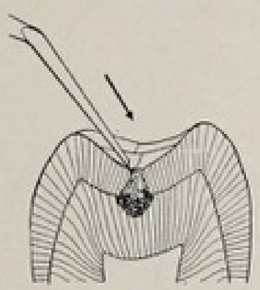


FIG. 317.

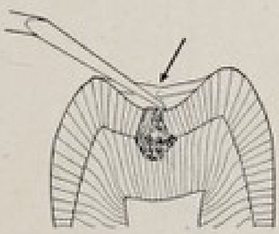


FIG. 318.

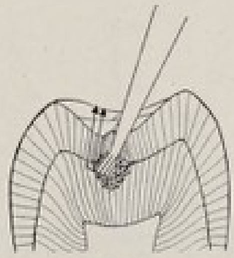


FIG. 319.

as necessary to open the fissure to the desired point. See Figure 319. By making a series of cuts, instead of one extended cut, less heat is generated and less pain is caused. On this plan there is very little actual cutting of enamel with the bur. The enamel is first undermined by slight cutting in the dentin, and the undermined portion is then broken out, rather than cut, as the bur is drawn occlusally. Any remaining enamel that has been undermined along the sides of the cut should be removed with a chisel.

The outline for the cavity prepared for the restoration shown in Figure 316D was very easily obtained by the use of an 18-9-6 binangle chisel, which, with access more or less parallel to the long axis of the tooth, was used to break down the undermined enamel all the way around the carious areas. The enamel of the disto-buccal triangular ridge was so extensively undermined that it was easily chipped away. A 6-2-23 bibeveled hatchet was then carried around the cavity with the cutting edge against the dentin at the dento-enamel junction, to locate points where the enamel was still undermined by lateral decay. See Figure 320. The outline was then extended accordingly with the same chisel.

RETENTION AND RESISTANCE FORM. In occlusal cavities the simplest plan of securing resistance and retention form is to cut the pulpal wall flat in the horizontal plane with a bur, and at the same time square out the line angles where the pulpal wall meets the surrounding walls. An inverted cone bur or a fissure bur may be used for this purpose. See Figure 321. The surrounding walls should be at right angles to the pulpal wall, with occasionally slight undercuts for gold foil or amalgam, but should have a slight outward inclination for inlays, so that a wax pattern or an impression may be readily withdrawn. These walls can not be of square box-form, but should have sufficiently irregular contours to give the restoration stability, with due regard for the recessional lines of the pulpal horns. Very small pit cavities should not be prepared with a round outline, but should have one or two slight lateral cuts along the lines of grooves. The dentin walls may be cut to form with chisels and single-bevel hatchets of appropriate widths and angles. For example, the 12-6-12 hatchets and the chisel 12-6-6 may be used for direct cutting of the surrounding walls, and with a scraping motion on the pulpal wall. See A and B,

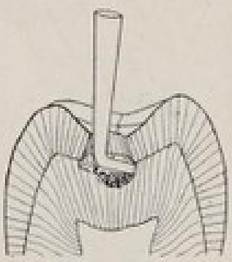


FIG. 320.

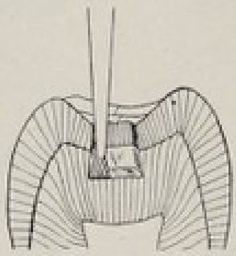


FIG. 321.

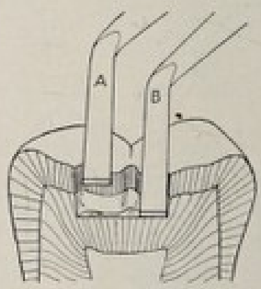


FIG. 322.

Figure 322, which illustrate the use of a chisel or hatchet in cutting one of the surrounding walls directly toward the pulpal line angle, and also cutting the pulpal wall with a scraping motion toward the same line angle. Smaller instruments may be similarly used in pit cavities in other surfaces.

STARTING POINTS FOR GOLD FOIL. Starting points for gold foil are practically the same for all cavities. They are usually made with an 8 tenths or a 1mm. inverted cone bur; (1) by placing the bur with its long axis nearly at right angles to the pulpal wall and the end against the pulpal wall, in the position where the starting point is to be made; (2) by pressing laterally, cutting with the side blades into the dentin from 5 tenths to 1 mm.; (3) by withdrawing the bur in the occlusal direction and gradually cutting less deep in the dentin as it is withdrawn. See Figure 323.

CONVENIENCE FORM. Whatever modifications need to be made in wall inclinations, as a matter of convenience in operating, are made with the same instruments as are used to prepare the walls.

REMOVAL OF REMAINING CARIOUS DENTIN. Spoons are used for removing any carious dentin that may remain. This is usually done by placing the edge of the blade at one edge of the carious area and endeavoring to remove the mass with a single sweep of the instrument, using rather heavy pressure. See Figure 324. Usually two or three cuts in different directions are necessary, and finally one and then the other instrument of a pair should be carried around the cavity to remove any slight areas that remain. Carious dentin should not be removed with a bur. Cutting with a spoon is more exact, as the operator has better control and can feel the difference between carious and normal dentin. As a rule, one should select the largest spoons that can conveniently be used, as the decay will be removed with the least number of cuts. When there is any question whether every particle of decayed dentin has been removed from along the line of the dento-enamel junction, the 6-2-23 or the 9-3-23 bibeveled hatchet should be carried around the cavity in that position, with its edge just beyond the dento-enamel junction. See Figure 320.

The carious dentin will in some cases be removed immediately after the outline form is obtained, as in Figure 324. If the decay is

FIG. 323.

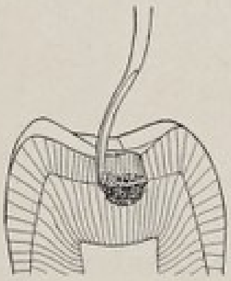


FIG. 324.

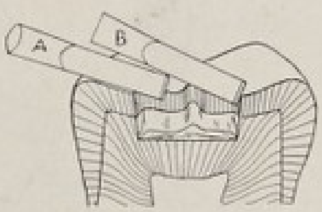


FIG. 325.

not extensive, all of the carious dentin will be removed in preparing retention form. When the decay is deep, some will remain after the retention form is completed.

FINISH OF THE ENAMEL WALL. The enamel wall is given a smooth finish by light planing with a straight or binangle chisel, the movement of the instrument being in line with the length of the margin. Either instrument may also be used with a scraping motion, with the blade held almost at right angles to the wall. See A and B, Figure 325. The bevel of the cavo-surface angle is made with the same instruments, used as described. If the instruments selected have been used for any previous cutting in preparing the cavity, they should be returned to the Arkansas stone to be certain that they have keen edges before the finish of the enamel wall is undertaken.

THE TOILET OF THE CAVITY has been sufficiently discussed on the preceding pages.

Smooth Surface Cavities.

The enamel rods in all locations of smooth surface decays are parallel to each other and approximately at right angles to the surface, and the penetration of the enamel is always deepest at the point where acid is first held in contact with the enamel at the central portion of the unclean area, and less deep in the surrounding area, corresponding to the gradual spread of the colony on the surface. The area affected is in the form of a cone with its base at the surface of the enamel and its apex toward the dentin.

The penetration in the dentin is the same as in pit and fissure cavities, and forms a cone with its base at the dento-enamel junction and apex toward the pulp. The base of the cone in the dentin is usually smaller than the base on the surface of the enamel. See Figure 326. In neglected cases, it may be larger, undermining enamel that is not involved on the surface. See Figure 327.

The forms of smooth surface cavities are usually not dependent so much upon the extent of the decay as the environmental condition. Two general rules may be stated, which apply to the prepara-

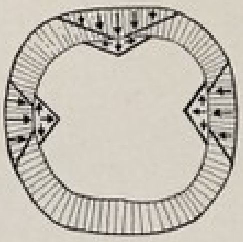


Fig. 326.

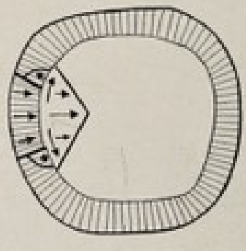


Fig. 327.

tion of the outline form of all smooth surface cavities: (1) if the surface involvement of the enamel is less than the area of liability to decay and the lateral decay in the dentin is also less than the area of liability of the enamel surface, it is necessary to cut away some sound enamel and dentin to place the margins in immune territory; (2) if, in neglected cases, lateral decay in the dentin has undermined enamel in immune territory by spreading beyond the line of surface liability of the enamel to decay, the outline of the cavity must be placed farther into immune territory than would be required under the rules of extension for prevention. Either of these rules may be applied to cutting in any direction.

The forms of the proximal surfaces of the teeth, the positions and closeness of the points of contact, and the health and form of the interproximal gingivae, are so interrelated that all must be considered when determining the outline form in preparing cavities, and in making restorations in these surfaces. This is of especial importance in the bicuspid and molar region, where much force is normally used in mastication. These factors all have to do with the opportunity for attachment of colonies of organisms and the

extent to which they may spread on the surface of the enamel. It is therefore necessary that each case be studied as a separate problem, in order that the health of all of the tissues concerned may be conserved in the highest degree.

The most important points to be considered are illustrated by four simple studies; (1) the relation of the position of the crest of the gingiva to the beginning and surface involvement of the enamel; (2) surface extensions of caries of enamel and progress of caries in dentin; (3) convexity of proximal contours in relation to outlines for prepared cavities; (4) the position and form of the contact and the mesio-distal width of the interproximal space in relation to proximal decays and the health of the gingiva.

RELATION OF THE POSITION OF THE CREST OF THE GINGIVA TO THE BEGINNING AND SURFACE INVOLVEMENT OF THE ENAMEL. For an indefinite number of years after the teeth erupt, the interproximal gingivae completely fill the septal space to the point of

FIG. 328A.

FIG. 328B.

FIG. 328C.

FIG. 328D.

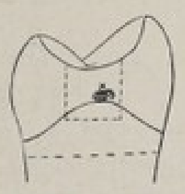


FIG. 329A.

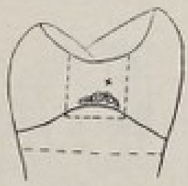


FIG. 329B.

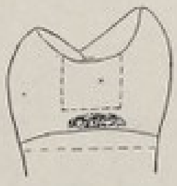


FIG. 329C.

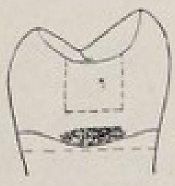


FIG. 329D.

contact, and this gives complete protection to the enamel so that caries does not occur. The gradual recession or shortening of the gingivae with advancing age is discussed elsewhere. It need only be mentioned here that the time and extent of the recession varies greatly. In those mouths in which it occurs very slowly, the period of greatest susceptibility may be passed before there is recession of consequence. A very gradual recession might be considered normal for most persons.

Figure 328A illustrates a slight recession, as frequently seen in the bicuspid and molar region from the tenth to the fifteenth year, and in the incisor region a few years later. The position of the contact is marked with a cross, and the position of the crest of the normal full gingiva is indicated by a broken line. The space between the broken line and the continuous line represents the extent to which the crest has receded, also the area of liability to decay of

the surface of the enamel of both proximating teeth. Such a recession precedes the occurrence of decay. Figure 328B illustrates a further recession which is rather common at about the twenty-fifth year. It will be noted that the area of liability is increased in both the bucco-lingual and the occluso-gingival directions. A greater recession, Figure 328C, is not common except as the result of a weakness of the contact which permits food to be forced through in mastication, or injury to the soft tissue, such as is caused by the use of tooth picks. The extensive recession shown in Figure 328D is practically always associated with a weak or open contact, which permits impaction of food between the teeth to the extent that the gingiva is compressed and eventually partly absorbed.

Figures 329A, B, C and D are four corresponding drawings, with what might be termed the average outline of the proximal portion of a prepared cavity indicated by a broken line. This outline is in the same position in the four illustrations. Its position is based on the line of the crest of the gingivae in Figure 329B, which rep-

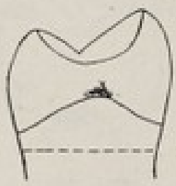


FIG. 330A.


FIG. 330B.

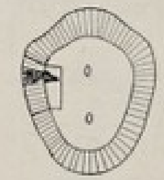


FIG. 330C.

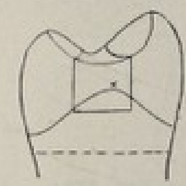


FIG. 330D.

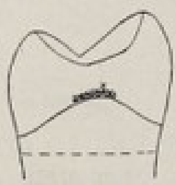


FIG. 331A.


FIG. 331B.

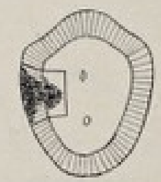


FIG. 331C.

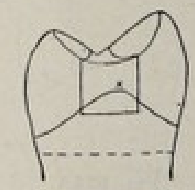


FIG. 331D.

resents the extent of recession that should be anticipated by the age of about twenty-five. All of the gingival margin of the cavity is covered by the gingiva. Therefore, in preparing a cavity for a younger person, some recession should be anticipated, as shown in Figure 329A. It will be noted in Figures 329C and 329D that the enamel beyond the margin of the restoration would be exposed and become vulnerable. Such a situation is usually prevented by maintaining good contacts.

SURFACE EXTENSIONS OF CARIES OF ENAMEL AND PROGRESS OF CARIES IN DENTIN. Figure 330A is a duplicate of Figure 328A, illustrating a beginning decay, which was discovered before it had involved the full width of the susceptible area. The penetration in the enamel and dentin are illustrated in Figure 330B, a mesio-distal section, and Figure 330C, a horizontal section. The

early discovery prevented deep penetration of the dentin and possibly also gave opportunity to immunize the corresponding surface of the proximating tooth. Extension for prevention required that the cavity be cut to the buccal and lingual as shown in Figure 330D. The outline to the gingival is farther than absolutely required at the time, in anticipation of further recession of the gingiva. The positions of the cavity walls in the dentin are illustrated in Figures 330B and 330C.

Figure 331A is a duplicate of Figure 328B, illustrating a decay which has spread over the full limit of the susceptible area to the buccal and lingual. The occluso-gingival width of penetration of the enamel, shown in Figure 331B, is the same as in 330B, but the bucco-lingual width, Figure 331C, is much greater than in 330C. The surface outline of the prepared cavity, Figure 331D, is the same as in 330D. There was no extension for prevention in this case, as the full width of the susceptible area had been affected. It will be noted, however, that the axial wall is a little closer to the pulp in Figures 331B and 331C, due to the deeper penetration of the dentin.

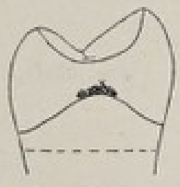


Fig. 332A.

Fig. 332B.

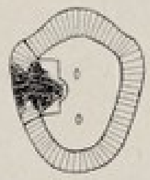


Fig 332C.

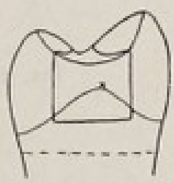


Fig. 332D.

Figure 332A is a duplicate of 331A; it illustrates the full surface spread of decay bucco-lingually. In this case it has been neglected, as will be observed in Figures 332B and 332C. Sufficient time has elapsed for almost complete penetration of the enamel corresponding to the entire area of surface involvement and lateral decay in the dentin has undermined the enamel in all directions beyond the area of possible growth of organisms on the surface; it has undermined extensive areas of enamel immune to surface involvement. There has also occurred considerable backward decay of enamel. The decay in the dentin controls the outline form shown in Figure 332D, and extension for prevention is not practiced, excepting possibly to square out the bucco-gingival and linguo-gingival angles. Incidentally, the preparation involves much more of the dentin and correspondingly endangers the pulp.

Convexity of proximal contours in relation to outline for prepared cavities. Figure 333A represents a normal bucco-lingual convexity of the proximal surface and a normal contact. Figure 333B shows a proximal surface decay which has not yet covered the full area of liability. Figure 333C is an occlusal view of the restoration showing the contact and the forms of the em-

brasures, which may be considered as normal. Figure 333D is a proximal view of the restoration.

Figure 334A illustrates a broad flat contact between the bicuspid and first molar and 334B a decay which has included the broad area or near approach of these teeth. It requires a much wider outline as shown by the restoration in Figures 334C and 334D. It was possible in this case to make the restoration more convex in its occlusal half than was the contour of the bicuspid, so that the

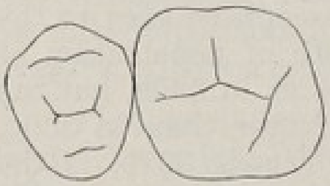


Fig. 333A.

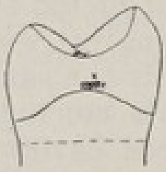


Fig. 333B.

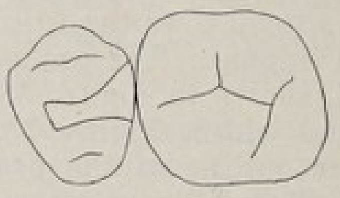


Fig. 333C.

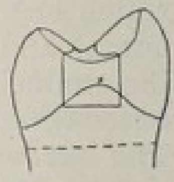


Fig. 333D.

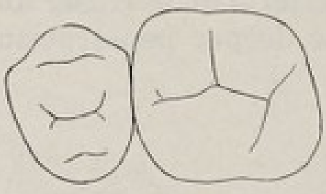


Fig. 334A.

Fig. 334B.

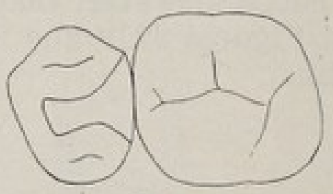


Fig. 334C.

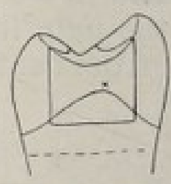


Fig. 334D.

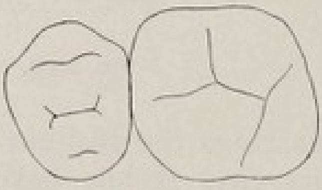


Fig. 335A.

Fig. 335B.

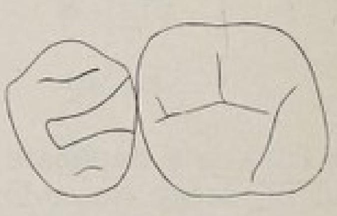


Fig. 335C.

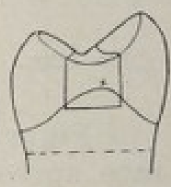


Fig. 335D.

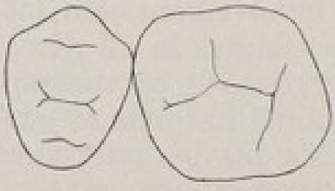


Fig. 336A.

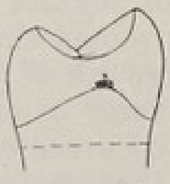


Fig. 336B.

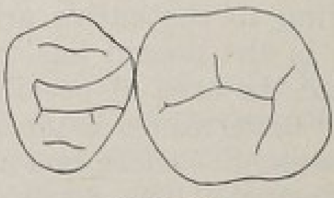


Fig. 336C.

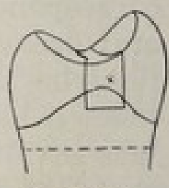


Fig. 336D.

embrasures are broader, yet not as wide as they should be. Ordinarily the mesial surface of the first molar would have been decayed and a restoration placed before the operation on the bicuspid, which would have made it reasonably safe with the bicuspid restoration as shown.

Figure 335A is a duplicate of 334A. However the decay, as shown in Figure 335B, was discovered earlier and it was possible to prepare a cavity less wide bucco-lingually. By separating

the teeth slightly, and making the restoration more convex than the tooth, the embrasures were made wider than those in the previous case. Figure 335C should be compared with 334C and 333C.

Special attention is called to the fact that proximal decays of both of the teeth illustrated in Figure 334A might possibly have been avoided, or the width of the decay shown in Figure 334B could certainly have been limited to a narrower area, if the embrasures had been made wider by the use of a disk soon after the bicuspid erupted.

Figure 336A illustrates the other extreme, in which, due to the partial rotation of the bicuspid, the embrasures are wider than normal. The decay is necessarily narrow bucco-lingually as shown in Figure 336B, and the cavity outline corresponds, as shown by the restorations in Figure 336C and 336D.

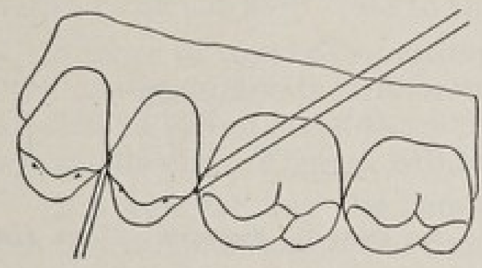


FIG. 337.

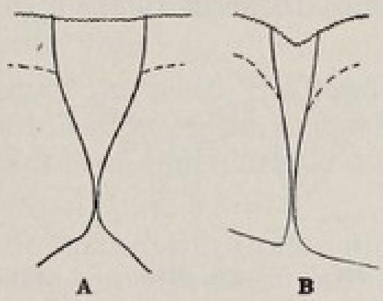


FIG. 338.

THE POSITION AND FORM OF THE CONTACT AND THE MESIO-DISTAL WIDTH OF THE INTERPROXIMAL SPACE IN RELATION TO PROXIMAL DECAYS AND THE HEALTH OF THE GINGIVAE. The normal contacts between the teeth are similar to two marbles held against one another with slight pressure. The area of near approach of the two surfaces is slight. It is as important that contacts be of proper form as in the right position. The method of testing the extent of the near approach of the surfaces of the teeth about the contact is illustrated in Figure 337. The ligature is first passed to the gingival of the contact; the two ends are then held parallel in the occlusal direction, as shown for the contact between the bicuspids. This measures the bucco-lingual width of the contact, or very near approach, of the two surfaces. Without removing the ligature, the two ends should be held parallel in the buccal direction, as shown for the contact between the molars. This measures the occluso-gingival width of the contact. In either position, if the parallel strands are more than 1½ or 2 mm. apart, the contact is too broad.

Figure 338 illustrates about the average mesio-distal comparative widths of the interproximal spaces between the posterior and anterior teeth. It will be noticed that the base is much wider mesio-distally between the bicuspids and molars than between the in-

cisors. This would seem to give more support to the septal tissue between the posterior teeth. However, the line of attachment of the gingivae to the incisors is very convex, extending far toward the incisal on the proximal surfaces, thus compensating for the narrower alveolar base.

Drawings of two upper bicuspids will be used to illustrate forms of contact and mesio-distal widths of interproximal spaces. Figures 339A, B and C represent normal conditions. In 339A the position of the contact is marked with an X, the area of near approach of the two surfaces is indicated with a broken line, and the position of the crest of the gingiva with a continuous line. Figure 339B is a mesio-distal section through the teeth at the point of contact, and 339C is an occlusal view. If one will note, first the slope of the surfaces from the marginal ridges to the contact in 339B, also the widening of the embrasures in 339C and will think of these in relation to the point of contact and the curvature

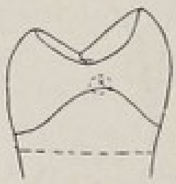


FIG. 339A.

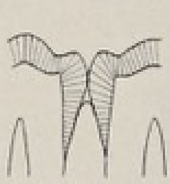


FIG. 339B.


FIG. 339C.

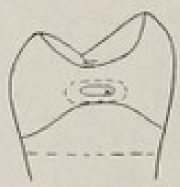


FIG. 340A.


FIG. 340B.


FIG. 340C.

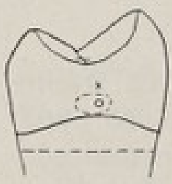


FIG. 341A.


FIG. 341B.

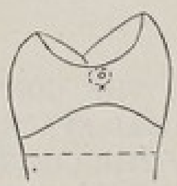


FIG. 342A.

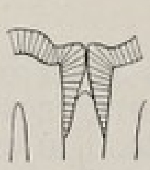


FIG. 342B.


FIG. 343A.

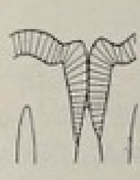


FIG. 343B.

of the gingiva in 339A, he should have a good understanding of the movements of food over these surfaces in chewing and their effectiveness in keeping them clean.

A broad contact bucco-lingually is illustrated in Figures 340A, B, and C. In the proximal view 340A, the position of a normal contact is marked X, while the contact of this tooth is the outlined oblong area; the area of near approach is the broken line. As a rule the crest of the gingiva is less arched, being almost horizontal along the area of near approach. Viewed from the buccal, in the mesio-distal section, Figure 340B, the contact appears to be the same as in Figure 339B, but a comparison of the occlusal views, 340C with 339C, shows the extra breadth of this contact, which prevents food from scouring the embrasures as far in as is the case when the contact is normal.

Figures 341A and B show a contact that is too far to the gingival. Its position, in comparison with normal, is shown by the

relation of the circle to the X in 341A. The danger in such a contact lies in the inclinations of the proximal surfaces from the occlusal margins to the contact. Stringy food is likely to become packed into this space and eventually force the teeth apart and injure the gingiva.

Figures 342A and B illustrate a contact too close to the occlusal. This form is frequently observed in restorations, seldom in the teeth, except in cases of abrasion. Such a contact prevents a proper amount of food from being forced into the embrasures, particularly close in, where it is most effective; also the crest of the gingiva is far from the contact, and invites decay of the proximal tooth if only one has a restoration.

Figures 343A and B illustrate a contact that is too broad in the occluso-gingival direction. The principal objections to this form of contact are that stringy foods are likely to be caught and held, also that decay occurs farther to the gingival, requiring cavities to be cut very close to the cemental line.

In cases of excessive proximal wear of the teeth, the condition of the contact areas is similar to a combination of the areas illustrated in 340A and 343A, there being a facet of considerable dimensions as shown in Figures 210 to 214.

In a general way the conditions described for proximal surfaces of bicuspids and molars apply to the anterior teeth, although their wedge form lessens the likelihood of injuries to the gum, and food which is forced through the contact is less likely to be held, or if held, is more often noticed and removed. The one contact in the incisor region which should receive early preventive treatment in the mouths of many persons, is that between the upper central incisors. This contact is often very long inciso-gingivally and the proximal surfaces should be reduced to proper contour, as described elsewhere.

Finally the operator must make the best possible estimate of the danger of susceptibility in relation to all of these conditions and to the age of the patient.

PROXIMO-OCCLUSAL CAVITIES IN THE BICUSPIDS AND MOLARS.

OUTLINE FORM. It will usually be more convenient to prepare the outline form of the occlusal surface in advance of the proximal portion, although in cases in which the decay is extensive the proximal portion should be prepared first. In cases in which the decay has undermined the occlusal enamel, it should first be removed sufficiently with a chisel to give room for a 1 mm. inverted cone bur. A series of cuts should then be made along a groove to the nearest occlusal fossa or pit. These cuts should be made as described for occlusal cavities and should be continued, by undermining and breaking out more enamel until the general form of the occlusal step has been obtained. See Figure 319.

In cases in which there is no decay of the occlusal surface, an opening should be made through the enamel with an 8 tenths to 1 mm. inverted cone bur in a fossa that will necessarily be included in the cavity outline. The opening may be enlarged, if necessary, and the same bur should be used to make a series of cuts along the line of the groove to connect with the proximal decay. The walls of the step should be trimmed to form with suitable chisels or hatchets.

In the proximal portion of the cavity, all undermined enamel should be cut away. Hatchets 18-9-12 or 12-6-12 may be used for the buccal and lingual walls. See Figure 344. When there is proper access, the buccal and lingual enamel may be cut more readily from the buccal and lingual directions. For mesial surface decays, the straight chisel 12 may be used from the buccal and the hatchet (right or left) 12-6-6 from the lingual. See Figures 345 and 346. For distal cavities, chisel 12-6-12 may be used from the buccal for bicuspids and the first molar, the 12-6-23 from the buccal for the second molar and from the lingual for most of the bicuspids and molars. Positions of these instruments are shown for a distal cavity in the second bicuspid in Figures 347 and 348.

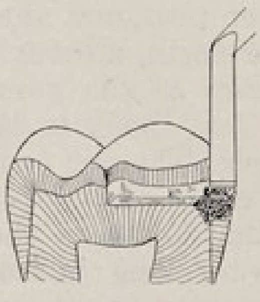


Fig. 344.

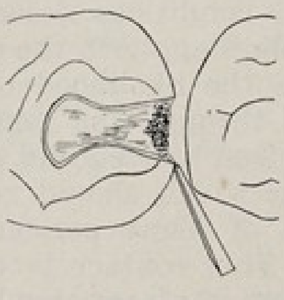


Fig. 345.

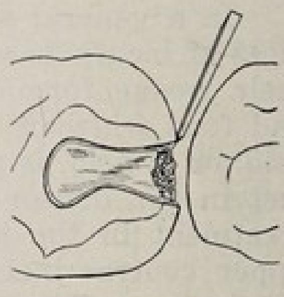


Fig. 346.

If further extensions require the cutting of a little sound dentin and enamel, an inverted cone bur is used in much the same manner as for occlusal extensions, except that there is no groove to follow. It is necessary to undermine, by cutting in the dentin, whatever enamel is to be removed. As a rule more cutting is required at the bucco-gingival and linguo-gingival angles than elsewhere. An 8 tenths mm. inverted cone bur may be pressed, while rotating slowly, into the dentin just beneath the enamel of, for example, the bucco-gingival angle, and then pressed laterally through the enamel to the surface. This may be repeated until the desired position of bucco-gingival marginal angle is reached. See Figure 349. Similar cuts may be made at the linguo-gingival. The bur may then be drawn occlusally in the dentin, undermining the enamel to extend the buccal and lingual margins. A cut may then be made at the gingival, from buccal to lingual, connecting the cuts previously made, in extending the bucco-gingival and linguo-

gingival angles. Hatchets should then be used to trim the buccal, lingual and gingival walls. This completes the outline form.

RETENTION AND RESISTANCE FORMS may be obtained by the use of a bur, as in the occlusal portion of the cavity, by cutting the gingival wall in the horizontal plane. The 12 angle hatchets are then used to cut the surrounding dentin walls to proper form. In no case should the pulpal, gingival or axial walls be cut deeper than is absolutely required; usually less than 1 mm. into the dentin. Deeper cutting endangers the pulp without advantage to the restoration. The line angles of the proximal portion should be made very definite. The chisels and hatchets may be used for all of these, or the margin trimmers may be preferred in some cases for the axio-buccal, axio-lingual and axio-gingival line angles. The

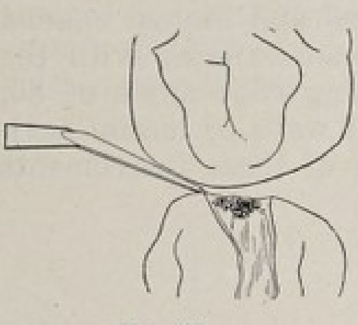


FIG. 347.

FIG. 348.

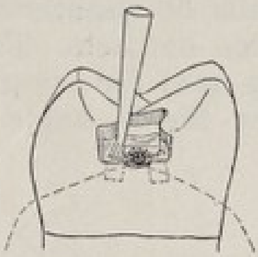


FIG. 349

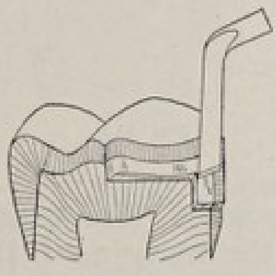


FIG. 350.

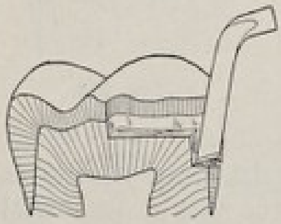


FIG. 351.

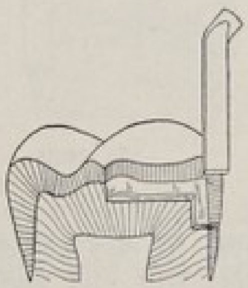


FIG. 352A.

instruments with the cutting edge of the blade at 80 angle may be used for distal cavities, and the 95 angle for the same line angles in mesial cavities. This use of one of the 95 angle instruments is illustrated in Figures 350 and 351. The hatchets illustrated in Figure 291 were especially designed for this purpose by Dr. Hartman. All walls in axial planes must be inclined slightly outward in preparations for inlays. For gold foil or amalgam they should be cut in the axial planes, with opposing walls parallel, or these walls may in some cases be slightly undercut.

STARTING POINTS FOR GOLD FOIL. When the smaller cavities of this type, most often in mesial surfaces, are prepared for gold foil, the starting points should be placed in the pulpo-disto-buccal

and pulpo-disto-lingual point angles, also in the gingivo-axio-buccal and gingivo-axio-lingual angles. See Figure 323.

CONVENIENCE FORM. No convenience form would usually be required for the cavities of this class.

REMOVAL OF REMAINING CARIOUS DENTIN. Except in rather large cavities, the carious dentin would have been entirely removed in the preceding preparation of the cavity. If any remained, it should be removed with a spoon of convenient size, and should be replaced with cement, rather than cut the cavity deeper.

FINISH OF THE ENAMEL WALL. The enamel walls of the occlusal step should be finished the same as for the occlusal cavities. All of the walls of the proximal portion should be made smooth with the 12 angle hatchets. See Figures 352A and 352B. The direction of the rods requires that the buccal and lingual enamel walls be slightly inclined outward, which can be done with the same hatchets. The margin trimmers, cutting edge angle of 80, are used for the gingival, buccal and lingual walls of mesial cavities, the 95 angle for distal cavities. Each of these instruments

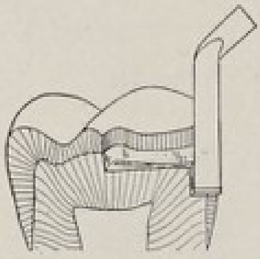


FIG. 352B.

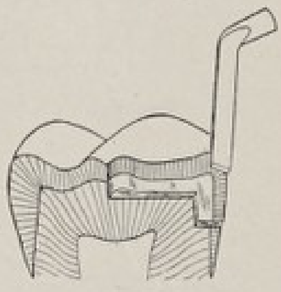


FIG. 353.

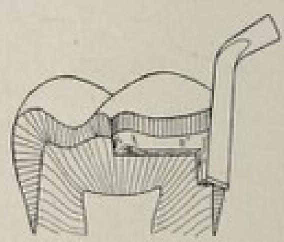


FIG. 354.

may be used effectively to trim margins of two walls. For example, the left instrument, angle 80, will trim the margin of the lingual wall of a mesial cavity in a lower right molar, cutting from occlusal to gingival, it will also trim the lingual half of the margin of the gingival wall, cutting from buccal to lingual. See Figures 353 and 354. In making both cuts it should be carried a little past the angle to make the marginal outline very slightly curved. This same pair of 80 angle, are also very convenient to bevel the cavo-surface angle of the distal wall of a mesio-occlusal cavity, and the 95 angle to bevel the cavo-surface of the mesial wall of a disto-occlusal cavity.

THE TOILET OF THE CAVITY. The toilet of the cavity should be made with the cavity dry, as has been described, before a gold foil or amalgam restoration is placed or a pattern is made for an inlay. Then before the inlay is cemented, the surfaces of the walls should be scraped with very sharp instruments and light pressure, without cutting the enamel, to clean the walls.

PROXIMAL CAVITIES IN THE INCISORS AND CUSPIDS WHICH DO NOT INVOLVE THE INCISAL ANGLE.

In the excavation of cavities of this class a much greater variety of forms of cutting instruments may be used interchangeably and effectively than in other classes, and a greater variation of method of instrumentation is consistent with rapid and thorough operating. Therefore, care should be exercised in forming habits of procedure that will limit the instruments used habitually to an efficient number that may be employed without confusion and delay.

Cavity forms in incisor proximal surfaces differ from all others in that they are in surfaces of the teeth that are triangular in form and the cavities must take a similar form. Therefore, instead of the typical form being the modification of a square box, as are all other cavities, the form is a triangular box, modified to suit the conditions.

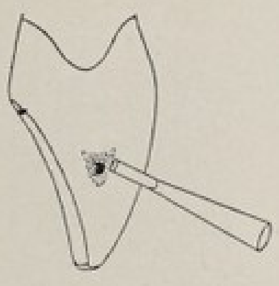


FIG. 355.

FIG. 356.

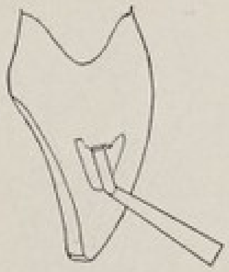


FIG. 357.

OUTLINE FORM. As with the proximal cavities in bicuspids and molars, the position of the outline must be determined in each case depending on environmental conditions, except in neglected cases in which lateral decay in the dentin has undermined enamel beyond the outlines that would satisfy the requirements of extension for prevention. On account of the prominent position of these teeth and the esthetic demands, it will be best when decay is extensive, to leave at the labial portion of the margin some enamel unsupported by dentin, rather than expose too much of the restoration to view. The labial enamel is usually thick and strong and is not exposed to the force of the bite. It will therefore stand better than in other positions. However, enamel that has been thinned appreciably by backward decay should be cut away.

The first procedure is to cut away the enamel that has been undermined. If the cavity is very small, it may be necessary to first apply a separator to give working space for the smallest chisel. The 6-2-6 or 9-3-6 chisel should be used to break down the labial enamel and the corresponding instruments of 12 angle should break

away the lingual enamel. See Figures 355 and 356. From both approaches, the cutting should be carried as far as possible in the incisal and gingival directions. The enamel forming the contact point should be broken down in this operation. A 6-2-12 or a 9-3-12 hatchet should then be placed between the teeth from the labial and, using the neighboring tooth as a fulcrum, with one extremity of the edge of the blade on the enamel near the gingival margin of the decay, the enamel should be chipped away as far as possible. See Figure 357. Either of these hatchets may then be introduced into the cavity to possibly cut away more of the enamel to the gingival.

It presumably being necessary to extend the cavity outline particularly in the gingivo-labial and gingivo-lingual directions, a 6 tenths mm. inverted cone bur should be inserted into the cavity from the labial direction and held in such position that with direct pressure the end of the bur will undermine the enamel and in a series of cuts break it out to the desired position of the linguo-gingival angle of the cavity outline. The position of the bur is

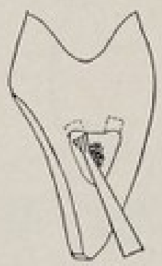


FIG. 358.

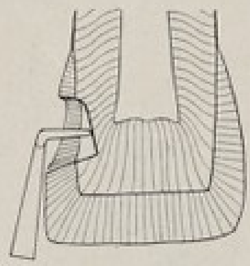


FIG. 359.

FIG. 360.

illustrated in Figure 358. The same bur may be then pressed laterally from the lingual to labial undermining the gingival enamel, and with a gradual change in the position of the hand piece the enamel in the labio-gingival direction may be removed to the position of that margin. It may be necessary to make the approach from the lingual side of the teeth to gain proper access for the bur in the labio-gingival position. The enamel walls should then be trimmed with the same chisels and hatchet.

In cavity preparations for either porcelain or gold inlays, the surrounding walls must be so inclined outward that a pattern or impression of the cavity may be withdrawn. This usually involves some cutting from the labial or lingual wall, beyond that required under the rules of extension for prevention.

RETENTION FORM. The principal retention for a gold foil restoration is at the incisal angle. First the incisal portion of the axial wall is cut deeper and the axio-labial and axio-lingual angles are made quite definite, with the 6-2-23 chisel, cutting toward the incisal angle. See Figure 359. The axial wall should be cut deeper

as the incisal angle is approached. The incisal anchorage should then be cut with a 28 angle bibeveled hatchet, introduced from the labial with the edge directed incisally as shown in Figure 360. Beginning in the axio-labial line angle, a little removed from the incisal angle, the edge should be carried toward the incisal and lingual around the angle, in part by a twist of the instrument. A similar cut should be then made from the lingual around the incisal to the labial. This cutting should be entirely in the dentin and should form a decided groove around the incisal angle. The depth of the retention should be tested with a right angle, hand-pressure, gold condenser placed in it.

The axio-labial and axio-lingual line angles should be made definite by using a 23 angle chisel with a pulling motion from gingival to incisal and a 6-2-6 or 6-2-12 chisel with a push motion from incisal to gingival. See Figures 361A and 361B. The same instruments may be used for the axio-gingival line angle. See Figure 362. All of these angles may be very nicely prepared with Dr. Woodbury's angle forming instruments. See Figure 290.

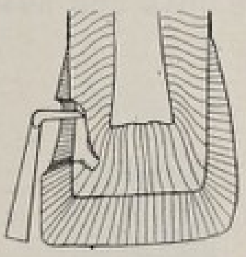


Fig. 361A.

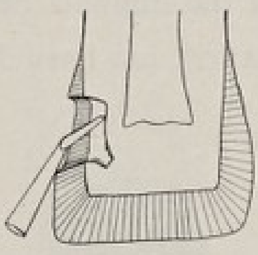


Fig. 361B.

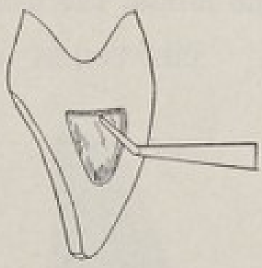


Fig. 362.

Starting points for gold foil should be made at the axio-labio-gingival and axio-linguo-gingival point angles, by lateral pressure on an 6 tenths mm. bur, while drawing it incisally and gradually away from the line angle.

Convenience form. The only convenience form that is occasionally necessary in these cavities is to cut the lingual wall a little farther in order to give sufficient access from the lingual to condense gold into gingival portion of the prepared cavity, thus permitting the labial margin to be placed so slightly to the labial of the contact that the gold will not show. In such cases the labio-gingival marginal angle should not be cut quite as far as the requirements of extension for prevention might demand. It is much better to take some chance on recurrence of decay than to use silicate cement. Attention has already been called, in discussing the outline form, to the necessity of cutting either the labial or lingual wall to such inclination as may be required for the withdrawal of a pattern or impression for an inlay.

REMOVAL OF REMAINING CARIOUS DENTIN. If any carious dentin remains it should be removed with a small spoon and replaced with a non-conductor of zinc cement.

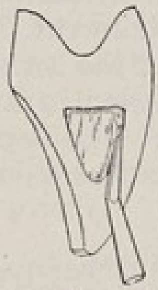


FIG. 363.

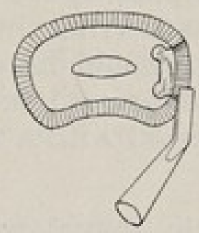


FIG. 364A.

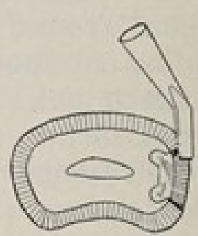


FIG. 364B.

FINISH OF THE ENAMEL WALL. Chisels 9-3-6 or 12-6-6 should be used to finish and bevel the cavo-surface angle of the labial enamel wall. See Figure 363. The 12 angle should perform the same service on the lingual wall and the pair 9-3-12 or the 12-6-12 hatchets should be used for the gingival wall, one introduced from the labial, the other from the lingual. See Figure 364A and 364B.

THE TOILET OF THE CAVITY has been described.


FIG. 365A.

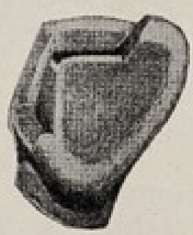


FIG. 365B.


FIG. 366.

PROXIMAL CAVITIES IN THE INCISORS AND CUSPIDS WHICH INVOLVE THE INCISAL ANGLE.

The rules and technical procedures involved in preparing the proximal portion of cavities of this class are the same as for the simple proximal cavities. The only variation is that an incisal or a lingual step is substituted for incisal anchorage. The incisal step is made by cutting away sufficient of the lingual enamel near the incisal edge to provide for a step in the dentin in the horizontal plane, from the axial wall to a point about two-thirds across the incisal edge, or beyond the second developmental line. This step is made with a bur and must be sufficiently deep for the retention of the restoration, and leave dentin to support the labial and lingual walls. A starting point or anchorage for gold foil may be placed in the extremity of the step, or the pulpo-labial and pulpo-lingual

line angles may be slightly undercut. If a gold inlay is to be used for the restoration there would be neither starting points nor undercuts. See Figures 365A and 365B.

The lingual step consists of a small dovetail preparation cut into the lingual surface, about midway from incisal to gingival, similar to the occlusal step in bicuspids and molars. Very little more than the enamel should be removed in the step portion to avoid thermal shock to the pulp from the close approach of the proximal and lingual walls. Such a step is more desirable for cuspid than incisor restorations of this type. See Figure 366.

CLASS 5. GINGIVAL THIRD CAVITIES IN BUCCAL AND LABIAL SURFACES.

OUTLINE FORM. Except in cases of extreme neglect, lateral spreading of decay in the dentin is of much less extent than surface involvement of the enamel, and the preparation of cavities of this class is very simple. In fact, these decays are often discovered

FIG. 367.

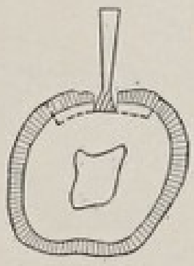


FIG. 368.

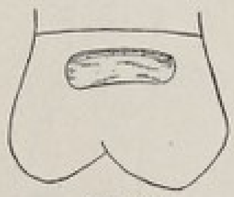


FIG. 369.

and the cavities prepared before the dentin is much involved. If the question of pain is eliminated, the entire cavity preparation, except the finish of the enamel wall may often be made with one cut with an inverted cone bur. It is usually desirable to first remove the bulk of the decay, including the chalky enamel, with a sweep of a spoon before using the bur. See Figure 367. This gives a better understanding of the depth to which the decay has penetrated. A 1 mm. or a 1.2 mm. bur held at right angles to the surface of the tooth should be placed in the position of deepest penetration of the decay, usually near the center of the area mesiodistally. Less than the full head of the bur should be below the line of the dento-enamel junction and it should be carried in a single cut entirely around the cavity; starting for example in the central area and cutting to the mesial along the incisal or occlusal limit of the area, then moving the bur to the gingival and returning distally the full length of the area of liability, moving the bur slightly to the incisal or occlusal, and returning to the starting point. See Figures 368 and 369. If the cutting with the bur is

painful, a series of three or four cuts, with the bur revolving slowly, will lessen the pain. A straight or 6 angle chisel should be used to trim the walls to form. See Figure 370.

These cavities are usually more sensitive than cavities of other classes, and in cases in which they occur in groups, often develop an extreme sensitiveness which calls for a variation of procedure in cavity preparation. In such cases, the use of a bur or the movement of an instrument over the surface with light pressure causes much more pain than heavy pressure and a quick deep cut with a sharp blade. A spoon may be used to cut away both the surface enamel that has been partly penetrated and the carious dentin. One or two cuts will usually suffice for each cavity. Cement restorations should then be made and left for a month or two, until the sensitiveness shall have subsided. The regular technic of the preparation may then be followed.

RETENTION FORM. For gold foil, amalgam and silicate restorations there should be undercuts for retention throughout the length of the axio-gingival and axio-occlusal or -incisal line angles, rather

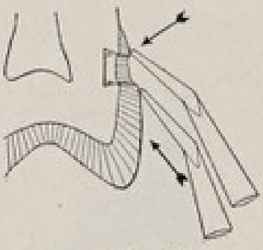


FIG. 370.

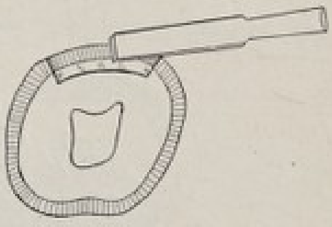


FIG. 371.

FIG. 372.

than at the mesial and distal extremities of the cavity. These may be made with the same bur with which outline form is prepared and at the same time. If this plan is followed and there should be a recurrence of decay to the mesial or distal of the restoration, due to lack of extension of the cavity, a repair may be made without disturbing the restoration. For gold foil, starting points are usually not required unless the cavities are large. They may be placed in the axio-disto-gingival and axio-disto-occlusal angles, or elsewhere, as may be most convenient. The undercuts along the axio-gingival and axio-occlusal line angles are shown in Figure 370.

CONVENIENCE FORM is not required for these cavities as they are of easy access, except when they occur far back in the mouth, where gold foil is not indicated.

REMOVAL OF REMAINING CARIOUS DENTIN. All of the decay will practically always have been removed in securing outline and retention form. In neglected cases, lateral decay may have undermined the enamel to the occlusal or gingival near the center of the cavity. This should be removed with a spoon and it will be neces-

sary to extend the outline of the cavity if all of the undermined enamel was not removed in preparing the outline form.

FINISH OF THE ENAMEL WALL. This may be done with the same instruments that were suggested for outline form. As in all other preparations in finishing the enamel wall, the blade should be used with a planing motion parallel with the marginal outline of the cavity. See Figure 371. In cavities far back in the mouth the margin trimmers may be conveniently used for the distal and mesial walls; the 80 angle for the distal; the 95 angle for the mesial wall, especially to bevel the cavo-surface angle. See Figure 372.

THE TOILET OF THE CAVITY is made as for other cavities.

Manipulation of Materials for Restorations

Comparative statement of physical properties of materials used for restorations in the teeth. The materials at present in use for permanent restorations are gold foil, amalgam, gold inlays and porcelain inlays.

The materials for temporary operations are the silicate cements, zinc phosphate cements, copper cements, and the different preparations of gutta percha. Notwithstanding the fact that silicate cements are extensively used as permanent operations, their physical properties, as judged from critical clinical examination, do not seem to justify listing them with the more permanent materials.

The qualities most desired in these materials for permanent operations are: (1) indestructibility in the fluids of the mouth, (2) adaptability to the walls of cavities, (3) freedom from shrinkage or expansion after having been placed in cavities in the teeth, (4) resistance to attrition and (5) sustaining power against the force of mastication.

The qualities of secondary importance are (1) color, or appearance, (2) non-conductivity of thermal impressions and (3) convenience of manipulation.

Gold foil. Of these qualities, gold foil seems to possess those most essential in much the greatest degree. It is perfectly indestructible in the fluids of the mouth; it is very perfectly adaptable to the walls of cavities; it is free from objectionable shrinkage or expansion; its resistance to attrition is good and it sustains the force of mastication satisfactorily.

The greatest intrinsic worth of gold foil as a material for restorations lies in the fact that it may be adapted to cavity walls with great force, and is capable of immediately and permanently sustaining that forcible adaptation. Dentin is one of the most elastic substances known. It is this elasticity that renders it so preeminent for billiard balls. Its range of elasticity is short as compared with that of soft india rubber, or even with well vulcanized hard rubber, but it is much longer than the range of elasticity of hard steel. In this, it is more comparable with the range of elasticity of well tempered spring steel. Its force of elasticity is much greater than the force of elasticity of vulcanized rubber and much less than the force of the elasticity of steel. The force of elasticity in dentin is closely comparable to the sustaining power of hammered pure gold. By measurement, the elasticity of human dentin is found to be 5 per cent under a stress of 300 pounds on blocks

1-10 inch square. At 350 pounds this may be increased to from 7 per cent to 8 per cent without injury to the dentin. Blocks of the same size of hammered pure gold are compressed 2.09 per cent (average) by a stress of 300 pounds. If the blocks of gold are fully annealed, they may be compressed 13.14 per cent (average) by 300 pounds. The resistance of gold foil restorations to compression may be made anything between these figures by more or less hardening by malleting in their placement. The strength of the grip of the elastic cavity walls upon the gold will depend directly upon the force with which the gold is wedged between them. It seems from these comparative measurements that, bulk for bulk, the force of elasticity of human dentin, when put to its full limit, is capable of pushing hammered gold aside so strongly as to change the form of the gold for a partial accommodation of its elasticity, but that a large residual elasticity will remain in the walls of the cavity sustained by the gold and exerting permanently a very powerful grip on the gold wedged into it. It is this quality of gold in its relation to the quality of elasticity and strength of dentin, or the mutual relations of these qualities in the two substances, combined with the indestructibility of gold, that renders gold foil so preëminent as a material for restorations. No other material can be so worked against the walls of a cavity as to make such full use of the sustaining power of the elasticity of the dentin. Any expansion of the gold by thermal changes is immediately and completely accommodated by this elasticity of the dentin and can be of no consequence whatever.

Of the secondary qualities, gold foil is not so good. It conducts thermal impressions strongly, its color is objectionable, and it is not very convenient of manipulation. Indeed, it may be said of this last quality that its successful manipulation requires much study and careful experience, and yet, when this study is given it and the required experience has been obtained, it may be manipulated more perfectly than any other material.

AMALGAM. As alloys for amalgam are at present prepared by the best makers, it is possessed of the first qualities in a high degree, yet inferior to gold in all. It is not completely indestructible in the fluids of the mouth, but oxidizes or sulphurets slightly, yet, when highly polished, the restorations will usually remain bright for several years and may be repolished with a fine disk or polishing powder when they become dull. Its adaptability to the walls of cavities is not so perfect as that of gold foil, though apparently so easy as to be deceptive. This is one of its greatest weaknesses. Much careful study and experience are required to work it well. Its resistance to attrition is good; its capability of resistance to the force of mastication is excellent in the material itself, but at the time it is placed in the cavity in a tooth, it is too soft and yielding to permit the operator to take advantage of the elasticity of the dentin. No matter with what force the condensa-

tion and wedging is made against the walls of the cavity, this material will yield, will be pushed aside and its form so changed as to accommodate this elasticity almost or quite completely; and the additional sustaining power that this mutual relation of the cavity walls and the material — the grip of the cavity on the amalgam, which is the prominent feature in gold foil, is lost to amalgam even with the best manipulation. This in itself must ever limit amalgam to an inferior place as compared with gold foil.

The possible shrinkage or expansion of amalgam after it is placed in the cavity must ever be a shadow over its usefulness. When all possible care is taken in making and testing alloys to see that the balance of the metals is exactly correct, this difficulty is eliminated. Yet the fear that this has not been perfectly done will be present.

Much of the difficulty attending the use of amalgam arises from a lack of an understanding of its qualities. It is a metallic compound in which each element entering into the alloy exerts its special influence upon the qualities of the product; and these qualities are varied with every little change in its composition. These changes of qualities and the laws controlling them are not generally understood by the dental profession.

In secondary qualities its color is bad; so bad, indeed, that it should never be used in the front teeth. Its conductivity of thermal changes is nearly equal to that of gold. Its working qualities render it much more convenient than gold in very large and difficult cavities. It can be placed in much less time. Perfection of adaptation is less certain.

Gold inlay. Considered from the viewpoint of the most desirable qualities for a restoration, the gold inlay may be said to be indestructible in the fluids of the mouth, although the cement with which it is set will gradually wash out if exposed to the saliva; it is not adaptable to the walls of cavities in such a way as to hermetically seal the cavity, but must depend upon cement for the sealing; it is free from shrinkage or expansion of consequence; its resistance to the force of mastication may be equal to or even better than gold foil, depending upon the alloy used for casting the inlay as compared with the hardness of the gold foil obtained by malleting. The greatest weakness of the gold inlay is its lack of adaptation to cavity walls and its dependence upon cement to seal the cavity. To counteract this weakness to the greatest degree, particular attention must be given to all enamel wall and cavo-surface angle preparations in order that the cement line at all margins may be reduced to the minimum.

Of the secondary qualities, the gold inlay is to be preferred to gold foil. The shock to the tooth from conductivity of thermal impressions is slightly reduced by the layer of cement between the inlay and the tooth; its color is objectionable in the same degree

as gold foil, but less so than amalgam; its convenience of manipulation appeals to both patient and dentist as one of its strongest features. In this connection, special emphasis should be placed on the opportunity afforded for absolutely perfect proximal contours and contact restorations, which, from the preventive viewpoint, as related to both recurrence of caries and the health of the interproximal soft tissues, should be one of the important considerations in choosing the gold inlay for proximo-occlusal restorations, especially in positions of difficult access for placing foil.

PORCELAIN INLAY. Of the most desirable qualities, the porcelain inlay may be said to be quite indestructible in the fluids of the mouth; it is not adaptable to cavity walls, but must depend upon cement to seal the cavity; it is free from shrinkage or expansion; its resistance to attrition depends upon the bulk of porcelain exposed to stress. It is especially weak in edge strength, being too brittle to maintain an edge in a position where stress is applied.

Of the secondary qualities, porcelain outranks the other materials in appearance and in its slight conductivity of thermal changes, but presents possibly the greatest difficulties in manipulation. In appearance, a porcelain inlay, which exactly matches the tooth in color, is an ideal restoration, yet it is more objectionable than a well polished gold restoration unless the porcelain is so perfect a match for the tooth that it passes unnoticed in ordinary social intercourse. If it is off shade, it attracts attention and is very objectionable. The difficulties of manipulation, both to secure a good fit and the best possible shade, are so great as to have caused a large percentage of operators to abandon the use of porcelain inlays, because of the time, patience and perseverance required to obtain satisfactory results in the general run of cases. Porcelain has been discarded by many operators for the very unreliable silicate cements, because of the easy manipulation of the latter. Porcelain inlays should be used much more extensively than they are being used, especially for proximal and labial gingival third restorations in the front teeth.

SILICATE CEMENTS. On their merits, the silicate cements should be listed as suitable only for temporary restorations. However, the fact that they are extensively used as permanent restorations, regardless of the degree of permanency, seems to justify a comparison of their qualities with gold foil, amalgam, porcelain and gold inlays. Scientific studies of silicate cements have been very limited by research workers not in the employ of manufacturers, who hold their knowledge as trade secrets. Therefore, it has been necessary for the profession to develop plans by which it may learn the facts, which will doubtless form the basis of further investigations leading to specifications for materials of better quality.

Of the most desired qualities for a permanent restoration, the silicate cements fall short, in that they are definitely destructible in the fluids of the mouth, although less so than zinc phosphate

cements; their adaptability to cavity walls is certainly inferior to the other materials described; they shrink after being placed in the cavity; they are not resistant to attrition and they do not satisfactorily withstand the force of mastication.

Of the secondary qualities, they lead all other materials in their appearance when first placed and in some cases hold their original color for an indefinite period, although many restorations change to much darker shades; they rank very high as non-conductors of thermal impressions, and they are easy of manipulation.

These cements must be rated far below gold foil, amalgam, the gold inlay or the porcelain inlay in all five of the primary qualities. They fare better in the comparison of the secondary qualities; unquestionably ranking first in color, or appearance when recently placed. In fact, their translucency aids much in making practically perfect restorations from the esthetic viewpoint. It seems likely that the changes in appearance as time passes may be indirectly due to shrinkage, or to porosity, particularly when the gel has been disturbed. They doubtless rank first as to ease of manipulation.

This comparison does not relate the entire story. A brief analysis of the end results of the physical deficiencies of silicate cements should be of value in determining when and where the dentist may be justified in using them. Since they are soluble in the fluids of the mouth and do not sufficiently resist attrition or withstand the force of mastication, they do not retain their surface form. They wash out slowly until in the course of a year or so, there being much variation, the contour of the surface of the cement will have been so reduced as to form a definite step between the surface of the enamel and of the cement, along all cavity margins. Similarly all proximal restorations will have lost their contacts so that food catches between the teeth and often causes a gingivitis. Also in positions in which these cements come in contact with opposing teeth, as do the larger proximal restorations in the upper incisors and cuspids, they are occasionally broken or pieces are chipped out. It has been claimed by some that the silicate cement causes pulps of teeth to become inflamed and die. The best available evidence seems to indicate that the death of pulps is not due to any direct effect, but rather to the shrinkage of the cement which opens the way to pulp involvement. It should be remembered that pulps die under restorations made of other materials.

In the one property of esthetic appearance, upon which the popularity of this material was in a measure justified in the beginning, the question may well be raised now as to its reality, if considered over a period of years. The initial splendid appearance is granted as being all that could be desired. As time passes and the surface is slightly washed, the margins become discolored, or give the appearance of discoloration, either as a result of the collection

of mucus and minute debris, or through change in light transmission or reflection. Shrinkage invites decay along cavity walls and the restoration appears to have become darker. In due time, the remaining portion of the restoration must be removed and replaced; the cavity is a little larger, but the good appearance is restored and the patient is pleased. After this cycle is repeated several times and particularly when there are six or eight of these restorations in the upper anterior teeth, the case gradually reaches the point when the teeth seldom look well for more than a short period. A pulp dies and the tooth itself becomes discolored. One after another, these teeth can only be restored to satisfactory esthetic appearance by placing porcelain jacket crowns.

This picture may be overdrawn for the average case. It is certainly true of many. The dentist, who conscientiously keeps records of his silicate cement restorations and has his mind on the conservation of the teeth as his highest obligation, will gain great satisfaction from the placement of small gold foil restorations, which may show a very little, but seldom require replacement and if nicely polished, are very satisfactory in appearance to both the patient and the dentist after the lapse of a quarter of a century.

RESTORATIONS WITH GOLD FOIL.

ILLUSTRATIONS: FIGURES 390-438.

The oldest authentic record of the use of gold foil for restorations of lost tooth structure is found in an anonymously written German book published in 1530.

Zum dritten das màn die ausholung
wegk nimmet/welchs auch auf zweyerley
weyſe geſchicht/ Zum erſten das man das
loch vnd die außfreſſunge mit einem ſub-
tilen meiſſelchen ader meſſerchen welchē/
ader mit einem andern inſtrument dartzu
bequemicklich/wegk ſchabe/vnd reinige/
als dy practickanten wol wiſſen/vnd dar
zu erhaldung des andern teyles des zanes
das lǒchlichen mit golt blettern zu fullet.
Zum andern das mann gebrauche ertztey
darzu dinlich welchs geſchict mit Galles
epffel vnd wilder galgen ſo der zan nach
der reinigung darmit wirdt gefüllet.

The following is very nearly its meaning. The writer is discussing plans of treatment of caries.

TRANSLATION. In the third plan, the hollow place is done away with (taken away — removed) which is done in one of two ways. First, the soft part of the cavity and the decayed part is

cut away with small chisels, knives, files or other suitable instruments, and cleaned, as is well known to practitioners. Then for the saving of the remaining parts of the tooth, the cavity is filled with gold leaf. Otherwise one may use a suitable gum prepared with nutgalls and hyssop to fill the cavity after cleaning it.

Fouchard, in his third edition, published in 1785, mentions the use of gold for filling cavities in the teeth, but condemns the practice apparently because of the expense, and because certain persons of evil disposition deceived the people by using tin so prepared as to appear like gold. He preferred lead or tin leaf (foil).

Chapin A. Harris[1] stated that it was not until the year 1800 that the use of gold for filling teeth was common among dentists. Eleazer Parmley[2] credits Robert Wooffendale with the introduction of gold in America in 1795, when he returned from England. It was evidently in use in England previous to that time.

In America, the first gold-leaf was beaten for dental use soon after 1812 in Hartford, Conn., by Marcus Bull and his apprentice, Charles Abbey, both of whom moved to Philadelphia in 1816, and continued in business there. Until 1855 all gold restorations were of non-cohesive foil. If the leaves of foil cohered, as happened occasionally, the dentist complained and possibly returned the gold for exchange.

Dr. Robert Arthur,[3] in 1855, announced the method of preparing cohesive gold foil by annealing, and the use of cohesive gold gradually supplanted the non-cohesive, particularly for the reason that contour restorations could be made in proximal surfaces, and thus protect the gum septum from injury by the impaction of food between the teeth. For non-cohesive gold, four surrounding walls were necessary in all cavities, and proximal cavities were prepared with the "floor" at an angle of about 12 centigrades (45 degrees) to the long axis of the tooth. The exposed surface of the gold was in a plane approximately parallel with the floor, and the marginal ridge was not restored, thus establishing inclined planes which guided food against the gum septum. It is interesting to note that sixteen years later, in Dr. Arthur's book on "The Treatment and Prevention of Decay of the Teeth," published in 1871, he recommended the filing away of proximal surfaces to the same form as the non-cohesive gold restorations, as a means of preventing decay. This illustrates the almost complete lack of appreciation, in that day, of the relation of operative procedures to the pathology of the soft tissues.

Restorations of lost tooth structure may be made with cohesive gold or non-cohesive gold; the restoration may be made in part with non-cohesive gold and finished with cohesive gold, or a certain

[1] Dictionary of Dental Science, p. 326.
[2] Am. Jnl. Den. Sci., 1st series, Vol. 3, p. 2.
[3] Dental News Letter, Vol. 9, p. 229.

wall of the cavity may be covered with non-cohesive gold and the operation completed with cohesive gold.

NON-COHESIVE GOLD is now used by comparatively few operators for complete restorations, although very satisfactory results may be attained. It is limited to cavities with four surrounding walls and requires special instruments, also a different order of skill. In making such restorations, the principle of wedging the gold between the surrounding walls is depended upon to hold the gold together and to retain it in the cavity. Foil only is used, and its lamina must extend from the bottom to the surface of the cavity. Either ropes or cylinders may be used. The gold is not annealed as it is essential that the leaves do not cohere in order that adaptation to cavity walls may be secured. Occlusal cavities that have complete and good surrounding walls are suitable for non-cohesive gold, although it can be used in buccal or labial cavities of considerable depth. It is not practicable to make good restorations in broad, shallow cavities.

In making a restoration in an occlusal cavity in a molar with non-cohesive gold cylinders, the cylinders should be so prepared that their length is a little greater than the depth of the cavity. Some should be large and some small, the size of the larger ones depending upon the size of the cavity. A cylinder, which, as loosely rolled, will about fill the cavity full, should be placed in the cavity with one of its ends upon the pulpal wall and the other protruding from its orifice. With the side of a large condenser the cylinder should be pressed against the distal wall. Holding this first cylinder with an instrument to prevent movement, a second cylinder should be placed in the same way and condensed against the first. This should be repeated by adding cylinder after cylinder until the distal half or more of the cavity is filled. The operation should be continued by condensing the cylinders against the mesial wall, and in turn the buccal and lingual walls, all the time using lateral pressure with the side of the condenser point, not with its end. As this progresses and the unfilled space in the center of the cavity is narrowed, the cylinders introduced must be smaller and smaller. Finally, to obtain room for additional cylinders, an instrument with a sharp point of wedge form with a large handle, suitable for the full palm grasp, should be pressed to the bottom of the cavity, and, with a prying motion, the gold should be wedged against the cavity walls in every direction with great force. The space thus gained should again be filled with small cylinders and the wedging repeated so long as it is possible to force in another cylinder. The small cylinders last introduced should be rolled very hard. When it is no longer possible to force another cylinder into the central portion of the cavity, efforts should be made at various points to force in the sharp, wedge-shaped point and any openings made should be filled with small cylinders. When no more gold can be introduced, the whole surface should be condensed as completely

as possible with the end of a finely serrated condenser. Then the surplus gold should be trimmed partially and the condensation repeated. The trimming and condensing should be repeated until the surface of the restoration is brought to proper form, with its margins just flush with the cavity margins. In the trimming and condensation, only the harder parts of the surface will be cut away and the softer parts will be condensed more and more. Finally the whole surface will become about equally hard. Generally these restorations should be finished with the burnisher.

Instead of the cylinders, ropes of foil may be used by carrying an end to the bottom of the cavity and folding in fold after fold, so that one end of each loop is on the pulpal wall of the cavity and the other protrudes from the orifice. These loops are condensed against the walls laterally, and finally condensed by wedging, as are the cylinders.

One who has become skillful with this manner of manipulating non-cohesive gold, can make gold restorations in cavities suited to this work in much less time than they can be made with cohesive gold. This plan is often very desirable for first molars for children.

Non-cohesive gold restorations do not stand attrition so well as those made of cohesive gold, in positions where great wear comes upon them. If very well done, however, they do excellent service where the wear is not extraordinary.

COHESIVE FOIL, or a combination of non-cohesive and cohesive foil, is unquestionably the most satisfactory material available for the conservation of the teeth. Its proper manipulation requires meticulous care and the highest order of skill. The instruments and appliances required especially for this service are: a carefully selected set of condensing instruments, an annealer for the foil, an instrument to carry the foil from the annealer to the cavity, a holding instrument to assist in the placement of the first pieces of gold until the mass is definitely anchored within the cavity, and a mallet, preferably in the hand of an assistant, or an automatic mallet in the hand of the operator, to supply the condensing force. Sufficient force may be applied directly by hand pressure with a suitable instrument, although this method is generally used only in portions of a cavity where it is not practicable to get the direction of force necessary with the mallet. Other special instruments are necessary to finish the restorations properly.

INSTRUMENTS USED IN PLACING GOLD FOIL RESTORATIONS.

CONDENSERS. The names of these instruments usually describe the condenser face or working point, and may also include the *nib*, or portion which is usually at a slight angle with the shaft. Condenser points may be round, or in the form of a square or parallelogram. The working point may be carried to one side of the line of the shaft by a nib in the form of a foot or a bayonet.

FORMULA NAMES. The formula names of condensers and rules for their measurement are as follows:

(1) The size of the working face of the condenser is given in tenths of a millimeter as the unit, the length of the nib in millimeters, and the angle of the nib with the shaft in centigrades.

(2) If the condenser is round, the diameter is given, followed by the length of the nib, and this by the angle with the shaft, thus: 5-10-3. The name is, condenser 5-10-3.

(3) When the point has the form of a square or a parallelogram, both dimensions are given, thus: 12x6-6-10. The figures 12 and 6 are the measurements of the sides of the working point which is a parallelogram form.

(4) When a pair is formed by placing the broad sides of the nibs in opposite relations to the angle of the nibs (see the first two

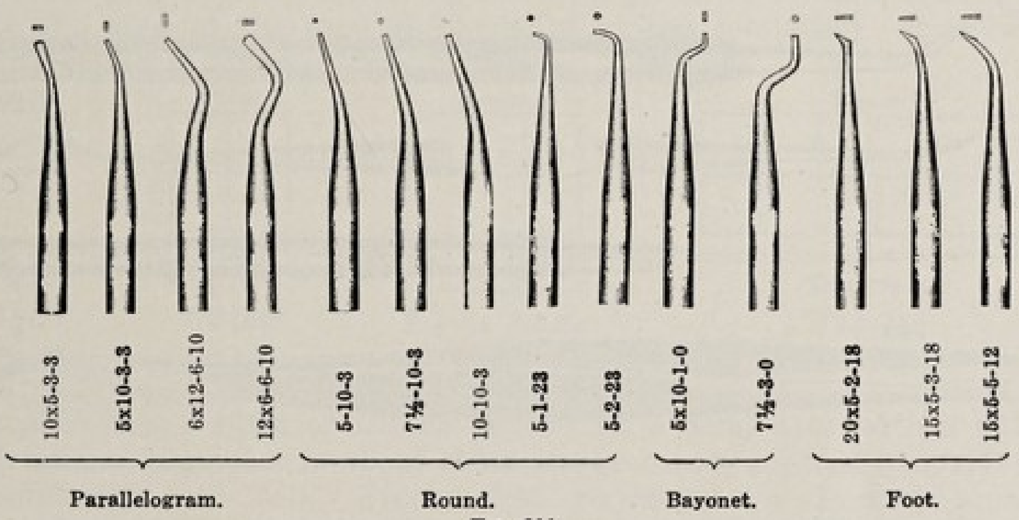


FIG. 390.

pairs reading from left to right of figure) that dimension in the plane of the angle is placed first as 12x6-6-10 and 6x12-6-10. The first of these is the hatchet form, the second the hoe or chisel form.

(5) Foot condensers have the working face on the distal side of the nib instead of in its end. They may be measured in the same way as others. The working face of the nib may be its full length or it may be shorter. Therefore, the working face of the condenser is given in the same way as other parallelograms. The distance of the toe of the foot condenser from the central line of the shaft is the length, and the angle of the working face with the shaft is its angle. This is illustrated by the three foot condensers on the right in Figure 390.

Ordinarily in naming condenser points we may say condenser 5-10-3, condenser 10-10-3, or condenser 12x6-6-10, or for the last the term parallelogram condenser 12x6-6-10 is often used; it is necessary to give the dimensions, 12x6, which indicate the hatchet

form. In naming condensers, the form of the nib may be used when necessary, as bayonet condenser 5-2, or the fuller formula would be 5-2-0, indicating that the nib is parallel with the shaft. It is not necessary to use the words monangle or contra-angle in speaking of condensers, as they are understood from the formulae. It is, however, necessary to mention the name, foot condenser, because this form is not indicated otherwise.

HOLDING INSTRUMENTS FOR STARTING RESTORATIONS. The double end instrument, with partial spiral curves in opposite directions, designed by Dr. H. Weston, is especially convenient to hold the first few pieces of gold in incisor proximal cavities and in gingival third cavities. See Figure 391.

The other instrument has its curve in one plane and was designed as a holding instrument for restorations in the bicuspids and molars.

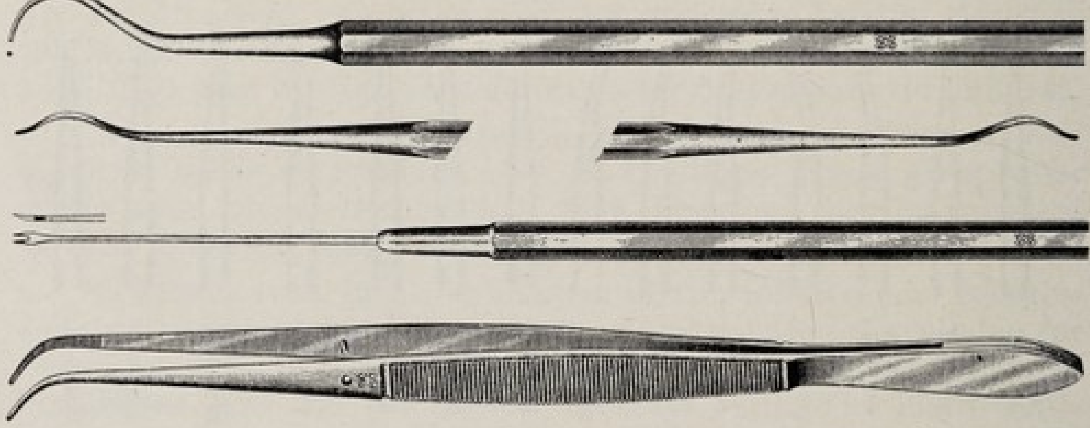


FIG. 391.

FOIL CARRIER. Instrument to be used in carrying pellets of gold foil from the annealing tray to the cavity. This instrument was designed by Dr. F. H. Marshall.

Some operators prefer a pair of pliers as foil carriers, particularly when using foil prepared in rolls or ropes.

THE RELATION OF THE SIZE OF CONDENSER POINTS TO THE APPLICATION OF FORCE. A correct appreciation of the relation of the size of the area of the condenser point to the force used is of first importance in making restorations with cohesive gold. The force that can be applied is limited by the capability of the peridental membrane to resist, and the possibilities of the use of more or less force will vary with the strength and endurance of the membrane. Persons who are accustomed to use their teeth very vigorously and have very strong peridental membranes, will bear much heavier blows of the mallet without discomfort than those who habitually use their teeth more delicately, and, as a result, have weaker peridental membranes. All of this must be considered in making gold restorations and the force used limited accordingly. The requirements as

to solidity and strength of restorations for different persons are of equal importance. Persons with strong peridental membranes, who use their teeth vigorously, require the strongest possible restorations. Persons who have weak peridental membranes and who habitually use their teeth feebly, will not require the same solidity and strength in the restorations in order that they may stand. In all cases, however, the adaptation of the gold to the cavity walls and margins should be perfect, and the condensing force must be not less than 15 lbs. on a condenser point 1 mm. in diameter in order that the restoration will be moisture-tight. Because a patient can bear heavy blows of the mallet is no excuse for using a condenser of large impacting area, for the reason that such persons require very dense restorations, which can not be made with points having too great an area.

AREA OF POINTS AND THE CONDENSATION OF GOLD FOIL. The effect of a blow in condensing foil in a given case varies according to the area of the face of the point of the condenser. It is esti-

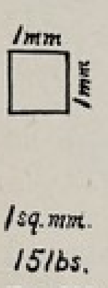


FIG. 392.

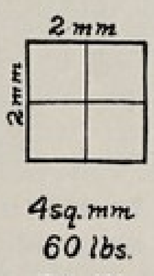


FIG. 393.

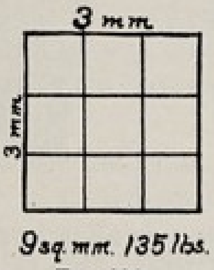


FIG. 394.

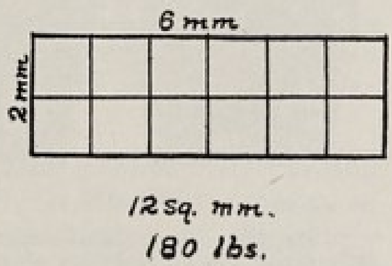


FIG. 395.

mated that a blow of fifteen pounds on a condenser with a point 1 mm. in diameter is about the average force required properly to condense gold foil. Figure 392 represents a 1 mm. square condenser point on which a 15 pound blow is struck. Figure 393 represents a 2 mm. square point; it will be noted that the area of this point is four times that of the 1 mm. point, therefore a blow of 60 pounds would be required to give the same condensation. Similarly a 3 mm. square point, Figure 394, would have nine times the area and would require a 135 pound blow. Figure 395 represents a foot condenser, with a face 2x6 mm. or an area of 12 sq. mm. If the entire face of this condenser was applied to the gold, it would require a blow of 180 pounds. In practice only a small area, as the toe, of such a condenser should be in contact with the gold when a blow is struck.

It should be quite clear that gold foil can not be properly condensed with points having large face areas. An area of .75 mm. should be the maximum for use in automatic mallets, and only slightly larger, about 1 mm., when hand malleting is used. On the other hand, frail cavity walls and weak supporting structures call for the smaller points, to gain proper condensation with a larger number of lighter blows. As mentioned above, the condi-

tion of supporting structures of the tooth must be considered in each case, both from the point of strain upon them and the extent of movement or cushion which reduces the condensing effect of the blow.

CONDENSER POINTS AND THEIR SPECIAL USES. With the simpler forms of cavities as more recently prepared, the condenser points may also be much simpler in the variety of forms of shanks and condensing area, Figure 390. The form of the impacting area or face of the points of condensers may be round, square, parallelogram, or what is known as foot form. Each of these has uses in special positions.

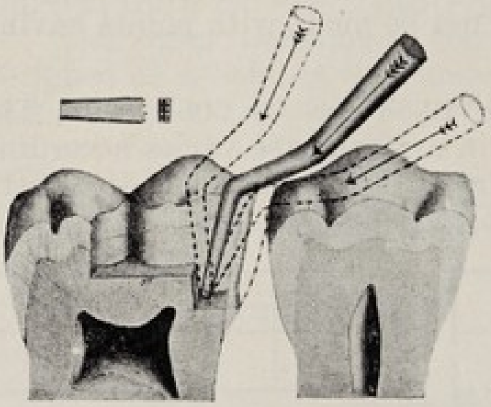


FIG. 396.

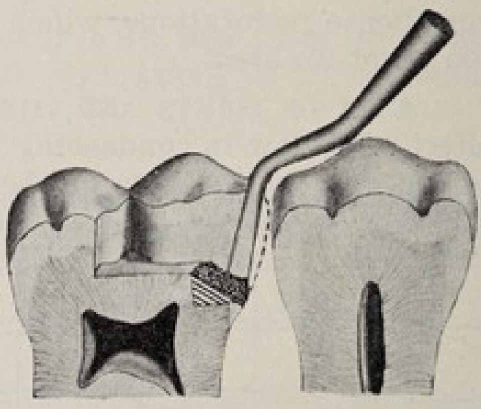


FIG. 397.

FIG. 396. The parallelogram condenser 6x12-6-10 in position in the mesial portion of a split cavity for condensation of gold against the axial and gingival walls and building across connecting the convenience points. The arrows and the dotted outlines show the directions at which force may be applied. The broad side of the end of the condenser and an illustration of its face are shown just above the molar tooth.

FIG. 397. Another view of the split cavity after the gingival wall has been covered. The diagonal lines show the order of the building of the gold by which it is progressively brought out to the margin of the cavity. The condenser is the parallelogram, 12x6-6-10, the flat sides of which are correct for building against the buccal and lingual walls, and over the cavo-surface angle of the gingival wall.

The parallelogram forms are particularly suited for the wedging process in building against the walls of cavities. There are two pairs of these instruments, also one bayonet form; the latter will be described later. The pairs have the long dimension in the plane of the curve or angle of the shank (hatchet form) in one, and perpendicular to that plane (chisel or hoe form) in the other. By this arrangement, the long dimension of one or the other instrument of the pair can be brought parallel with the plane of any wall of a cavity. The dimensions 10x5-3-3 and 5x10-3-3, are particularly suited for use in proximal cavities of the incisors. Those of the dimensions 12x6-6-10 and 6x12-6-10 have the shank contra-angled, suiting them especially to the building of gold in mesio-occlusal cavities in the bicuspids and molars, which will be more fully explained later. See Figures 396 and 397. Both of these pairs have the face rounded, or slightly convex, on the longer dimension for the purpose of severe packing of gold without chopping into it. By rounding this dimension, the first

impression on a fairly solid bit of metal is on a limited area of the face of the point, but immediately this gives way, a larger area is engaged which prevents it from sinking deeply into the metal. These instruments should often be used for condensing the final pieces of gold along margins. The convex surface minimizes the danger of injury to the enamel margin. The area of the parallelograms 12x6 and 6x12 is .72 square millimeters.

The round point 5-10-3 is especially suited for starting restorations, with the assistance of a holding instrument, and for special uses by hand pressure, or for any purpose when good condensation with light pressure is desirable. The area of the point — .196 square millimeters — is too small for use in the general building of gold. The 7½-10-3 round point has an area of .44 square millimeters, and may be used in the larger starting points. It is suited for general building of gold in incisor teeth, and, occasionally, in other positions. The 10-10-3 may be similarly used in bicuspid and molar cavities in which heavy malleting may be employed. This condenser face — .78 square millimeters in area — is the largest point that should be used in the automatic mallet. With the hand mallet used by an assistant, more force may be employed, and, in a few selected positions, an instrument with a larger area may be used.

The bayonet form was designed for the purpose of gaining better direction of force in positions in which the instruments of 3 centigrade angle cannot be held in proper relation to the cavity wall. The offset of the nib permits the shank of the instrument to be moved from the position required for the more nearly straight instrument. The bayonet 5x10-1-0 is a parallelogram in hoe form. It should generally be used in building against the incisal or occlusal walls of gingival third cavities in the labial surfaces of incisors and in the buccal surfaces of bicuspids and molars. It may often be used for condensation against the labial wall of incisor proximal cavities, working from the labial. The round point bayonet 7½-3-0 is used instead of the 7½ or 10 diameter round points, in positions where it will give better direction of force. Bayonet condensers require slightly heavier blows to secure equal results in condensation, as compared with the nearly straight instruments of the same size, on account of the spring of the offset in the nib. The curve of the shank gives considerable spring to blows and limits its impacting force.

The hand pressure condensers of 23 centigrade angle are used for condensing foil in the incisal retention points of incisor proximal cavities, and in positions in other cavities where access with other points is impossible. In this use, hand pressure only is employed. With their small impacting area — .196 square millimeters — a very solid restoration can be placed.

The foot-condensers are especially for after-condensation. By the phrase "after-condensation" is meant that condensation of the

surface of a restoration after all of the gold has been placed, especially on proximal surfaces. In this position it is often best to leave these surfaces a bit ragged, with more or less gold imperfectly condensed overhanging the area proper of condensation in the work of building. This is given its final surface condensation with a foot instrument, which is made to reach well into the interproximal space and condense with the toe of the instrument. The shorter foot, 20x5, is often valuable for building over margins, though generally this should be done with one of the parallelogram condensers. Its full area is one square millimeter when the whole of the foot comes into play, which will occur only occasionally. The shank of this is perfectly straight, and there will be no spring limiting its blow. It is, therefore, a dangerous instrument to bring in contact with an enamel margin. An ample amount of

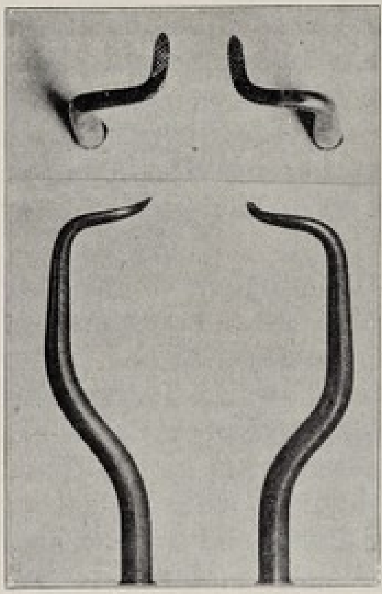


Fig. 398.

Fig. 399.

gold should always separate it from actual contact with margins over which it is used.

Quadrangle condensers. The quadrangle instruments are designed especially to relieve one of the difficulties that occur from the use of a mechanical separator. It is often found difficult so to place the foot condensers (mentioned above) as to get the toe of the instrument in position for a direct stroke on the surface of mesial or distal restorations in incisor teeth for the final condensation of the surface, because the bows of the separator interfere. Further, it is desirable that the toe of the instrument reach fully to the labio-lingual center of the gingival margin of the restoration so as to get a direct blow of the mallet on the gold in its final condensation.

Figure 398 shows the points and shanks only of the quadrangle instruments. There are four angles in the shank, hence the term

"quadrangle." They are in such form that the instrument will pass around the bow of the separator and reach into the interproximal space. A direct blow may be made, as the instrument point is sufficiently near the line of the shaft. The immediate point is shown in two positions in order that its form may be better understood. It is made in rights and lefts.

In Figure 399 one of these instruments is shown in position for the final condensation of the gold in the mesial surface of the left central incisor, with the separator in position. Particular attention is called to the grasp of this instrument. Otherwise than in the form of its shank, it does not differ materially from other foot condensers used with the hand mallet. The number of its angles, however, requires that a much heavier blow of the mallet be used than with condensers that have fewer angles. This instrument can be used upon mesial surfaces and distal surfaces in the

FIG. 400.

incisor teeth, also on mesial surfaces in the bicuspids and molars.

In Figure 400 the instrument is shown in position on the buccal portion of the mesial surface of a lower tooth on the right side. Incidentally, this is an excellent illustration of a half-inverted pen grasp. The other instrument of the pair may be introduced from the lingual as well, and with the two every part of the proximal surface of the restoration can be reached and condensed.

These quadrangle instruments are not used at all for gold building, but only for the condensing of the proximal surfaces of restorations after they have otherwise been completed with other instruments. Their use is more particularly desirable when considerable non-cohesive gold has been used in the gingival portion of the cavity. The form of the point is such that the toe can be used

effectively fully to the labio-lingual center of a molar tooth, the one entering from the labial and the other from the lingual. Therefore, every part of the gingival portion of a proximal restoration can be reached and condensed. This does much to insure these restorations against leakage from any imperfections in the packing of the gold in the first instance.

Technic for Gold Foil Restorations.

Preparation of the foil. Number 4 gold foil is generally used for restorations in the teeth. Each sheet of gold is four inches square and the number indicates the weight of one sheet in grains. The foil is available in several forms; the roll or rope, made by rolling all or part of a sheet; cylinders, prepared by first folding a sheet into a ribbon and then rolling the ribbon into a cylinder; and blocks, which are made by cutting a sheet into 4, 8, 16 or 32 pieces, and forming these into cubes or blocks. Each piece is crumpled together with the fingers (chamois finger tips being used unless the hands are very dry) and formed into a very loose ball. The balls are shaped into blocks with a pair of flat-nose spring pliers. The rolls, ropes and cylinders are prepared by concerns that deal in precious metals, and are therefore ready for immediate use. The cylinders may be "poured" directly from the container to the annealer; the rolls or ropes are cut into pieces of several sizes and placed on the annealer with pliers. The blocks, prepared in the several sizes mentioned are also ready to be placed on the annealer. The foil should not be touched with the fingers, but should be handled with special pliers made for the purpose.

There is no form of gold which can be used with as much certainty and so rapidly as the block form. As each block is placed in position, it may be condensed in an orderly way without the delay of folding projecting portions to place, as is frequently necessary with the other forms. This makes for accuracy of placement and evenness in condensation.

The application of force in the adaptation of gold to cavity walls. The condensation of gold has been shown to be the resultant of the force applied and the stress or resistance of the supporting structures of the tooth. It has been noted that the condensation resulting from a given blow is in proportion to the area of the faces of the condensing instruments. Good condensation depends primarily on the *amount of force* applied, but good condensation does not assure a tight restoration. The most perfect adaptation is necessary and adaptation is secured by the *direction* at which the condensing force is applied. The operator must therefore be constantly attentive to both the *amount of force* and the *direction of its application.*

Starting the restoration. The first few pieces of gold should be definitely anchored in a convenient position in the cavity.

Generally the first pieces are placed in a *starting point*, prepared for the purpose. In very small cavities this may be accomplished by placing several pieces along a line angle, between two parallel walls.

BUILDING INTO A POINT ANGLE. In building gold into a point angle, the holding instrument should be held in the left hand, the condenser 5-10-3 or 7½-10-3 in the right. The condenser should be placed in the cavity to test the position and access. See Figure 401. The starting point is usually in a point-angle, where three walls meet. The condenser should preferably be held in such position that it makes the same angle — about 12½ centigrades — with all three walls. A piece of gold should be placed in the cavity and held in position over the starting point with the holding instrument. Then the gold should be lightly pressed to place with hand pressure, gradually forcing it into a small mass over and partly into the starting point. The holding instrument should be placed on the gold a little to one side of the starting point and held firmly, while several pieces are condensed with rather heavy hand pressure, as illustrated in Figure 402. The gold should certainly be carried before the condensing point, instead of the

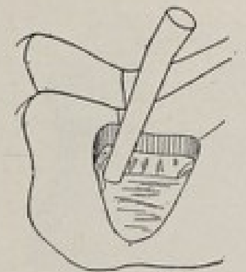


FIG. 401.

FIG. 402.

FIG. 403.

FIG. 404.

point punching through it. Another piece of gold may be added and thoroughly condensed. Additional gold should fill the angle somewhat as shown in Figure 403.

The gold should be built about the same distance on the three walls that meet at the starting point, and the surface of the gold should be in the form of an equilateral triangle. The condenser should be held in the position previously mentioned — equidistant from all three walls — at an angle of 12½ centigrades to each. This is of the utmost importance in securing adaptation to cavity walls, as will be explained. If the cavity has a second starting or anchorage point, the gold should be built across to it as shown in Figure 404. The anchorage in the first starting point might be sufficient to justify one in discarding the holding instrument when it is filled. However, it is usually safer to maintain pressure with the holding instrument on the already condensed foil until the second starting point is filled.

The angle at which the condensing force is applied in relation to the plane of the wall is very important in making perfect adapta-

tion. The direction of force should never be perpendicular to the plane of the wall that is being covered. Whenever possible, the angle of force should be inclined as much as twelve centigrades from the perpendicular of the plane of the wall.

Figures 405 and 406 illustrate the impossibility of condensing gold with blows in a direction perpendicular to the wall of the cavity, in making restorations with cohesive gold against pulpal walls of occlusal cavities or gingival walls of proximal cavities in the bicuspids and molars. In Figure 405 a perfectly plane piece of gold plate is laid on an anvil and an instrument placed as shown. This is struck a blow that will bruise the metal plate. In Figure 406 the metal plate is curled away from the surface of the anvil on all sides of the instrument point. No amount of hammering will bring it again to the perfect fit. This will be the result in any effort to condense a thin sheet of gold against any

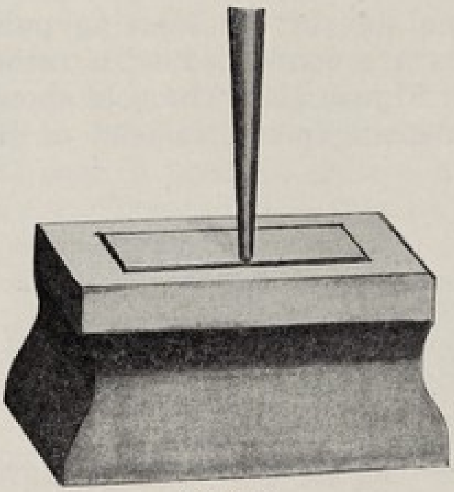


Fig. 405.

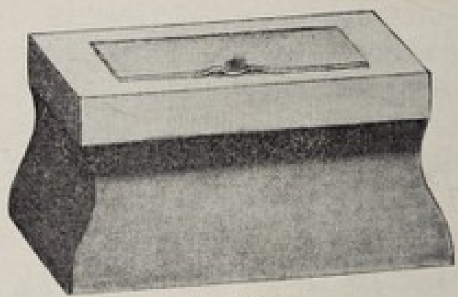


Fig. 406.

cavity wall by pressure perpendicular to that wall. See Figures 396 and 397, for the method of avoiding this difficulty in condensing gold against the gingival wall.

Therefore, in starting the restoration with the condenser held at an angle of 12½ centigrades to all three walls, it is possible to secure adaptation to all three, without changing the direction of the condenser. After the gold has been built to cover a little of the three walls, the first blow on each new piece should be near the center of the *previously condensed* mass and the last blows should be next to the cavity walls. The last blows should also be heavier to secure the best possible condensation and perfect adaptation by pressure of the gold against the elastic dentin.

Building along a line angle. In building along a line angle, the gold should preferably be built out on both walls the same distance from the line angle with the condenser held at the angle 12½ centigrades to both walls. In this case a vertical section through the condensed mass of gold is a right-angle triangle. This

gives the best adaptation to both walls. See Figure 407. After the restoration is well anchored, the parallelogram condenser, 10 x 5-3-3 (hatchet form), may be used for placing the bulk of the gold, although the 7½-10-3 round is to be preferred for cavities of moderate size.

STEPPING THE CONDENSER POINT. One should follow a definite routine or system in stepping the condenser point as the blows are struck on each piece of gold. In making additions to the mass of gold already condensed along a line angle, as shown in Figure 408, it may be presumed that the vertical wall is the distal and the horizontal wall the pulpal wall of an occlusal cavity. A pellet of foil is added so that one edge covers slightly more of the pulpal wall of the cavity, extending a little beyond the previously condensed foil. The upper edge of this piece is near the center of the previously condensed foil. In this case the condenser point should first be placed near the upper or occlusal edge of the new pellet in the position marked 1, Figure 409, and a blow struck. The condenser should be stepped along this edge of the pellet,

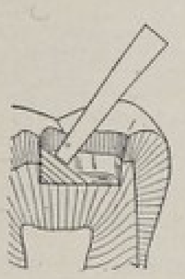


FIG. 407.


FIG. 408

FIG. 409.


FIG. 410.

FIG. 411.

moving only the width of the condensing point at each step, as additional blows are struck. Then it should be stepped to position 2, just the width of the point closer to the pulpal wall, and another series of blows should be made along that line. The condenser should then be stepped in position 3, near the pulpal wall, and a series of blows struck there. On this plan, it will be noticed that, with the condenser held at the 12½ centigrade angle it will necessarily, in the last series of blows, drive the gold against the pulpal wall, while welding it to the previously condensed gold, so that it will hold its position of close adaptation. On the other hand if the order of stepping the condenser were reversed and the first series of blows on the new pellet were delivered in position 3 near the pulpal wall, and the next in position 2, and if this should be repeated several times, the tendency would be for the edge of the gold to turn up a little from the pulpal wall and thus loose its close adaptation as illustrated in Figure 410.

In no case should there be any attempt to spread a thin layer of gold on the pulpal wall, or any other wall of a cavity, and condense it in a thin sheet. Any such attempt insures a failure of

perfect adaptation. A thick mass of gold should be built along the line angle and the walls should be covered gradually as the mass of gold is increased. As each new piece of gold is added, most of it should be placed in contact with the mass already condensed, and only a little should be in contact with the cavity wall. By this plan there is never a thin layer of gold as the building progresses over the wall, and the edge will not curl away from the wall as it is condensed.

The next piece of gold should be placed to overlap slightly the margin of the previously condensed gold covering the distal wall. See Figure 411. In this case the first series of blows should be struck along position 4, the second position 5, and the third in position 6, as illustrated in Figure 411.

If, in any case, it might not be practicable to build the gold equally on both walls, the distal or other surrounding wall should be given preference in the matter of securing good adaptation. In fact, perfect adaptation to the four surrounding walls would preclude the possibility of decay of the pulpal wall.

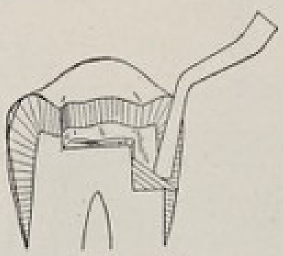


Fig. 412.

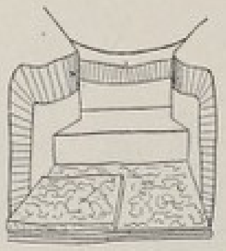


Fig. 413.

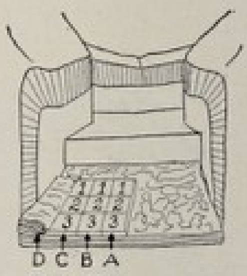


Fig. 414.

It is not necessary that the direction of force be at an angle of 12½ centigrades, although that is the most convenient angle in the positions just described. It should never be perpendicular to the plane of the wall being covered. Good adaptation may be secured if the angle is six centigrades or even less. It is quite possible, in fact, to secure good adaptation under certain conditions if the direction of force is almost parallel with the wall, by using the *wedging principle.*

THE WEDGING PRINCIPLE OF ADAPTATION. The wedging principle applies particularly in the condensation of gold between two parallel walls. The principles involved in securing adaptation in building along a line angle have been presented. In that, attention was called to the stepping of the condensing point to secure proper adaptation to the distal and pulpal walls. However, it is also necessary to consider the method of securing adaptation to the buccal and lingual walls. The distal and pulpal walls are at right angles to each other, while the buccal and lingual walls are in parallel planes.

In presenting this method of adapting gold against the buccal and lingual walls, it may be presumed that gold has been condensed

against the axial and gingival walls as shown in Figure 412. The next piece may be placed to cover the buccal half of the mass of gold previously condensed. See Figure 413. The first blow on the new pellet of gold should be struck at a point near the *center of the mass of previously condensed gold,* position A 1, Figure 414. Two or more additional blows should be struck in a row as indicated by the figures 1, 2 and 3. It should be noted that this row of blows, indicated by the arrow A, is parallel to the buccal wall, but they were struck on that edge of the newly added pellet farthest away from the buccal wall. A second row of blows, indicated by the arrow B, also parallel to the buccal wall, but closer to it should be struck in the same 1, 2, 3 order. Then another row, indicated by the arrow C, should follow. The time has now come to drive the wedge which assures good adaptation to the buccal wall with the condenser held at about a six centigrade angle, or at a slightly less angle, to that wall. Figure 415 is a view of the

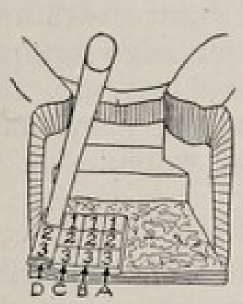


FIG. 415.

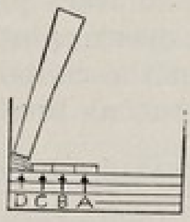


FIG. 416.

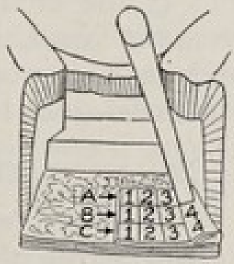


FIG. 417.

surface of the mass, after the blows indicated by the arrows A, B, and C have been struck, leaving the uncondensed portion of the last piece between row C and the wall of the cavity. In Figure 416 the tooth has been cut through in the bucco-lingual direction in the axial plane and the restoration has also been cut through. There is a little trough between the *condensed* row C and the buccal wall, with *uncondensed* gold overlying this trough. The parallelogram point should then be held, as in Figures 415 and 416, with its flat face against the buccal wall, and the blow will drive the uncondensed gold into the trough, *wedging* it between the already condensed gold of row C, and the buccal wall of the cavity. It may be wedged so tightly as actually to push the elastic dentin back and thus take advantage of its elasticity. To attain the desired results in the highest degree, the condensation along the cavity wall should be sufficiently increased to spread the condensed gold laterally with considerable force. This may be done by (1) increasing the force of the blow, (2) by an additional number of blows, (3) by repeating the line of blows with a condenser having a smaller point. No other means is known by which a restoration may be so rigidly secured in its seat in a cavity as by

this plan of wedging between parallel walls.* Undercutting or dovetails will not increase its rigidity.

In Figure 417, the point of the parallelogram condenser is shown in the best position for securing adaptation in applying the wedging principle in condensing gold against the lingual wall. This illustration also demonstrates another plan in stepping the condenser by which the same result is obtained as with the method illustrated in Figures 414, 415 and 416. If blows are first struck in 1, 2, 3, 4 order in row A, and additional blows follow in the same order in rows B and C, the fourth blow in each series will wedge the gold between that condensed by blow 3 and the cavity wall. It will also be observed that, by following either of these plans of stepping the condenser in applying the wedging principle, one is also following the rule for building gold against the axial and gingival walls, as illustrated in Figures 409 and 411 for the distal and pulpal walls. The succession of blows is not only from the center of the previously condensed mass toward the buccal or the lingual walls, but also toward the gingival wall in Figures 415 and 417. If the next piece of gold were placed with one edge against the axial wall, instead of overlapping the gingival margin, the condensation would be from the center of the mass of previously condensed gold toward the buccal, lingual and axial walls.

Recapitulation: Adaptation of Gold to Cavity Walls.

When reduced to its ultimate terms, there are in the box-like cavities, three plans on which gold should be condensed against the walls of prepared cavities to secure the most perfect and permanent adaptation by taking advantage of the elasticity of the dentin.

1. Building gold into right angle point angles with three walls to build against, using force at 12½ centigrades to the plane of each of the walls. It is not necessary to change the direction of the condenser as it is at the 12½ centigrade angle to all three walls at the same time. If the gold is built equally over the three walls, the condenser will be held at right angles to the surface of the gold.

2. Building gold into right angle line angles with two walls to build against, using force at 12½ centigrades to the plane of each wall. Again it is not necessary to change the direction of the condenser as it is at the 12½ centigrade angle to both walls at the same time. If the gold is built equally over the two walls, the condenser will be held at right angles to the surface of the gold.

*Some years ago, when the author was engaged in the study of this problem, a hole ⅛ x ⅛ inch square and ⅛ inch deep was cut in a piece of ivory, and gold was condensed into this hole. After the bottom of the hole was covered with gold, one end of a small threaded steel rod was placed in the hole, so that the rod was standing approximately in its center, and the gold was condensed around it, using the wedging principle in securing adaptation to the walls. After the cavity was filled, the ivory block was turned over and weights were attached to a loop in the rod, to determine what force would be required to dislodge the gold. The walls of the hole were exactly parallel, therefore the weight required to pull the gold out would correspond to the elastic grip of the dentin. In the experiment in question the gold held a weight of sixty pounds. Additional weight dislodged it.

3. Building between parallel walls with the direction of force at a slight angle, about 6 centigrades, to the plane of each wall. It is not necessary to change the direction of the condenser, other than to incline it slightly toward each of the parallel walls for the final row of blows which wedge the gold against the wall.

It should be apparent that it is possible, in a simple occlusal cavity, after the first pieces of gold are definitely anchored, to adapt gold properly to the distal, pulpal, buccal and lingual walls without changing the condensing instrument and without altering its position in relation to the cavity, except a slight inclination toward the buccal and lingual walls as each is approached. For many occlusal cavities, good access is available so that the approach may be from the buccal or lingual direction, or both, thus permitting the use of the wedging principle between the mesial and distal walls, or between the mesial wall and the gold that has been built from the distal toward the mesial as far as the mesial approach will permit. When good access from buccal or lingual is not available, it may be necessary to use a hand pressure condenser, 5-2-23, to secure adaptation against the mesial wall.

The method of stepping the condenser is practically the same for all three conditions of building the gold. For each new piece of gold added, after the gold is anchored, the first blow should be struck near the center of the *previously condensed mass,* and the condenser should be stepped, usually in rows of blows toward the surrounding walls. The blows should be heavier as the wall is approached, and the last row of blows against the wall should be sufficiently strong to take advantage of the elasticity of the dentin and thus secure a permanently perfect adaptation. Gold foil is the only restorative material which presents the opportunity to obtain this elastic grip of the dentin, and it is mainly for this reason that gold foil has held, and probably will continue to hold first place as the most reliable material for permanent restorations.

The method of stepping the condenser should become an established habit with each operator to the end that it will be followed as a regular systematic plan, without special effort or thought. It requires fewer blows to assure the *proper condensation* of the foil if the instrument is stepped along in regular order, than on a hit or miss plan. It does not require a single additional blow to secure the *best possible adaptation* if the condenser is stepped from the center of the mass toward the surrounding walls, while held at the proper angle in relation to each wall as it is approached.

BUILDING CONTACTS. In condensing the gold which is to form the contact with the proximal tooth, the blows should be as heavy as possible, without causing pain, and the condenser should preferably be held almost parallel to the long axis of the tooth.

COVERING THE CAVO-SURFACE ANGLE. In condensing gold over the cavo-surface angle it is especially important to secure good condensation and adaptation and at the same time avoid injury of

the smooth surface of the enamel margin. The direction of force should correspond to an angle of from 6 to 12 centigrades with the plane of the particular cavity wall. The parallelogram condensers were designed especially for this purpose. The greater diameter of the working point should be held at right angles to the margin. The face of the point is convex in this direction and it is therefore less likely to injure the enamel.

In the approach to and the covering of margins, great care should be taken not to step the instrument upon the uncovered cavo-surface angle of the cavity. If this is done, the cavo-surface angle of the enamel may be chipped and rendered imperfect. As the margin is approached, the gold should be laid over the cavo-surface angle in sufficient quantity to admit of malleting directly over it, without danger of the condenser point punching through it and coming in contact with the enamel. The gold should be built completely over the margin at every point.

Combination of Non-Cohesive and Cohesive Gold in Proximal Cavities in the Bicuspids and Molars.

Combinations of non-cohesive and cohesive gold may be used effectively in many positions in making restorations; the greatest importance of this combination is in the gingival portion of proximal cavities in the bicuspids and molars.

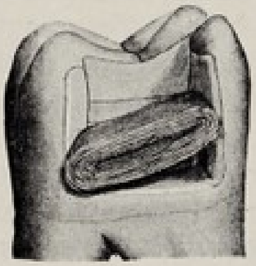


Fig. 418.

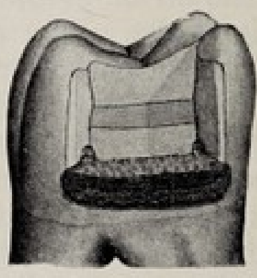


Fig. 419.

The starting points in the axio-gingivo-buccal and axio-gingivo-lingual point angles are cut farther toward the pulpo-axial line angle than for restorations to be made entirely of cohesive foil.

This combination consists of laying a large flat cylinder or mat of non-cohesive foil on the gingival wall and building cohesive gold upon this. The beginning and continuation of the building with cohesive gold is the same in every respect as if the non-cohesive gold had not been used, except that it will be necessary to continue the use of the holding instrument for a longer time before the mass is perfectly secure in its position.

The flat cylinder or mat is made by first folding a sheet of foil, or such part of a sheet as may be required, to the right width, and then rolling the ribbon formed upon a flat steel instrument of suitable width. The length of the cylinder is controlled by the width of the ribbon, and the breadth is controlled by the width of

the flat instrument. The length should be such that when placed flat upon the gingival wall with one end against the axial wall, the other end protrudes over the gingival cavo-surface angle of the cavity. The breadth should be such that it will extend fully from the buccal wall to the lingual wall and require some crowding to make it lie flat. This is placed in position, as shown in Figure 418, and pressed lightly against the gingival wall and into starting points, as shown in Figure 419. The cohesive foil is then built over it practically as has been described for complete restorations with cohesive foil.

Instead of this flat cylinder or mat, round cylinders may be used by laying the first in the linguo-gingival angle, a second in the bucco-gingival angle, and crowding a third between the two, as in Figures 420 and 421. Or, two cylinders may be used that have breadth enough to fill the space from buccal to lingual. See Figure 422. The noncohesive gold should be pressed to place before beginning with the cohesive, and condensed by building cohesive gold upon it. After the restoration is otherwise finished, the gingival portion should receive very thorough after condensation.

The reason that non-cohesive gold is safer in this position is that there is less disposition to curl from the margin, and if the

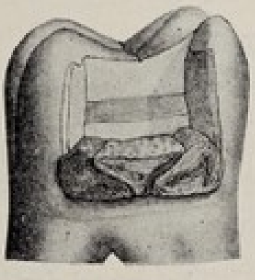


FIG. 420.

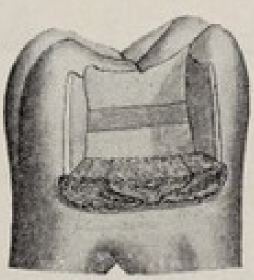


FIG. 421.

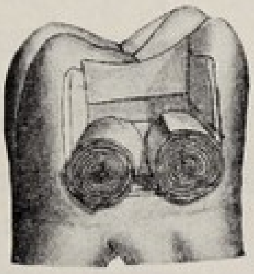


FIG. 422.

margin is not absolutely close, it is easier to make it tight by the after condensation, because, if it is not tight, it moves readily under the blows of the mallet, while cohesive gold does not. Generally a considerable quantity of non-cohesive gold may be used in this way and greatly reduce the labor of making the restoration. Yet, caution should be exercised in the amount of non-cohesive gold used. If the gingival wall is broad, as in a deep proximal cavity, and the step in the occlusal surface is very good and reliable, much more non-cohesive gold may be used — a greater thickness — than in a case in which the proximal cavity is shallow and the gingival wall narrow. Also when a thick mass of non-cohesive gold is used, it can not be sufficiently condensed by building cohesive gold over it.

Finishing Gold Foil Restorations.

Every restoration should be finished as smoothly as the polished surface of the natural enamel covering the surface of the

tooth. This finish should be so made that a sharp explorer point will, when used lightly, glide smoothly, and without catch or hitch from the enamel onto the restoration, or from the restoration onto the enamel at every point. There should be no overlap of the restoration onto the enamel at any point. This accuracy of the finish is as necessary as any part of the adaptation of the restoration to the walls of the cavity.

As the general rule, to which exceptions will be noted later, the restoration should represent, in its contour, the exact form of the surface of the part of the tooth lost by decay; and, in the preparation of the cavity, so to form these restorations day by day, requires the most accurate knowledge of dental anatomy and the modeling of tooth forms that years of careful study and practical clinical experience will give. This is necessary to the highest form of success in the esthetic sense, in the general usefulness of the restoration in mastication, and in the protection of the tooth against recurrence of decay. Many otherwise good restorations are left unsightly, so out of form as not to serve the purposes of mastication well, or in such form as to promote, instead of prevent, lodgments of food débris, and cause, by these faults, a recurrence of decay that will defeat the object of their placement and cause the loss of the teeth.

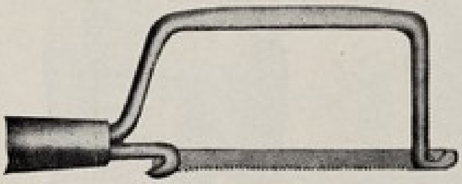


FIG. 423A.

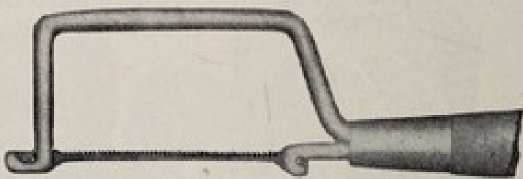


FIG. 423B.

INSTRUMENTS FOR FINISHING RESTORATIONS. The hand instruments used in finishing restorations are illustrated in Figures 423 and 424. The disks and other devices used in the dental engine for finishing restorations to form and for polishing are mentioned in connection with the discussion of the uses of the dental engine. Narrow strips, coated with sand and other grits, are also used for the final polishing of proximal restorations, particularly that portion to the gingival of the contact point.

PROXIMAL SURFACES. The hand instruments required for finishing proximal surface restorations are the Koëber saw, three knives and six files. Individual operators prefer other forms, some of which will be mentioned. However, these serve to illustrate the need and the principles involved. They are for the particular purpose of finishing gold foil operations in proximal positions. The files and knives are also used for gingival third gold foil restorations, and the knives for finishing both proximal and gingival third restorations of amalgam. The Koëber saw and files may be employed in trimming amalgam restorations that have been permitted to set thoroughly hard, without being properly finished.

These instruments are designed to trim restorations to proper form and are not concerned with the final polishing, except to make preparation for it. Therefore, they are not used for inlays, except occasionally to correct the form of a gold inlay which, through some error, was not properly finished before it was cemented to place.

SEPARATION. It is obvious that, in the placing of a gold foil or amalgam restoration, provision must be made for the reduction in contour which necessarily results from proper polishing. As a rule, this calls for a slight separation of the teeth in order that the contour may be overbuilt. Therefore, it is presumed that sufficient separation will be gained by use of a mechanical separator, or otherwise, as described elsewhere. In gold foil restorations the gold is condensed solidly against the proximal tooth in the region of the contact, while the separator is in place; with amalgam a thin sheet of matrix material usually stands between the condensed amalgam and the proximal tooth. A little extra separation is therefore required for amalgam restorations if a tight contact is established. In the case of the gold foil restoration, the separator is in place while the gold is condensed, and the smooth finish and polish

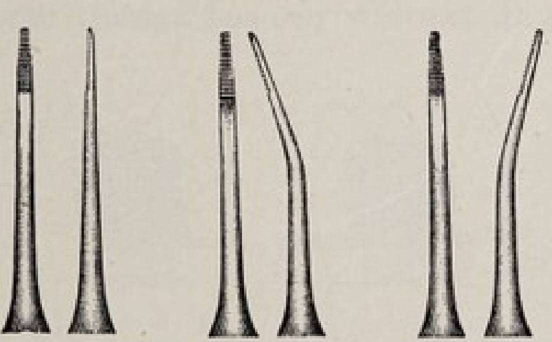
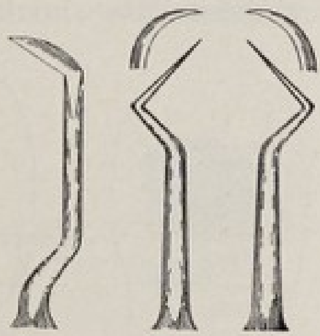


FIG. 424.



A. B. C.

of the contact requires sufficient space to pass a finishing strip between the gold and the proximal tooth. This may be gained in either of two ways: By additional turns of the adjusting bars of the separator, or, by trimming a little from the surface of the gold.

SAWS. The surface may be trimmed by holding the blade of a Koëber saw against the proximal tooth and cutting away a little of the gold that is in contact with it. See Figure 425. If this plan is followed, the operator must be certain that sufficient separation had been previously made to assure the return of the teeth into close contact, when the separator is removed. A combination of the two methods is usually the best, in which case the separator bars are first turned only one quarter turn making a slight space which will lead the saw past the contact position. The saw may then be carried through with one or two motions and without discomfort to the patient. The thickness of the saw blade is sufficient to permit the use of strips, and the slight cutting of the surface of the gold by the saw smooths the portion immediately about the

contact. However, the strips which give the final polish over this area should be the last step in polishing a proximal surface. By polishing every other part and leaving this area until the last, there is better opportunity to use the strip over the entire surface of the restoration, and give it an evenly smooth contour and polish.

The Koëber frame, with a thread saw (a regular blade, reduced in width by grinding the back edge with a stone) reversed in the same frame, is used for the purpose of trimming excess of gold along the gingival margins, but should not be used in cases in which the decay has caused the margin to be placed so close to the cemental line that the saw would injure the gingiva. See Figure 426. The saw should be carried past the contact and the blade should be pressed against the enamel, just beyond the gingival margin of the gold. Then with pressure exerted in the occlusal direction, the gold that overlaps the surface of the enamel should be cut away. One must be careful to see that the saw does not cut too deeply into the gold. It should be so directed that it will gradually cut out to the surface of the gold after a few movements of the blade. For any one cut, the saw should engage the gold along not more than one third or one half of the gingival margin. Two or three cuts should be made with the saw pressed against the


FIG. 425.

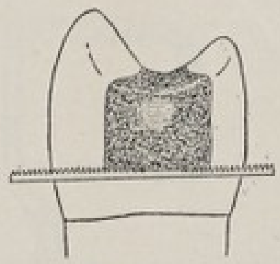


FIG. 426.


FIG. 427.

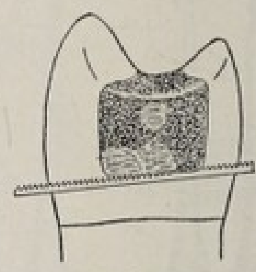


FIG. 428.

enamel at different angles for each cut, according to the convexity of the surface. Thus the margin of most difficult access is easily, effectively and quickly trimmed. See Figures 427 and 428.

Amalgam restorations that have been allowed to harden with an overlap along the gingival margin may be trimmed to form in the same manner as described for gold.

FILES. The gold finishing files, shown in Figure 424, are arranged in three pairs, each of which has the cutting side of one blade flat, with the back convex in the direction of the width of the blade, while the other has the cutting side convex and the back is flat. The blades taper from 20 tenths mm. at the shank end to 15 tenths at a point near the extreme end, which is rounded. One pair of blades is straight with the shaft, a second pair has the blades set forward at an angle of 6 centigrades, the third pair has the blades set backward at an angle of 94 centigrades. The edges of the file-cut blades are about .5 mm. apart; they are sunk at right angles to the plane of the surface and the depth of the cuts

is slightly less than .5 mm. They all cut with a pull motion. The blades are gradually thinner from shank to end. These files are similar to those designed by Dr. E. K. Wedelstaedt.

The files are used for trimming gold foil restorations in all proximal surfaces and in gingival third positions in buccal and labial surfaces, to proper contour and form, including the margins. They may also be used to trim amalgam and gold inlay restorations in the same positions, in cases in which the amalgam was not trimmed at the time it was placed, or the inlay before it was set. The straight instruments are particularly convenient for the anterior teeth and the buccal surfaces of the posterior teeth. Those with the blades bent forward are for trimming restorations in distal surfaces of the bicuspids and molars, those bent backward are for the mesial surfaces.

The files are useful in trimming to form all of the surface to which they are accessible. See Figures 429, 430, 431 and 432. When trimming margins to an even smoothness with the surface of the enamel, the motion of the file should preferably be from the surface of the gold over the margin, although it may be used in positions where the blade of the file is held parallel with the margin. The files may be drawn in any direction in relation to the

Fig. 429.

Fig. 430.

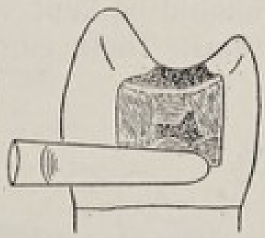


Fig. 431.

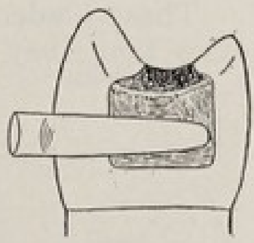


Fig. 432.

margin for the bulk of the trimming when there is considerable excess of material to be removed.

The files are equally effective in improving contours and trimming any marginal excess of amalgam or gold inlay restorations, although the careful operator will be certain that the contours and margins of gold inlays are right before they are set, also that amalgam restorations are trimmed at the same sitting at which they are placed.

The edges must also be kept sharp. When dulled by use, they are readily sharpened with knife-edge Arkansas stone slips, which may be had from the jewelers' supply houses. The dentist may do this for himself, or have the instrument-maker do it for him. The files must be frequently sharpened or they will become useless.

Knives. Three finishing knives are recommended. The blades are 8 mm. long; one is a triple-angle contra-angle with the blade placed at an angle of 18 centigrades with the shaft, Figure 424

illustration A; there is a pair, also triple angles in the shank, but the angle of the blades with the shaft is not a contra-angle, but at a lateral angle of 20 centigrades; one to the right, the other to the left, illustrations B and C. The knife A is used for trimming the buccal and lingual margins of gold foil restorations in bicuspids and molars, and the labial and a part at least of the lingual, also the gingival, margins of incisor proximal restorations. See Figures 433, 434 and 435. They are also used for trimming the gingival margins of gingival third restorations in both labial and buccal surfaces, without injury to the gingivae. Knives B and C are for trimming the excess at the gingival margins of proximal restorations in the posterior teeth. They may be substituted for the reverse cutting Koëber saw, or to catch any slight excess that the saw might have missed. They are to be preferred to the saw for trimming the gingival margin in all cases where the decay has extended far to the gingival, as the knives reach this margin without injury to the gums. The pair with curved blades were designed by Dr. Fred W. Gethro.

All three of the knives may be used very effectively for trimming the margins of proximal surfaces of amalgam restorations, immediately after the removal of the matrix, before the amalgam has become hard, also for gingival margins of restorations in buccal surfaces.

These blades should be kept very sharp. They are sufficiently heavy that they retain their edge very well. In use, the blade


FIG. 433.

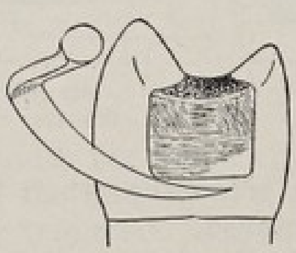


FIG. 434.

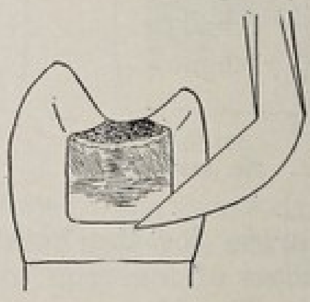


FIG. 435.

should be laid flat against the enamel with the point in position to trim away a little at a time. As the blade engages, it should be turned slightly so that it will remove only a small flake or shaving. This should be repeated again and again until the entire margin is trimmed. At no time should the effort be made to remove more than a thin shaving. If there is some thickness of gold to be removed, it should preferably be first reduced with the files or saw.

FORM OF CONTACT POINT. The form of the immediate point of contact should be similar to the rounding of the surfaces of two marbles when placed in contact. The proper position of the contact point and the convexity of the surface as it slopes away in all directions are discussed in the preceding chapter, with accom-

panying illustrations, Figures 328 to 343. It need only be emphasized here that the contact point of every restoration should be tested as suggested in the reference to Figure 337, to be certain that it is not too broad in either the bucco-lingual or the occluso-gingival direction. The mesio-distal width of the interproximal space should be sufficient to give support to the gum septum, and the surface should be sufficiently convex to give width of embrasures which correspond to the positions of the margins of the restoration, and thus insure cleaning in mastication. In the occluso-gingival direction, the surface should be convex with a definite slope from the marginal ridge to the contact. This convexity should continue beyond the contact, changing gradually to a slight concavity which in turn flattens to meet the surface of the tooth in an even plane.

The finishing files were designed for contouring the proximal surfaces of gold foil restorations. The concavity between the contact and the gingival margin may be made with the convex files, and the convex portions with the flat files.

OCCLUSAL SURFACES. The occlusal restorations and the occlusal surfaces of proximo-occlusal restorations are trimmed best with finishing burs and disks. Large finishing burs can be used to great

FIG. 436.

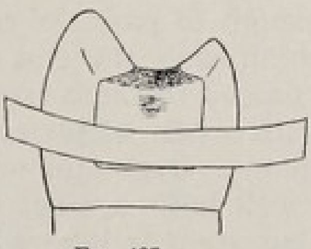


FIG. 437.

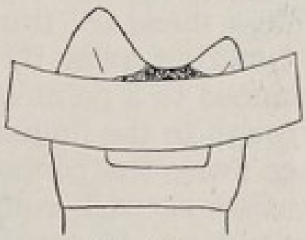


FIG. 438.

advantage so long as the blades are kept sharp, as they will cut the gold but will not cut enamel. Stones will do the work with less pressure, but they cut both gold and enamel and the enamel margins are likely to be damaged. Much care should be taken to finish the restoration fully to the enamel margin without cutting into the enamel. Every part of this should be made perfect so that there will be no overlaps. The discoid and the spoon excavators serve to trim the gold where little irregularities of surface prevent perfect trimming with rotary instruments.

After the trimming of the occlusal surface, the rounding of the marginal ridge to the contact point is done best with the files. With the safe side of these against the proximating tooth, this form is readily obtained in condition to be polished with disks.

GINGIVAL THIRD RESTORATIONS. The general contour of gingival third restorations in labial and buccal surfaces may be trimmed with finishing files. The knives may be used particularly for the

gingival margin. Disks, generally in the contra-angle hand piece for bicuspids and molars, are desirable to secure the final smooth contour.

POLISHING. All parts of the restoration should be well polished. This may be done with disks, wood points, rubber cups and polishing strips. Disks, in the engine, should be used in polishing the buccal and lingual margins and as far into the embrasure as practicable without endangering the contact point, as shown in Figure 436. In no case should the disks be allowed to pass between the proximating tooth and the contact point on the restoration. The narrowed space will cause the disk to press hardest on the contact point, cut it away rapidly and quickly remove its prominence and destroy its usefulness. All scratches left by the files should be perfectly removed and the surfaces evenly rounded. Much of the rounding of the proximal surface onto the occlusal surface forming the marginal ridge, including the occlusal portion of the rounding of the contact point itself, may be done with the disks, after the rougher part of this has been done with the files.

When this part of the polishing has been completed, the gingival portion of the restoration should be polished with narrow polishing strips, that may be used in the interproximal space without reaching or passing over the contact point, as shown in Figure 437. Unless these are thin enough to pass the contact easily, and without cutting away its prominence, the end of each strip should be trimmed to a point and passed through from the buccal and pulled through to the lingual with a pair of pliers to avoid injury by cutting away the contact point. Over and over again students, and dentists as well, ruin a well built contact point by failure in this precaution. If a polishing strip is allowed to be passed over the contact point, bound against it tightly by the proximating tooth, it cuts the gold very rapidly. When this part of the work has been completed, the final finish of the contact point may be made. For this purpose a wide but very thin flexible tape, with fine grit, should be carefully passed over the contact point with a pull sufficient to cause it to close around it, and round it into form. The use of this should continue only long enough to produce a smooth surface. Much cutting that will materially reduce the prominence of the gold should be strictly avoided. This will finish the restoration neatly and with proper prominence of the contact point. See Figure 438.

RESTORATIONS WITH AMALGAM.

ILLUSTRATIONS: FIGURES 451-471.

Amalgam is more extensively used than any other material for restorations in the teeth. The present trend is to find ways and means by which dental service may be made available for a much larger portion of families, particularly in the low income

groups, and amalgam restorations should play a large part in this movement, as the material of itself is inexpensive.

High grade alloys, made according to specifications set up by the American Dental Association, as a result of investigations by the United States Bureau of Standards, are thoroughly reliable. Proper understanding of the new alloys and careful manipulation according to the requirements for each, assure a high degree of permanence for restorations made of this material. Amalgam earned a very bad reputation in the past, because of the unreliability of the alloys on the market and the very careless manner in which the restorations were made.

The manipulation of amalgam calls for exactness in every detail of the technic. Lack of understanding of this very sensitive material and consequent neglect of seemingly minor details, have resulted in many failures which might have been avoided.

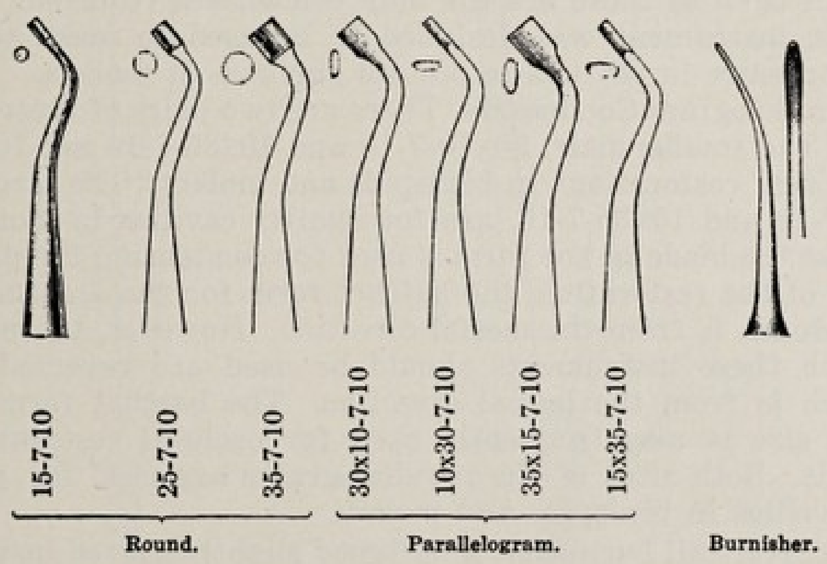


Fig. 451.

CONDENSERS FOR AMALGAM. Comparatively few instruments are required for condensing amalgam. They are much larger than those used for gold, for the reason that amalgam is placed in the cavity in a plastic state and a small instrument would penetrate the mass without condensing it. The condensers should be as large as can well be used in the cavity so as to grasp and compress the mass as a whole as nearly as possible in the first instance, and then used with all the power of the hand in making final pressure.

FORMULA NAMES. The formula names and rules for measurement of amalgam condensers are as follows:

(1) The size of the working face of the condenser is given in tenths of millimeters as the unit, the length of the nib or reach of the working point is in millimeters, and the angle of the nib with the shaft in centigrades.

(2) If the condenser is round, the diameter is given, followed by the length of the nib and the angle, as 15-7-10.

(3) When the working face is in parallelogram form, both dimensions are given, as 30x10-7-10.

(4) When a pair is formed by placing the broad sides of the nibs in opposite relations to the angle of the nibs, that dimension which is in the plane of the angle is placed first, as 35x15-7-10 (hatchet form) and 15x35-7-10 (chisel form).

The seven instruments illustrated in Figure 451 answer every purpose in condensing amalgam:

Round Condensers. There are three instruments with round flat faced ends. Their diameters are 15, 25, and 35 tenths millimeters; all are at angles 10 centigrades to the shaft, and all have nibs 7 mm. long. The 15 and 25 diameter instruments are used particularly for compressing the first small pieces of amalgam placed in the cavity, and adapting them to the several walls. In small pit cavities these are the only condensers required. The 35 diameter instrument was designed to be used to make the final heavy pressure in cavities in occusal surfaces of molars.

Parallelogram Condensers. There are two pairs of these instruments. The smaller pair, 30x10-7-10 and 10x30-7-10 are for proximo-occlusal restorations in bicuspids and molars. The larger pair 35x15-7-10 and 15x35-7-10, are for similar cavities in molars. In each case the blade in hoe form is used for condensing the proximal portion of the restoration, the hatchet form for the occlusal, when the approach is from the mesial direction. However, the positions in which these instruments should be used are reversed if the approach is from the buccal direction. The hatchet form of the smaller size is also frequently used for occlusal restorations in bicuspids. Both sizes of the parallelograms are used for gingival third cavities in bicuspids and molars.

A beaver-tail burnisher, a flattened slightly curved instrument with round edges, is helpful in making amalgam restorations. It is also illustrated in Figure 451. The burnisher may be used in many cases to push the amalgam into the cavity previous to the use of the condenser, also to do the first bulk trimming and apply additional compression along margins after the amalgam is partially set.

Preparation of the amalgam. The manufacturers of all high grade alloys supply with each bottle specific directions as to the proportion of the alloy and mercury to be used in preparing the amalgam, the proper time for trituration, the time the mass should be mulled, etc. These directions should be meticulously carried out. Each dentist should have a weighing or measuring device by which the proper proportions may be determined. A definite number of grains of the alloy — 15 grains is probably the most convenient quantity — should be selected as the standard, and quantities of this weight should be placed in transparent capsules for future

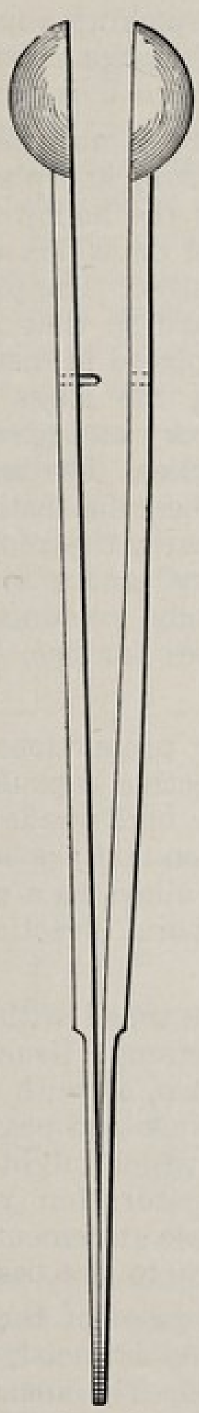


FIG. 452.

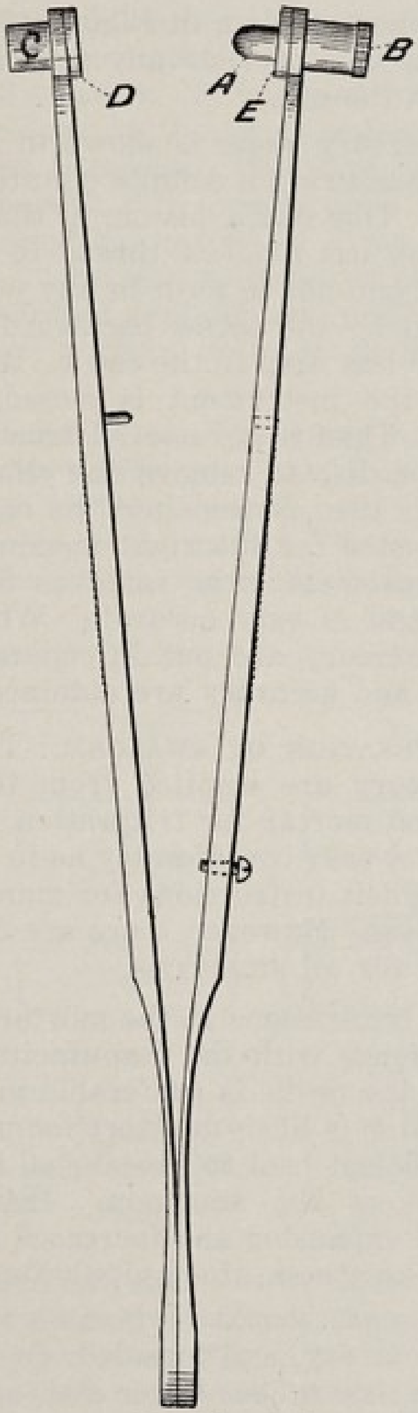


FIG. 453.

use. Similarly, distilled mercury in proper amount for the particular alloy, as specified by the manufacturer, should also be placed in capsules. By this plan, the proper proportions are always ready and the repeated mixing of the same quantity makes for greater accuracy. For extra large cavities, twice the standard amount will be prepared.

A pair of special mercury spoon pliers for picking up small globules of mercury in weighing and removing from the scales to

the capsules is shown in Figure 452. It will pick up any quantity the spoon will hold, or any separate globule large enough to be seen with the eye.

A mercury meter is shown in Figure 453. It may be used for rapidly measuring a definite quantity of mercury and placing it in capsules. This has a piston, A, that fits into the hollow of cap C. The piston has a screw thread in the barrel on which the nut B acts as a jam-nut to fix it in any position desired. The piston may be turned by the screw backward or forward so that it will go deeper or less deep in the cap C. When C is placed in mercury and is filled, the instrument is closed, bringing the rings D and E together. Then it is removed from the mercury and given a light tap on the dish to remove any clinging globules. The mercury in the cap is then poured into the capsule. When the instrument is once adjusted for the right amount of mercury, the repetition of the measurement is as rapid as the mercury can be dipped and poured, and is very accurate. When the right amounts of alloy and of mercury are put in separate capsules for use, both convenience and accuracy are obtained.

TRITURATION OF AMALGAM. The proper proportions of alloy and mercury are emptied from their respective capsules into a small hand mortar for trituration. Since the high grade alloys on the market vary considerably as to composition and previous treatment, explicit instructions for manipulating alloys as a group can not be given. However, there are certain general directions which will hold for all amalgams.

The triturations in the mortar should be timed with a watch, in accordance with the manufacturer's directions. Usually a pen grasp of the pestle is preferable to a fist grasp, as with the latter the operator is likely to exert too much pressure and possibly generate sufficient heat to overanneal the alloy, which might result in shrinkage of the amalgam. Insufficient trituration results in abnormal expansion and increased flow. These statements emphasize the exactness of manipulation necessary to the best results.

The mass should be transferred to the palm of the hand, if the hand is dry, and kneaded, or, if the hand is moist, it should be placed in a rubber finger stall and kneaded. The kneading time should be specified by the manufacturer. If the proportions of alloy and mercury are right, the mass should, after thorough kneading, make a smooth paste that will take good impressions of the skin markings of the fingers, without being sloppy. It should be tough enough to be rolled into a long, slender roll without much breaking. It should be stiff enough so that it will not change form perceptibly when rolled into a ball and laid on a table. To obtain these results will require considerable hard kneading with the right amount of mercury. If there is too much mercury, the mass will become sloppy, can not be rolled into a slender roll without

breaking, and if rolled into a ball, will flatten out perceptibly when laid on the table. If there is not enough mercury, the mass will not cohere well and will break readily. It will not become soft enough to readily take impressions of the skin markings of the fingers. Any considerable excess of mercury should be removed by wringing in a piece of clean chamois skin as soon as it is noticed. However, there should be no effort to express all of the mercury, as the first pieces to be placed in the cavity should be rather soft.

The mass should be rolled into a cylinder approximately one-eighth inch in diameter, laid on a clean piece of gauze and cut crosswise into small pieces.

PRINCIPLES IN CONDENSING AMALGAM. In making restorations with amalgam, conditions are very different from those required for gold foil. Its use is limited to the bicuspids and molars, on account of its tendency to discolor in the mouth. The cavity must be absolutely dry from the period of the insertion of the amalgam

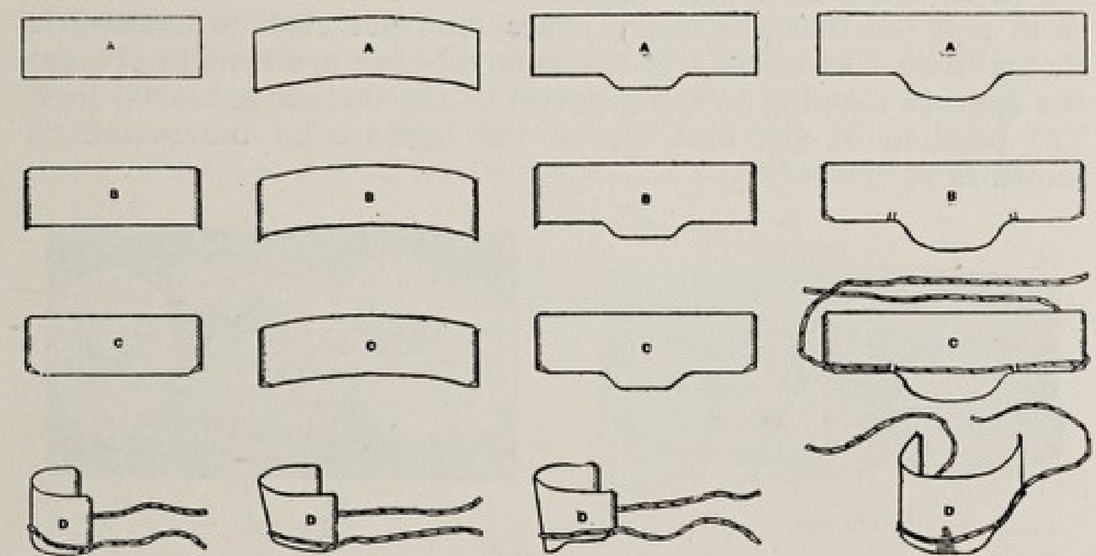


FIG. 454. FIG. 455. FIG. 456. FIG. 457.

until it is sufficiently set to preclude entrance of moisture along the margins. Four surrounding walls are necessary for all cavities for amalgam restorations. Therefore, all proximal cavities in bicuspids and molars must have the mesial or distal wall supplied by a matrix. This matrix should be so adjusted to the tooth that it will withstand the pressure that should be used in packing. Amalgam is a plastic material when placed in the cavity and must be compressed against cavity walls at just the right time during the setting process to secure the best possible adaptation. If heavy pressure is made while the mass is too plastic, it moves from under the condenser instead of being compressed. With amalgam it is not possible to take advantage of the elasticity of the dentin, as sufficient force can not be applied with large condensers. If it were possible to make pressure that would force the dentin walls

back, the dentin would resume its normal position as soon as the pressure was released, as the plastic material would not hold against it. Amalgam restorations must be polished at a time subsequent to their placement; at least twenty-four hours afterwards.

THE MATRIX AND ITS APPLICATION. The matrix should be applied after the cavity is completely prepared and the rubber dam is in place. There are several ingenious devices with which a matrix may be quickly applied and securely held. One of these is illustrated. In order to be certain of a proper contact after the amalgam is polished, it is usually necessary to place a separator over the matrix. To do this, the most satisfactory method is to cut a piece of very thin stainless steel in one of the forms suggested in Figures 454 to 457. Stainless steel is stronger for a given thinness than German silver, which was formerly used for this purpose.

Figure 454 shows the simplest form and that which may be used for the smaller and medium cavities. The matrix as cut is shown in drawing A. The matrix with the ends bent toward the tooth side, so that the sharp edges may not cut the ligature is shown in B. The corners at the gingival edge are bent to prevent the ligature slipping to the gingival of the matrix as shown in C. The position of the first lap of the ligature on the matrix is shown in D.

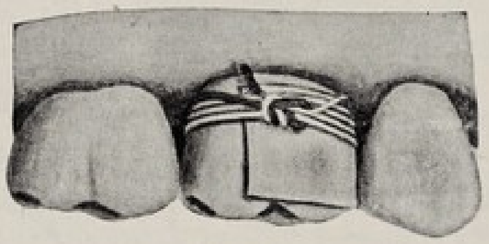


FIG. 458.

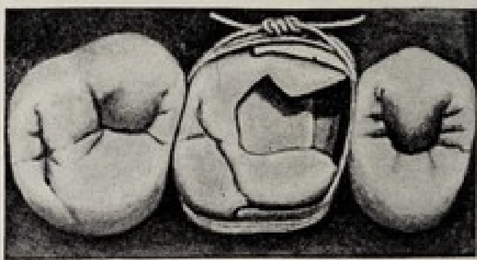


FIG. 459.

Figure 455 illustrates a matrix for a tooth the crown of which is badly broken down. The matrix should reach nearly around the tooth to keep it in position when securely wrapped with the ligature, and must be cut on a curve to give the proper bell-crown form of many molar teeth. This can be cut to suit the case.

Figures 456 and 457 are forms for cases in which decay has extended far in the gingival direction. The extension of the matrix is intended to cover this extension of decay. In Figure 457, C shows a method of attaching the first lap of the ligature to the matrix before placing it in position, by cutting two slits, turning up the piece between them, laying the ligature in and closing the pieces on it to hold it in place. In D, a crimp is bent in the center part of the gingival edge which will catch on the gingival wall of the cavity as it is pressed gingivally. A beaver-tailed burnisher may then be placed in the cavity to push this edge outward beyond the

margin of the gingival wall. In this way any fullness of the rubber dam will be pushed aside and the edge of the matrix will slip to place *between* the surface of the tooth and the rubber. It avoids the possibility of the rubber being caught by the edge of the matrix.

This form of matrix should be tied with a ligature wrapped around the tooth three or four times and tied with a surgeon's knot, as illustrated in Figures 458, a buccal view, and 459, an occlusal view.

After the matrix is in place, its closeness of adaptation at the position of the margin of the gingival wall should be assured, either by the use of a wedge of orange wood, cut to proper form and forced to place while held in a pair of heavy flat nosed pliers, or by the use of a Ferrier separator as illustrated in Figure 460. As a rule the separators are not required *between* the temporary molars, because the constant pressure of these teeth to move mesially will quickly close a space as slight as the thinnest sheet of matrix material that may be used. It should be remembered, however, that a very slight loss of space and the re-establishment of the contact by the mesial movement of teeth, reduces the width of embrasures and increases the susceptible areas. This is of real concern *between second temporary and first permanent molars.*

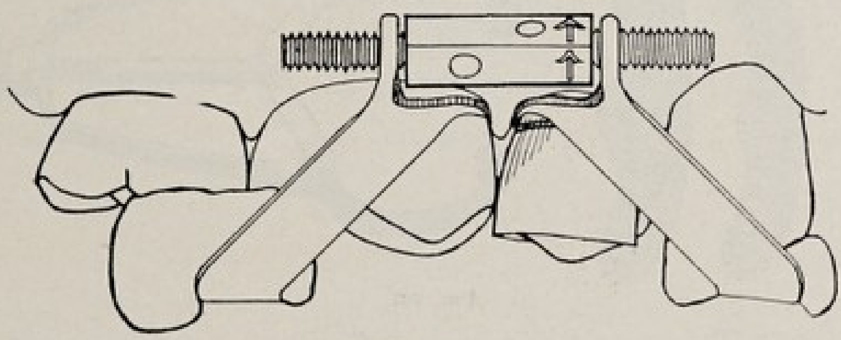


FIG. 460.

Occasionally the spring of the steel will tend to hold the occlusal position of the matrix away from the proximating tooth. It may be kinked to form by holding it against the proximating tooth with one amalgam condenser, while pressure is made with another in the opposite direction, first on that part of the matrix which extends beyond the occlusal portion at the mesio-buccal angle and then similarly on the extension at the mesio-lingual angle. As a result, the matrix should remain in contact with the proximating tooth. In some cases, particularly if the cavity is narrow buccolingually, the matrix may be held in place with the wedge or separator without the assistance of the ligature, or with but a single wrapping of the ligature about the tooth.

In placing amalgam restorations in disto-occlusal cavities in second permanent molars, when the third molars are not present

also in proximo-occlusal cavities in the temporary molars and particularly in disto-occlusal cavities in the second temporary molar, the matrix retainer designed by Dr. J. W. Ivory, illustrated in Figure 461 is especially convenient. It may be quickly placed and removed, and a ligature is not required. It will be noted that the points of the jaws are drawn closer together by tightening the adjusting screw. These jaws may be engaged in the proper holes so that the prepared matrix encircles three sides of the tooth and the points just overlap the angles of the crown on the surface opposite the cavity. The matrix may be drawn very tightly and the form in which it is cut causes it to fit closely about a slightly bell crowned tooth. This matrix may also be used for mesio-occlusal restorations, although a Ferrier separator can not be placed over it.

There are many other devices which are helpful in connection with the application of matrices. A properly adjusted matrix is so essential to the proper placement of proximo-occlusal amalgam restorations that no effort should be spared to secure the best results with least discomfort to patients. Tightness of the matrix which prevents the amalgam from being pressed beyond the margin

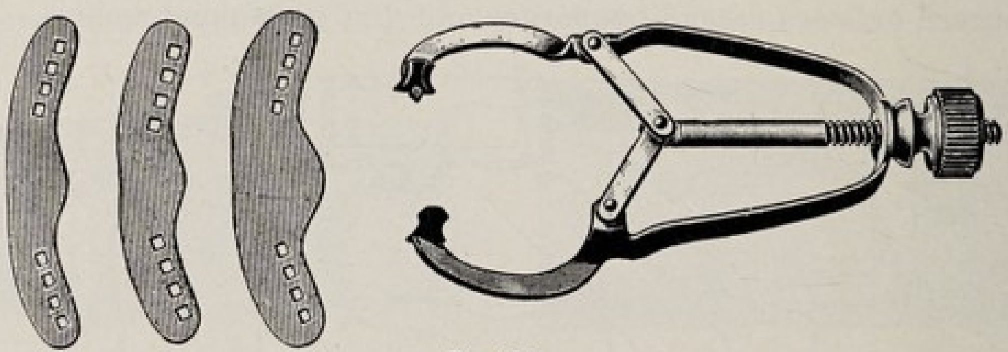


FIG. 461.

of the gingival wall is an important precaution against inflammation of the septal gingivae, as it is often difficult to trim this margin perfectly, especially if there is considerable excess of amalgam.

CONDENSING THE AMALGAM. Everything should be in readiness for placing the amalgam before the trituration of the alloy and mercury is begun, so that the condensation may be begun at the most opportune moment to secure the best adaptation. The one thing most needful in the condensation is to apply pressure to each mass as a whole as nearly as is possible, and compress it into the cavity. The principle of making a perfect restoration is contained in the *one* word, *compression*.

The rope of amalgam should be broken in bits the size desired before beginning so that they can be handled quickly with the pliers and placed in position. This may be done by an assistant or

by the operator. Each piece should be immediately condensed. A small point should always be used for special condensation into the angles of junction between the surrounding walls and the "floor" of the cavity, also for any narrow extensions. This should be done on the same principle as the stepping of the instrument in condensing gold to secure perfect adaptation to walls and margins. That is, the stepping should be *from the mass of the restoration already condensed toward the walls, finishing at the walls with heavy pressure to secure the best possible adaptation.* In using small instruments about the walls and angles, the force should be sufficient to condense the amalgam, but not so great as to force the instrument into the already condensed material and cause it to move. It requires some experience to learn this and use force judiciously.

A mesio-distal section of an occlusal prepared cavity is illustrated in Figure 463, with a piece of amalgam ready to be condensed. The smallest round condenser is used to compress the

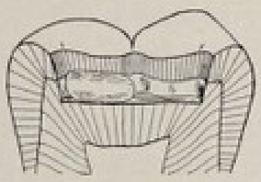


Fig. 463.

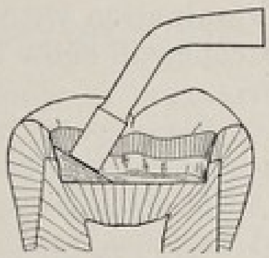


Fig. 464.

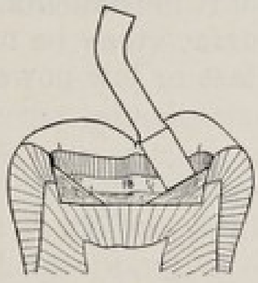


Fig. 465.

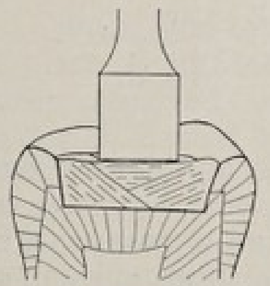


Fig. 466.

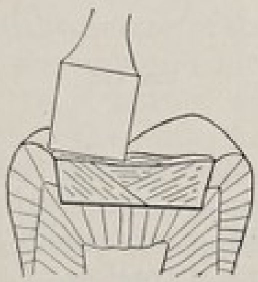


Fig. 467.

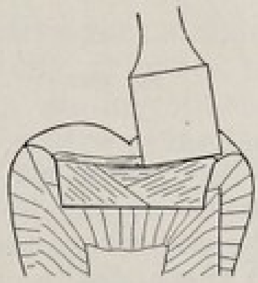


Fig. 468.

amalgam into the disto-pulpal line angle and against the distal and pulpal walls, as illustrated in Figure 464, the direction of the force being the same as for condensing gold foil. Other pieces are placed and compressed against the various surrounding walls, as shown in Figure 465, for the mesial and pulpal walls.

The condensing should be continued with instruments as large as can be conveniently used and the restoration should be built up evenly, until the cavity is full and more than full. The amalgam should be heaped over the margins. Then, the largest instrument available, which will grasp and compress the amalgam as a whole as

nearly as possible, should be used with all the power of the hand, and with a slight shaking motion, which tends to settle the amalgam into any irregularities or angles of the cavity. It should if necessary, be moved several times to include every portion of the surface. This should be direct pressure without lateral movement. See Figures 466, 467 and 468. Then the bulk of the surplus may be gradually trimmed off with the large burnisher. This should be done without making any considerable pressure on the mass and the burnisher should always be moved in a direction toward the margins; otherwise it might disturb the adaptation.

It is a general rule that amalgam restorations should not be burnished, because of the danger of disturbing adaptation. For experiment, an amalgam restoration should be made in a long, narrow cavity (similar in shape to a gingival third cavity in the buccal surface of a molar) cut in a piece of ivory. The amalgam should be placed with direct heavy pressure, including pressure on the margins. The excess at the margins may be trimmed as described with a beaver tailed burnisher and pressure with very short movements over the margin from amalgam surface to enamel surface may be made. Examination with a good hand magnifying glass or low-power microscope will show the margins to be perfect.

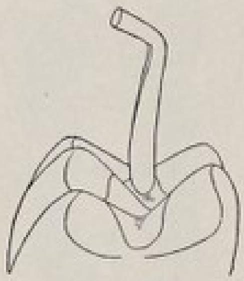


Fig. 469.

Fig. 470.

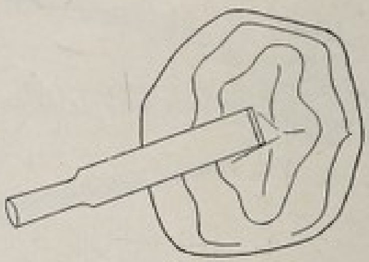


Fig. 471.

If the burnisher is then carried over the surface of the amalgam from one end to the other, reexamination will show a crevice at the end where the burnishing movement began and a close margin at the opposite end. If the direction of the burnishing movement is reversed, the crevice will be at the opposite end. The burnisher will move the mass of amalgam slightly away from one end and against the other.

A little time should be given the amalgam to stiffen; from two to five minutes, depending upon the rapidity with which it sets, after which it should be trimmed to form with sharp instruments at the same sitting, and polished at a subsequent sitting. Spoons and the discoid should be used for the bulk of the trimming on the occlusal surface. One of these instruments should be carried lengthwise of each margin, with the edge of the blade at right angles to the margin and a portion of the edge resting on the surface of the enamel. In this way every particle of excess is

removed without danger of removing too much and thus exposing a portion of the enamel which forms the cavity wall. A straight or binangle chisel may often be used to accentuate the lines of grooves in large occlusal restorations. See Figures 469, 470 and 471.

The knives, Figure 424, are used for trimming the proximal portion of proximo-occlusal amalgam restorations. See Figures 433 to 435.

POLISHING. At the next sitting the restoration should be polished. This polishing is done in the same way and with the same instruments as the polishing of gold restorations. It should be done with the same care, and just as perfectly in every part. Also the same care should be taken in separating the teeth, in the formation of the contact point, and for the same reasons. Nothing less will be doing justice to the material. Nothing less will be doing justice to the operator, the patient, or to the public.

RESTORATIONS WITH GOLD INLAYS.

ILLUSTRATIONS: FIGURES 472-478.

Gold inlays grew rapidly in popularity after the introduction by Dr. Taggart in 1907 of the process by which a wax pattern of the restoration was reproduced by a casting in gold. Inlays are particularly suitable for proximo-occlusal cavities in the bicuspids and molars and have replaced gold foil for the larger cavities of this class as well as those of average size that are of difficult access for the condensation of foil.

When first introduced the entire process appeared very simple. A piece of softened wax was pressed into the cavity, trimmed to form, removed, attached to a sprue, encased in an investment material, heated to dissipate the wax, and pure gold was melted and forced into the mold with compressed air or centrifical force, or drawn in by a vacuum. That was practically the entire process. It was soon discovered that cast pure gold was too soft, that many proximo-occlusal inlays did not fit against the gingival wall, that others were too large, etc., etc. This was the beginning of studies by many investigators during nearly thirty years, which are reviewed in the chapter on materials. These studies have centered on two main problems; the methods and materials which will enable the dentist to cast an inlay in the exact form of the wax pattern before it was removed from the cavity, and the alloys of gold that are best for inlays. During recent years great progress has been made through a cooperative effort by the American Dental Association, the Bureau of Standards and many teachers of operative dentistry. Yet all persons connected with the study appreciate the fact that further refinements of materials and methods are necessary.

However, progress has been made to the point where the large majority of gold inlays are giving very excellent service. As to the hardness, the ideal is that an inlay should wear as rapidly as the teeth and no faster. The present alloys meet the situation as well as can ever be expected, in view of the fact that there is no standard of wear for the natural teeth. Alloys of any desired hardness are available. It must be born in mind, however, that too hard a casting may do injury to the supporting structures of the teeth by increasing the strain on them when the teeth wear more rapidly than the gold.

One of the most valuable features of the inlay is the opportunity afforded to make perfect contact restorations, and thus give the septal gingivae the best possible protection. After the inlay is otherwise ready to set, contact with the proximating tooth may be established in the most perfect form possible for the case in hand, and tested to make certain that it is correct. It also presents the additional opportunity of tightening contacts of neighboring teeth, discussed elsewhere. Possibly one would be justified in making the statement that the greatest benefit from the gold inlay has been in the prevention of diseases of the peridental structures.

A. B. C. D.

Fig. 472.

Instruments, Appliances and Materials.

The most important advances in inlay restorations during recent years have been in the perfection of waxes, investing materials and the casting process, all of which are discussed in the chapter on materials. This presentation will consider primarily the technic employed in the preparation of the wax pattern, its investmen and the casting and setting of the inlay.

The wax pattern. There are three principal methods of preparing a wax pattern; the *direct* method, which consists of making the pattern in the mouth, doing all of the contouring and polishing before removing it from the mouth; the *impression* method, by which an impression of the cavity is made by forcing wax into it, and this wax later becomes the wax pattern; and the *indirect* method, by which an impression is taken of the cavity and the wax pattern is made from a metal model, counterpart of the impression.

The direct method. For most cavities of average size the

direct method is generally used. A piece of wax may be softened in warm water or the end of a stick of wax may be slowly rotated while held in the fingers over a gas flame. It should be gradually pressed between the fingers to the desired form for insertion into the particular cavity, being certain that the point may be immediately passed to the deepest part. In the illustration, Figure 472, a piece of wax is shown at A. In B the end has been softened and pressed into wedge form. The wax forming the end, which is the softest, should be placed against the gingival wall of a proximo-occlusal cavity before pressure is applied to the large end. This insures more perfect adaptation to the gingival portion of the cavity than would be possible without having prepared the wax in advance. If the cavity is wide enough bucco-lingually to permit much of the wax to be forced into the embrasures, the thumb and finger of one hand may be used to make pressure from buccal and lingual, while pressure is exerted on the occlusal with a finger of the other hand.

The wax as molded in B may be used for simple occlusal cavities and for most small cavities of all classes. However in the very small cavities it is desirable to use a less bulky piece of wax than that in the illustration.

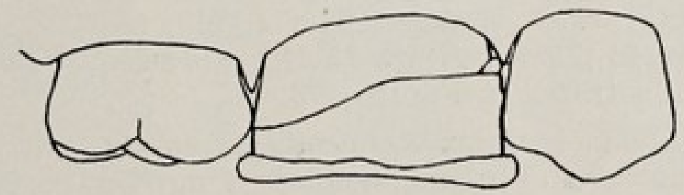


FIG. 473.

In many cases it will save time and a more perfect pattern of a proximo-occlusal cavity will be secured by placing a specially trimmed thin copper band about the tooth, as illustrated in Figure 473. This is of such size that the edge will be slightly engaged between the marginal ridges of the opposite surface of the tooth for which the pattern is to be made and its neighbor, while the band is sufficiently large to stand slightly away from the margins of the proximal portion of the cavity. The band should then be filled with soft wax and both the band and the wax should be pressed to place. The wax will be removed with the band and after the bulk of the wax is cut away, the band may be removed by cutting it through with an emery disk on the opposite side. The wax should be a perfect pattern of the cavity with a slight surplus about the margins. It should be replaced in the cavity and the occlusal portion may then be carved. This plan facilitates the trimming of the wax on proximal surfaces.

A piece of wax that has been softened and flattened at one end is shown in C in Figure 472. This is the first step in preparing the wax to take a pattern of a mesio-disto-occlusal cavity in a bicuspid. The central portion of the flattened end should be cut out with a hot burnisher as shown in D. The ends are then again softened and so positioned that they may be placed against both gingival walls before pressure is made on the wax. A copper band may be placed about the tooth to facilitate the taking of the pattern of such a cavity. Other forms of softened wax will be suggested by cavities for which patterns are to be made.

After the wax has hardened in the cavity the bulk of the wax is cut away with a hot burnisher or a sharp knife. Then, if it should be a cavity involving the occlusal surface or any position in which the opposing tooth might touch it, the wax is further trimmed very close to proper form. The surface is then made sufficiently soft with a warm instrument and the patient is requested to bite gently into it. It may then be again softened and the mouth may be completely closed without danger of disturbing the adaptation of the wax to cavity walls and margins. The pressure of the teeth should be maintained for a short time until the wax has cooled. The surplus wax is then trimmed to form as will be described.

THE IMPRESSION METHOD. An impression of the cavity is made with inlay wax, which is enclosed in a thin, seamless metal band and is pressed to place over the tooth, as described for the direct method and illustrated in Figure 473.

If the case is a mesio-occluso-distal cavity, portions of the band on the buccal and lingual surfaces, gingivally of the points of greatest convexity of these surfaces, should be cut away. In all cases the gingival portion of the band on the mesial or distal (both mesial and distal in mesio-occluso-distal cavities) should extend a little beyond the gingival margin of the cavity, but not so far as to cause injury to the gum. In some cases the occlusal portion of the matrix may be trimmed to permit the patient to bring the teeth into occlusion. The matrix is removed and filled with softened inlay wax and is then placed over the tooth and forced to its proper position, as was determined by previous trial. Heavy pressure should be applied to the wax to insure its being forced into the deepest angles of the cavity. At this time the patient, if the matrix will permit, may close the teeth in order to show in the wax the points of occlusion with the opposing teeth. Or a mark may be made on the outside of the band indicating the height of the marginal ridge of the proximating tooth. This mark may be later transferred to the wax and will serve as a guide in carving to occlusion. The impression should be held firmly in place for about a minute, chilled with room temperature water and then carefully removed. The cavity side of the impression should now be filled with an ex-

panding investment material that sets rapidly and very hard. After the investment has hardened, the band is cut and removed and the wax pattern carved on the investment model. When the pattern is finished a sprue is attached. The pattern with its model is then immersed in room temperature water to thoroughly wet the investment model, after which both model and pattern are invested. From this point the case is treated as if it were an invested wax pattern made by the direct method.

It is readily seen that some sacrifice of tooth substance will occasionally be necessary in order to insure a free withdrawal of the wax impression. This applies particularly to bell-crowned teeth. Since the wax impression includes the surface of the enamel for some distance from all margins of the cavity, it is necessary to so cut the buccal and lingual walls of the proximal portion of the cavity that, in a mesial cavity, for example, they will not only be inclined outward—to the buccal and lingual, but will also be slightly inclined to the distal, in the direction from gingival to occlusal. Otherwise the wax which is in contact with the surface enamel near the gingival will be distorted in removing the impression.

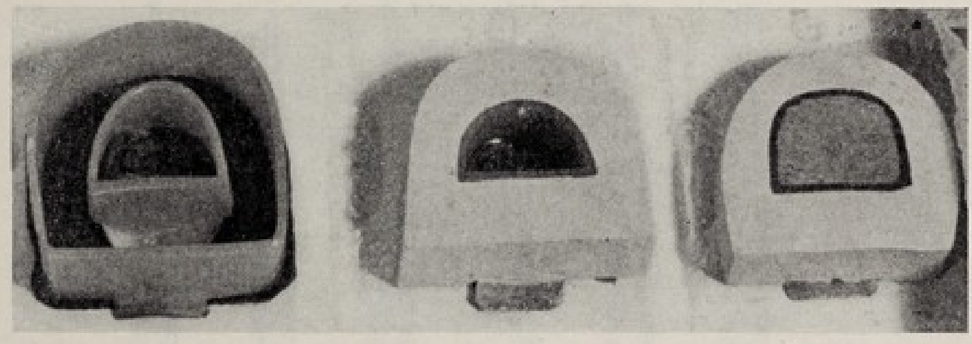


Fig. 474A. Fig. 474B. Fig. 474C.

THE INDIRECT METHOD. An impression is taken of the prepared cavity, using modeling compound in a matrix band. A model of the impression is made of amalgam, or of some material which sets more rapidly and becomes sufficiently hard. The wax pattern is secured from the model.

This plan is often used for the larger and more complicated cavity forms, and involves the taking of the patient's bite in order that the pattern may be carved to proper occlusal form. It simplifies the technic of carving the wax and requires less chair time for both patient and dentist. All of the steps subsequent to the taking of the impression may be performed by an assistant. However, it introduces additional elements of possible error.

The amalgam model may be made by first boxing in the modeling compound impression, as illustrated in Figure 474A. It will be noted that this has two wax boxings, one considerably larger than the other. The space between the two is filled with a hard

setting investment, as shown in Figure 474B. This gives support to the inner wax boxing, to withstand the pressure exerted in condensing the amalgam to form the model of the cavity. See Figure 474C.

INSTRUMENTS FOR CARVING THE WAX PATTERN. The instruments used in the construction of inlays are very few. They consist of a few carvers to trim wax to surface form after it has been pressed into the cavity. Several are illustrated in Figure 475. Instrument A may be used for trimming the wax within the embrasures by holding the side of the tine against the surface of the enamel as a guide. Instrument B is a blade that is useful in trimming the proximal portion of the wax; C is the same shape as B, only it is at right angles to it in relation to the shank of the instrument. The illustrations B and C are opposite ends of an instrument

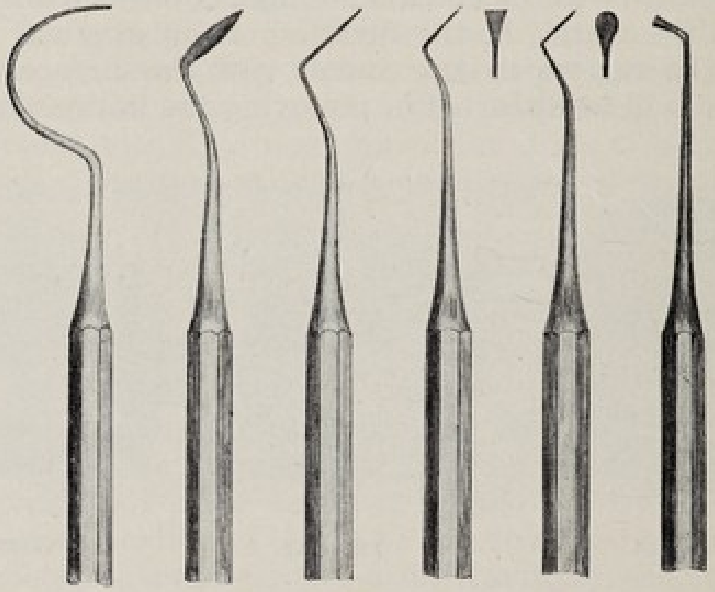


FIG. 475.

designed by Dr. Marcus Ward. Instrument D is a convenient shape of blade for carving grooves and planes of the occlusal portions of the wax. Instrument E is a discoid which is used for the same purpose. Instrument F is a burnisher for smoothing all parts of the occlusal surface. This instrument is rounded on its end. The proximal portion of the wax should be made smooth with a silk or tracing cloth strip.

Instruments D and E are designed to be used for two purposes in trimming the occlusal portion of the wax pattern. They should be used to trim away portions of wax that overlie the enamel margins. In doing this the edge of the blade should be held at right angles to the length of the margin, with a part of the cutting edge resting on the surface of the enamel, and moved along the

marginal outline of the cavity. The wax may thus be trimmed even with the surface enamel without danger of cutting away too much. These instruments are also used to contour properly the occlusal surface after the margins are trimmed.

In proximo-occlusal restorations, the occlusal portion should always be trimmed first as the wax is usually held securely in place by the portion occupying the embrasures between the teeth. Even in cases in which a matrix is used to form the proximal portion of the pattern, it is best to secure proper occlusal form before trimming the proximal portion.

Instruments B and C are used to trim the proximal portion of the wax to form. The excess wax should first be removed from the buccal and lingual embrasures without disturbing that in the position of the contact. The point of the blade C should be placed against the proximating tooth near the position of the contact point and the blade carried gingivally while continuing to hold its

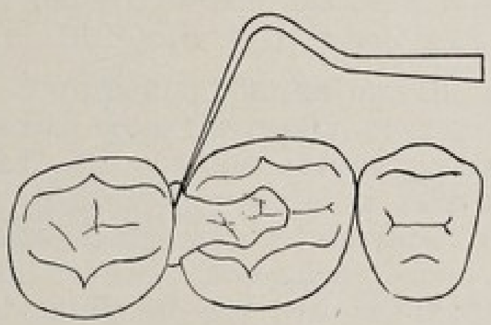


Fig. 476A.

Fig. 476B.

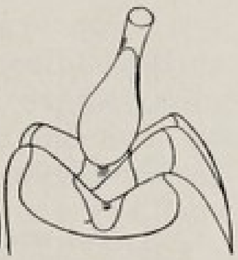


Fig. 476C

point against the proximating tooth. In this way the bulk of the wax is cut away without danger of removing too much and exposing the gingival margin. For subsequent trimming, a flat side of the blade should be held against the surface of the enamel and carried along the margin of the cavity with the end of the blade projecting into the wax. The final trimming of the wax at the margin of the gingival wall may be completed with the same instrument. The wax to the occlusal of the contact should next be trimmed to the form of the marginal ridge. Then a ligature should be passed from occlusal to gingival between the wax model and the proximating tooth, holding it hard against the surface of the proximating tooth to avoid the possibility of injuring the wax, particularly near the gingival margin. Finally a tracing cloth or silk strip should be passed between the teeth and moved slowly back and forth with light pressure to give proper contour to the proximal portion of the wax and insure close adaptation to the buccal, lingual and gingival margins.

The use of instrument C in trimming the wax pattern on a

proximal surface is illustrated in Figure 476A. For trimming the bulk of the excess wax from the occlusal surface, instrument D is used as shown in Figure 476B, and instrument E for carving the occlusal surface to proper form. See Figure 476C.

Attention is called to the order of carving a proximo-occlusal pattern: (1) the occlusal surface, except the wax near the contact point, (2) the buccal and lingual embrasure areas, keeping away from the contact, (3) the gingival area, (4) the contact and final smoothing of the proximal surface.

Care in trimming and polishing the wax pattern as nearly as possible to the exact form of the finished inlay, will save much time later in grinding the gold.

For proximo-incisal cavities, or mesio-inciso-distal cavities, the procedure of trimming the wax is much the same. Usually the lingual surface should be trimmed first, because there is more wax exposed on the lingual and, after this is trimmed, a finger may be

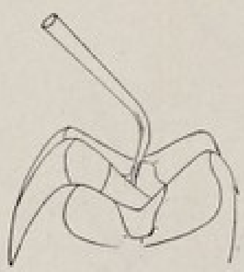


FIG. 477A.

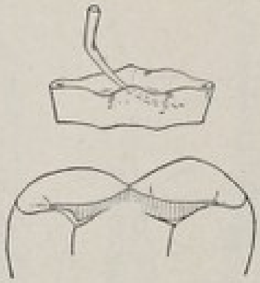


FIG. 477B.

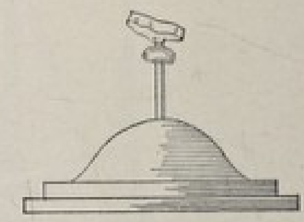


FIG. 477C.

held against the wax in this position while the remainder is trimmed. The trimming may proceed in the following order: the lingual embrasure, the incisal portion, the labial embrasure, the gingival portion, the contact, and finally the polishing with a tracing cloth strip.

During the entire process of trimming the wax to form, the debris should be frequently washed away with water at a temperature of about 102°, to avoid chilling the wax. When the wax pattern is finished, the mouth should be flooded with room temperature water. Then an exploring tine may be inserted in a convenient position and the pattern carefully removed. For simple occlusal cavities and for gingival third cavities, an exploring tine, having the end bent at approximately a right angle to the shaft, should be inserted near the center of the wax and the pattern carefully removed. For proximo-occlusal or proximo-incisal cavities, the explorer should be inserted near the contact point. For mesio-occluso-distal and mesio-inciso-distal cavities, some operators prefer to attach the sprue-wire to the wax before it is removed from the cavity. Others think there is less danger of distortion if the pattern is gradually teased out with an exploring tine, or witb

two tines, one inserted in the mesial portion, the other in the distal. The sprue-wire should be attached near the center of the occlusal or incisal portion.

In removing the wax from the cavity it should be noted that all of the margins of the wax pattern lift away from the cavity margins at the same moment, indicating the loosening of the entire mass of wax from the cavity walls without binding, which might cause distortion of the pattern. Many inlays do not fit, because the wax is improperly adapted to the cavity walls or because it is distorted in removing. Faulty cavity preparation, such as undercuts or walls which do not incline very slightly outward, may prevent the removal of the wax without distortion; or the step may be so shallow or so narrow that the bulk of the wax may be insufficient and therefore be bent or broken. If the cavity is found to be at fault, it must be corrected. But even with perfect cavity preparation, patterns may be distorted if carelessly handled.

Figure 477A shows the exploring tine inserted in an occlusal wax pattern, which has been removed from the cavity in Figure 477B. In Figure 477C it has been mounted on a sprue former.

THE SPRUE-FORMER may be attached to the wax before it is removed from the cavity, or should be attached immediately afterward. Its position should preferably be near the contact point for all proximo-occlusal or proximo-incisal cavities, and near the center of the occlusal surface for all occlusal and mesio-occluso-distal cavities. The sprue-former should be warmed in a gas flame by holding one end with the thumb and finger while the other end is placed in the flame. The former should be warmed only enough that it will melt a very small portion of the wax at the point where the wire is inserted slightly into the wax. By holding the former in the fingers while heating it, one is able to judge the temperature more accurately than if it is held in the pliers, and there will be less danger of heating it too hot. If the sprue-former is attached to the wax pattern while the latter is still in the cavity, the assistant may immediately chill the sprue-former and the melted wax about it with a pellet of cotton which has been dipped into room temperature water. In affixing the sprue-former to a pattern which has been removed with an explorer, it is a good plan to allow the pattern to lie in the hollow of the hand, where the margins will not be injured by the soft skin of the palm. The exact size of the sprue-former does not seem to matter particularly, although it should be from 14 to 18 gauge, and it should be remembered that the heavier formers will hold more heat and the danger of injuring the pattern is greater in proportion to the size of the former.

INVESTING AND CASTING. The sprue-former, with the pattern attached, should be placed on the sprue-base with the top of the wax pattern in such position that it will be about one-third the distance from the open end of the ring.

To prevent the gold from freezing in the mold when casting and causing a porous inlay, a reservoir should be provided by placing a ball of wax on the sprue very close to the wax pattern—within $\frac{1}{16}$ of an inch of it, and the connection between the pattern and the ball should be enlarged with wax if a small sprue-former is used. The wax ball should be approximately as large as the thickest portion of the pattern.

The pattern should be washed with equal parts of tincture of green soap and hydrogen peroxide to remove any blood or saliva that may be adhering to it, and then syringed with room temperature water. The pattern should be dry before it is invested. It should then be painted with an investment mix, which should be added little by little to enclose the pattern in a ball of investment. See Figure 478A.

The ring should be lined with asbestos to provide for setting and thermal expansion of the investment during the elimination of the wax. It should then be placed on the sprue-base.

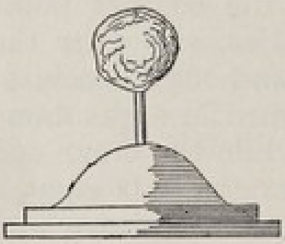


Fig. 478A.

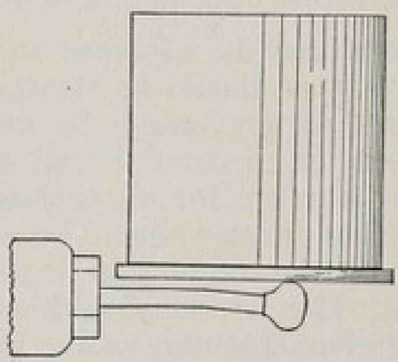


Fig. 478B.

Fig. 478C.

The main investment mix is made in a mechanical mixer and the pattern ring, or flask, is filled, and is vibrated by holding the base in contact with a bent shaft in the laboratory lathe, as illustrated in Figure 478B. It is then allowed to harden. The sprue-base and sprue-former are then removed and the flask is placed in the oven for the elimination of the wax. When the proper temperature has been reached, the cast is made at once. Figure 478C is a sectional view of the flask, with two gold ingots in place ready for casting.

The treatment of the wax, the elimination of the wax and the casting are considered in detail in the chapter on materials.

Finish and cementation. After casting the inlay, the surplus of gold is detached by cutting the stem close to the inlay. The cavity side should be examined with a hand lens for minute globules caused by possible bubbles in the investment. These may be cut away with a small fissure bur. The outer surface of the casting

should be polished. On the return of the patient it should be tried in the cavity. It will often require a little force to press it to place.

Occasionally a very slight undercut in the cavity wall will be reproduced in the gold and will require grinding before the inlay will go to place. If only the surface of the wax is chilled before removal, the pattern might be withdrawn without noticeable effort, notwithstanding the slight undercut, and the wax would regain the cavity form as a result of its elasticity. Sometimes the casting can not be completely seated in the cavity. This may be due to some obstruction within the cavity, to a globule or irregularity of the gold as a result of a defect in the investment, or to the distortion of the pattern in removing it. Unless the cause can be detected and corrected at once, a new pattern should be made.

If the inlay is for a proximo-occlusal cavity and the contact was cut away in the final preparation of the wax pattern, the inlay should go to place without making contact with the proximal tooth. It is important to look carefully to the contour of the occlusal and proximal surfaces, to build a proper contact, and be certain that all margins fit perfectly. One of the advantages offered by the inlay is the opportunity to be sure that all of these details are right before it is cemented to place and no circumstance should be permitted to induce one to cement an inlay that is not as perfect as it can be made. The honor of the professional man is often in the balance at this time. The line of least resistance is to cement an inlay which does not make a really good contact, or the gingival margin of which is not perfect, or the occlusal surface not of the very best form. In some cases only a few additional minutes are required to correct the contact or add to the occlusal contour; in others a defective margin requires that a new wax pattern and a new casting be made. It may be a matter of some embarrassment to the operator to acknowledge the imperfection of his work, but honesty and frankness will always be the best policy to pursue in such a case. The patient, not being able to judge the quality of the operation, must rely upon the honor and integrity of the professional man, and that confidence must not be abused. It should be realized that in a process involving so many details, each of which must be carried out with great exactness, there will be a percentage of error, which must be accepted by all parties.

CONTOUR AND CONTACT. The effort should always be made to secure the exact contour of the occlusal surface in preparing the wax pattern. However, a little grinding with stones or gold finishing burs will usually be required; in fact, it is to be desired in order to be certain that there is actual occlusion. The restoration of proper occlusal contour should have careful study in each case, remembering that a restoration which is either overfull or short may result in the shifting of one or more teeth in either arch, thus jeopardizing the gingivae and peridental membrane. Each inlay

should reproduce the normal occlusal surface for the particular mouth. The cusps, inclined planes and marginal ridges should correspond with those of neighboring teeth. Particular attention should be given to the forms and locations of marginal ridges, as these have much to do with the excursions of food through the embrasures and the maintenance of the best natural cleanliness of proximal surfaces. While the normal grooves of occlusal surfaces should be reproduced, it should be remembered that fissures are imperfections of enamel structure, which should not be reproduced. The aim should be to reproduce the normal rather than the abnormal tooth form, making due allowance for the wear as shown by the other teeth.

The contact should be made of 18k or 20k gold solder, and should be of well rounded, even convexity. This may be done over a Bunsen flame, the inlay being held in a pair of fine wire pliers. With inlays there is the fullest opportunity to restore proper contact and no time nor pains should be spared to make contacts of most perfect form. The contour of the adjoining surface of the proximating tooth should be observed and modified if conditions require. If that surface is not in good form it may be impossible to make a proper contact. It is a part of the dentist's obligation to correct malforms of the teeth and of previous operations, sometimes without mentioning this highly important service for the conservation of mouth health, and no such opportunity should be overlooked. The relation of the contact to the marginal ridge and to the contour of the proximal teeth should all be studiea. As the contact is formed, the inlay may be placed in the cavity and tests made with a ligature, as illustrated in Figure 337. Neighboring contacts should also be tested at the same time, as it will often be advantageous to make them tighter by increasing the mesio-distal diameter of the tooth in which the inlay is placed. The final test of the contact should be made after the contact point and neighboring area has been finally polished to be certain that too much has not been removed in polishing. Then the remainder of the outer surface of the inlay should be finally polished, except the margins. In case the gingival margin is not easily accessible, it should have its final polish before the inlay is cemented to place.

The contour of every surface of the inlay should be such that there will be no abrupt change in passing over any margin from the surface of the inlay to the surface of the tooth. Margins should be finished flush with tooth surfaces. Gingival margins should be critically inspected and made perfect before inlays are set. There can be no reasonable excuse for neglect of so important a matter.

It is extremely important, in proximo-occlusal restorations, that the full mesio-distal breadth of the tooth be restored; in fact, it is often desirable to increase the mesio-distal breadth slightly. It should be borne in mind that there is more or less wear of the proximal surfaces of the teeth, which may or may not be compen-

sated by the mesial movement of the teeth which maintains tight contacts. In every operation of placing a proximo-occlusal restoration, the neighboring contacts should be tested, and if they are not of normal tightness, they should be tightened by building out the proximal surface of the inlay. The contacts should be tested at the time the cavity is prepared, so that if separation is desired, a separator may be placed at that time and a base-plate gutta percha filling inserted, which will hold the space gained by the separator. If the gutta percha is left for three or four days before the inlay is set, it will not be necessary to employ a separator at the time when the inlay is cemented. It is also important to restore the full mesio-distal width of the interproximal space in each case. Sometimes slow separation will be necessary. The method of procedure is described in the section on the separation of the teeth in connection with the description of the illustrations of the Ferrier separators, Figures 501 to 504.

The proximal contour of bicuspids and molars should conform closely to the anatomical form of the tooth being inlayed. In general the occlusal third, more or less, is convex occluso-gingivally, while in the gingival portion there is often a distinct concavity. The reproduction of these details to a nicety makes the inlay serve better in the protection of the septal tissue. These proximal surfaces, as they near the buccal and lingual margins, should take the same general direction as the surfaces they approach.

Inlays in other positions require special studies of contours. Inlays will usually not be employed in proximal cavities in the incisors, or in gingival third cavities in either front or back teeth, except when cavities are large for the respective locations, and particular attention to contour is necessary for the best protection of the gingivae. Proper contacts for incisor proximal cavities and correct forms of both proximal and lingual surfaces are important in relation to the soft tissues. Inlays occupying gingival third positions should have the proper convexity in the occluso-gingival direction to give the best protection to the margins of the gingivae from the impact of food, and the gingival margins of these inlays should certainly be finished flush with the surface of the tooth to prevent irritation of the gum margins. The finish of the gingival margin should usually be completed before the inlay is set.

Cementation. The cavity must be absolutely dry when the inlay is cemented to place. This usually requires that the rubber dam be in place or that there be a competent assistant who will either maintain the dryness of the cavity or mix the cement while the operator attends to the cavity. The least lack of attention at this point may result in an early recurrence of decay and the occasional loss of a pulp; therefore, the procedure should be so planned that the cavity will certainly be absolutely dry, the cement mixed to the proper consistency and the inlay properly seated. All cavity walls and the entire cavity side of the inlay should be thoroughly

covered with cement. Pressure on the inlay should be maintained for several minutes until the cement has become fairly hard.

POLISHING. After a few minutes' delay the excess of cement may be removed. The margins should be finally finished with strips and discs. Care should be taken to rotate discs in the direction from the surface of the inlay over its margins.

Before the patient is dismissed the bite should be again tested to be certain there has been no error in the occlusal contour, and it is desirable to see the patient a few days later, when it will often be noted that a little further trimming is necessary.

RESTORATIONS WITH PORCELAIN INLAYS.

ILLUSTRATIONS: FIGURES 481-487.

Porcelain inlays should be used for restorations in a fair proportion of cavities in the front teeth by every dentist who has or will master the exacting technic of making them. This technic includes not only the making of an inlay that will fit the cavity, but also of obtaining the correct shade, in order that the porcelain will match the tooth so perfectly as to pass unnoticed. The porcelain inlay, to be successful from the esthetic standpoint, must be unseen. It must be practically perfect work. It is time consuming and the technic is in several respects more exacting than any other. It is therefore more expensive for the patient. These facts, coupled with the ease of manipulation and fine initial appearance of silicate cement, have resulted in the substitution of a material deficient in nearly all the desirable qualities for a permanent restoration, for porcelain, a material of proven reliability. There can be no question but that many dentists contributed to this change by their failure to explain to patients the hazard of the silicate cement. The time must come when the silicates will be sufficiently improved to entitle them to be listed with gold foil, amalgam and gold and porcelain inlays, otherwise the public will demand that these or other reliable materials be used. So many people have come to understand the value of their teeth in relation to health that they will not jeopardize both health and esthetic appearance in later years for the temporary advantage of better appearing teeth during a few years of early adult life.

A simplified technic for porcelain inlays is described after the technic of the standard porcelain inlays is presented. By this method, the use of a platinum matrix is obviated.

Whether or not a porcelain inlay will give a better appearance than a gold restoration in any particular case will depend upon the comparative neatness of the adaptation to esthetic conditions in the two cases. A gold restoration in view, always declares itself without question and is a decided blemish if not neatly done. When well done and in good form, it gives an expression of neatness and good taste that does much to obliterate the unesthetic sensation of

"a patch." On the other hand, a porcelain restoration that is ever so little out of form, or off color, or shows a dark cement line, so that it is noticed as something wrong, is a blemish undefined and questioned by every observer. Nothing violates esthetic principles more radically than this condition of question. It is for this reason, very largely, that the porcelain inlay is often contra-indicated in teeth from which the pulps have been removed. If the inlay be adjusted ever so nicely and the tooth becomes opaque later, the inlay will be off color and become a blemish that will usually be more objectionable than a gold restoration. When the pulp has been removed from a tooth and the root canal filled under favorable conditions, there should be no hesitancy about placing a porcelain inlay, for there should not be sufficient discoloration to be noticeable. If, however, a dead pulp has remained in a tooth or the root canal has been open to the saliva for some time, discoloration should be expected.

The dentist who desires to give his patients the best service should devote sufficient time to the study of porcelain manipulation to master the technic. He will then find the porcelain inlay a very satisfactory restorative material for selected cavities in positions which show prominently.

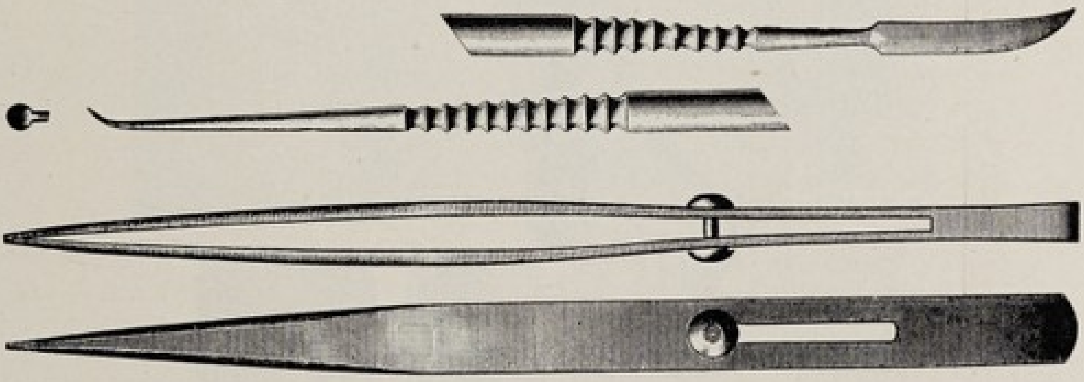


Fig. 481.

SELECTION OF CASES FOR PORCELAIN RESTORATIONS.

Porcelain restorations should be made for those cases most prominently demanding esthetic consideration. In cases in which gold restorations would show so much gold as to injure materially the facial expression of the individual, porcelain should be used. This may again be defined as any showing of gold that will attract prominently the attention of associates, or in public singers and speakers, the attention of an audience. For the most part these will be young adults or those not long past maturity, although they are not contra-indicated for older persons. In fact, they are likely to give longer service in the teeth of older persons, because, as a group, these enjoy a higher degree of immunity.

Dental porcelains, their composition, physical properties, manufacture, condensation, and firing are discussed in the chapter on

materials. They are classed as high, medium and low fusing, according to the temperatures at which they fuse.

Porcelain restorations are indicated in all positions in which the showing of gold is objectionable. This includes proximal and gingival third cavities in the upper incisors and cuspids, mesio-occlusal and gingival third cavities in upper bicuspids, and occasionally in first molars. More rarely, they should be selected for occlusal cavities in upper bicuspids and molars.

INSTRUMENTS AND APPLIANCES USED IN MAKING PORCELAIN RESTORATIONS. The principal instruments and appliances required consist of a carving instrument, an agate spatula for mixing the porcelain powder with water, a pair of locking tweezers to hold the matrix, a small camels-hair brush to place the porcelain in the matrix, a swager and an electric furnace. A pair of locking

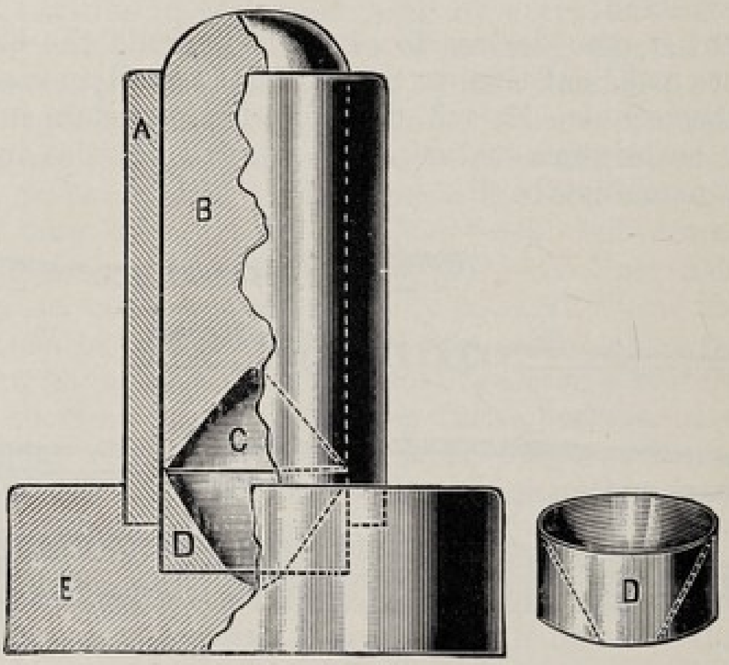


FIG. 482.

pliers is illustrated in Figure 481, also a carving instrument designed by Dr. O. M. LeCron. This instrument has a blade at one end, a discoid at the other, and the handle is so formed that it may be used as a vibrator. A recently designed swager is shown in Figure 482. The furnace should have a pyrometer attachment in order that the temperature may be regulated as desired. A small furnace, made especially for this work, should be used.

ESTHETIC REQUIREMENTS. It is important that the inlay shall have the proper translucence and color. Both are discussed in the chapter on materials. To facilitate the production of the varying shades of color of the natural teeth porcelain bodies are available in a variety of shades. The tooth operated upon and those in the immediate neighborhood should be carefully cleaned as a first step

and the translucence and color carefully examined, compared with specimens of porcelain made from the bodies at the operator's command, and the color and gradations for translucence determined. This should be done prior to the completion of the preparation of the cavity. The effort should be made to copy in the porcelain the appearance of the clean moist tooth. One of the principal points in obtaining the proper translucence is to use the more opaque color first, bake or biscuit this separately, then add the more translucent colors in one or more layers. This plan of building up the inlay is found to be of great importance in obtaining esthetic effects, and will do much to hide the effects of the opaque cement, which must be used later to fix the inlay in position. Often a prepared inlay will appear as perfection itself when laid in the cavity without cement, but when cemented in place will look very badly because the opaque cement shows through the porcelain and completely changes its tone of color and translucence. In this regard much may be accomplished by a judicious arrangement of the cavity walls and margins, especially by such an arrangement as will place the edge of the cement line toward the observer.

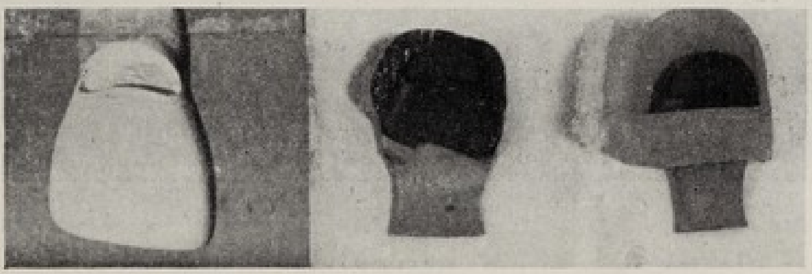


FIG. 483A. FIG. 483B. FIG. 483C.

THE PREPARED CAVITY. The cavity, in whatever position, must be so prepared that all surrounding walls are inclined outward, and it must be possible to withdraw an impression that overlaps the enamel sufficiently about all margins to permit the making of a model which will reproduce at least a little of the adjacent surface contours. This requirement calls for critical study of the conditions presenting in proximal cavities in incisors, remembering that from the esthetic point of view, the labio-proximal angle is the position for the labial margin.

The taking of the impression is simplified in cases in which decays are discovered very early, so that the labial wall of the cavity may be so prepared that its margin is very slightly to the labial of the contact. Such a preparation violates slightly the rules of extension for prevention, but in well selected cases the esthetic result is good.

IMPRESSION AND MODEL OF THE PREPARED CAVITY. The taking of the impression and other steps in the technic will be illustrated

with photographic reproductions of a cavity in the gingival third of the upper central incisor,* illustrated in Figure 483A.

An impression of the cavity may be taken in modeling compound or hard wax by coating the walls with vaseline or flooding the cavity with water and glycerin to prevent the compound from sticking. Thin pieces of rather stiff steel may be bent in any desired shape to carry the wax or compound to the cavity. This acts as a matrix, with which pressure is applied to insure the adaptation of the impression material against the walls and margins of the cavity, while it is in a softened state. The impression may be removed in very perfect condition if well chilled.

The impression is shown in Figure 483B. It is boxed in with a thin sheet of wax, as shown in Figure 483C. This boxing is to be filled with amalgam. However, to use sufficient pressure in condensing the amalgam, the wax box must be supported. This is

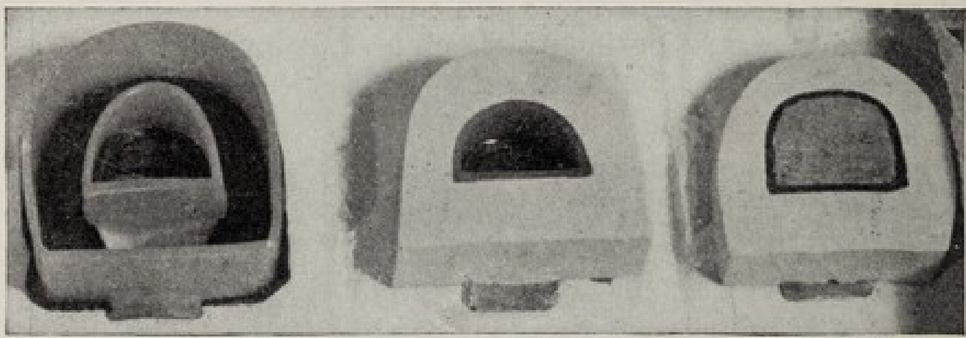


FIG. 484A. FIG. 484B. FIG. 484C.

accomplished by a second and larger wax boxing, shown in Figure 484A, which is filled with hard plaster. The outer wax is then removed, Figure 484B, and amalgam is condensed into the smaller box, thus securing a model, Figure 484C, which is an exact reproduction of the cavity, as shown in Figure 485A, where it is mounted in a metal cup of the swaging device, illustrated in Figure 482.

THE PLATINUM MATRIX. A piece of .001 platinum foil is annealed and placed over the model. It should be burnished to the approximate form of the model with hard rolled cotton pellets held in a pair of blunt end tweezers, and with hand burnishers. Every effort should be made to prevent folds in the platinum, particularly near the margins, and frequent annealing will be helpful. Platinum may be cold welded by burnishing, much the same as gold, so that folds not involving margins may be thoroughly burnished. The cup, with the model and partly prepared matrix, is then placed in the swager. The receptacle in the plunger of the swager is filled with unvulcanized rubber and two or three blows on the plunger should be sufficient to swage a perfect matrix. Before the porce-

* Models prepared by Dr. Loren D. Sayre.

lain is applied for the last baking, the matrix should be returned to the amalgam die and again placed in the swager to correct the fit of the matrix in case it may have drawn slightly away from the margins in the previous bakings. The swaged matrix is shown in Figure 485B.

Before the matrix is removed from the amalgam die, the "cavity" is filled with sticky wax, which is also flowed over the entire piece of platinum, so there will be no danger of distortion in removing it with the locking pliers. It is then invested in a high heat casting investment to prevent distortion while baking the porcelain. See Figure 485C.

CONDENSATION OF PORCELAIN. The powdered body is first mixed with water to form a creamy paste of even consistence, using an agate spatula in preference to a steel spatula in order to avoid discoloration of the fused porcelain. The porcelain should be kept wet at all times, air bubbles must be completely removed, and the work kept spotlessly clean. The slightest foreign particle may ruin the appearance of the restoration.

FIG. 485A. FIG. 485B. FIG. 485C.

A porcelain which fuses at about 1800° is recommended, in order that the refractory material, which duplicates the mold into which the matrix was swaged, may be placed in the oven when the porcelain is baked.

The porcelain may be condensed into the matrix by several methods. The aim is to get the mass of porcelain powder as closely packed as possible. The majority of operators apply the wet mix to the matrix with a brush and add a little dry powder to bring the excess water out by capillary attraction. Or, the matrix may be vibrated by rubbing the rough portion of the handle of the carving instrument crosswise of the tweezers which hold the matrix. The excess of water should be removed with a piece of blotting paper or a clean towel. The vibrating process is very important in the matter of gaining solid, strong porcelain, and in preventing shrinkage in baking. Its object is to obtain the greatest possible solidity of the body. This should be repeated until no more water will come to the surface. In this way enough of the body is placed for the first layer and then fired.

FIRING THE PORCELAIN. Porcelain body is a very poor heat conductor and therefore too rapid heating is to be avoided. In firing inlays of considerable size, the first porcelain placed in the matrix should fuse at a considerably higher temperature than that baked on subsequently. The shrinkage of porcelain is so great that each case must be fired several times. Before the first firing, a number of crosswise cuts should be made with the carving instruments, as shown in Figure 486A. This illustration was made after the first bake and shows considerable shrinkage of the porcelain. However, the shrinkage has occurred within each of the little cubes, leaving the porcelain attached to the matrix in the position of the surrounding walls. The porcelain has also shrunk in depth, its surface being below the desired contour. For all bakes, except the last, the temperature should be kept below the point of vitrification of the particular porcelain body that is used.

For the second bake, additional porcelain should be vibrated into all the crevices and the contour should be overbuilt sufficiently to allow for shrinkage. Figure 486B shows the case after the sec-

FIG. 486A. FIG. 486B. FIG. 486C.

ond bake. One or two additional bakes may be required to obtain the right contour. Additional porcelain should be placed to fill in all minor deficiencies and the final bake should be made, carrying the temperature to the proper heat for glazing, as shown in Figure 486C.

SETTING THE INLAY. When the inlay has been completed, the platinum matrix is stripped off. Generally this may be pulled away with the pliers. If the last traces of it can not be removed by picking it away, it may readily be removed by placing it in aqua regia and heating a little.

The inlay should now be placed in the cavity and closely examined to see that the fit and color are satisfactory. The method of handling the inlay deserves some attention. It may be taken up in a pair of light tweezers and placed in the cavity, or it may be stuck to the end of some instrument with a little sticky wax. Whatever the arrangement, the handling should be done very lightly and accurately, for there is considerable danger of chipping either the sharp margins of the inlay or the equally sharp margins of the cavity. Both are very hard and also very brittle. The inlay is to

be secured in the cavity by cementing with one of the zinc phosphate cements.

As the inlay is held in position by the adhesion of the cement, this may be increased by etching all of that portion of its surface that is to lie in contact with the walls of the cavity. This roughens the surface slightly so that the cement has a better hold. This is readily done by covering with wax to protect that which is to be the exposed surface of the inlay when set, and exposing the rest of its surface to the action of hydrofluoric acid for a minute or more; then washing with ammonia, followed by water. The wax may be dissolved away with chloroform. Slight undercutting of the dentin walls may serve to strengthen the hold of the cement.

When all arrangements for handling the restoration in setting have been made, the cement should be mixed to a creamy consistence and spatulated until it is very smooth and evenly mixed. Then a very small amount should be taken on the point of a spatula and placed in the cavity and so worked about, either with this or a smaller instrument, that it is seen to take to every part of the cavity walls and displace all air bubbles. In the same way the under surface of the inlay should be covered. A small, flat end toothpick makes an excellent spatula for this purpose. The cavity should be filled sufficiently to insure that, in the introduction of the inlay, no air will be included between it and the cement at any point.

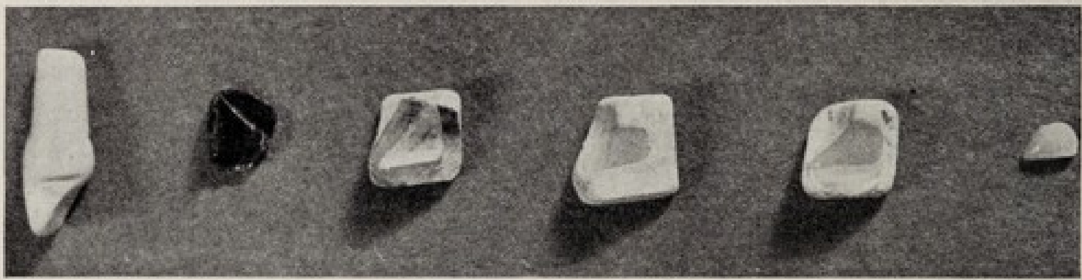
The inlay should then be placed in the cavity, displacing the superfluous cement by pressure. This is best done by light sidewise and in-and-out movements, pressing the inlay gradually deeper into the cavity until the inlay has settled firmly into place. The adhesion of the cement to both the inlay and the cavity wall will be much increased by this vibratory motion. Then a very considerable pressure should be made and some of the redundant cement removed from about the margins to see that the inlay has gone properly to place. This pressure should now be kept up for some minutes until the cement has firmly set. Generally it will be seen that more and more cement is gradually oozing from the margins, so that really the inlay is sinking into the cavity, thinning out the cement between it and the cavity walls. If the pressure is removed too quickly, and a margin closely watched with a hand magnifier, it can usually be seen that the inlay rises just a little out from its bed; hence this sustained pressure is important. This pressure should not be with steel instruments, for these are too liable to chip the inlay, especially if any slip should occur. A wood point is best for the purpose.

When the cement has become fully hard, the redundant cement should be removed and the operation is completed. It should, however, be protected from saliva by keeping the rubber dam in place for some minutes longer, in order that the cement may become as hard as possible.

TECHNIC FOR PORCELAIN INLAYS WITHOUT PLATINUM MATRIX.

Low fusing porcelain may be fired directly in a model of the cavity, made of a refractory material which will withstand sufficient heat without shrinkage or expansion. Recently such materials have been used successfully for porcelains that fuse at about 1800° F. and lower. These materials have not passed through a sufficient period of experimentation to justify their general use, but there is so great need for a simplified method of making porcelain restorations for the front teeth, that the technic is briefly stated for the particular purpose of stimulating further experimentation.

The cavity preparation must be such that an accurate impression can be secured; one that very clearly outlines all of the margins of the cavity and a little of the surface contours of the tooth. See Figure 487A. Cavities should be prepared with cavo-surface angles at as nearly right angles as is possible, with no bevel of the margins. This is to prevent fragile margins of porcelain which are apt



A. B. C. D. E. F.

FIG. 487.

to fracture during handling and setting, also to prevent thin edges of porcelain through which the cement would reflect. For esthetic reasons, the labial margins of cavities should be kept as near to the mesio-labial or disto-labial angles of the anterior teeth as is possible.

The impression, Figure 487B, is secured either in inlay wax or modeling compound. Into this the refractory investment material, mixed as stiff as can be handled, is packed or vibrated and allowed to crystallize. The impression material is then removed by heat, leaving an accurate copy of the cavity in the investment. Figure 487C.

The investment is coated with collodion up to the margins of the cavity and allowed to dry. This prevents the brush, with which the porcelain is applied, from disturbing the refractory material. Otherwise a fine powder might be brushed from the surface. The entire investment is then soaked with water to prevent the moisture of the porcelain mix from being absorbed out. Into this soaked investment is placed the porcelain mix of correct shade in a thin layer entirely over the floor and walls of the cavity, but not over

the margins. This is cut with a thin, sharp lancet to permit shrinkage to a number of centers. Care must be exercised in applying the final porcelain mix not to carry any of the porcelain over the margins, but terminate it exactly flush.

The investment containing the porcelain is dried out before the oven door, then placed inside and brought up to a temperature that will produce a biscuit bake. When it has cooled down, the investment is again soaked in water and porcelain is again added, building up to full contour, as shown in Figure 487D and again fired to a biscuit bake. The same procedure is repeated as often as necessary, depending on the bulk of the inlay, until the final glaze is given, Figure 487E. The investment is then removed and the inlay washed ready to cement to place. See Figure 487F. The steps in the technic from which these illustrations were made were prepared by Dr. Loren D. Sayre.

RESTORATIONS WITH THE CEMENTS.

ILLUSTRATION: FIGURE 491.

Zinc phosphate, copper and silicate cements are available for dental operations. Copper cements are composed of zinc phosphate with the addition of a black, red or white salt of copper. These two cements behave much alike. The exact composition of silicate cements is known only to the manufacturers. The cements are received from the dealer in two separate bottles, one containing the phosphate of zinc or other powder, the other a liquid containing mainly orthophosphoric acid. In use a small portion of the powder is placed upon a porcelain or glass slab and a drop or two of fluid is placed beside it. The powder is drawn into the liquid a little at a time and the two are thoroughly mixed by rubbing them together with a spatula.

As yet there has been insufficient study of the physical properties of these cements. The formulae are kept secret by the manufacturers. However, investigations are now under way by the Bureau of Standards with the expectation that reliable specifications will be set up in the near future. The dentist should use only those cements which meet the specifications of the American Dental Association. The composition, physical properties and biologic aspects of dental cements are discussed in the chapter on materials. They are all alike in four respects: they shrink; they are soluble in the fluids of the mouth; they must be kept dry until they set; and they must be kept continuously wet after they set. There is no dental cement that is hydraulic.

USE OF THE CEMENTS.

The zinc phosphate cements are used for setting crowns and bridges, for temporary restorations, and for preserving for a time teeth that are very badly broken down, or in other conditions which

seem to render the use of metallic restorations or inlays undesirable at the time. They may also be used for temporary restorations in cases of very sensitive dentin for the purpose of allaying the extreme sensitiveness, which is generally found to disappear, in large part at least, within a few weeks or months. They should be used for temporary restorations in cases of hyperemia of the dental pulp, for the reason that their conductivity of thermal impressions is less than that of the metals, though in this respect gutta-percha is to be preferred; also they may be used in capping exposed pulps.

These cements are also much used for sealing treatments in pulp chambers and root canals. This use of the cements is not recommended. They do not perfectly exclude moisture, and in sealing treatments the perfect exclusion of moisture is of first importance. Gutta-percha is much better for this purpose for the reasons, first, that it is impermeable to fluids and moisture-tight fillings can be made with it; second, it is much more easily removed from the cavity in opening it for changing the applications. It is very painful to cut out a cement filling when the peridental membrane of the tooth is sore, while gutta-percha may be softened by a heated burnisher and removed with very little pain.

Copper cement, particularly the black variety, is used soon after the eruption of both the temporary molars and the permanent molars and bicuspids, as a protective treatment, without cavity preparation, for non-carious pits or fissures, to carry them along until such time as permanent operations may be made. It may be used following the opening of the defects with a bur, but without cutting of consequence into the dentin, as would be required for a metal restoration; or, copper cement may be used temporarily with more nearly complete preparation, particularly for children who are too young or too difficult to control. Copper cements are also used for adults in gingival third cavities in second and third molars and occlusal cavities in third molars in cases in which it would be very difficult or impossible to make a satisfactory metallic restoration.

The silicate cements have been extensively used in recent years as substitutes for porcelain or gold foil for restorations in the anterior teeth, because of their splendid initial appearance. Both the color and to a considerable extent the translucency of the teeth can be closely matched. In fact, in many cases, even the dentist will have difficulty in discovering recent restorations. The color harmony is so perfect that the patient is delighted. Unfortunately, these cements are deficient in practically all other desirable qualities for a permanent restoration and much actual harm to the teeth, followed by pulp involvements and their sequellae in the form of localized and systemic infection, are the price that must be paid by the patient for the better appearance of the teeth, usually over a comparatively brief period.

A review of the properties which an ideal cement should possess, in the chapter on materials, closes with the statement that "there is no cement at the present time which even approximately meets these requirements."

INSTRUMENTS. A variety of spatulas are available for the purpose of incorporating the powder with the liquid on a glass or porcelain slab. Other instruments are used to place the cement in the cavity and condense it. Some of these should be in the form of thin flat blades, others similar to amalgam condensers with a round end, having a flat face. Steel instruments may be used for the zinc phosphate and copper cements, but not for the silicate cements. For the latter, instruments of agate or of a metal which will not affect the chemical properties of the cement and result in discolora-

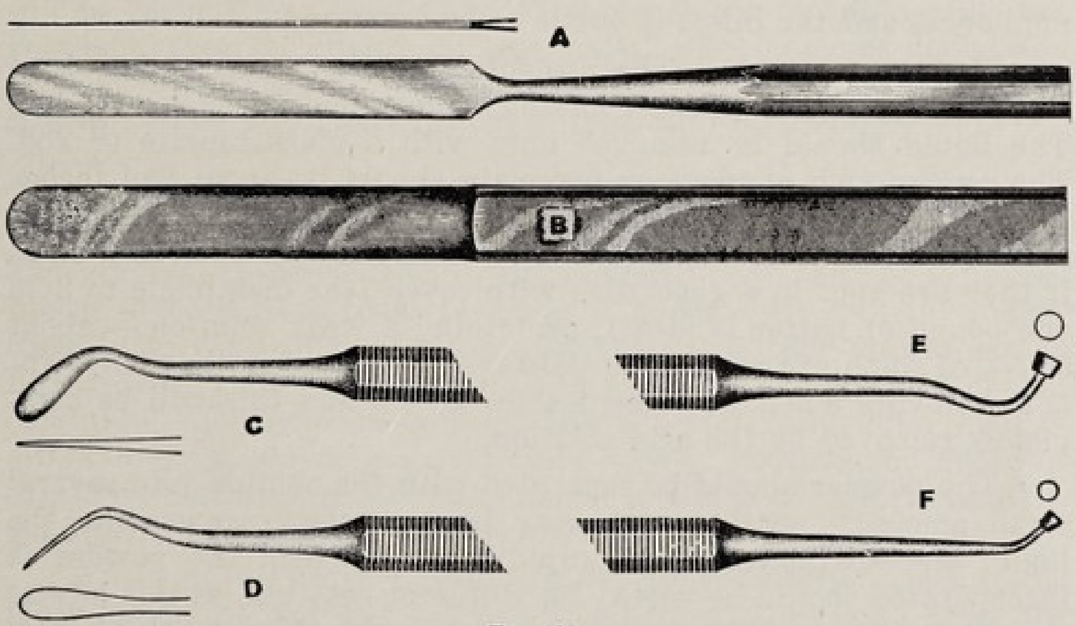


FIG. 491.

tion are required. Several instruments are illustrated in Figure 491; A is a metal spatula, B is an agate spatula, C and D are condensers with flattened blades, E and F are round, flat faced condensers.

TECHNIC OF MANIPULATION. Everything should be in readiness to the last detail before the mixing of the cement is begun. Whatever the operation, the cavity walls should be thoroughly dry, without dehydrating the dentin. The tooth structure to which the cement is to be applied should be maintained in a dry state for several minutes after the application of several cotton pellets. This can certainly be done in the large majority of cases only by applying the rubber dam. Thorough dryness insures better adhesion and a harder set. The recurrence of decay at the gingival margins of proximal inlay restorations is doubtless due, in many cases, to the presence of the least bit of moisture when the inlay

was set. The dentist who operates without an assistant should use the rubber dam in many cases in which the dentist who employs an assistant need not do so. In the latter case, the dentist may devote his entire attention to the field of operation while the assistant mixes the cement. However, an assistant should not be expected to mix cement properly without special training.

There are a number of devices which may be used instead of the rubber dam in special cases, such as bow attachments to clamps and special spring clamps with a plate to go under the chin, for holding rolls of gauze or cotton on both sides of several lower teeth; some also have tongue holders. However none of these give the assurance of certain dryness as does the rubber dam, which, among other things, causes the patient to breathe through the nose.

All instruments should be laid out in order, also all accessory appliances and the inlay, if one is to be cemented.

MIXING CEMENTS. The cement liquid bottle should be kept tightly stoppered to prevent loss of water, which prolongs the set. The liquid should be removed only with a glass pipette or rod. The cement slab of glass or porcelain should be about 2x4 inches in size, and should be scrupulously clean and dry when the powder and liquid are placed upon it. The slabs may be assuredly clean if they are kept in a glass dish with cover (the dish made to hold one pound of butter is ideal), containing a weak solution — about 5% — of sulphuric acid. The slabs may be placed in the dish without removing adherent cement after a mix and this will be completely removed by the acid solution.

The powder should be separated with the spatula into several small amounts, so that each may be separately drawn into the liquid and spatulated. The rapidity with which the powder is incorporated should be varied for different cements, as this affects the setting time. The faster the powder is added to the liquid, the quicker will it set. A thick mix sets faster than a thin mix. Prolonged spatulation slows the setting.

The zinc phosphate cements should be mixed to a thinner consistency for setting inlays than for cement restorations. For nonconductors in cavities in which the dentin is very sensitive, a much stiffer mix should be used as it will cause less pain. The black copper cement calls for the most perfect timing if the restorations are well made. A difference of a few seconds in placing this cement in a cavity may mean its success or failure. It should be mixed to that consistency which will allow only sufficient time to place it in the cavity and press it firmly against all walls before it begins to lose its plasticity. There should be just time enough to remove the bulk of the excess material with the condensing instrument. This cement maintains a smooth, lustrous surface at all times, although it is gradually dissolved by the saliva as are the other cements.

In mixing and condensing silicate cements, spatulas and other instruments that come in contact with the material should be of agate or of special metal which will not so affect the cement as to cause a change of color. The powder should be incorporated with the liquid more rapidly than in the case of the zinc phosphate cements to hasten the setting time. It should be spatulated until it is inclined to draw slightly away from the slab as the instrument passes over it. It should then be compressed into the cavity and pressure should be applied for several minutes. A strip of very thin celluloid may be used to maintain the pressure. This should be so trimmed in advance as to shape, that the cement may be formed to as near the desired surface contour as is possible. As the cement hardens a gel begins to form, which should not be disturbed. Movement of the mass at this time may be disastrous to the restoration. After the silicate cement is thoroughly set, it must thereafter always be kept moist. If it becomes dry at any time, it will contract. This is a contra-indication for the use of silicate cements for restorations for mouth breathers.

USE OF SILICATE CEMENTS.

Silicate cements are used mostly for restorations in proximal and gingival third cavities in the anterior teeth, and to a limited extent in occlusal cavities in molars. Since their esthetic quality constitutes the principal reason for their use, they appear not to be indicated for occlusal restorations, notwithstanding the fact that conditions are favorable for making a better restoration than in either a proximal or gingival third cavity, because the operator can more certainly press the material to the desired form and the gel need not be disturbed by trimming.

The gingival third position in the upper anterior teeth is the most logical of any for the use of silicates; this is so from the esthetic point of view, in the opportunity afforded to place the cement with sustained pressure, and because it will be free from wear against opposing teeth. The most perfect precautions should be taken for dryness of the field. The preparations should occasionally include the injection of a drop or two of procain into the gingiva so that it can be painlessly held away by a Hatch clamp, or other similar instrument. If practicable, a millimeter of the enamel beyond the gingival wall should be in view in order that the cement can be well adapted to that margin. When the cavity is prepared, it may be filled with inlay wax, which should be trimmed to proper contour and moistened with cocoa butter. A modeling compound impression should then be made of the labial surface of the tooth. The wax may then be removed and the silicate cement should be pressed into all parts of the cavity, with only a slight excess at the surface. The modeling compound impression should then be replaced and heavy pressure maintained until the cement has set. An ordinary pen point may be used as a convenient tray

for the modeling compound, as described in the clinical treatment of cavities of this type during the young adult period, on page 241, in Volume III. Very little trimming should be required about the margins. After waiting a few minutes, a varnish should be applied to keep the restoration dry for about twenty-four hours, until it is thoroughly hard.

Proximal cavities in the upper anterior teeth constitute the largest group for which esthetic considerations are fully satisfied only with a material that will not be noticed. It is largely for this reason that silicate restorations have been extensively used. The cavities should be prepared with the same care as for gold foil or porcelain, and with better anchorage. Outline form should generally be limited rather closely to the area involved by decay, and the rules of extension for prevention should not be followed, except for slight extensions of the labio-gingival and linguo-gingival angles. If the enamel forming the contact point has not been undermined by decay, it should not be cut away, as it will maintain a better contact than the cement. The enamel margins should be as strong as they may be in consideration of rod directions and the recognized weakness of silicates in edge strength. The gradual washing out of the material must be anticipated in preparing the enamel margins. The rubber dam should be applied and it is usually desirable to secure at least a little separation in order to establish a good contact in both form and tightness.

Sufficient separation can usually be gained by twisting a one-inch wide strip of rubber dam, forcing it between the teeth at the position of the contact and allowing it to remain for a few minutes. After the rubber dam is in place and before the cavity is prepared, a piece of modeling compound or gutta-percha should be pressed against the lingual surfaces of the two teeth on either side of interproximal space where the restoration is to be made. If the cavity has already involved the enamel of the lingual marginal ridge, so that a portion of it is broken away, gutta-percha should be placed in the cavity to restore the lingual contour. The surface of the gutta-percha should then be lightly coated with cocoa butter, before the lingual impression is made. The gutta-percha is then removed from the cavity of decay and it should be prepared for the silicate restoration. A celluloid strip should be placed in the interproximal space with one end turned back over the lingual surface of the tooth in which the silicate restoration is to be placed. The gutta-percha or modeling compound impression of the lingual surfaces is replaced and it serves to hold the strip in exact contact with the enamel along the lingual enamel margins of the prepared cavity. After the silicate is pressed to place, the labial end of the celluloid strip is drawn tightly over the labial enamel and pressure maintained on the labial surface, while the modeling compound is held firmly against the lingual surface. If the cavity is small, this technic will answer very well. If the cavity is large, and extends

a little distance to the incisal of the contact, it is generally impossible to hold the strip in close adaptation to gingival, lingual and labial margins, and also keep it close at the incisal. A better plan, in such cases is first to place a Ferrier separator, then the celluloid strip and pack base plate gutta-percha over the strip and under the separator bows on the lingual surfaces of the two teeth to which the separator is applied. The separator will thus serve to hold the gutta-percha tightly against the lingual surface. When the silicate is placed, pressure may be made on the labial side with a finger of the left hand, while the strip is held against the proximal surface of the enamel at the incisal margin of the cavity with a flat instrument in the right hand.

In following either of the above plans, a first small globule of cement is pressed into the deepest part of the cavity in the direction of the axial wall, then a second mass of the cement, somewhat in excess of the amount required, is pressed into the cavity. After it has been forced against the celluloid to the lingual, to be certain that the lingual margin will be fully covered, the labial end of the strip is drawn tight and heavy pressure is made from the labial as just described.

The best effort should be made in each case to compress the silicate to the proper contour, with every margin exactly even with the surface of the enamel and maintain pressure until the initial set of the material. However, it nearly always happens that an excess remains in one or more positions.

After the cement has had sufficient time to set, the impression material on the lingual should be removed, also the separator if one has been used, and the celluloid strip. Any excess of the cement should then be removed, and the restoration should be covered with varnish.

It is a matter of common observation that the enamel tc the incisal of these restorations frequently becomes discolored, and subsequently breaks away. This may be due to shrinkage of the silicate or lack of sufficient condensation, either of which invite decay of the dentin which supports the incisal angle. This calls for especial care in the condensation of the material in this position, even though the shrinkage may not be prevented.

Whenever it becomes necessary to replace a restoration made of silicate cement, every particle of the previous restoration should be removed from the cavity, to be certain whether there may have been some disintegration of the tooth structure of the cavity walls, and to prevent dehydration of the new cement.

The greatest use of silicate cement has been for proximal restorations in upper anterior teeth, and it is in this group that the highest percentage of failures have resulted, doubtless due to a number of causes: Cavities have generally been less carefully prepared than for gold or porcelain, too often enamel walls are left without dentin to support them. It is difficult to maintain pressure

from both the labial and lingual directions and at the same time keep the cement in contact with the proximal tooth. As a rule a little of the proper contact tension of these teeth is lost with each operation, as compared with the easy opportunity to increase that tension slightly with porcelain or gold. These restorations usually wash out and therefore do not maintain contacts, violating one of the most important rules for proximal restorations, that they should give this protection to the septal gingivae and prevent the possible eventual loss of the teeth themselves.

It can not be said with justification that the above criticism is of a few careless operators. Doubtless some have been more careless than others and without question many have been very conscientious in making good cavity preparations and in every other detail. The statement is a judgment formed after careful observation of restorations with this material by the profession as a whole, as nearly as that may be done by one person.

The use of silicate cements has been a gamble in which the beautiful first appearance of the restorations has been the alluring element to both the dentist and his patient. As in most other gambles, one is led along to eventual disaster. Certainly the most unfortunate persons are among those who have visited their dentists regularly and who, jointly with their dentists have been conscientious in the effort and desire to preserve their teeth. For these persons, now of middle age, a succession of silicate cement restorations have been placed in the upper anterior teeth over a period of years, and they are approaching the time when porcelain jacket crowns are to eradicate the blemish of those years during which the pulps from several teeth have probably been lost.

Finally, from the esthetic viewpoint, may this individual be compared with a person of the same age whose dentist, a little more far seeing than most others, may have discussed with him or her fifteen or more years ago, the respective merits of gold foil and silicate cements. It was then agreed that the preservation of the teeth, by the use of the smallest possible gold foil restorations was preferable to the better immediate appearance of silicate cements, and the possible gradual destruction of the crowns of the teeth. Today this individual has the prospect of keeping his teeth throughout his life time, and his mouth has been much better from the esthetic viewpoint if considered for the period of years, as compared with the one who gambled with silicates.

The dentist who has used silicate cements most conscientiously, following the manufacturer's instructions with the greatest care, and has kept accurate records of the necessary replacements due to discolorations of the material, to recurrence of caries on account of shrinkage, or to the washing out of the material with loss of contact of the teeth and gingival inflammation, has been forced to the opinion that the ideals of practice in the conservation of the teeth demand a rational limitation in the use of silicate cements

until decided improvements are made in their physical properties and methods of manipulation. The profession is only now beginning to extricate itself from its very embarrassing position of having used this material for a quarter of a century without scientific knowledge of its properties.

In view of the studies now in progress at the Bureau of Standards, and by a number of our dental colleges, it is to be hoped that the silicate cements may be so improved as to justify their extensive use. The fact that a limited number of restorations made with this material have stood up well for many years suggests that coördinated studies of its physical properties, the conditions under which it is used as to temperature, humidity, etc., and its manipulation by the dentist, should result in much improvement.

RESTORATIONS WITH GUTTA-PERCHA.

ILLUSTRATION: FIGURE 496.

Gutta-percha is used for various purposes in operative dentistry. The best forms for this purpose are the ordinary base-plate gutta-percha. However, a multitude of special preparations of this material are in the market. None of these are superior to the ordinary base-plate, and generally they are very inferior. Many of them seem to be mixtures of gutta-percha and wax that soften very readily by heat. These are especially to be avoided.

Base plate gutta-percha is an excellent material for root canal fillings, for sealing treatments in root canals, and for most of the temporary restorations used in connection with treatment cases. Under certain conditions it is occasionally used for more or less permanent restorations in cavities in the teeth, particularly for old people in large gingival third cavities, which extend below the cemental line.

Gutta-percha is also very useful in the treatment of sensitive dentin, and in cavities of teeth with hyperemia of the pulp. It is tolerated in both these conditions better than any other material, and, if well put in, will generally stand long enough to accomplish good results. It must be made to adhere to the walls of the cavity, otherwise it is liable, on account of its softness, to slight movement in the cavity and to admit moisture. In that case the condition, especially of sensitive dentin, is liable to be made worse instead of better.

TECHNIC OF RESTORATIONS WITH GUTTA-PERCHA.

INSTRUMENTS AND THEIR USES. Three burnishers are illustrated in Figure 496. These burnishers and the amalgam and cement condensers are the instruments used in making restorations with gutta-percha. Two beaver-tail burnishers are desirable, as one should be used cold for packing, the other hot for trimming. The egg shaped burnisher may be used in contouring occlusal surfaces. The other instruments are all used for packing.

Facility in making good restorations with gutta-percha depends very largely on the skillful use of the hot beaver-tail burnisher. This instrument should be so hot that it would cause pain if it were pressed into the mass of material in the cavity. When it is hot, the excess of gutta-percha may be easily removed painlessly with a quick stroke. Its heat permits one to cut the excess away so quickly that the bulk of the restoration is not heated. If the instrument is not sufficiently hot, it will drag in the gutta-percha and possibly dislodge it.

In making restorations with gutta-percha, the cavity should be prepared almost as for gold or amalgam, and should be made strongly retentive. When otherwise ready, every portion of the cavity walls should be slightly moistened with eucalyptol or oil of cajuput. These oils take strongly to the cavity walls and also dissolve slightly the surface of the gutta-percha. The oil then diffuses through the mass of the gutta-percha and is lost, apparently, leaving the gutta-percha adhering firmly to the cavity walls. An excess of the oil is likely to soften the whole mass of the gutta-percha.

The gutta-percha should be prepared by gently warming it over the flame, or upon a warm tray. Care should be had not to heat the gutta-percha too hot. This will develop an inordinate stickiness of the mass and it will not again become fully hard; the quality of the material is permanently injured.

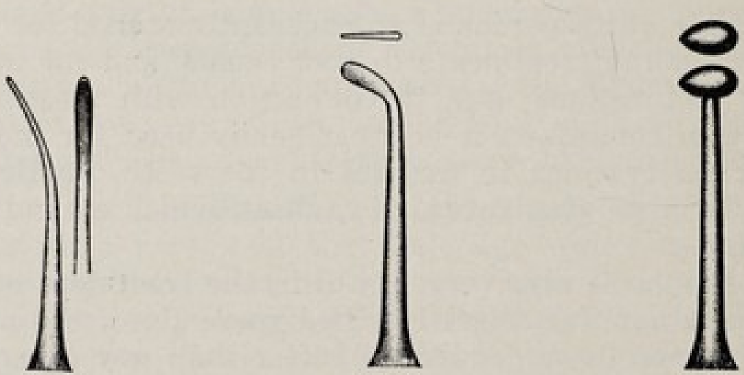


Fig. 496.

When it is made just plastic by heat, it should be conveyed to the cavity in small pieces and packed into the most convenient angle or wall of the cavity, piece by piece, sticking the warm pieces to the mass in the cavity with a considerable pressure, and condensing well against all walls and margins. One should use little more of the material than will just fill the cavity, so that very little will need to be trimmed away. If, however, a surpus has been added, a small flat burnisher should be heated sufficiently to soften quickly the gutta-percha upon contact, and cut away the surplus. A cold burnisher should then be used to readjust the margins against the cavity walls. The finish should generally be made entirely with the burnisher. By waiting until the restoration is hard, it may be trimmed with a quick movement of a hot burnisher. This is the

best instrument for removing overlaps and making a good finish of margins.

Another plan of placing a gutta-percha restoration, especially in cavities of easy access, is to form a mass that will just fill the cavity and warm it only sufficiently to obtain the necessary plasticity, and insert it in one piece, condensing with a broad, cold instrument, finishing afterward as before described.

Much experience is required to handle gutta-percha well, but when once the manipulation has been learned, it is not difficult, and requires but little time. It should be the only material used for sealing medicaments in the teeth.

In the author's practice, careful notes were made on the matter of the discoloration of teeth after removal of pulps, and especially with reference to the discoloration of the teeth as time elapsed. The practice was in families where results could be followed to the best advantage, and in this it was shown that to prevent discoloration it was absolutely necessary to prevent admission of any saliva or other decomposable material whatever to the dentin after the pulp was removed. When the living pulp was destroyed and the dentin absolutely protected from saliva and other decomposable material, no discoloration occurred. This condition could not be attained in any case where the pulp was found in a condition of suppuration, where it was decomposed. The amount of discoloration, however, could be made very much less by great care in mechanical cleaning, and especially by rigid care in perfectly sealing the cavity in the intervals between treatments.

SEPARATING THE TEETH.

ILLUSTRATIONS: FIGURES 501-504.

In making restorations in proximal cavities in cases in which the proximating tooth is present, the existing conditions as to proximal contours, and their relation to the soft tissues should be observed. To maintain the health of the interproximal gingivae, the gums and the peridental membrane, it is often necessary to separate the teeth in order that the lingual and buccal, or labial, embrasures and the septal area may be widened. If the proximal surfaces are too flat, either as originally formed, or have become so from wear at the positions of contact, or if the teeth have moved closer as a result of proximal decay or a previously placed restoration that was too flat, normal conditions should be reestablished whenever this is possible. This statement applies to all types of proximal restorations.

If a contact is not tight, and the embrasure widths are satisfactory, it will only be necessary to increase the convexity of an inlay, or other restoration, thus making the contact more prominent, but where the space between the teeth near the cemental line has been reduced as a result of any of the conditions mentioned,

separation should be gained in advance. In many cases, this may be done at the same sitting at which the wax pattern is taken for an inlay or at which a gold foil or amalgam restoration is made; in some, it should require several appointments to gain sufficient space.

Also, in all cases in which proximal restorations are to be made of gold foil or amalgam, sufficient separation should be obtained to provide for the finishing of the proximal surface of the restoration, without loss in the full mesio-distal width of the tooth.

If the contact of the restoration with the proximating tooth is not made in correct form, food will be held between the teeth and will be crowded upon the interproximal gum tissue, causing inflammation and absorption, and finally injure the gums and peri-

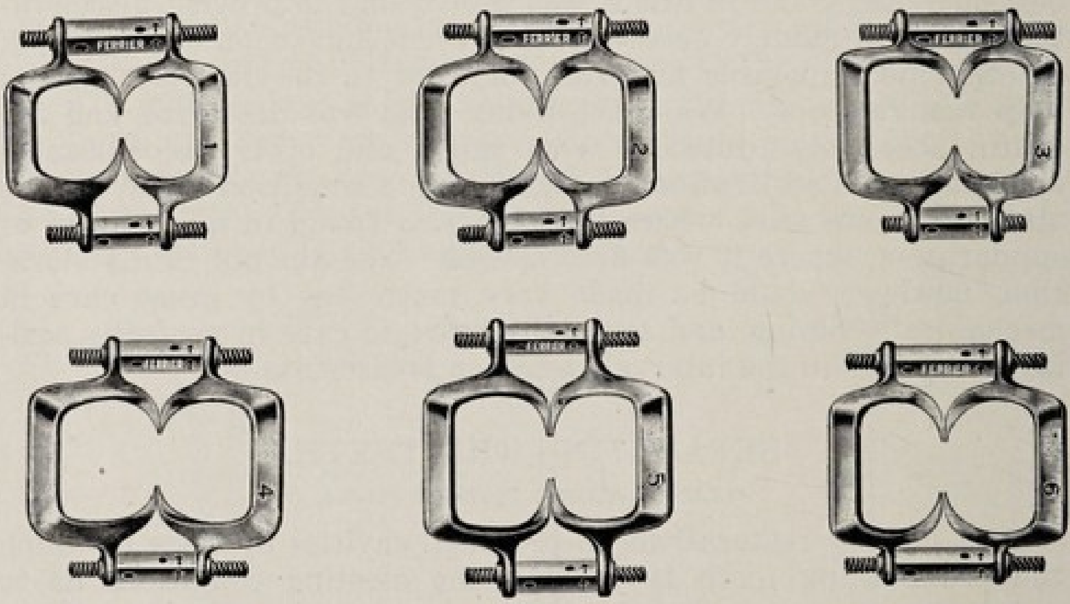


Fig. 501.

dental membranes, perhaps causing incurable disease of the supporting structures and final loss of the teeth. If a pocket is formed in the gum tissue about the gingival margin of the restoration, and the food débris which collects undergoes fermentative decomposition with acid formation, it will cause recurrence of decay. The manner of the recurrence of these conditions is fully stated elsewhere. These considerations, derived from careful clinical observation, render it imperative that provision be made for finishing proximal surface restorations to very exact form by first separating them to give sufficient room. Lack of attention to this requirement has caused the loss of many otherwise good operations.

The Ferrier Separators.

In all ordinary cases, the separation of teeth to gain room for finishing is done best by the use of separators of the type originally designed by Dr. S. G. Perry* and subsequently improved by him. The most recent design is that of Dr. W. I. Ferrier. See Figure 501. There are six instruments in the set made in shapes and sizes adaptable to the teeth in various positions in the mouth. Each instrument has two pairs of jaws which may be placed against the enamel of the proximating surfaces of the teeth to be separated, and the teeth may be moved a little apart by turning threaded bars on the buccal and lingual sides of the instrument.

The two separating bars have right and left threaded ends, which move the jaws back and forth mesio-distally. Three of these instruments have one adjusting bar shorter than the other; these are for the anterior teeth and the short bar should be placed to the lingual. The separator should generally be placed with the

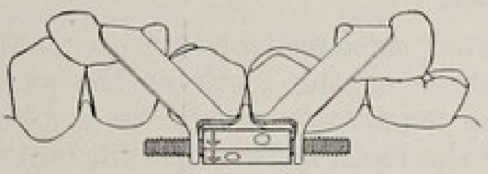


Fig. 502.

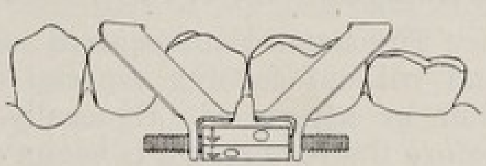


Fig. 503.

jaws closed fully together, but occasionally they may be separated a little before putting it on to give room for the septal gingiva between the jaws. By turning the separating bars in the direction shown by the little arrows, the jaws are forced apart, separating the teeth. First one bar should be given two or three quarter turns and the other the same number. This is done with a wrench supplied with the instrument. If one bar is turned much more than the other, it causes the screws to bind and to work hard.

When the separator is applied, it should be definitely stabilized by propping the bows with either gutta-percha or modeling compound. To do this, the gutta-percha or modeling compound is softened by heat and placed between the bows of the separator and the incisal or occlusal surfaces of the teeth, and a little time allowed for it to harden before the adjusting bars are turned to move the teeth apart. These props are shown in Figure 502 with the teeth separated. They should be placed at once when the separator has been made just tight enough to retain its position well, for, in the after tightening of the screws, there is a tendency for the jaws of the separator to slip farther to the gingival, and cause unnecessary pain and possibly some injury. The props should prevent this. Figure 503 shows a separator, placed

* Dental Cosmos, Vol. XXVIII, 1886, p. 508.

without the props. It will be noted that the separating jaws have impinged upon the gingivae.

The general design and principles of the Perry separator are retained in the new instruments. Their improvement consists in greater convenience and efficiency, both in the application of the instrument and in the access to the field of operation. The relative positions of jaws, adjusting bars and bows are modified to permit of easier application, without undue pressure on the gingivae. In this connection the curvatures of the anterior part of the arch were considered. The portion of the bows which pass over the occlusal surfaces of the adjacent teeth are flattened, thus providing certain means of stabilizing the instrument by packing base plate gutta-percha or modeling compound between the bows and the occlusal surfaces of the teeth. This eliminates pain and injury to the gingivae, due to movements resulting from lack of stability, which has been one of the principal objections to all mechanical separators. The instrument should be so well stabilized that the operator may use it for a finger rest.

The separation required is usually accomplished without pain and without causing especial soreness of the teeth at the same time or afterward. Generally, the separator should be applied before the restoration is begun and the teeth separated sufficiently. Occasionally, and especially with the molar teeth, when the teeth are very firm, they are difficult to move. In such cases, if the screws are turned until considerable pressure is applied, there may be very little immediate movement of the teeth, but within a few minutes, due to continuous spring force of the instrument, the teeth will gradually move apart. If necessary, the adjusting bars may then be turned a little more. The continuous spring force of the separator causes them to yield gradually and the movement is accomplished with little discomfort to the patient. One should be careful not to tighten the separator too tightly upon the single-rooted teeth, as the spring of the instrument may gradually move them apart farther than is necessary and injure the supporting structures.

Slow separation. In cases in which the width of the interproximal space is too narrow, the teeth having moved closer together as a result of loss in their mesio-distal diameters, due to decay or other causes, one should not undertake to secure the desired separation immediately. A little movement should be gained with the separator, and then the cavity, which should be partly prepared in advance, should be packed tightly with base plate gutta-percha. If the gutta-percha is allowed to become cold and thoroughly hard before the separator is removed, it will hold the separation gained, and within a few days the instrument may be again applied and the process repeated. The gutta-percha should be left with full occlusal contact with the teeth of the oppo-

site jaw and the patient should be instructed to chew vigorously upon it. This will aid materially in the movement of the teeth. Care should be taken, however, to so trim the gutta-percha that it does not press on the gum, and in no case should more than two or three weeks elapse before seeing the case, as the force of mastication might crowd the gutta-percha against the interproximal tissue and seriously injure it. Pure, tough, base-plate gutta-percha should be used for this purpose. Anything softer will do harm to the gum without being helpful in securing separation. In this way any desired movement of the teeth may be made to secure space for the restoration of proper proximal contours and embrasure areas, thus promoting the health of the supporting structures.

Three pairs of extra long adjusting bars have been designed for these separators, which make them serviceable occasionally in cases where much space has been lost on both sides of a tooth, as for example, when, due to extensive decay of a second bicuspid, both the first bicuspid and the first molar slightly overlap it. See Figure 504. The regular adjusting bars of the appropriate instrument may be removed and replaced by a pair of the long bars, thus permitting the operator to place the jaws against the mesial sur-

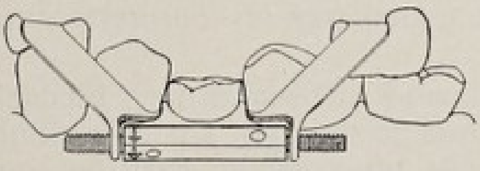


FIG. 504.

face of the first molar and the distal surface of the first bicuspid. These two teeth may then be gradually moved apart, by the process of intermittent slow separation mentioned above, using base plate gutta-percha, packed into a mesio-disto-occlusal cavity in the bicuspid, to maintain the space gained with each application of the separator.

There are many cases with teeth so out of position that none of the separators may be applied. This objection will naturally attach to all mechanical devices for this purpose, although one of different design may occasionally be used where one of this set may not be applied.

When the teeth are very irregular in the arch, other means of separation often have to be devised. Wedges of wood may sometimes be used, or cotton can be crowded tightly between the teeth and tied over, or about, the contact point with a ligature and accomplish a sufficient separation within a few days. Slips of rubber may be drawn between the teeth and the ends cut short; this is a very effective method of slow separation, but is apt to make the teeth very sore. In using rubber for separating, great care should be had that the rubber does not press upon the gum septum. This not

only creates unnecessary soreness, but is liable to do great injury to the tissues.

In all cases in which teeth are moved ever so little in one arch, the bite should be tested at the same sitting, and adjustments made by slight grinding wherever necessary to avoid undue pressure on opposing teeth. If contacts have been lost and the teeth have moved so close together as to require considerable separation, the occlusion may have become adjusted to the abnormal form. In gaining separation to restore the contacts in good form, it is frequently necessary to move these teeth very slowly so that the occlusion may become readjusted in the opposite arch without annoyance to the patient. This may be aided by slight grinding of occlusal areas which strike, or it may be necessary to build out more prominent contacts as special operations for the purpose. The health of the supporting structure will often demand a proximal restoration where there is no caries present; restorations should frequently be made for this purpose alone. This subject is discussed elsewhere.

Positions of Operator and Patient

ILLUSTRATIONS: FIGURES 506-515.

In the training for one's life work in dentistry the positions assumed at the dental chair become a very important matter, and should be considered with great care in order that the best may be done for both the operator and the patient. (1) The position should be such that the operation may be well done. (2) The position should be as comfortable as possible for the patient. (3) The position should be the most comfortable to the operator in each case as is consistent with (1) and (2). It is obvious that the dentist who expects to stand at his chair during most of the hours of each day, should study positions of reasonable comfort; and also those changes of position that will give rest without interfering with his progress should be studied very closely in the formation of his habits at the chair. Observation has shown men to be in a large degree creatures of habit, and that habits once formed are not very easily changed. Therefore, every young man should give this matter very careful attention as one among the many elements of success.

Each dentist should train himself to do some part of many operations while standing on the left side of the chair. To stand in practically the same position on the right side of the chair hour after hour puts an unnecessary strain on the muscles most concerned, and a shift to the left side, even for a few minutes, changes the muscular tensions and prevents one from becoming tired during the later hours of the day. This becomes increasingly important as the years pass, but the habit of frequent changes of position should be formed during the early years of practice. Many things can be better done while standing on the left side of the chair than on the right. This applies very particularly to certain parts of examinations of the mouth, the preparation of many cavities and less frequently to the placing of restorations.

Much effective operating may be done on the lower teeth while standing behind the chair, and this position also affords a restful change from the position to the right of the chair, somewhat in front of the patient.

The positions of both operator and patient must also be adjusted in relation to the source of light. This may usually be accomplished in large measure by turning the chair a little to the right or left.

Positions of the Dental Chair and Patient.

The modern dental chair needs no description. Many styles are offered in the market, but all the better ones agree fairly well

in the essentials of usefulness. All are made to raise and lower as a whole on their pedestals sufficiently for the practical purposes intended. The chair should be adjusted (1) to the height of the operator; (2) to the height of the patient; and (3) so that the mouth of the patient shall be level with the lower half of the operator's upper arm when standing upright with his elbow at his side. The range of one-half of the humerus will be quite sufficient for all ordinary operations in any part of the mouth. Only a few things out of the usual order may require different positions.

Adjustments of the patient must be made to facilitate operating at this particular height. If the patient is to sit upright for operations on the lower teeth, the chair will be correspondingly low. If, on the other hand, the chair is thrown far back for operations on the upper teeth, this movement brings the patient's head lower, and the chair should be raised to correspond in order that the field of operation may come to the proper height. The patient's head must be turned to one side or the other, to bring the particular part of the mouth desired into view, so that operations may be performed easily. If the field of operation is too low, too much bending of the back is required. If too high, the arms must be raised. Either one of these positions becomes tiresome to the operator, but of the two, holding the hands up is much the more tiresome. The object is to find those positions in which the operator can work many hours with the least fatigue, month after month for years together. This is of especial importance from the point of the continued health and endurance of the dentist.

Positions of the Operator at the Chair.

Otherwise than height there are four positions of the operator at the chair which are best defined as: (1) Right side in front, Figure 506 for the upper, and Figure 507 for the lower teeth. In this position both of the operator's hands are at the front or side of the patient's mouth without passing the left arm around the patient's head. In each case the position is defined by the position of the operator's hands rather than the actual position of his person. (2) Right side behind, Figures 508, 509. In this position the left arm is passed around or over the head of the patient. (3) Left side behind, Figures 510, 511. The right hand is around or over the head of the patient. (4) Left side in front, Figures 512, 513. In this, both hands are in front of the patient on the left side. These four positions for the upper and four positions for the lower teeth, form the basis for all definitions of the operator's position at the chair. In the exhibit of finger and instrument positions in which the hands and a part of the face only are shown, the actual position of the operator will be easily read. Besides the instruction in position, it affords a language, or nomenclature of positions which may be of especial use in all teaching, whether in school or society work.

FIG. 506.

Figure 506 illustrates a right side in front position which is a very easy and comfortable position for doing many things of the lighter sort for the upper teeth of the right side.

FIG. 507.

Figure 507 shows a right side in front position for the lower teeth, which is excellent for the teeth of the right side of the lower jaw. The face of the patient is turned rather too much away from the camera to show the left hand, which is holding the lips away. It is a position that should be carefully cultivated.

FIG. 508.

Figure 508 is a right side behind position in which the greater bulk of operating upon the upper teeth should be done. It will often be more convenient if the patient's head is turned slightly to either side, depending on the location of the cavity.

FIG. 509.

Figure 509 is a right side behind position which is best for the greater amount of operating on the lower teeth. The head of the patient should always be so well forward that the light will fall full upon the lower teeth.

Fig. 510.

Figure 510 shows the left side behind position for the upper teeth which enables the operator to make use of the inverted pen-grasp. This grasp is well shown in Figure 535, with the third finger resting on the upper teeth.

Fig. 511.

Figure 511 is the true left side behind position. This gives a very desirable position for operations in the occlusal surfaces of the lower molars of the right side, when these teeth have not too much lingual inclination.

Fig. 512.

Figure 512 shows a left side in front position which is very comfortable for operating the buccal surfaces in the upper bicuspids and molars of the left side. The upper lip is held out of the way with the third and fourth fingers of the right, or instrument, hand while also using the instrument.

Fig. 513.

Figure 513 illustrates the full left side in front position which is especially useful for distal cavities in the lower incisors and cuspids, and for buccal cavities in the bicuspids and often also in the first and second molars.

FIG. 514.

Figure 514 is a position that is decidedly undesirable; it becomes very tiresome and should be avoided. The natural position to assume is looking downward at whatever one is doing, not upward, and one tires much more in any position where this is required.

FIG. 515.

Figure 515 shows a left side behind position for the operator, with a special adjustment of the chair for a tall person, who sits far forward so that the head will be lower.

From the foregoing statements it is seen that one may work practically all around his chair, finding favorable positions to do particular things, and also positions that bring other muscles in play to relieve those that are tired, contributing to comfort and health while continuing needful operations.

INSTRUMENT GRASPS.

ILLUSTRATIONS: FIGURES 520-523.

The manner of holding instruments in performing dental operations is very important, and especially is it important that young men beginning their life work should begin right; that they assume at the start a grasp which will give them power, facility and delicacy of touch. When one has been in practice for some years using a wrong grasp, it becomes difficult to change to a better form. A careful study of the form of grasp used by noted operators, those who have made much more than an ordinary reputation based on their dexterity and power in manipulation, has shown a remarkable uniformity in the grasp of instruments.

THE PEN GRASP is the grasp used for the principal part of the excavation of cavities and in placing restorations. It is illustrated

in Figure 520. The bulbous portion of the thumb and the first and second fingers are upon the shaft of the instrument, so that the full power of all three are used to prevent the instrument slipping when making a powerful thrust. Careful observation of the form of the grasp and power of thrust of many men has shown that on the average men who use this particular form of grasp have nearly one-third stronger thrust than those who use any other form. The form of the grasp shown in Figure 521 gives good facility of movement, but much less power. A careful noting of the difference shows that the instrument crosses the nail of the second finger instead of having the pulp of the finger end on the instrument as shown in Figure 520. The power of the thrust is much less in this second form. Figure 522 shows the worst form possible of the so-called pen grasp. It gives neither power of thrust nor facility

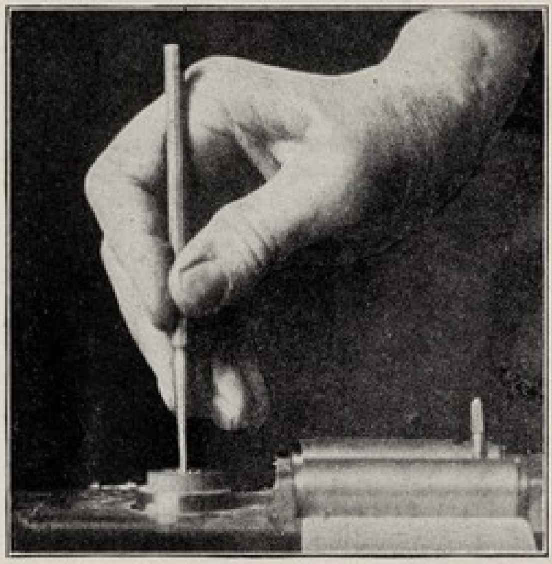


Fig. 520.

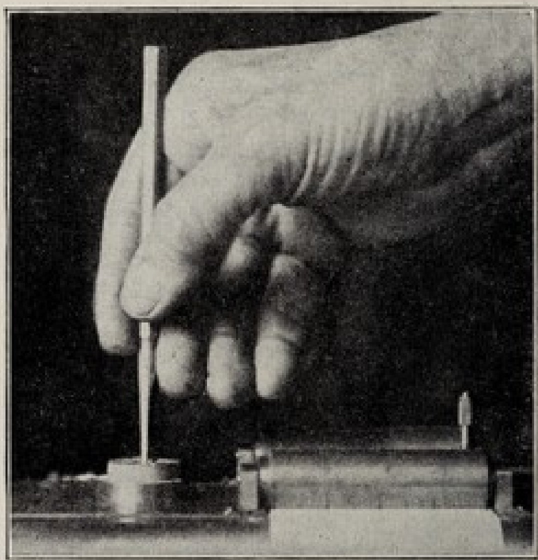


Fig. 521.

of movement. The fingers are much bent and the instrument crosses the second finger at the first joint. The power that should be exerted by that finger is almost entirely lost. The fingers are so bent that the range of movement is handicapped.

The palm and thumb grasp, Figure 523, has a limited range of use in dentistry. In this the instrument is grasped in the palm of the hand and is brought in opposition to the thumb. Its use depends upon finding a suitable thumb-rest in the position of use. This can be done many times in the front of the mouth, particularly in using cleavers in stripping enamel from teeth in preparation for the bands for artificial crowns, and also a limited use of it may be made in placing restorations. This grasp should be cultivated by every operator.

FINGER POWER.

ILLUSTRATIONS: FIGURES 524-526.

The power exerted by the pen grasp is directly dependent upon the ability of the person so to grasp the shaft of the instrument as to prevent it from slipping in the fingers. In this the placing of the instrument so that the bulbous portion of the thumb and finger ends grasp it, is of principal importance. Pressure of the instrument on the side of the finger gives some support in movement, but very little increase of power over a grasp with the forefinger and thumb alone. The power of the finger grasp is, of course, the important feature of difference between operators. Few persons realize the difference that really exists between persons in this respect. The range of difference in power of thrust with the pen grasp runs from five to thirty-five pounds, with the average at about fifteen pounds, as shown by numerous tests made at meet-

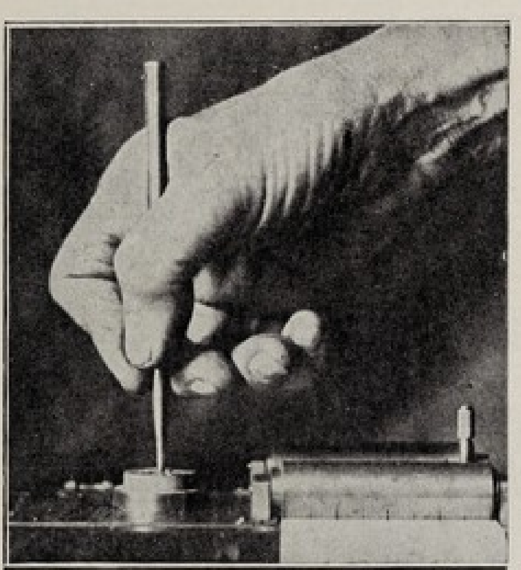


Fig. 522.

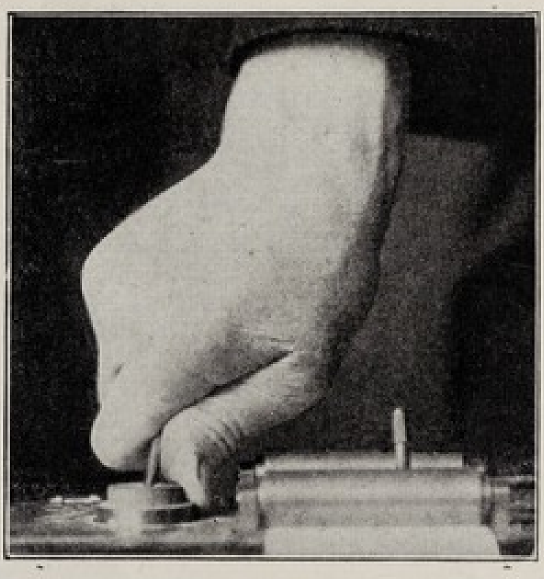


Fig. 523.

ings of dentists. It seems very curious to find large muscular men with feeble finger power, yet a man's general muscular development is no index to his power in handling delicate instruments.

Figure 524 represents the dentist's manu-dynamometer, designed by the author, with which these tests are made. It is a registering spring scale of moderate delicacy, that is arranged with paper slips, Figure 525, for permanent automatic records. Figure 526 represents one of these record slips bearing the records of three persons of widely different finger power, one of seven pounds, one of fifteen pounds and another of twenty-seven pounds. The highest record made on this instrument with the pen grasp was thirty-five pounds, made by the late Dr. J. H. McKellops, of St. Louis. He took the instrument as nearly as possible as represented in Figure 520, with the wrist and hand bent as shown, as most men will when

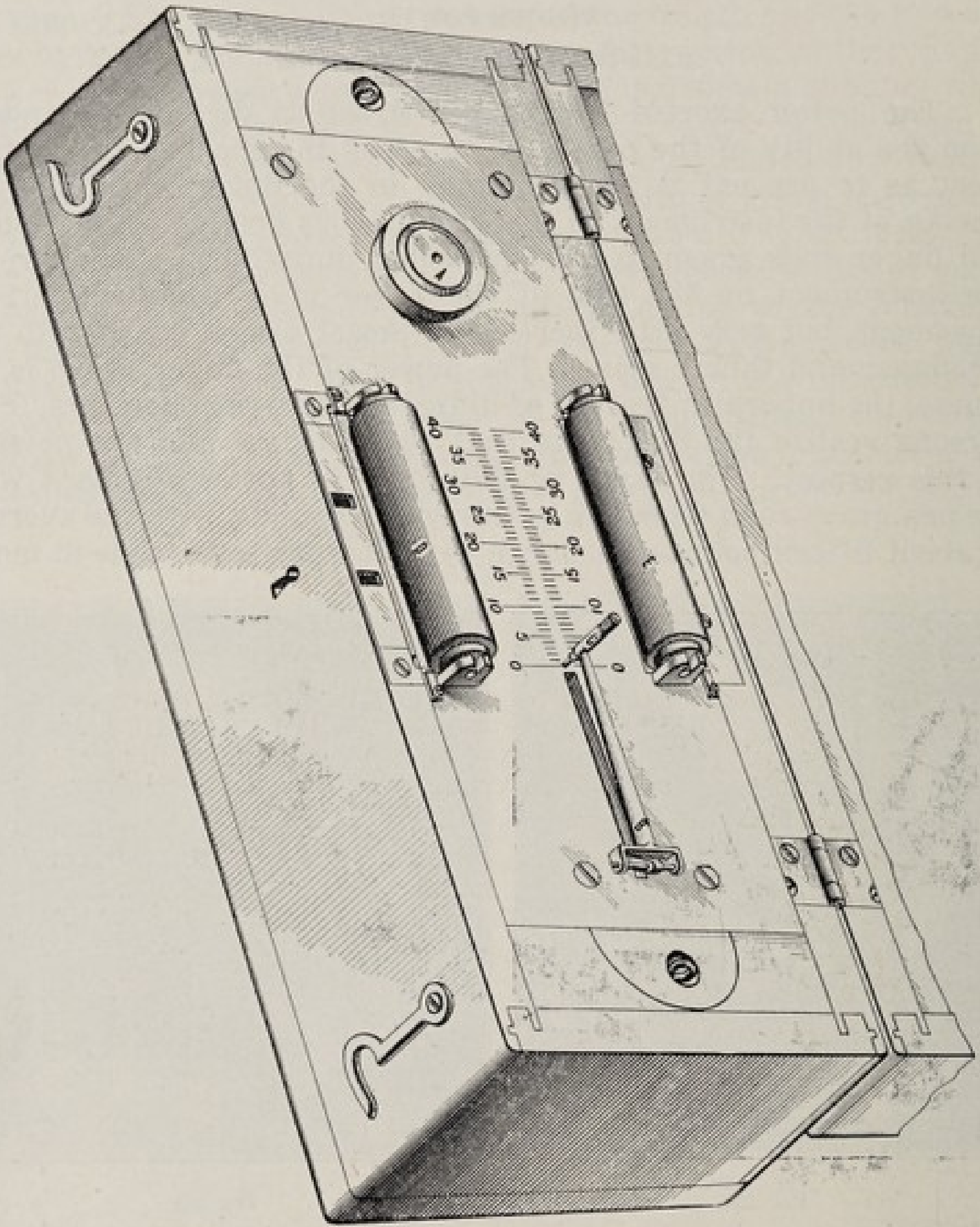


Fig. 524.

making the thrust downward, and without haste went across the whole page of the slip with less than one pound variation. The possession of this extraordinary finger power gave him enormous advantage over the average man in doing dental operations, and it is certainly to be desired that every dentist should cultivate this to the full limit. Much careful observation has shown conclusively that delicacy in the accurate control of instrument movement is very generally an accompaniment of a high degree of finger power.

A study of the instrument grasps in the illustrations of finger and instrument positions will do much to enable one to form correct conceptions of them. The positions assumed at the chair are more natural than those assumed in trials on the manu-dynamometer. Among these will be found a few illustrations in which the grasp

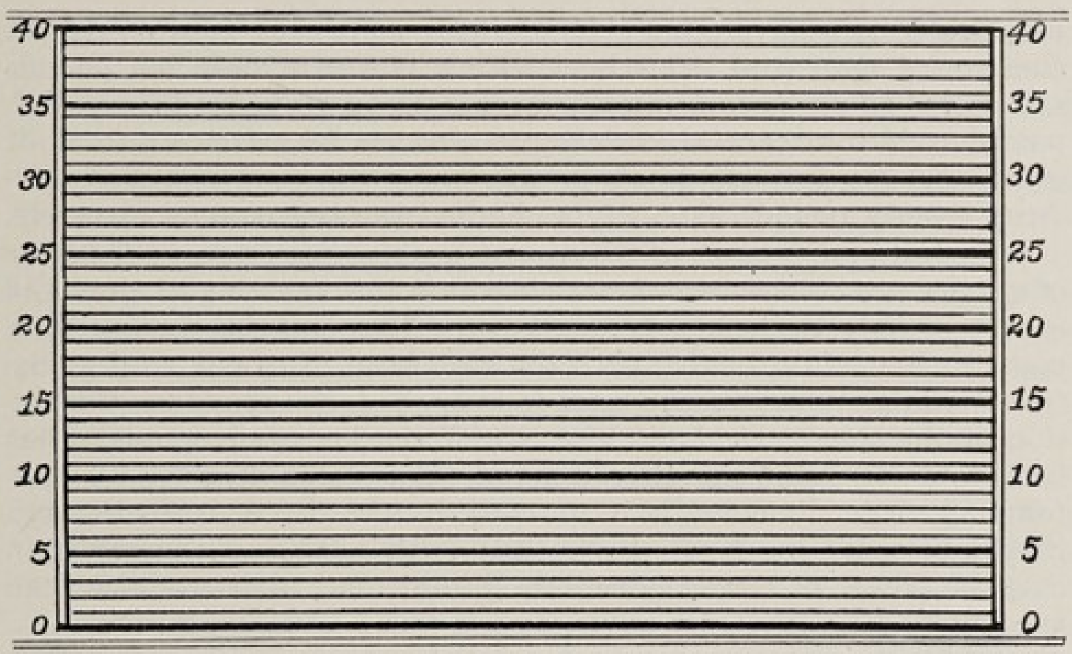


FIG. 525.

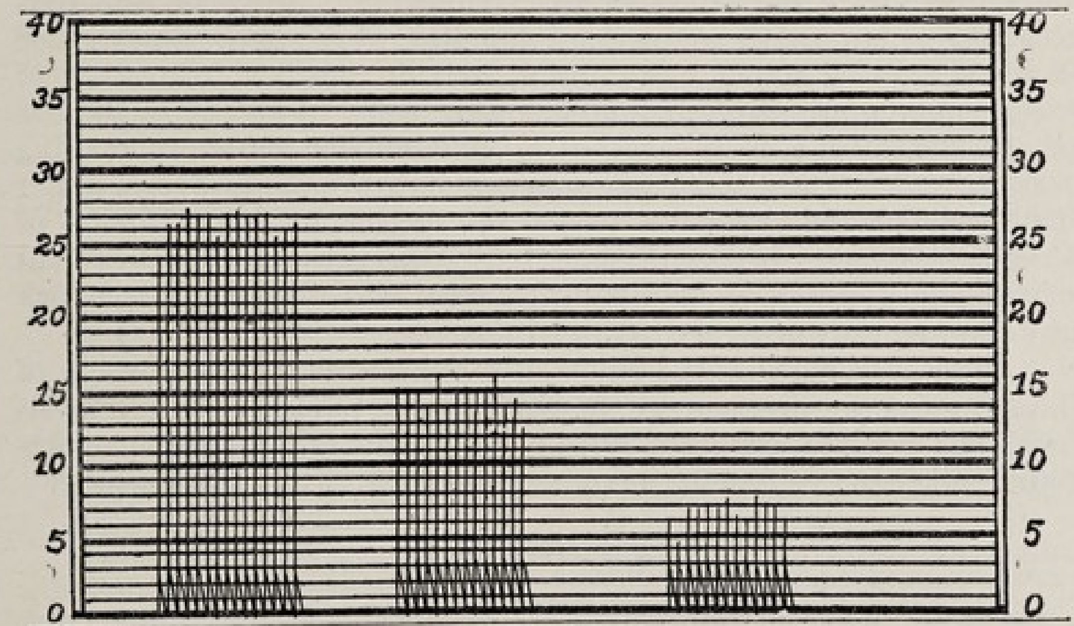


FIG. 526.

is put at ease as in doing some very light manipulative work. In this the instrument is often shifted to the true pen grasp with the shaft crossing the nail of the second finger.

An experience of many years in taking these measurements shows that much increase of finger power, as well as delicacy of movement, can be acquired by careful training, and also that it is easily lost by careless habits. For instance, a class of one hundred and sixty students made an average of nine pounds at the end of their first year, thirteen pounds at the end of the second year, and seventeen pounds at the end of the third year. Some of these same young men fell into careless habits and went backward in finger

power. Others gave later tests showing continued gain of power. One young man who left school with a power of only ten pounds and failed to gain anything during his first two years in practice, put himself into careful training in the use of a correct form of grasp and the full use of his power, and within six months registered twenty pounds as easily as he had the ten pounds formerly.

Delicacy of control of movement usually increases with power of movement. Therefore, from all points this training of the hand is exceedingly desirable in dentistry. The training is purely a matter of careful practice with the best form of grasp, so that the full muscular power of the hand is brought into exercise some portion of the time each day. The size of the instrument handle has little to do with the exertion of force. An instrument handle one-fourth inch in diameter is large enough, and three-sixteenths will generally show no diminution. But with anything smaller than that the power of thrust is rapidly diminished. A larger size than one-fourth inch gives no advantage.

There is much evidence that in the days when restorations were made with non-cohesive gold, using hand pressure, and particularly when small instrument handles were used, experienced dentists exerted much more force than do the best operators of today. The diminution of finger power seems to be due to the use of the dental engine in excavating and of the mallet in making restorations. These are both marked improvements over former methods, but the excessive use of the engine to the exclusion of hand instruments in the preparation of cavities has lessened that power and delicacy of manipulation with hand instruments which is to be had only with well trained muscles.

Whatever may be the cause, a distinct loss in the average of finger power by dentists, as shown by tests made at society meetings, has become apparent within recent years. Fewer men are found who can use twenty pounds pressure with the pen grasp.

Finger Positions.

ILLUSTRATIONS: FIGURES 527-542.

In considering finger positions, the use of rests for the instrument hand is to be considered, and also the use of the left hand in holding the tissues away, thus aiding the right hand by exposing the field of operations to view. Occasionally also the left hand should aid the right hand more directly by guiding the instrument point with a finger. The guiding by a finger of the left hand is often a very important item in accurate operating. It must not be forgotten, however, that a considerable part of the instrumental work in the mouth should be done by the free hand without any rests whatever. Rests are to be sought continually, for with a good finger rest the hand becomes very much steadier than it can possibly be in free-hand work. This is important in positions in which

an instrument is liable to slip and do damage. If there is a good finger rest, such slips are under very much better control than if the finger rest is not used. It must not be forgotten, however, that finger rests always limit freedom of motion.

A finger rest, to be reliable and definite, must be upon the teeth of the same jaw with the tooth operated upon. At least, this is much the best finger rest. In any effort to rest the finger upon the teeth of the opposite jaw, the movements of the jaws are apt to derange the relative positions of the instrument and tooth. Finger rests upon the soft tissues are very much less reliable than finger rests upon the teeth, and yet they may often be used to advantage, particularly if the rest can be made on portions that are not movable, or where the bones are but thinly covered with tissue. However, a rest upon the face will often be upon the opposite jaw and the movements of the patients are apt to disturb it seriously. Such rests must always be reckoned as unreliable.

In some degree, rests are shown in the illustrations, though this has not been an especial object. In this group of illustrations, the position of the operator at the chair will be indicated by the position of the right or instrument hand and of the left in exposing the field of operations. The positions of both the hands should be carefully studied. When both hands are on the right side of the face, the position of the operator is to the right side in front. He could not stand elsewhere and use his hands in the positions shown. When the right hand is on the right side of the face and the left hand on the left side, the positions of the hands will readily indicate the position of the operator, although the right hand is on the right side and the left hand on the left side in both the right side behind position and left side behind position. In the left side in front position, both the hands of the operator are on the left side of the patient, or reaching across from the left side. Observing the hands carefully will always indicate the relative positions of the operator and patient.

Right side in front. Upper teeth. Figure 527 illustrates a common position when operating upon the upper molars of the right side, especially in opening cavities with a chisel, or with the hatchet, also in doing various other things upon the occlusal or proximal surfaces of these teeth. It is a position to be used in very many cases. The left hand exposes the field of operation easily, while the right is free in the handling of the instrument. Generally the rest is not a good one for it must be on the soft tissues of the lower jaw, and is necessarily an unreliable rest for that reason, but it is the only finger rest than can be had in this position. The effort to rest the fingers on the lower teeth would be just as bad as the rest shown in the illustration. It is an excellent position for free-hand manipulation in the use of the chisel, or other cutting instruments, and in condensing gold. With the patient's head well back and the chin well up from the patient's

chest, the position is very easy and should be much used in the operations in the occlusal and proximal surfaces of the molars of the right side.

RIGHT SIDE IN FRONT. LOWER TEETH. The approach to the lower molars of the right side is much easier from the right side in front than from other positions for the reason that it brings the left hand in good position to expose the field of operation to view. This is very well seen in Figure 528, illustrating the use of an enamel hatchet with a half inverted pen grasp. As the operator would ordinarily stand in using this position, his person would be between the field of operations and the camera. Changed to that position, the instrument hand would be much

FIG. 527.

FIG. 528.

less bent, though the position as shown is very good for many operations. The third finger of the instrument hand is on the lower incisors, which gives a very secure rest. For heavy cutting with the enamel hatchets the operator should stand more to the front, bring the right hand and fingers nearly straight, the palm down, third finger on the incisors and the thumb of the left hand well under the body of the lower jaw, while the fingers expose the teeth as shown. Then the full power of the hand can be exerted and the control of the instrument is as perfect as it is possible to make it. This position, with its variations, is the best for much of the operating on the lower molars of the right side. Some of the operating upon the lower right bicuspids may also be done in this position, but as the front of the mouth is approached. the right side behind becomes the better position.

A modification of this position, such as is shown in Figure 529, is especially good for the buccal surfaces of the lower teeth. Notice in this that the third finger is resting on the lower teeth, affording a very steady and secure rest, which gives great steadiness to the instrument hand.

In both of these positions it should be particularly noted that the head of the patient is upright and the chin is down. If the patient's head is inclined a little to the left side, it will usually make the position easier for the operator when working in buccal surfaces. These positions on the right side in front should be much used for operations on the lower molars. They afford a very great variety of modifications for reaching various positions easily. When the patient's head is properly adjusted to height, the position is very restful after long confinement in some other position, such as the right side behind.

RIGHT SIDE BEHIND. UPPER TEETH. This position is the most important of all at the dental chair. The operator can reach more varied points and do more things than from any other position.

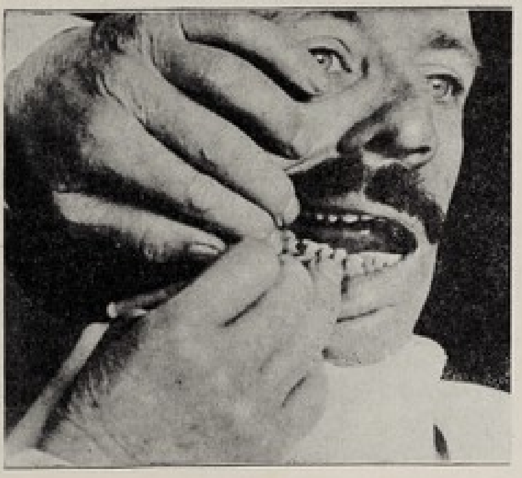


FIG. 529.

FIG. 530.

This finger position is shown in Figure 530 in the use of a binangle chisel opening a cavity in the distal surface of an upper second bicuspid. Note particularly that the left hand is passed over the head of the patient, the fingers exposing the bicuspid or molar teeth of the upper jaw. The thumb of the left hand is holding the tissues away, while the forefinger, resting upon the teeth lightly, is guiding the point of the instrument, rendering the operating more precise than could be done with the free hand alone. In this position, only an imperfect rest may be had by the fingers of the instrument hand on the tissues of the lower face, and yet the position is a satisfactory one for either the proximal or occlusal surfaces of the bicuspids and molars. This picture shows the position of the second finger in the instrument grasp to advantage. In this particular picture, the grasp is very well seen, though the instrument hand is not in sharp focus. In Figure 531 the rubber dam has been removed to show the grasp and the position of the fingers more definitely than could be done with the rubber dam in position. It also shows the use of a chisel in opening a distal cavity in a

bicuspid. Often the position may be changed so as to turn the right hand partly over, and bring the third, and sometimes the third and fourth fingers, upon the upper teeth, forming a rest. That can usually be done if the instrument can approach its work upon an angle a little more from the front of the mouth.

This is shown in Figure 532 in the representation of the use of two instruments in starting a gold foil restoration in the mesial surface of a second bicuspid. The left hand is holding the tissues away with the second and third fingers, and also holding the holding instrument principally with the thumb and first finger, but it lies across the second finger as well. This holding instrument is so formed that, when placed, only light pressure is needed to keep it steady. The use of a left-hand instrument should be carefully culti-

Fig. 531.

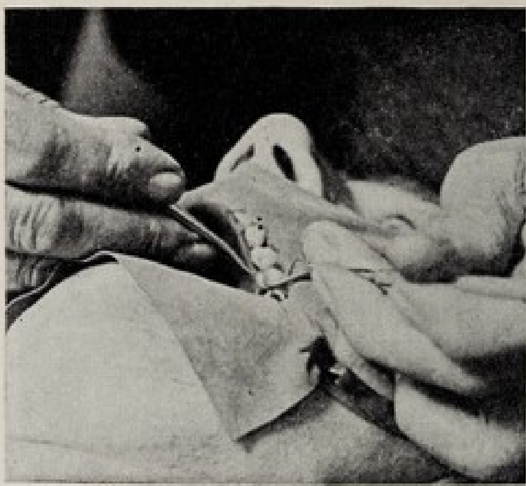


Fig. 532.

vated by every operator. The right hand has the third finger resting upon the upper teeth of the other side of the mouth, giving great precision in the use of the condenser point. In this notice that the condenser crosses the nail of the second finger, a grasp that is unsuited for heavy pressure, but may often be used well with mallet pressure, or anything in which light hand pressure only is to be used.

Positions quite similar to these last three may be used almost all around the mouth in the upper jaw, the patient's head being thrown well back, as shown in these illustrations. The patient's head should often be turned this way or that to gain better positions. The right side behind is the position for the largest amount of operating in either the upper or the lower jaw.

Right side behind. Lower teeth. Figure 533 illustrates very nearly the most usual position for operations upon the lower molars of the left side. It is exactly the position that should generally be had in introducing a broach into the distal root of any of the lower molars upon the left side of the mouth. For this use

of the broach in any of the lower molars that stand normally in the arch, the shaft of the instrument should cross the upper teeth at about the median line, when the mouth of the patient is thrown widely open. The broach will then glide evenly and smoothly into the canal of the distal root. On the right side the position would be the right side in front with the instrument handle crossing the incisors at the median line. If any of the lower teeth are inclined much to the lingual, the better position will be over the lateral incisor, or even the cuspid of the right side of the upper jaw to the molars of the left side, making it almost a cross-mouth position. The fingers of the left hand are exposing the parts to view, a position that is found an excellent one, for, if the field of operation is not too far back in the mouth, the forefinger of the left hand may

FIG. 533.

FIG. 534.

pass across the teeth and keep the tongue out of the way, while the second finger and thumb control the lips. This position with its modifications, which are very numerous, is the position for the greater amount of instrumental work upon the teeth of the left side of the lower jaw.

Figure 534 illustrates a finger position and form of grasp that will be found very excellent for the use of the engine in the buccal surfaces of the lower teeth of the right side. Most operators will find it difficult to obtain facility in the use of this position and grasp without considerable practice. This is most suitable for the straight hand piece, for by its use we may place the square end of a bur against the axial wall of a buccal cavity and make such extensions as may be necessary to the mesial and to the distal, preserving the flat form of the axial wall. This can be done as far back as the second molar usually, and, in some cases, even to the third molar. Of course, this class of cutting must be done before the rubber dam is placed, or at least without a clamp in such a position as to interfere. It will be noticed that the end of the third finger has drawn

the lips back and has found a rest upon the teeth, or upon the gums, to the distal of the tooth operated upon. The instrument point is passed across the finger and is operating to the mesial of the finger end.

When this position and grasp are once well learned, the operations are easily done, provided the position is not continued too long, and generally there will be no necessity for holding it more than a few minutes at one time, as the work is accomplished very quickly.

A position very similar to this may also be found for using the engine in cutting gingival third cavities in the buccal surfaces of the teeth of the left side of the mouth, the operator standing to the left in front. By the use of these positions, the necessity for

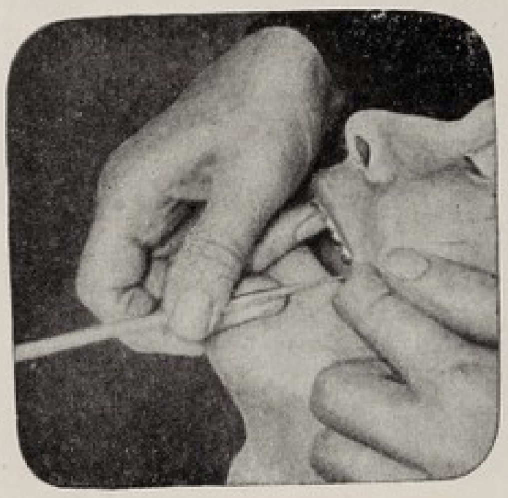


Fig. 535.

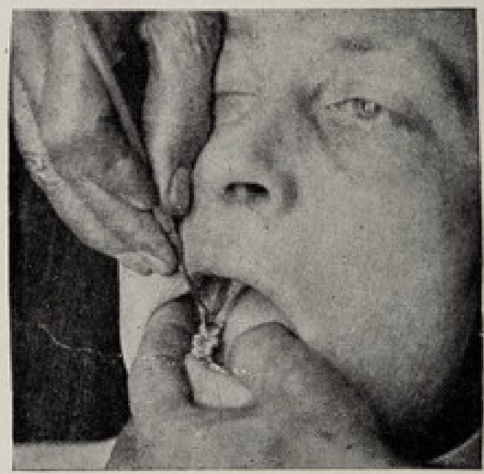


Fig. 536.

the contra-angle hand piece is very much diminished. In fact, that instrument should rarely be used in buccal cavities.

Left side behind. Upper teeth. In Figure 535 is represented a position obtained on the left side behind, which is occasionally useful. In this the inverted pen grasp is illustrated particularly. The instrument point is directed in almost the opposite direction from its usual position by the bending of the fingers. Hence the term, inverted pen grasp. The grasp may be considerably varied to suit different positions. Notice that the third finger is on the upper incisors, forming a rest that is safe and the control very accurate for doing any delicate thing in operating, while the forefinger of the left hand, with the first joint sharply bent, is holding the tissues away. It is easy to expose the teeth much more perfectly than is shown in this picture by holding the lower lip away with the second finger, or by holding the upper lip with the thumb and the lower lip with the first finger. In using this position as shown, the head of the operator, in order to see the progress of the work, would generally be between the camera

and the instrument hand. The grasp is not one of great power, but one in which very accurate work may be done after a little practice. Positions calling for its use are not very frequent.

LEFT SIDE BEHIND. LOWER TEETH. Turning now to Figure 536, a most excellent position is shown for operating upon the occlusal surfaces of the lower molars and bicuspids of the right side. In opening cavities particularly, this position is especially good when the teeth are not inclined too much to the lingual. It is often an excellent position for condensing gold. It will sometimes happen that a lingual inclination of the teeth will defeat any effort at operating in the position shown. Generally in the molar teeth the cutting of the enamel away from the buccal side of a cavity with the chisel will be best done from this position, while the lingual side will be cut more easily from a position to the right

FIG. 537.

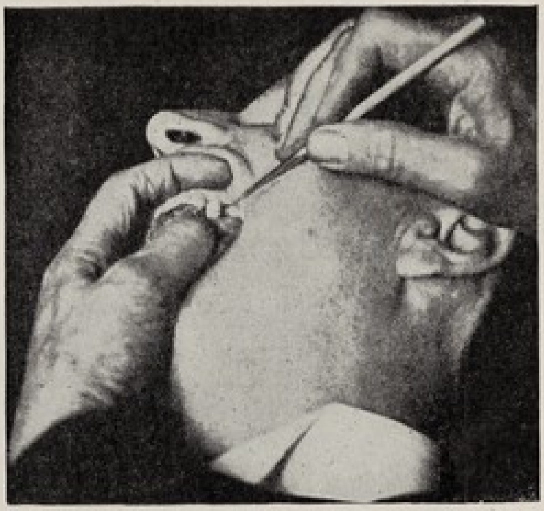


FIG. 538.

side in front, using the enamel hatchets. In this case, the right side in front will give the left hand a better position for exposing the field of operation to view. This position is shown in Figure 528. Sometimes in this work a position on the left side in front, with the patient's face turned toward the operator, will give the left hand a much better position in which to both expose the field of operations and support the lower jaw.

LEFT SIDE IN FRONT. UPPER TEETH. Figure 537 illustrates a position for operations on the buccal surfaces of the upper teeth of the left side. In this, note that there is a finger rest upon the bones of the cheek that is very good, and the grasp is one giving great power. When this position has been used considerably, it is found to be excellent for much of the excavating and also for making restorations in buccal cavities. In this position the left hand exposes the field of operation very conveniently. Positions of this kind should be very carefully cultivated. To persons who

have operated only from the right side behind, as some do, such positions are at first very awkward.

In Figure 538 is shown a method of reaching the distal surfaces of the upper bicuspids of the left side, and occasionally the distal surface of the first molars may be reached in a similar way. Access from the left side in front position is important in both excavating and the introduction of restorations in many of the very large cavities in the distal surfaces of these teeth, in which the enamel of the buccal surface has been so undermined by caries that it must be cut away; but only for a part of the operation, however. The bulk of the operation is done from the right side behind. It is only those portions of the operation where it is required to cut from the buccal portion of the cavity, or to condense gold from that position.

LEFT SIDE IN FRONT. LOWER TEETH. Figure 539 represents a position somewhat similar to that shown in Figure 538, for oper-

FIG. 539.

FIG. 540.

ations upon the buccal surfaces of the lower molars and bicuspids. Frequently most of the operations upon these may be done from this position more conveniently than any other. When the position has been assumed often enough for the operator to become familiar with it, it is found to be excellent, and a great relief from continuous standing at the right side behind.

CROSS-MOUTH POSITIONS. Occasionally it is desirable to hold an instrument across the mouth in what may properly be termed "cross-mouth positions." Generally it is impossible to use the full force that may be used with the instrument in other positions, because it must be grasped so far from its point. This is illustrated in Figure 540. The finishing of restorations and various points in the cutting of cavities is occasionally facilitated by assuming

this cross-mouth position. It may be used anywhere on the lingual of the bicuspids and molars of the upper jaw. Occasionally, when it is used upon the right side, the operator will stand to the right side in front, or upon occasion on the left side in front, but for positions on the left side, the operator need not change his position; but may change the position of the patient's head to gain a better view. It is not a suitable finger position for doing any considerable amount of operating.

In Figure 541 is shown another cross-mouth position, in which the grasp of the instrument comes out very clearly, the instrument reaching across the mouth to the occlusal surface of the lower molars on the opposite side. The left hand, it will be noted, is in an excellent position for exposing the field of operation, and it steadies the lower jaw by its grasp on the teeth with the third and fourth fingers under the chin. On lower molars that have a very strong lingual inclination, this position becomes very important in some parts of the operation of condensing gold, also in some parts of the operation of chipping enamel, and various portions of the work of excavating. The position may be changed frequently

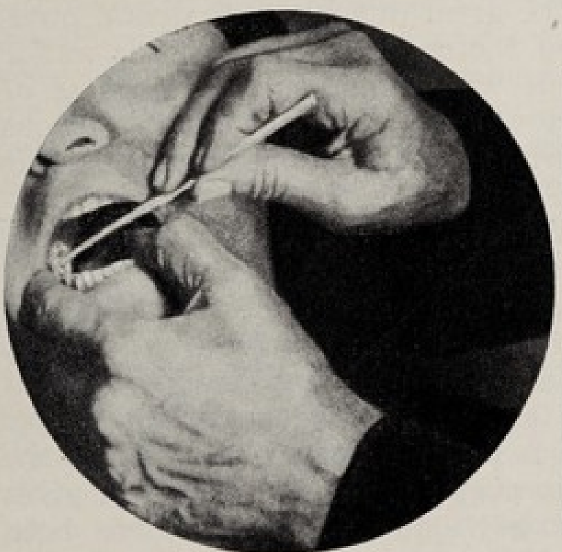


FIG. 541.

FIG. 542.

with other positions, especially a position on the right side behind for the use of enamel hatchets. By turning the patient's face sharply toward the operator, very much of the work in occlusal and mesio-occlusal cavities may be done from this position. The principal objection to it is the long reach of the instrument.

In Figure 542 we have the opposite cross-mouth position, in which the instrument reaches across from the right side to the teeth on the left side of the mouth, which is used for similar purposes and can be assumed at will without particular change of the position of the operator from the usual one in operating upon these teeth. It is only a change in the position of the hands, for in operating on the left side of the lower jaw, the position on the

right side behind will be the better position for general use; and the instrument hand of the operator will vary according to the necessities of the case. In the few cases in which cavities occur in the lingual surfaces, facility in the use of cross-mouth positions becomes especially important. In some of these, the entire operation must be done across the mouth.

The few finger positions and finger rests illustrated will afford much opportunity for forming variations of the cases shown to suit the varied conditions that are presented in practice.

In these suggestions of finger positions, no pretense has been made of illustrating, or even mentioning, all of the better positions. The object has been to give such notice of this subject of positions at the chair and of finger positions as will be something of a guide in the search that each student or dentist may make for convenient finger positions and rests to serve him in cases as they appear in practice. They should be carefully sought, first, to the end of accomplishing the operations easily and expeditiously, and second, for that change of position of the relation of the operator to his patient that will be a rest to his muscles as he continues at the chair hour after hour. One of the great difficulties in dental practice has been the confinement of the operator to one position for long intervals at a time, in this way tiring out certain sets of muscles, which comes to be very wearing upon the whole nervous system. This tends to break down the operator prematurely, while the frequent changes of position that may be had by seeking favorable finger positions in other than the principal position for the operator, which is the right side behind, bring movement and rest and keep the operator in a condition very much better fitted for prolonged service at the chair. It has been the observation that many of those who stand in unfavorable positions steadily without much change about the chair, tend to break down much earlier than those who are moving from position to position frequently. The introduction of the fountain cuspidor in the form that gives it a permanent position in the left side of the chair, has been serving to limit the positions of the operator much more than it should. If the cuspidor is so arranged that it is easily pushed aside for the moment, allowing the operator to assume the position of left side in front upon occasion, it should not interfere with these movements. Such an arrangement should always be selected.

Heretofore we have had no nomenclature of this subject or any systematization by which discussion of it could be had. Generally in teaching operative dentistry, or in writing, the subject has been passed almost without notice. The definitions of positions introduced here should enable students and teachers to understand each other better than heretofore and discussion should do much good in amending bad positions which cause needless wear to both operators and patients. This whole subject should be very closely studied for the benefit of all concerned.

Keeping the Operating Field Dry

ILLUSTRATIONS: 551-595.

FOR many dental operations, it is required that absolute dryness be maintained for a variable period of time, occasionally for an hour or more. This may be most certainly accomplished by applying a rubber dam in such a way that the teeth selected for the purpose will be isolated from the moisture of the mouth. In the early days of dental practice, before the discovery of the rubber dam and of the cohesive properties of gold foil, operations were rather commonly performed in the presence of some moisture, although the effort was made to keep the field dry by packing the mouth with small napkins and rolls of cotton. In addition, there were many ingenious contrivances designed to prevent or retard the flow of saliva from the ducts. For example, metal clamps were pinched on the cheeks, in the position of the orifices of Stenson's ducts. Other clamps, with an arm extending under the chin, held napkins in the floor of the mouth and also served as tongue depressors.

The use of the rubber dam assures absolute dryness of the teeth included in the operating field, while permitting the free flow of saliva from the glands, the bulk of which is carried away with the saliva ejector. Restorations of cohesive gold foil and amalgam, also in many cases gold and porcelain inlays require the application of the rubber dam. It is also necessary as a first step in establishing a sterile field for pulp treatments and for all procedures in connection with preparation and filling of root canals. This is absolutely demanded by present knowledge of the relation of mouth foci of infection to the general health.

There remain many other procedures which call for perfect dryness for a very short period — from one to several minutes. In some mouths and in certain locations, this may be satisfactorily accomplished by packing with gauze rolls, aided by the saliva ejector. Consideration must be given to many factors in deciding which method shall be employed in a particular case. The decision should often depend on the presence of an assistant, which permits one person to look after the dryness of the field, while the other is engaged with the details of the immediate service to be rendered.

The student or dentist who earnestly desires to give the best service will, when in doubt, apply the rubber dam.

Air, blown through the nozzle of a syringe, is used as an aid in removing debris, also in drying the field of operation. Particular attention is called to the fact that a field may be dry without being either clean or sterile. The cleansing of the field is discussed in consideration of the making of the toilet of cavities; sterilization under the technic of pulp treatment.

SALIVA EJECTOR. A saliva ejector should generally be used when a rubber dam is applied, also when the mouth is packed with gauze. It is rather more important in the latter than the former case. The ejector tubes are made of glass, metal or waxed paper; the last named is prepared by wrapping the paper about a wire to maintain its form. If one uses the glass or metal type, he should have several with different lengths of ends that curve over the teeth and into the mouth. The end should preferably not quite touch the floor of the mouth when the curved portion rests upon the lower teeth. If it is longer, it may be painful whenever the operator's hand presses downward on it. It should be so placed as to be most out of the way of the operator, also so that it will remain in the desired position. This may be accomplished in part by turning the tube in the socket by which it is attached to the hose, and in part by the position of the hose, which may be placed to the patient's right or left side, sometimes over the shoulder. Occasionally the patient may be requested to hold the hose in a particular position. If the end of the tube hurts the mouth, the patient may raise it a little if he is holding the hose.

If the suction on the tube is strong, the soft tissue of the mouth may be sucked into the hole in the end of the tube. When this happens, the valve, which controls the flow of water which causes the suction, should be shut off, or the hose should be disconnected from the tube, to release the suction on the tissues. If necessary a pair of cotton pliers may be used to withdraw the tissue from the tube.

AIR. A blast of air is generally used in the final drying of cavities after the rubber dam is applied, also in cases in which the mouth may be packed with gauze or cotton rolls. The air may be warm or at room temperature, from a hand syringe or from a nozzle connected with a compressed air system. The use of air is discussed elsewhere, but it should be mentioned here that the vitality of the pulp may be endangered by the use of air that is too hot or too cold. If an air pressure system is used the pressure should be reduced to about five pounds per square inch, otherwise the released air will be too cold. Care should be exercised to have the temperature very close to that of the body. It may be tested on the operator's own hand or face. As a rule, air should be blown against a tooth with frequent short puffs, rather than a long blast.

THE RUBBER DAM.

The rubber dam is a thin sheet of rubber used for the purpose of keeping any field of operation on the teeth clean and dry; also to make it possible to keep the field sterile when that is required. In use, a piece of the rubber of suitable size for the purpose is selected and holes much smaller than the teeth are punched at proper positions. These are stretched over each of as many teeth as may be necessary. The rubber draws tightly around the necks of the teeth and becomes moisture tight if well arranged. Then so many teeth as are in this way exposed, can be kept clean and dry for any desired operation. The rubber is furnished in several grades as to thickness. Generally, a medium thickness is to be preferred. If of good quality, it is very elastic, tough and strong.

As a rule, a rubber dam clamp is used when the rubber is applied to the bicuspid and molar teeth, to prevent it from slipping off and to hold the rubber away from the crown of the tooth to give the operator more room and a better view of the field. The clamp is preferably placed on a tooth posterior to the one upon which an operation is to be performed, and usually on a molar tooth, because it will grasp the broad buccal and lingual surfaces with little possibility of slipping. Several forms of clamps are used, some designed to overcome particular difficulties which present. These will be referred to in discussing methods of applying the rubber.

The edges of the rubber extend outside the mouth, covering the lips and adjacent tissues, and are attached to a holder on either side of the face. The holders are connected with an adjustable elastic ribbon passed around the patient's head.

One or two weights may be attached to the lower edge of the rubber to hold it down over the lower lip. A *chin pad* of pressed absorbent cotton or cloth may be placed between the rubber and the chin, with its upper edge even with the lower lip to absorb moisture from the mouth, and a saliva ejector may be placed in the mouth to remove saliva as it accumulates.

For many operations, which do not absolutely require the placing of the rubber dam, time will be saved and the success of the procedure assured by placing the rubber. This is particularly so if the dentist is operating without an assistant. The student should be required to place the rubber for certain operations which the practitioner of experience might safely do without the dam, and in other cases he should place it at an earlier period in the procedure, in order that he may have better visibility and also have both hands free for some accessory purpose.

Preparation for placing the rubber dam. Teeth upon which the rubber dam is to be placed should be clean. This should always be looked to carefully as the first step preparatory to placing the rubber dam. Especially any accumulations about the

margins of the gums should be carefully removed. Often these accumulations are composed mostly of microörganisms, and, if they are not removed, will frequently be pushed under the margin of the gum in placing the rubber dam. This may cause some bruising of the soft tissues, followed by inflammation and possibly serious infection, which should be avoided by careful cleaning in advance. Especially great care should be had to clean the interproximal spaces. This is most easily done with the ligature. The ligature should first be passed between the contact points to determine whether or not there will be any difficulty in passing them with the rubber dam. While this is being done, the space may be well cleaned with the ligature. In many cases where it is desirable to place the rubber dam, there is more or less decay with sharp edges of broken enamel margins which will cut the ligature, and which will be liable to cut the rubber also. In any such case, the sharp edges should be found and so cut away that they will not interfere with the placing of the rubber. Peridental membrane explorers should be used to determine whether the gingivae have been detached from the enamel and if so, to what depth. When this cleaning and examination have been satisfactorily done, the parts should be flooded with tepid water as the final step to the cleaning.

PREPARING THE RUBBER DAM. PUNCHING THE HOLES. A suitable piece of rubber dam should be selected for the case. It should be washed with water and dried between the fold of a clean towel. If it is for the upper incisors, for example, a piece of the size and form shown in Figure 551 will answer. There should be enough rubber that it will, when in place, fully cover the upper lip, but it should not cover the patient's nostrils. There should be enough to cover the lower lip and chin. To the sides there should be sufficient to give good room to place the rubber dam holders to stretch it back out of the way. If, in any case, the part covering the upper lip should be a little long and interfere with the breathing, by covering or partly covering the nostrils, it should be cut away with the scissors. The position of the holes in the rubber should be such as to allow the edges to extend as far as desired in the several directions.

The punching of the holes for the teeth is done with the rubber dam punch. It is very important to have these in the right position and the proper distance apart. The rubber should generally be placed over two or more teeth to either side of the one to be operated upon, if in the front of the mouth. If it is the central incisor, the rule should be to expose the six front teeth. For a cuspid, an equal number of teeth on either side should be exposed. If it is a bicuspid or molar, one tooth to the distal and two or three to the mesial should be exposed. Special conditions will often require deviations from these rules. In individual cases there may be missing teeth, bridges, etc., that will interfere and make something different necessary. The cutting of the holes will depend in

part upon conditions of interference with the ordinary rules of procedure.

When the holes have been punched and the rubber dam placed, it should lie smoothly without wrinkles or drawing. The distance apart of the holes and their relation to each other, whether in a curved line or otherwise, must depend upon the individual case. For the incisors and cuspids in the normal arch, the holes should be in an arc of a circle somewhat larger than that described by the arch, as shown in Figure 551. This will cause that part of the rubber covering the roof of the mouth to be loose and it will

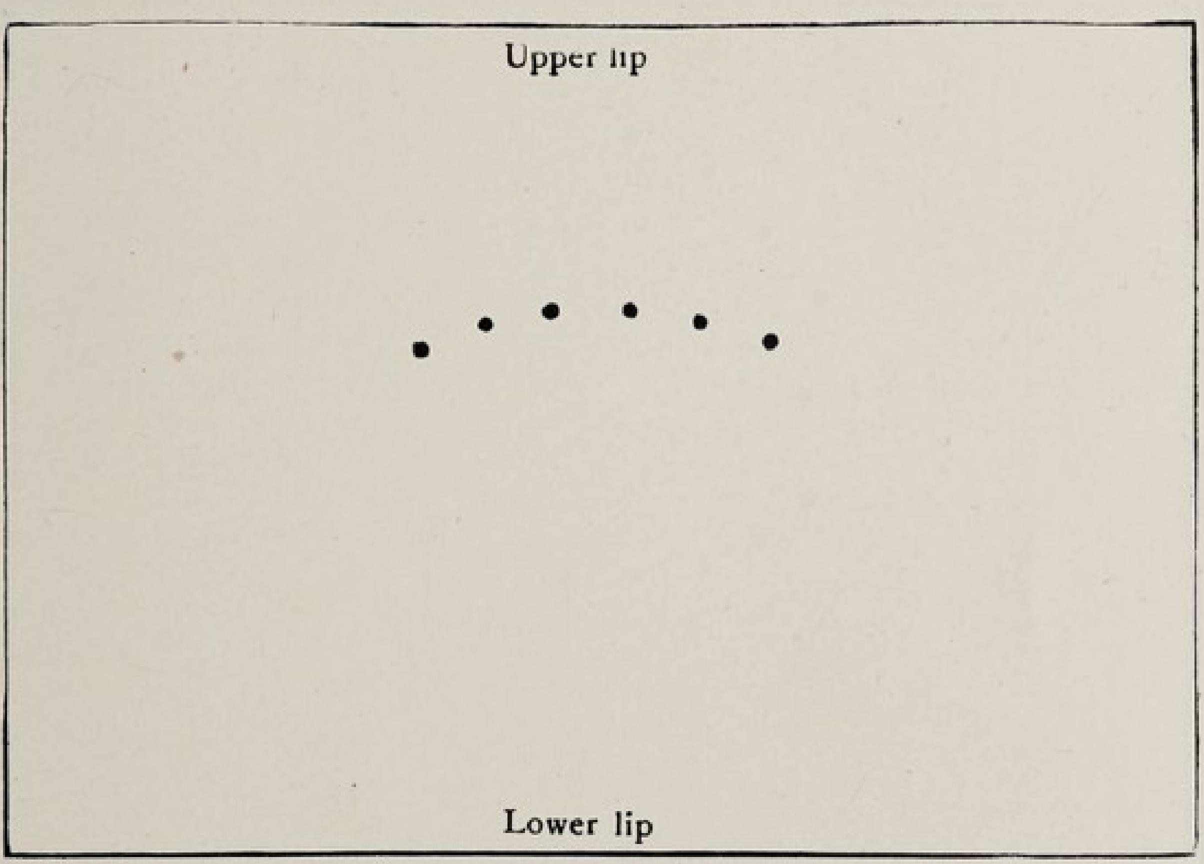


FIG. 551.

be apt to lie well up against the tissues out of the way in operating upon the lingual surfaces, or in using the mouth mirror. To serve this purpose, the holes should be cut slightly farther apart than the whole width of the teeth over which the rubber is placed. The holes should be of a size to hug the necks of the teeth tightly, but not so small as to endanger the rubber by too severe stretching in getting it over the teeth. When the rubber is in place, the septum of the rubber between the holes will be stretched much more than any other part, and, unless there is much more width of it than at first glance would seem necessary, it may be too narrow to hug closely around the necks of the teeth and leakage will result. This

will occur whenever the holes are cut too close together, which is a very common error. In case of the lower incisors, it is often necessary to cut the holes so far apart as to cause just a little wrinkling of the rubber in order to have the septum of rubber between the teeth broad enough to make it tight. The necks of these teeth are much the broader from labial to lingual, and their mesial and distal surfaces are often very nearly flat. It is there-

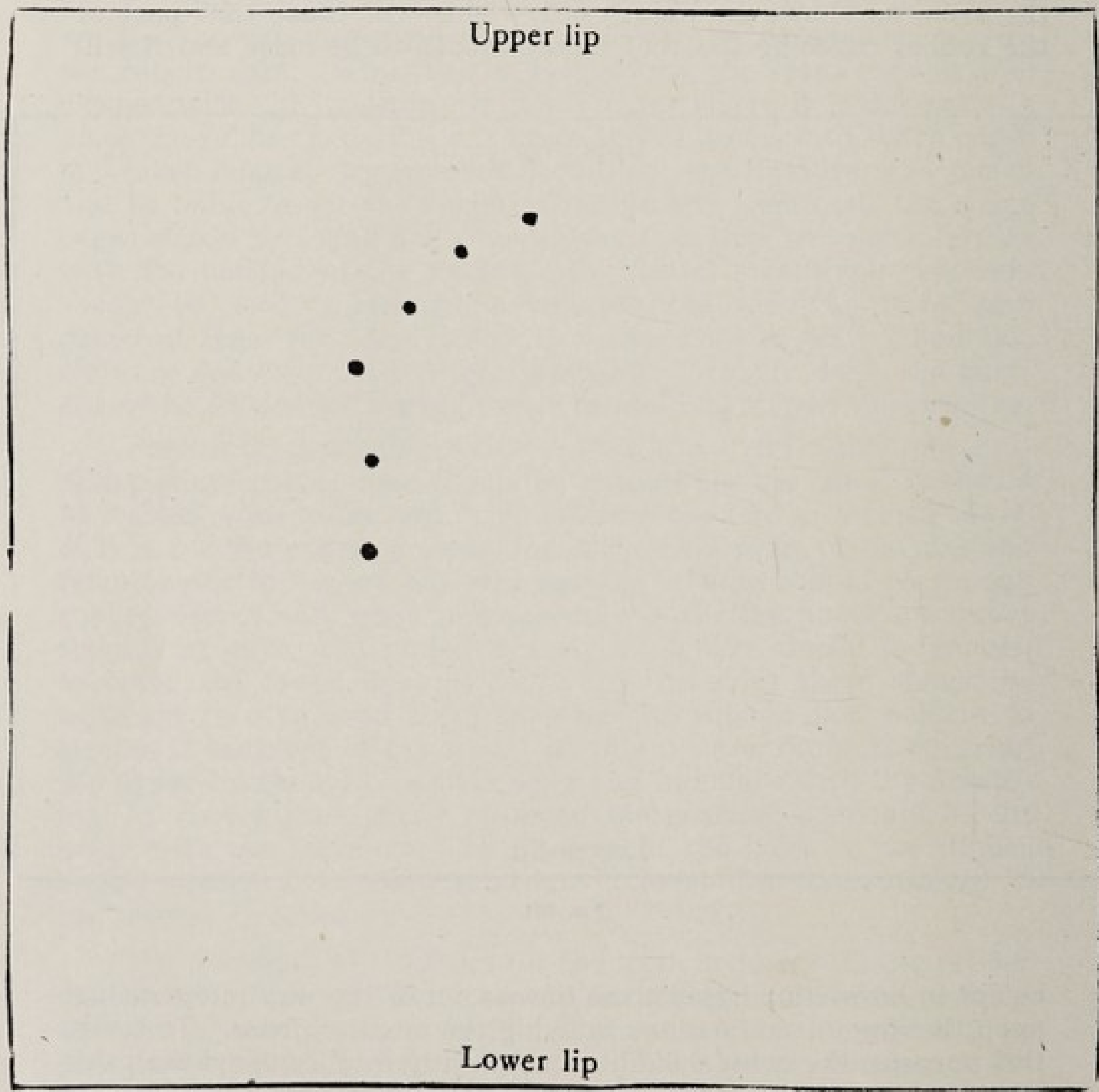


Fig. 552.

fore sometimes difficult to make the dam moisture tight. It will not be tight unless the space between the holes is broader than the teeth. The bicuspids often offer a similar difficulty. This is to be remedied by cutting the holes a little farther apart than the mesio-distal breadth of the teeth. Therefore, the rule should be to cut

the holes as much farther apart than the mesio-distal breadth of the teeth as can be done without causing the rubber to wrinkle. If in any case the proximal surfaces are very flat, it is better to overstep this a little, as a slight wrinkling of the dam is better than leakage.

One may soon learn the best locations for the holes and the proper distances apart to punch them, if he will for a time, in each case test the relation of the holes to the teeth by holding the rubber over the teeth to which it is to be applied. If, for example, the dam is to be applied to the first molar, the two bicuspids and

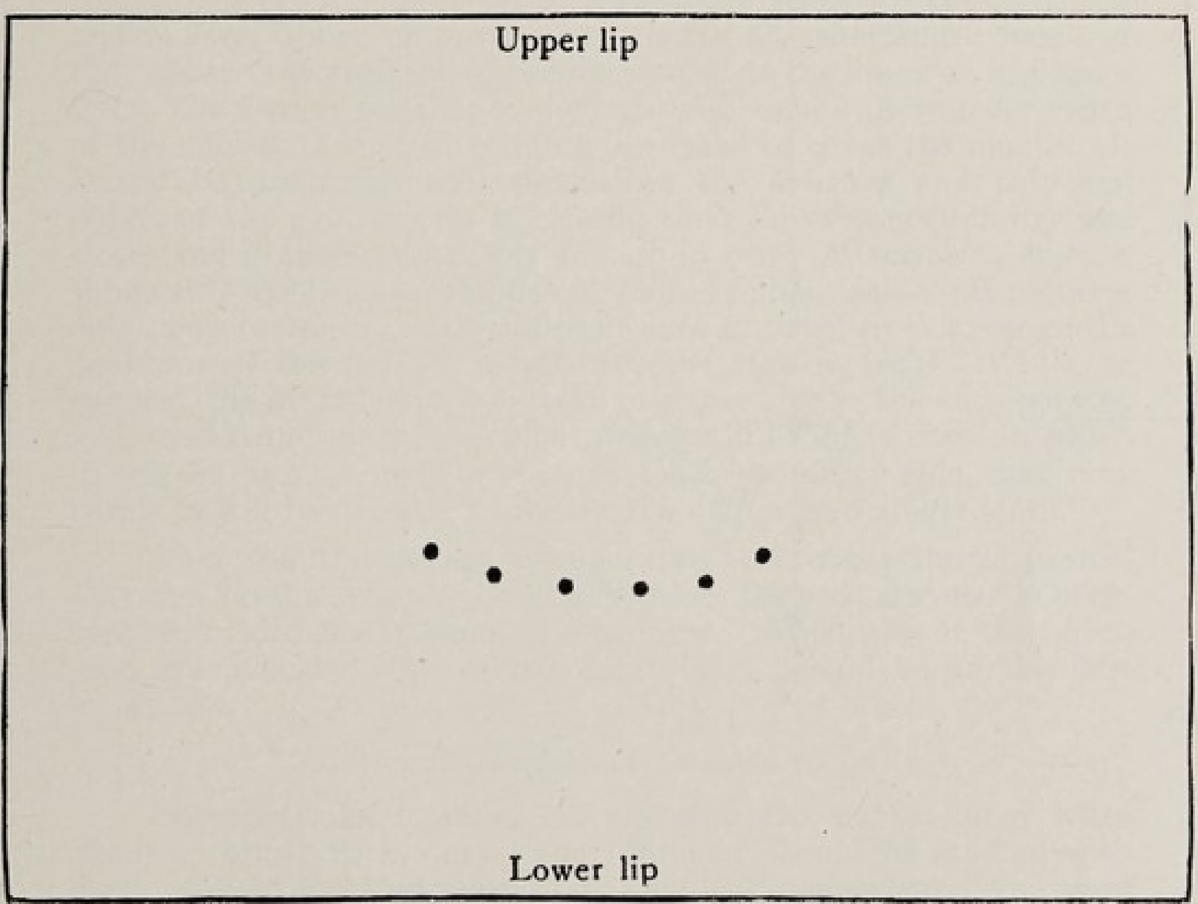


FIG. 553.

the cuspid, then one should lay the rubber over the teeth with the first molar hole over the center of that tooth and the other three holes over the occlusal surfaces of the bicuspids and the point of the cuspid. If, without stretching, the cuspid hole is a little to the mesial of the position of the point of the cusp of the cuspid, there should be no leakage when the dam is properly applied.

One may demonstrate this by punching two holes a half inch apart in a piece of rubber dam, and then passing the handles of two instruments through the holes; so long as the handles are held the same distance apart as the holes in the rubber, the rubber will

conform snugly about the handles. If the handles are moved more closely together, the close fit of the rubber will not be disturbed. However, if the handles are moved a very little distance apart, thus making their distance from centers greater than the distance between the centers of the holes, it will be observed that the stretch-

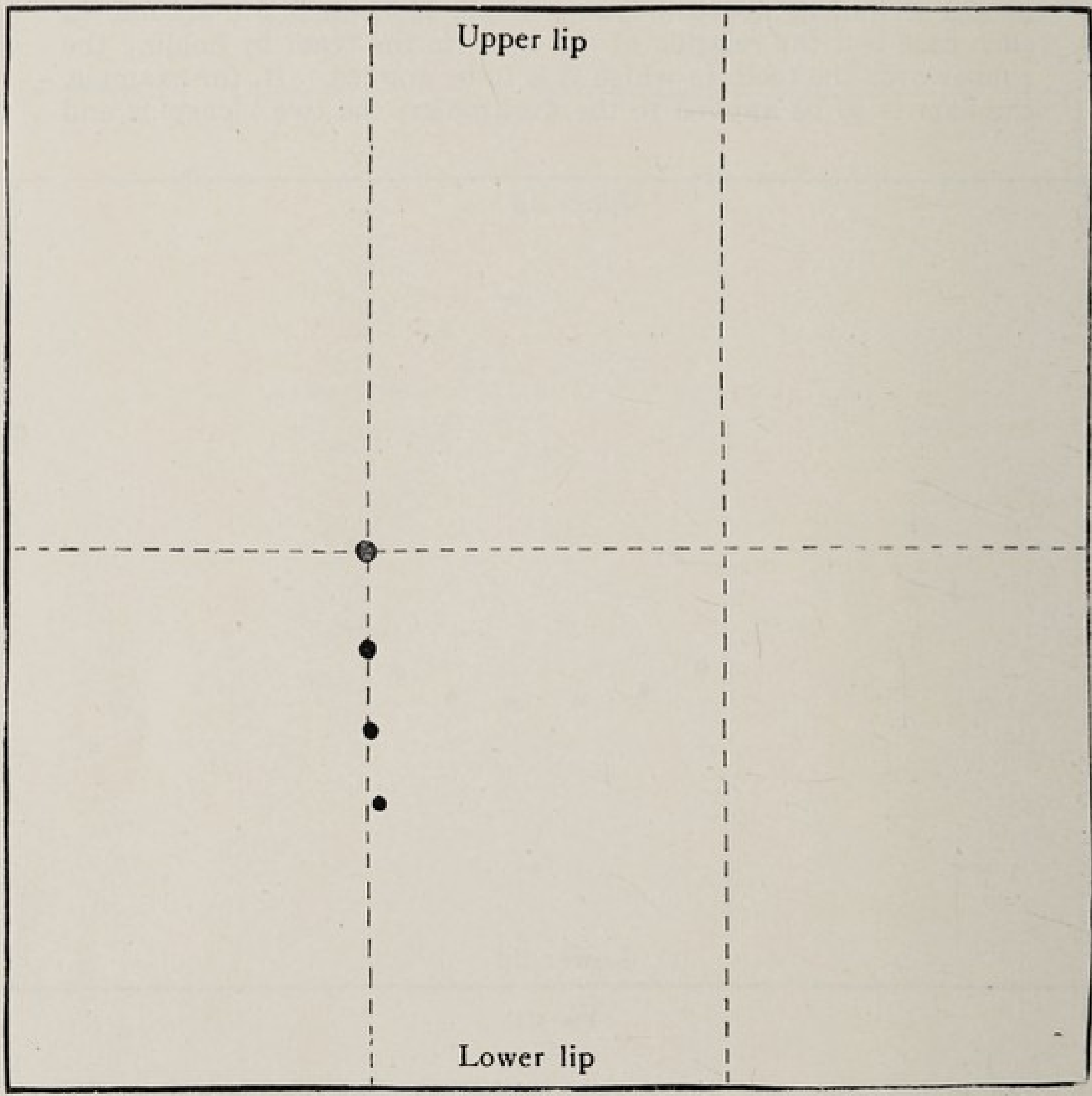


FIG. 554.

ing of the rubber will cause it to be pulled away from the handles. Under similar conditions about a tooth; if the holes are punched closer together than the centers of the teeth, the septum of the rubber will be stretched and leakage will be likely.

In case there are special conditions, the position of the holes in the rubber dam must be varied to meet them. For instance, Figure 552 illustrates the position of the holes for a case of some

recession of gum with decay far to the gingival on the buccal surface of an upper first bicuspid, on which it is intended to set a Hatch clamp. The hole intended for the first bicuspid is a little out of the line of the arch, in relation to the holes for the other teeth. If this were not so, by stretching the rubber to the gingival sufficiently to expose the cavity, it is likely to be pulled away from the cuspid and second bicuspid and cause leakage. See Figures 591, 592, 593. In other cases, the positions of the holes must be varied to meet the conditions; as when teeth are very irregular in the arch or the rubber is to be stretched this way or that, a tooth missing, etc. Forms for other parts of the mouth are shown in Figure 553 for the lower incisors and Figure 554 for the bicuspids and molars, upper or lower. In Figure 553 the longer reach of the rubber is toward the upper lip instead of the lower as in Figure 551. The reason for this is sufficiently obvious. A broader reach of the rubber in that direction is essential to cover the mouth. It should be distinctly understood that the primary and principal object of the rubber dam is to keep the field of operation dry and clean, and it should reach far enough in every direction to do this. When this has been accomplished, more is undesirable. It requires only good reasoning with sufficient care in practice to arrange the positions of the holes correctly for the case in hand. While, in general, the inclusion of two teeth to either side of the one operated is desirable and most convenient, there will be many cases in which it will be best to include but one tooth on either side, and very rarely it will be necessary to place the dam over a single tooth.

When the first molars are operated, the rubber should preferably include the second. Generally, when the second molar is operated, the third molar should be exposed. When any of the bicuspids are operated, the rubber dam clamp should be on the first molar, etc.

Rubber Dam Grasps.

The particular manner of grasping the rubber dam when about to apply it, is very important and should be studied with much care in the beginning of the student's experience, and good habits of practice formed. There are five ways of grasping the rubber dam, which are called the *rubber dam grasps,* each of which is effective for placing it upon teeth easily and quickly. Certain ways of grasping the rubber dam are particularly suited to the application of it in certain positions in the mouth, or to certain teeth; also to certain positions of the operator when applying it.

The following table presents in condensed form the necessary preparations for applying the rubber; the several methods of grasping it; the positions of the operator at the chair; the positions of the chair and of the patient; and the teeth over which it may be most conveniently applied with each of the five groups. Directions for the removal of the rubber are included.

Table to be Used as a Guide in the Application of the Rubber Dam.

PREPARATIONS FOR APPLYING.

1. Remove all calculus, gummy material, etc., from necks of teeth, and douche them with warm water.

2. Pass ligature through interproximal spaces to clean them and test contacts. Trim contacts if necessary.

3. Punch holes as far apart as centers of teeth to be included, and include two teeth on each side of one to be operated on, if convenient.

No.	Operator's Hands (L. R.)	Position at Chair	Position of Chair and Patient	Teeth Patient R.	Teeth Patient L.
1.	occl. x o x	Right side, in front	Tipped well back	6 5 4 3 2 1	1 2 3
	ging. 1 1	Left side, in front	Tipped well back		3 4 5 6
2.	occl. 1 o x	Right side, behind	Tipped well back		2 3 4 5
	ging. x 1	Right side, behind	Upright, chin down	EDCBA	
3.	occl. x o 1	Right side, behind	Tipped well back	5 4 3 2	
	ging. 1 x	Right side, behind	Upright, chin down		ABCDE
4.	occl. 1 o 1	Behind, above	Low, tipped back	6 5 4	4 5 6
	ging. x x	Right side, in front	Upright, chin low	FED	DEF
5.	occl. x 1 o 1 x	Behind, above	Low, tipped back	8 7 6	6 7 8
	ging. 2 2	Right side, in front	Upright, chin low	HGF	FGH

REMOVAL.

1. Remove all ligatures and clamp.

2. Draw rubber to buccal or labial, and cut portions extending between the teeth with blunt-ended scissors, draw rubber to lingual, and remove

3. Douche gums with warm water and knead them to restore circulation.

In the first column of this tabulation, the numbers of the five grasps are given; in the second column the grasps are listed; x represents the thumb, 1 the first finger, 2 the second finger, o the hole in the rubber, and the line the piece of rubber, with the surface that will, when it is in place, be toward the occlusal surfaces of the teeth marked *occl.* and the side that will be next to the gums marked *ging.* At the head of this column an L and an R indicate the left and right hands of the operator. In the third column the position of the operator at the chair is given; in the fourth column the position of the chair and the patient. In the fifth column the teeth over which the rubber may be applied by the various grasps are represented by figures for the upper teeth and letters for the lower. The perpendicular line in the center of this column indi-

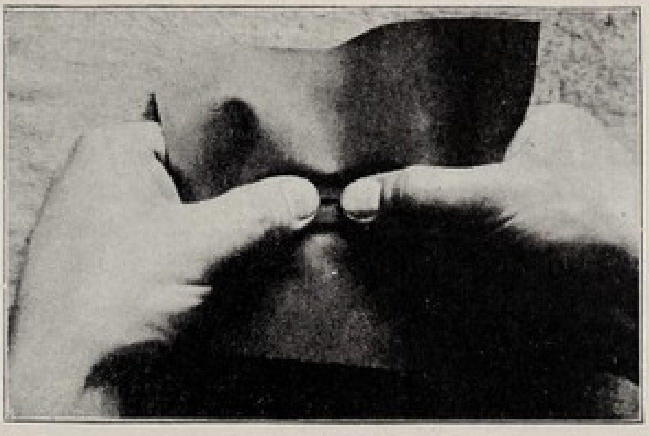


FIG. 555.

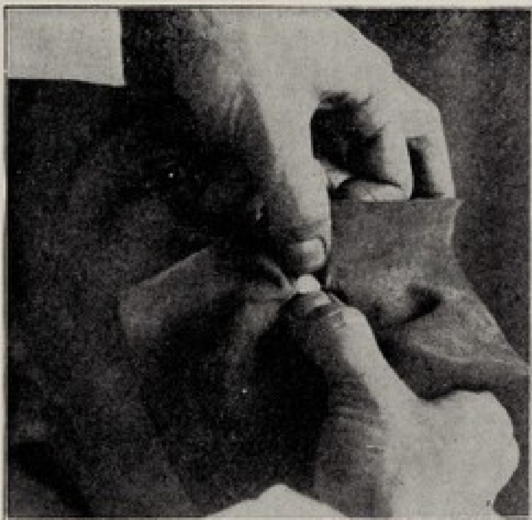


FIG. 556. FIG. 557.

FIG. 555. First rubber dam grasp, for upper front teeth. See tabulation of grasps, also text. The two thumbs on the occlusal side with the nails of each over the edges of the hole, which is stretched a little. The two forefingers are on the gingival side opposite the thumbs.

FIG. 556. First grasp. Position right side in front; patient's head thrown back. First movement; pass the rubber over the tooth; thumb nails are next to tooth and carry the edge of the hole hard against the gums. Notice particularly that the object is to carry the edges of the hole in the rubber fully to the gingivæ.

FIG. 557. First grasp. Second movement; hold the thumbs firmly in position as in Figure 556; let go the grasp of the rubber with the forefingers, still holding it with the thumbs, with **the nails against the tooth.** A little shaking motion of the thumbs, without releasing the pressure, allows the rubber to close around the tooth; remove the thumbs. If these movements are rightly made, the edges of the hole will be turned under the gingivæ. Grasp the next hole in the rubber in the same way and repeat the same movements for tooth after tooth. **This particular use of the nails is essential in all rubber dam grasps.**

cates the median line of the mouth and the upper and lower teeth of each side are numbered from 1 to 8, and A to H, in each direction from the median line. For example, with the second grasp, the operator's left first finger would be on the occlusal side of the rubber and the left thumb on the gingival side, while the right thumb would be on the occlusal side and the right first finger on the gingival. The operator would stand on the right side behind the chair, and have the chair tipped well back to apply the rubber over the upper left lateral incisor, cuspid, first and second bicuspid teeth; or have the chair upright, and the patient's chin down to apply the rubber over the lower right central and lateral incisors, cuspid, first and second bicuspids.

It is not attempted in this tabulation to give the exact teeth over which the rubber may be placed by each grasp, but to suggest the general positions in the mouth.

It will be noted that each of the five grasps may be used for applying the dam to teeth on both the right and left sides of the mouth, also that all grasps, except the first, are recommended for certain upper and certain lower teeth, which are listed for each grasp. In applying the dam to the teeth listed for a particular grasp, there should be no change in the relative positions of the thumbs and fingers; nor any change from the indicated sides of the rubber in relation to the gingivæ, but it should be apparent that the gingival side of the rubber must be up when it is applied to the upper teeth and down when applied to the lower teeth. Reversing the rubber without changing the finger grasp is accomplished in some cases by a change in the position of the operator at the chair, in others by changing the position of the chair, and in others by turning both the dam and hands other side up without a change in the position of the operator or of the chair.

The illustrations representing the rubber dam grasps and different movements are comprised in Figures 555 to 572, and will be treated as a group to which frequent references will be made. Each grasp of the rubber is illustrated. Another illustration shows the position at the end of the first movement in placing it on the teeth; or, at the time the rubber has been carried over the tooth to the gingivæ. A third illustration shows the position when the grasp on the rubber has been released, but while it is still held against the gingivæ to allow it to close around the tooth. These are the critical points in placing the rubber dam. If the definitions given, and the systematization of the plans are carefully studied in the beginning, the placing of the rubber dam will be relieved of much of its difficulty.

After it has been determined that the contacts of the teeth offer no special hindrance to the application of the rubber, there are two main considerations in every case. The first has to do with the technic of slipping the rubber over a tooth. This involves the

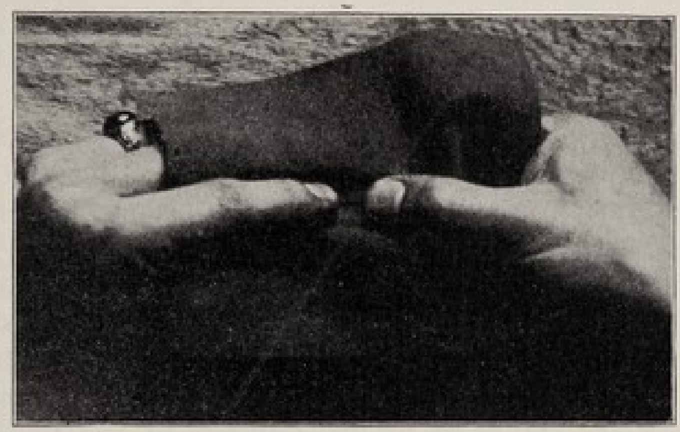


FIG. 558.

FIG. 559.

FIG. 560.

FIG. 558. Second rubber dam grasp, for upper left incisors, cuspid and bicuspids, and lower right incisors, cuspid and bicuspids. Right thumb and left forefinger on occlusal side; nails of each over margin of hole. Left thumb and right forefinger on gingival side.

FIG. 559. Second grasp. Position right side behind; head of patient thrown back. First movement; nails of both thumb and finger next to the tooth, pass the rubber over tooth and with the nails carry it to the gingivæ.

FIG. 560. Second grasp. Second movement; release the grasp with the left thumb and right forefinger, on gingival side of rubber, but hold it with right thumb and left forefinger on occlusal side until rubber has closed around the tooth. Repeat movements for tooth after tooth as shown in illustration.

passing of portions of the rubber into the interproximal spaces on either side of the tooth to which it is applied. Whatever the grasp, there should be, on the occlusal side of the rubber, a finger or thumb of one hand, back to back with a finger or the thumb of the opposite hand—the finger nails touching. The finger ends should be in such position that the rubber may be stretched to open the hole by moving the fingers apart. There must also be a finger or thumb of each hand on the gingival side of the rubber, opposite those on the occlusal side, to hold the rubber. The free edge of the rubber, at one side of the hole, should be passed between the teeth and it should be forced past the contact with a slight sawing motion. The rubber should then be slipped over the tooth, and the edge should be passed through the contact on the opposite side in the same way. The ends of the two fingers (back to back) should next carry the rubber against the gingivae, one finger nail being in contact with the labial or buccal surface of the tooth, the other with the lingual surface.

The second consideration is to turn the edge of the rubber of each hole to the gingival, so that there will be no leakage of moisture. To do this the hold of the fingers on the gingival side of the rubber should be released, while the fingers on the occlusal side are pressing the rubber against the gingivae. The rubber should then slip away from the fingers and draw close around the tooth. Slight movement of the fingers back and forth will aid in this.

It is just as important to know how to remove the fingers from the rubber without pulling the rubber away with them after it has been placed on the tooth as it is to place the rubber over the tooth. Special attention should be given to the necessity of noting very carefully the manner of doing this, and to the fact that the dam should be allowed to close fully around the tooth while the fingers are still pressed against the tooth and gums on its buccal and lingual sides. When this is done, it will generally be found that the margins of the hole in the rubber are turned toward the gingival.

The application of the rubber will be facilitated if it is slightly moistened with cocoa-butter on both sides in the region immediately adjacent to the hole.

This technic, in its main features, should be followed in applying the rubber, regardless of the location of the tooth or the grasp used. If the rubber is to be applied to posterior teeth, a clamp will usually be placed and the rubber will be slipped over the clamp first. The clamp will hold that portion of the rubber while it is being applied to neighboring teeth. The edge of the rubber may often be turned to the gingival with a ligature. The use of both clamps and ligatures will be discussed later.

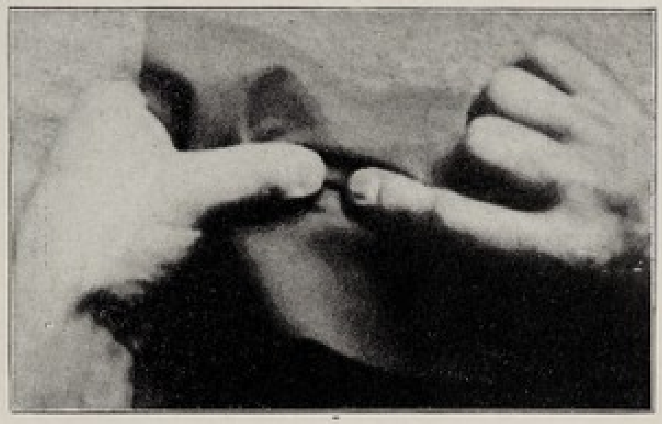


FIG. 561.

FIG. 562.

FIG. 563.

FIG. 561. Third rubber dam grasp, for upper right incisors, cuspid and bicuspids, and lower left incisors, cuspid and bicuspids. Left thumb and right forefinger on occlusal side, with nails over margin of hole in rubber. Right thumb and left forefinger on gingival side.

FIG. 562. Third grasp. Position at chair right side behind. First movement; rubber passed over tooth; nails of thumb and finger on occlusal side against the tooth.

FIG. 563. Third grasp. Second movement; release the grasp on rubber by thumb and finger on gingival side, holding it against the gums with the nails of the thumb and finger on the occlusal side until the rubber has closed around the tooth.

In applying the rubber to a group of several teeth without the aid of a clamp, the first tooth over which the rubber is to be placed should be carefully chosen as to its form and the condition of the contacts. The latter should be such as to permit quick application, and the tooth should be of such form that the rubber will be likely to stay in place. A cuspid tooth in the mouth of a young person, with full gingivae and with no actual contacts with either the lateral incisor or first bicuspid, would be about the poorest selection one could make. In the mouth of an adult, the cuspid usually presents no especial difficulty if the contacts are normal. Any tooth in a group of five or six may be the best tooth for the initial application.

The technic for the several grasps is given in the legends accompanying the illustrations. It might be said that the first four grasps are alike. They include the four possible combinations of thumbs and first fingers in holding the rubber. One will naturally take the grasp that is most convenient, depending upon his position at the chair and the location of the teeth to which the rubber is to be applied. In each of these grasps the rubber is held between the fingers and thumbs, which are opposite one another.

The fifth grasp is quite different from the others in that the actual hold on the rubber is at a considerable distance from the hole. This grasp is used for placing the dam on the second and third molars, or where it is necessary to reach far back into the mouth; and particularly for placing the rubber over the bow of a clamp previously placed on either one of these teeth, upper or lower. In doing this, the dam is first taken between the first and second fingers of each hand, with the forefingers and thumbs on the occlusal side. Then the second, third and fourth fingers are closed, or nearly closed, and the dam grasped between the thumbs and second fingers, with the thumbs placed opposite the second joint of the fingers, or between the first and second joints, as in Figure 569. The first fingers of both hands are free. With this grasp, the dam should be stretched a little and the two forefingers should engage it close on either side of the hole to be used, and with them the hole should be stretched open, as in Figure 570. To the beginner it is generally necessary that the hole be opened sufficiently wide so that the tooth to which it is to be applied can be seen through it; but when its use is well learned, the tooth will be found by the sense of touch. The rubber should be carried back into the mouth and passed over the tooth with the forefingers, the one on the buccal, the other on the lingual. The technic of slipping the rubber over the clamp will be given later.

It is suggested that one should learn to the most minute details the technic of the first and fifth grasps. Thereafter the use of the other grasps will be acquired without special study.

Fig. 564.

Fig. 565.

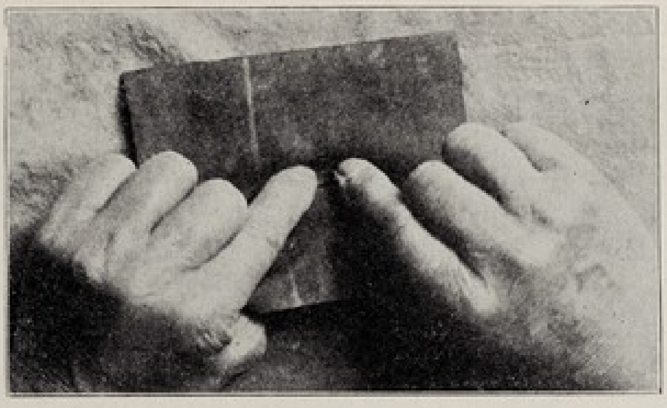


Fig. 566.

Fig. 567.

Fig. 568.

Fig. 564. Fourth grasp. For upper left bicuspids, position right side behind; head of patient thrown back. First movement; nails of both fingers against the tooth; passing the rubber over tooth, bringing the nails of both forefingers hard upon the gingivæ and hard against the tooth.

Fig. 565. Fourth grasp. Second movement; release the rubber from the grasp by the thumbs on the gingival side while holding it firmly on the gingivæ by the finger nails on the occlusal side until the rubber has closed around the tooth.

Fig. 566. The fourth rubber dam grasp, for bicuspids and first and second molars, both right and left sides, upper and lower. Both forefingers on the occlusal side, with the finger ends coming together in the form of an inverted letter V, with the nails over the margins of the hole to be used. Both thumbs on the gingival side.

Fig. 567. Fourth grasp. For lower left bicuspids, position right side in front; head of patient upright. First movement: pass the rubber over the tooth, bringing the nails of both fingers hard against the gums close against the tooth.

Fig. 568. Fourth grasp. Second movement; release hold by thumbs on gingival side of rubber, while holding it firmly down by the fingers on the occlusal side; see that the rubber has closed around the tooth, then remove the fingers.

THE USE OF LIGATURES.

There are many cases in which the rubber can not be carried between the contact points of the adjoining teeth with the fingers, and a ligature must be used as an aid. One should usually be able to estimate the probable difficulties to be encountered at the time the contacts are tested in preparation for the placing of the dam. Oftentimes, particular attention must be given in advance to a rough surface of a tooth or a restoration and occasionally a separator should be placed for a moment to permit the use of a strip to make it smooth. Time is saved in the long run, also considerable discomfort to the patient is avoided, by strict attention to every little preliminary detail, which will facilitate the application of the rubber.

The silk floss for dental ligatures is twisted rather loosely and a little beeswax is applied so that it will be flattened into ribbon form and pass more easily through a close contact. A little extra beeswax should be applied to many of ligature silks now on the market. The use of the ligature will be facilitated if it is cut into

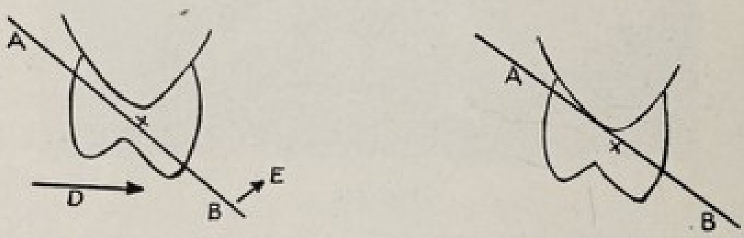


FIG. 573.

pieces 18 inches long, and each piece is wound around two fingers into a loose roll. A few pieces should be kept conveniently at hand for immediate use. The length is just right to permit one end to be wrapped around a finger as an aid in the manipulation and yet leave a sufficient portion to be grasped by the fingers of the other hand.

The use of ligatures as an aid in carrying the rubber through contacts or in holding it in position on the tooth should be strictly limited by the necessities of the particular case, in order to avoid pain and possible injury to the gingivæ. Dentists are inclined to use the ligature more than they should, also to tie it on the teeth when it would hold the rubber as well if the ends were left loose. In a large percentage of cases, a ligature is needed only to turn the edge of the rubber under the margin of the gingiva. After that is done, the ligature should be immediately removed. In such application, the ligature should always be removed in the incisal or occlusal direction and not by pulling it at right angles to the long axis of the tooth. Preferably one end should be held in a direction parallel to the long axis of the tooth and pulled past the

FIG. 569.

FIG. 570.

FIG. 571.

FIG. 572.

FIG. 569. Fifth grasp, for molar teeth, particularly the third molars. See text for description. First position; the rubber is caught between the first and second fingers of both hands, with both thumbs on the occlusal side; each thumb grasps the rubber against the second joint of the closed second finger.

FIG. 570. Fifth grasp. Second position; stretch the rubber by the grasp between the thumbs and second fingers; by bending the two forefingers, catch them in the rubber close on either side of the hole to be used, which is cut a little larger than usual, and stretch the hole open as shown. See that the distal margin of the hole comes over the end portion of the pulps of the fingers and that the median sides of the fingers are well over the margins of the hole as shown.

FIG. 571. Fifth grasp. Position right side behind, head of patient thrown well back. The special rubber dam clamp has previously been set over the upper third molar of left side. First movement; find the rubber dam clamp by the sense of touch; pass the distal margin of the hole in the rubber over the lingual portion of the distal margin of the clamp; it may be heard and felt to snap as it goes over; bring the finger on the lingual side to the lingual foot of the clamp, then holding carefully, direct the patient to close the teeth lightly on the fingers to move the ramus of the lower jaw backward out of the way and sweep the finger on the buccal side over the clamp to its buccal foot.

FIG. 572. Fifth grasp. Second movement; release the hold on the rubber with the thumbs and second fingers; generally the rubber will be felt closing on the fingers; a slight shaking movement will cause it to slip by the fingers and close around the tooth under the clamp. These movements should be conducted by the sense of touch; and for this reason it is unnecessary to have the rubber held away by the fingers of the assistant, as shown in the illustration, except for the purpose of photographing.

contact. A continued slight pull will free the ligature from the lingual surface of the tooth and it may finally be pulled through the other contact.

PAIN. Generally, the use of the ligature should not cause pain, although conditions occasionally arise which call for unusual tension on the gingivæ which would be painful. In such cases a few drops of a local anesthetic may be injected into the gums near the gingivæ. Especial care should be exercised not to injure the anesthetised tissues.

PASSING LIGATURES THROUGH CONTACTS. In using a ligature as an aid in carrying the rubber through a contact it is desirable that one end be wrapped around the little finger of the left hand. The other end may hang loose until the occasion arises when it is needed. The operator may proceed with the application of the dam, knowing that it will not be necessary to release his hold on

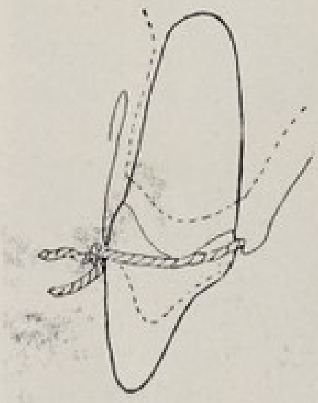


FIG. 574.

FIG. 575.

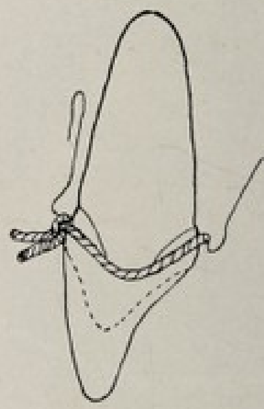


FIG. 576.

the rubber in order to use the ligature. If an assistant is employed, she should be trained in the use of ligatures, thus permitting the dentist to occupy himself with the manipulation of the rubber. Usually only one, or possibly two, of several contacts will require the ligature. It will, therefore, be most convenient to first slip the rubber through at least one contact which does not require the ligature, thus anchoring the rubber and facilitating the technic for the remaining spaces.

In carrying a ligature past a contact, care should be exercised to keep it so under control that it will not snap against the gingivæ and cause pain or actual injury. To avoid this, the ligature should be held close to the tooth on either side, and the movement past the point of contact should be from buccal to lingual, or the reverse, rather than from occlusal to gingival. This may be accomplished by holding the ligature in a direction diagonal to the long axis of the tooth, one end close to the gum, the other at a position beyond the occlusal surface of the crown, far away from the gum. One

edge of the rubber having been carried into the space between the teeth as far as the contact will permit, the ligature should be drawn into the space alongside the rubber and carried laterally through the contact, while held in the position diagonal to the long axis of the tooth. See Figure 573; the ligature is held at A and B and is moved in the direction of the arrow D, while B is moved very slightly in the direction E. The two illustrations show the positions in which the ligature is held before and after it passes the contact.

In carrying the rubber through the contact with the ligature, the grasp must be maintained on the rubber, particularly if it is the first contact in the series. This is done by shifting the fingers after the edge has been turned between the teeth and the hole has been opened to expose most of the tooth to view. If the ligature is wrapped around the little finger of the left hand, the fingers of that hand which grasp the dam need not be shifted, as the end of the second or third finger may hold the ligature in the proper position, while tension is made with the little finger. The right hand grasp of the dam may be released by using the second or third finger to hold the rubber by pressing it gingivally and thus maintain tension on the edge that is engaged at the contact position. The thumb and first finger may then be used to grasp the ligature and draw it through the contact. In different positions in the mouth, the movements and shiftings of fingers will vary according to circumstances, but the general plan will be the same.

It will often be necessary to pass the ligature through the same contact several times to carry a sufficient amount of rubber through, or to carry the entire septum through, when teeth on either side of the hole are to be included. The method of removing this ligature is important. If there is sufficient space between the teeth to the gingival of the contact, the silk may be withdrawn by lateral traction, while tension is maintained on the rubber with a finger of the opposite hand to prevent the rubber from being drawn into a fold in the interproximal space and thus oftentimes causing severe pain. The other method is to turn a loose end, usually the lingual end, back over the occlusal of the contact and pull on both ends in the labial or buccal direction. The ligature may thus be passed through as many additional times as may be required, carrying the rubber a little farther with each passage of the ligature.

Far back in the mouth, it is often necessary to have the ends of the ligature wrapped around the little finger of either hand, in order to apply greater force, also to free other fingers for the manipulation of the rubber. To do this, the ligature should be wrapped on the little finger of each hand, noting carefully that the length between the fingers is just right. It will often be necessary to try this length a number of times before getting it to exactly suit the particular case. The ligature should then be brought over

the contact and under one of the fingers or thumb with which the rubber is forced down, and the rubber should be carried into the embrasure as far as possible; the ligature should then be drawn with the little fingers so as to tighten it on the rubber to hold it, the finger on the opposite side of the tooth being slipped onto the ligature, so that it may be forced on both sides of the tooth at the same time. The accomplishment of this last movement is the most difficult point, but it can generally be done after a few efforts. Then the operator has command of the situation. After forcing the first contact, the grasp of the rubber must generally be released, a second ligature wrapped on the fingers, the rubber grasped anew, and the second contact forced in the same way. This may now be continued until the rubber has been placed on a sufficient number of teeth. Generally, when the rubber has been forced past one close contact, this holds the rubber as a starting point and the rest is much easier of accomplishment.

TURNING THE EDGE OF THE RUBBER GINGIVALLY, WITHOUT LIGATING THE TOOTH. In most cases the edge of the rubber is easily turned gingivally by allowing it to slide away from the ends of the fingers, as has been described. The edge is less likely to remain in position about the anterior teeth, because of their wedge form. If it does not stay, it may be turned gingivally by carrying the end of a beaver-tailed burnisher along first the lingual, then the labial contour of the tooth. If this fails a ligature should be employed.

The ligature should be carried through both contacts of the particular tooth, with the loop on the lingual side. It should then be drawn closely against the lingual surface of the tooth and the burnisher should be again used to press the silk gingivally, while making slight tension on the ends which are free on the labial side. The burnisher should again be used to turn the labial edge under without the aid of the ligature. If it stays, the ligature should be removed immediately, by carrying one end over the incisal edge to the lingual, drawing it through the contact, carefully withdrawing it from the lingual and finally past the other contact.

In case the edge of the rubber does not maintain its gingival direction with the above technic, every other conceivable method should be tried to avoid tying the ligature around the tooth. With the ligature about the lingual, as described, the labial edge may be again turned back with the burnisher and while so held, a small bit of copper cement may be stuck to the labial enamel in contact with the fold of the rubber. Sticky wax may be used for the same purpose.

If the rubber has been placed over a number of teeth, it may not be necessary that the edge be turned gingivally about every tooth. One or two may be sufficient, depending on the conditions in the particular case. The others, with edge turned occlusally, in

many cases, may be safely sealed with a varnish coating over the edge of the rubber and the enamel.

LIGATURES TIED ABOUT THE TEETH. In some cases a ligature must be tied about a tooth to hold the rubber dam in place; particularly where the application is to the anterior teeth and a clamp is not used. It may also be necessary to prevent leakage of moisture about the margins of the rubber.

The technic of placing the ligature around a tooth and tucking in under the margin of the gingiva has been described. It is only necessary to complete the ligation by tying a surgeon's knot, usually on the labial or buccal side. See Figure 578, upper knot. In doing this, the silk should be very carefully drawn about the tooth and tucked under the gingiva on the labial side as the first half of the knot is tied.

A caution should be given regarding the tying of ligatures on the incisor teeth, and particularly on the teeth of young people. The photograph of an incisor tooth, Figure 575, shows the arching of the cemental line over from labial to lingual, which is the

FIG. 577.

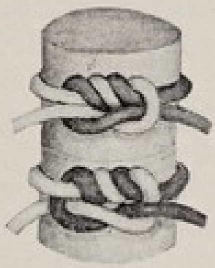


FIG. 578.

line of the normal attachment of the peridental membrane to the tooth. This arch of the cemental line is met with continually in the illustrations of incisors.

If the ligature is forced close to the cemental line on the lingual side and then is forced also hard to the gingival on the labial side of the tooth and tightly drawn, it will cut the tissue arched over in the interproximal space on both the mesial and the distal surfaces, and, occasionally, cases occur in young persons in which the ligature has actually passed between the interproximal bone tissue and the root of the tooth. The pain caused by this is often extreme. There may result a permanent diseased condition of the peridental membranes from which the teeth will remain sore for many years and eventually be lost.

If ligatures are placed on the incisor teeth, they should never be pushed hard to the gingival on the labial side after pushing them beneath the edge of the gingiva on the lingual side and then tightly drawn; or, the ligature should not be drawn tightly and held so, while the lingual portion is pushed under the gingiva. The

ligature should generally be tied in the position shown in Figure 574, and in the tying, it should be drawn only tight enough to hold. The ligature may rest upon the attachment of the tissue at the crest of the arch, as shown in Figure 576, but should not injure that tissue. This should always be done with great care. Incurable disease of the peridental membrane has been traced to this as the initial lesion so many times that this warning must be repeated with much emphasis. Opportunity is here presented for each dentist to make a definite contribution to the prevention of disease of the peridental membrane.

On the bicuspids and molars there is not the same danger from tying ligatures for the reason that the arching of the cemental line does not occur in them.

Ligatures should not be tied on teeth on which any kind of a clamp, matrix or separator is to be placed. In case ligatures have been tied in connection with the preparation of a cavity, they should be removed before placing the separator. The same rule should apply to any kind of clamp or matrix.

It becomes necessary in rare instances to tie a ligature about a molar tooth to serve instead of a clamp, when conditions are such that a clamp may not be used. For example, if the third

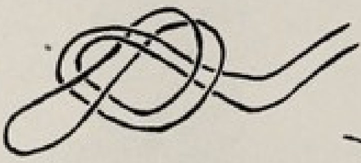


Fig. 579.

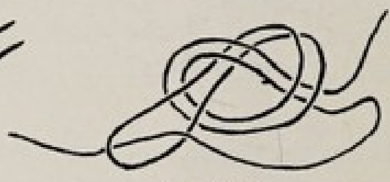


Fig. 580.

molar has been lost, and a restoration must be placed in the second molar in such position that a clamp would interfere, the rubber may generally be held in place with a ligature which has been threaded through a glass bead and tied, to hold the bead at a point midway the length of the ligature. In tying the ligature about the tooth, the bead should usually be placed near the disto-lingual angle of the tooth. This tends to prevent the rubber from slipping off. A special loop knot, or a group of knots, tied one over another, will answer the same purpose, or if something larger is required, a small piece of cotton may be tied into the ligature. The manner of tying the special loop knot is illustrated in Figures 579 and 580 and described in the accompanying text.

Tying ligatures. In tying ligatures about the teeth, the first half of a surgeon's knot (the upper one in Figure 578) should first be formed and tightly drawn. In doing this, the ligature should be grasped as close to the knot as practicable and held close against the teeth, one end to the mesial and the other to the distal. If the ligature is over the bicuspids or molars, the distal end should be caught over the end of the forefinger of one hand and forced

to the distal close against the teeth while pulling the mesial end with the other hand. If the ligature has been well waxed, the first half of the knot should not slip or loosen; but it must not be pulled or disturbed in the least while forming the other half of the knot. The ends should be allowed to fall perfectly loose while forming the second half, which should be worked up carefully until it is just right and then drawn tight at a single pull, again keeping the fingers close against the arch, both to the mesial and distal. A ligature tied in this way should always remain tight around the tooth. It is essential that the knot used should be the true surgeon's knot shown in the upper knot in Figure 578, and not the granny knot below this. The first half of these two knots is formed in the same way, but in the second the crossing of the ends of the ligature has been different so that the end does not come out of the knot beside the entering end in the granny knot, as it does in the true surgeon's knot above. In the granny knot these come out in such a way that the ends of the twist in making the first half are pulled away instead of being tight, as in the upper knot. This allows such a knot to loosen just a little, which is often fatal to the hold of the ligature on the tooth. The ends of the cords with which these knots were made for these pictures were of different colors in order that each thread could be traced through and its return on itself, or its variation from that, discovered. The upper knot in Figure 577, which is the most perfect tie for ordinary purposes, is the square knot. It should be compared with the granny square knot below. The cords should be traced in and out and knots should be made in each way to learn the difference in the direction of crossing the cords for forming the second half of the knot. The square knot is the same as the surgeon's knot, only that in forming it, a single wrap of the cords is made in the first tie, while an extra wrap is made for the surgeon's knot. The first tie of the square knot is more likely to slip while the second tie is being made. The two wraps of the surgeon's knot prevent this, provided sufficient care is taken not to disturb them while forming the second half. To make a knot that will not be liable to slip, both of the ends must be turned upon themselves and crossed in forming the second half. A dentist should always have the surgeon's knot, the upper one in Figure 578, so perfectly at his finger-ends that he will make no mistake in tying it.

The loop knot is the most convenient to use in tying a knot in the center of a ligature, before the ligature is tied around a molar tooth, in cases in which the ligature is used instead of a clamp. Before tying the loop, the two ends of a piece of silk about eighteen inches long should be placed together, so that the loop will be in the center. Then the loop knot should be loosely tied, as shown in Figure 579. One loose end of the ligature should be passed through the loop, as shown in Figure 580, and the knot should be drawn tight by pulling on the two ends of the ligature.

There are certain other uses of ligatures in connection with the rubber dam clamps, which will be mentioned in describing the uses of clamps.

Rubber Dam Clamps

Rubber dam clamps are used upon the teeth to secure the rubber dam in position, and incidentally to hold the rubber more out of the way than it would be without them. They contribute greatly to the usefulness of the rubber dam by rendering it secure and relieving the operator of care or anxiety as to the dryness and cleanliness of his field of operation.

Several clamps are shown in the illustrations. Most dentists have a larger number, but this selection will answer for prac-

Fig. 581.

Fig. 582.

Fig. 583.

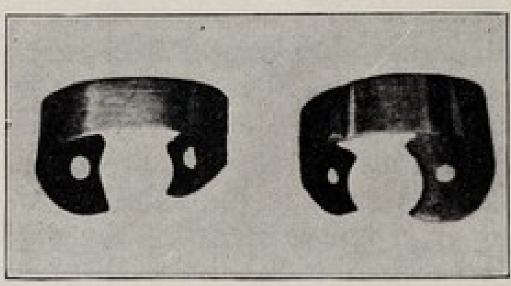


Fig. 584.

tically all cases. There are clamps of special design which have flanges of various sizes to hold the folds of the rubber farther away from the tooth than will those illustrated; others are for the purpose of holding cotton rolls in position, etc. The principles may be well established with the clamps in the illustrations.

Three clamps are shown in Figures 581 to 583. The one with small jaws is for application to bicuspid teeth, the other two are for molars. Clamp No. 18, Figure 581, may be used on almost any first or second molar, upper or lower, and should be used in possibly ninety per cent of all applications for operations from the cuspids to the second molars, which call for a rubber dam. Clamp No. 26, Figure 582, is similar to No. 18, except that edges of the jaws are more inclined in the gingival direction and will hold more securely on a tooth that is not fully erupted. Clamp No. 27, Figure 583, is for bicuspids, but may also be applied to temporary

molars. However, it should be the rule that this clamp be not used if a permanent molar is present on which some other clamp might be applied. This clamp is needed in only an occasional case.

Two special clamps for third molars are illustrated in Figure 584. They are a pair, with very strong bows and a forceful grip. The bow is inclined only very slightly to the distal in relation to the jaws, to permit their use on third molars without impingement on the soft tissues. The jaws are inclined gingivally at such an angle that they will often hold when placed slightly to the occlusal of the height of contour of the crown. They were designed to be applied to any molar which is not fully erupted, or which has buccal and lingual surfaces so much inclined toward the median axis that the other clamps slip off occlusally.

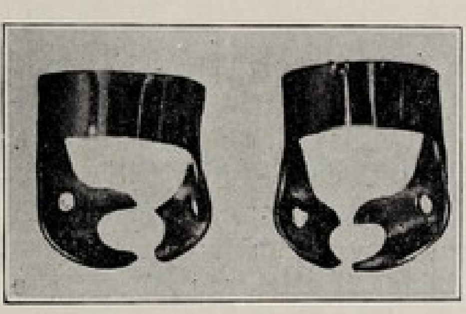


FIG. 585.

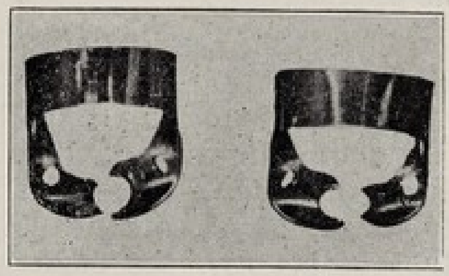


FIG. 586.

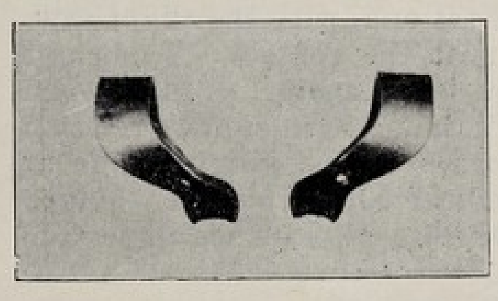


FIG. 587.

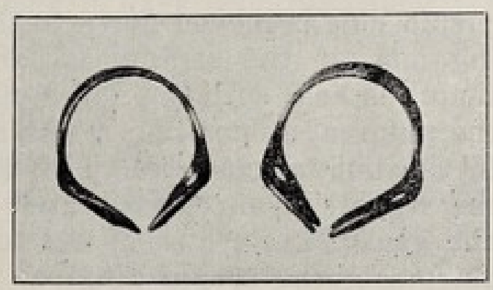


FIG. 588.

Two pairs of special root clamps are shown in Figures 585, 586, 587, and 588. They were designed for application to roots of almost any tooth, the crown of which might have been lost as a result of decay or accident. The smaller pair is for anterior teeth, the larger pair for molars. The jaws are very much inclined to the gingival and when spread apart they become so nearly parallel that the points will grasp the end of a root which does not project above the gum. A rubber may be placed over such a clamp after the clamp is in place and will be guided by the sides of the clamp to conform to the root contour with the edge of the rubber turned gingivally. They are generally used in those cases in which one desires to treat the pulp of such a tooth.

Application of the Rubber Dam.

The application of the rubber dam is, in possibly ninety-five per cent of cases, one of the easiest technical procedures which the dentist performs. Like most other clinical services, it requires knowledge of the principles and fingers experienced by training. In most cases the rubber should be fully adjusted, with the head band attached in less than two minutes. If there are difficulties with contacts, which should usually be largely eliminated in advance, it will take a little longer. The technic of applying the dam in various parts of the mouth will be briefly described. It will be understood that all necessary preliminary steps have been taken, including the punching of the holes in the rubber.

If both surfaces of the rubber are moistened with cocoa-butter in the region about the punched holes, this lubricant will facilitate its application.

Incisors and cuspids. Taking as an example the six upper teeth, cuspid to cuspid. The chair is tipped well back, the operator stands right side in front, the rubber is held with the first grasp. The thumbs spread the hole open for the left cuspid and the distal edge of the hole is slipped between the first bicuspid and cuspid to the point of contact. With a slight sawing motion it passes the contact and the edge is carried beneath the margin of the gingiva on the distal side of the cuspid. The thumbs and fingers are moved a little closer to the septum between the cuspid and lateral, and with the rubber on stretch the mesial edge of the cuspid hole is moved down to the contact and, with the slight sawing motion, the septum is carried past the contact. The right thumb is held with the nail against the labial enamel as far toward the gingival as possible, while the left thumb is in similar relation to the lingual surface. The first fingers on the gingival side of the rubber are released and the rubber slides off the thumbs and grasps the crown of the tooth with its edge turned under the margin of the cuspid gingiva.

The first grasp is again taken and, with the thumbs stretching the hole for the lateral, the septum of rubber is passed between the lateral and central; the edge is then turned gingivally as before. This is continued for each of the six teeth and the application is completed by attaching the head piece and the weights, placing a pad over the chin and the saliva ejector in the mouth.

If the contacts are not too tight, the entire procedure may often be completed in less than one minute, with the aid of an assistant.

Especial attention is called to the carrying of the septum of rubber (between two holes) past the contact, as it is one item in the technic which many operators fail to follow. Consider for a moment the septum between the left lateral incisor and cuspid. *One edge only* of the septum is placed between the teeth; the rub-

ber which constitutes the septum is flattened out and on stretch in the plane between and parallel to the proximal surfaces of the teeth. The lower edge is the edge which will conform to the mesial surface of the cuspid when it is in place. The upper edge will conform to the distal surface of the lateral incisor. The first concern is to get this piece of rubber past the contact; therefore one edge is carried to and through the contact while the entire piece of rubber constituting the septum is flat and on stretch and so held that there will be no fold in the rubber and therefore nothing more than the single thickness of stretched rubber to pass the contact as the entire septum is carried through.

Difficulty in carrying the rubber through the contact is usually due to an effort to force a piece of folded rubber, possibly two or three or even four thicknesses, past the contact at one time. Because of this difficulty many operators cut the holes too close together so there will be less septum to pass the contact; then the rubber does not hold closely about the teeth and moisture leaks through. It should be recognized that the difficulty of carrying the rubber septum through the contact is not due to its width, but to the fact that it is not kept flat as it is passed through.

If it is necessary to use a ligature to carry the septum through, it is even more important not to have a fold in the rubber. The ligature should carry a millimeter or so of the rubber through with it, each time it is carried past the contact. If the edge of the rubber about any tooth does not remain with its edge turned under the gingiva, the means of fixing it have been described.

The application for the lower anterior teeth is in all essentials similar to that for the uppers. The grasp, the position of the operator and the position of the chair are different.

BICUSPIDS AND MOLARS. In making restorations in the bicuspids, the rubber should be secured with a rubber dam clamp on the first molar. The bow of the clamp holds the rubber out of the way and gives space and a better view of the field of operation. Whenever practicable, the clamp should be placed upon the first molar for operations on the bicuspids, and on the second molar for operations on the first molar. Generally, it is thought that in operations on the second molar involving the occlusal or mesial surfaces, a clamp with a bow standing well to the distal should be placed on the same tooth in order to avoid the difficulty of placing the dam on the third molar. But if one has learned to handle the special clamp and the rubber with the fifth grasp, it is as easy to place it on the third molar for all operations on the second molar. For cavities in the distal or buccal surfaces of the second molar this is usually essential.

There are three different plans by which the rubber dam may be placed in the bicuspid-molar region. The application of the dam to the cuspid, first and second bicuspids and the first molar, will be used as an example.

1. By placing the rubber over the bow of the clamp, then setting the clamp in position over the first molar, and stretching the rubber over the jaws of the clamp, and incidentally over the molar. The rubber should then be applied to the second bicuspid, first bicuspid and cuspid, in order. This is generally the easiest plan for an operator without the aid of an assistant.

2. By placing the clamp on the first molar as the first procedure and then applying the rubber over both the clamp and the tooth. The rubber should then be applied to the other teeth in the order just mentioned. This is very similar to the first plan and is also easy for an operator without an assistant.

3. By first placing the rubber over the first molar, and then applying the clamp. This is often the easiest plan for an operator with the aid of an assistant, who places the clamp, while the operator holds the rubber in position over the first molar. It is obviously more difficult if the operator must hold the rubber with one hand and place the clamp with the other.

The technic of getting the rubber in position over both the clamp and the first molar by the first plan is as follows: The No. 18 clamp should be placed in the clamp forceps; the holes should be punched in the rubber in their proper positions; the first molar hole should consist of two punches, one overlapping the other to make an oval hole, with the long diameter in the bucco-lingual direction. This is to reduce the danger of tearing the rubber in stretching it over the clamp. The hole should be carried over the bow only of the clamp and all sides of the rubber should be folded back over the upper side of the clamp forceps so that the operator can see the jaws of the clamp while placing it on the first molar. The clamp forceps should then be removed and the rubber should be spread out to cover lips and cheeks. The lower half of the rubber should be held with the fifth grasp, the first finger of the right hand to the buccal side of the hole, the first finger of the left hand to the lingual. The hole should be stretched and the edges carried under the buccal and lingual jaws of the clamp. If the edge is inclined to catch and not slip under the jaw, it may usually be guided under with a beaver-tail burnisher, or the clamp may be lifted slightly on the tooth, using the clamp forceps for the purpose. The jaws of the clamp should not be lifted away from the tooth; it should be moved occlusally while the jaws maintain slight contact with the tooth. When the rubber slides under, the clamp is replaced in its former position. It may be easier to raise first one jaw of the clamp and replace it, then the other jaw.

The septum between first molar and second bicuspid is carried edgewise through the contact. The procedure already described for the incisors is followed for the bicuspids and cuspid. There remains the distal edge of the hole for the first molar, which overlies the distal portion of the occlusal surface of that tooth. It must be carried past the contact between the first and second

molars. This may be done by carrying a ligature over the bow of the clamp to the distal and first drawing it down over the rubber. With a beaver-tail burnisher the ligature is drawn mesially past the edge of the rubber, then both the edge of the rubber and the ligature are drawn into the space and past the contact by pulling on both ends of the ligature.

This entire application should be made in from two to three minutes if there is no unusual difficulty with the contacts.

The only difference between the second plan and the first is in carrying the rubber over the clamp, after it has been placed on the tooth. This requires a little experience, but one should learn to do it with his eyes shut. The fifth grasp should be used, with the ends of the fingers in position to stretch the rubber on the distal side of the hole. One should first feel the clamp with the fingers, then, by holding one side (the lingual, for example) of the hole against the gum, with the first finger of the left hand, the first finger of the right hand should, with a sweeping motion, carry the rubber over the clamp to the buccal and on until the edge is lodged under the gingival side of the jaw of the clamp. The lingual edge of the hole should then be carried under the jaw of the clamp on the lingual side. From this point, the procedure is the same described for the first plan.

The third plan involves nothing in technic that has not been described. The operator should stand on the right side in front with the chair upright and should use the fourth or the fifth grasp, whichever is more convenient. He should hold the rubber in position over the tooth, being certain that the edges are held away so that the jaws of the clamp will rest on the tooth. As the grasp on the rubber is released, the edge should slip under the jaws of the clamp.

It is obvious that the same procedures are to be used when the clamp and rubber are to be placed on the second molar. The several plans are the same for the teeth of either side of the mouth, above or below. The grasps are the same, the positions of the operator and the positions of the chair are different.

THIRD MOLARS. The rubber dam is applied to third molars for two principal purposes; to make restorations in the third molars, and in applying the rubber for operations on the second molars in cases in which it is not practicable to place the clamp on the second molar. The special third molar clamps are used. See Figure 584. The clamp is first placed on the tooth and the rubber is slipped over it. It is easier to place the rubber over this clamp than the No. 18 clamp, as it is usually only necessary to pass the rubber over the bow, which slopes in continuous curves to form the jaws, and the rubber slides to place about the tooth. The technic will be given for the upper right third molar. The operator should stand in the position behind and above, with the chair tipped far back. The fifth grasp should be used, with a large

hole in the rubber. The ends of the forefingers should be placed fully to the distal side of the hole, or so that its distal edge is fully between the finger ends and upon their palmar surfaces. Then it must be so stretched that the distal edge of the hole may be passed over the distal edge of the bow of the clamp, Figures 569, 570, starting it first over its lingual portion, and bringing the first finger of the left hand under the lingual side of the clamp and sweeping the first finger of the right hand around over the buccal portion, ending with both fingers against the outer margins of the jaws of the clamp, Figure 571. The grasp of the thumbs and second fingers should then be released, and, by a little careful motion of the fingers, the rubber is allowed to close around the tooth under the clamp, Figure 572. The passing of the rubber over the clamp should be done entirely by the sense of touch, and should first be practiced out of the mouth for the purpose of learning the points to be made by this sense. These are: first, the ability to feel the position of the distal margin of the hole in the rubber on the fingers; and, second, by the sense of touch, to bring this over the distal edge of the bow of the clamp. This may readily be made to snap over the bow of the clamp so that it is felt and heard. Then the finger on the lingual should feel its way to the lingual foot of the clamp and hold that position while the finger on the buccal side slides to the buccal foot of the clamp. The rubber should then be released with the fingers and the operation completed as directed below. In other words, when the rubber has been passed to the distal of the clamp, a sweep of one finger on the lingual to the gums, then a sweep of the other to the buccal over the bow of the clamp following its curvature, completes this part of the movement. Then, while the fingers are held against each foot of the clamp, the rubber dam is released with the thumbs. Figure 572. As the rubber is felt to draw on the fingers, a little oscillating movement should be made, which allows the rubber to close around the neck of the tooth under the jaws of the clamp. This is generally done easily and quickly when the particular relation of the fingers to the hole in the dam is appreciated. After this starting point has been secured, it is not very difficult to secure the rubber over the teeth mesial to it. When the rubber dam has been placed in this way on a second molar, the rubber may catch on the cusps of the third molar and require to be pulled forward into position between the teeth; or it may refuse to enter the contact between the teeth sufficiently to exclude moisture. Often it may be teased into place with a beaver-tail burnisher. If this does not succeed promptly, a ligature should be placed around the clamp over the rubber dam, and with this the rubber is readily drawn into position between the teeth.

In the upper jaw the most serious difficulty met with in placing the rubber over the bow of the clamp placed on the third molar is the interference of the ramus of the lower jaw, which comes

forward when the mouth is opened wide and does not leave room for the finger to pass over to the buccal side. This difficulty may be seen when the clamp is applied. The patient should be instructed to close the teeth lightly on the operator's fingers at a word from the operator, when he is ready to make the movement over the buccal portion of the clamp. This clears the way for the finger to pass easily. As these movements are directed entirely by the sense of touch, the closing of the mouth, or the lapping of the rubber over the fingers is of no consequence.

In the lower jaw the bow of the clamp will sometimes be found hard against the soft tissues near the foot of the clamp on the buccal side. Generally this may be remedied in a degree by changing the position of the clamp slightly. Or, if the rubber can be brought over the bow and to the lingual foot of the clamp and held, it may generally be forced or teased between the clamp and the tissues on the buccal side. In any case in which it is far enough over the bow of the clamp to have a tendency to slide toward the foot, it may be released and a ligature passed over the bow of the clamp, with which the rubber may be pulled into place.

In cases in which a restoration with amalgam is to be in the occlusal surface of a third molar that is only partially erupted and the grasp of the clamp may be rather insecure, it will often be best to make but one hole in the rubber and apply it to the third molar only. This avoids the danger of dislodging the clamp in applying the rubber to the second molar. With the special clamp, this application of the rubber, usually considered difficult, becomes the simplest and quickest of any in the mouth. After the clamp is in place the rubber may be applied in ten or fifteen seconds. It should be done entirely with the sense of touch and the operator's eyes may be closed while the application is made.

In some cases in which molar teeth have been lost and there is no tooth posterior to the one on which an operation is to be made, a clamp may not be used. The several plans of using a ligature as a substitute for the clamp have been mentioned in discussing the uses of ligatures. It is occasionally necessary to secure the rubber to permit the removal of the clamp in order to place a separator or a special clamp for a gingival third restoration in the next tooth to the mesial of the one on which the clamp was placed. In all such cases, a ligature may be tied in place, sometimes before the clamp is removed, sometimes afterward.

Labial and buccal cavities. Cavities in the gingival third of labial and buccal surfaces present a different problem in the application of the rubber dam, particularly when they approach near to, or extend beyond, the cervical line. The difficulty is so to apply the rubber that this area may be kept absolutely dry.

The special molar clamp, illustrated in Figure 584, may be used for gingival third cavities in any of the molar teeth if the

decay has not extended too far gingivally. The clamp should usually be placed first to be certain that the jaw on the buccal side is in the best position in relation to the gingival margin of the cavity. The rubber may then be slipped over the clamp, using the fifth grasp. In those cases in which the prepared cavity extends far to the gingival, it will usually be best to punch but a single hole in the dam.

In all cases in which the cavity has extended slightly to the gingival, special attention should be given to the positions of the holes in the rubber dam. The hole to be applied to the tooth for which the restoration is to be made, should be punched a little to the buccal of the line of the holes on either side. Figure 552 shows the proper position of the holes in a rubber to be applied from first molar to central incisor in a case in which there is a gingival third cavity in the buccal surface of the first bicuspid. If the hole is not punched in this position, the rubber will be stretched so much in drawing it beyond the gingival margin of the prepared cavity, that it will lack the fullness necessary to permit the edge to be turned under the gingival, and leakage will occur.

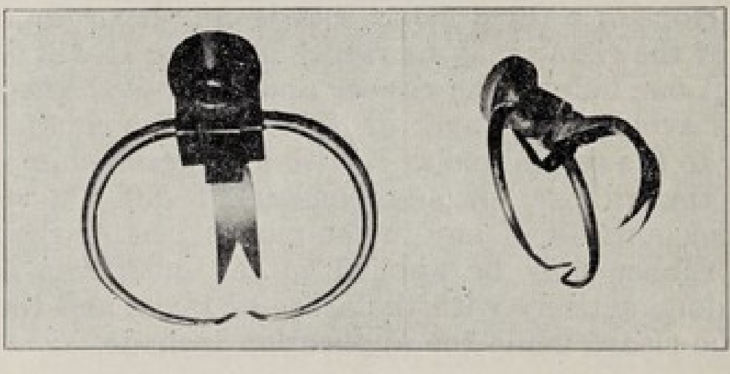


FIG. 589. FIG. 590.

A number of special clamps have been designed for gingival third cavities in labial and buccal surfaces. Two of these are illustrated. The Hatch clamp, shown in Figures 589 to 593, was designed for incisors, cuspids and bicuspids, but may often be applied for buccal cavities in first molars, and occasionally for second molars. The Prime clamp, Figures 594 and 595, is also applicable in the same positions.

THE HATCH CLAMP. As an illustration, the placing of a Hatch clamp on the lower right cuspid will be described. The operator's position should be left side behind, with the chair upright. In Figure 591, the operator's right hand is above, the left hand is below the tooth. The clamp should first be adjusted and tried, to see that it is open just sufficiently to be slipped in place and no more, so that a turn of the thumb screw will fasten it. In making this test, the clamp should be placed exactly in the position desired,

to be certain that it will be secure. If pain of consequence is caused in applying it, or if the patient complains of the effort before it is in position, a few drops of local anesthetic solution should be injected into the gingival portion of the gum on both the labial and lingual sides of the tooth.

In cases in which it is evident that the rubber cannot be placed without injuring the labial gingiva, it will often be best, after securing local anesthesia, to cut the edge of the gingiva away with a sharp knife. This tissue will be rebuilt within a few days. The gingiva is likely to suffer greater permanent injury from severe bruising than clean cutting. A restoration demanding dryness, should not be undertaken unless conditions are such that the prepared cavity may be kept absolutely dry.

In applying the rubber dam, the operator should so modify his position that the right hand may manipulate the clamp, while

FIG. 591.

the left holds away the rubber. There should always be one finger in place to steady the clamp and prevent it from moving when tightening the screw. If, in stretching the rubber dam, it is caught with the thumb and second finger of the left hand, as in Figure 591, the first finger may be used to steady the clamp. The rubber dam should be pulled well out of the way so that the place to set the points of the clamp is in full view. When the jaws are in position, they should be held with a finger of the left hand while the adjusting screw is tightened. The rubber is then released to draw against the points of the clamp. The flat burnisher may be passed underneath the piece of rubber dam, and its end brought into position between the gum and the *gingival side* of the rubber. The gum may then be pressed back with one side of the instrument end, while the burnisher is so inclined as to guide the margin of the hole to draw down next to the tooth. This will give a per-

fect view of the cavity, keep it perfectly dry and give command of the conditions for any operation needed.

Attention is called to the difference in the grasp of the rubber with the left hand in Figures 591 and 592. In Figure 592 the first finger, instead of the second, is used to hold the rubber. The first finger should be free to assist in holding the clamp jaws in position, while the set-screw is tightened. Figure 593 shows the clamp properly adjusted for treatment of the gingival third area of the cuspid with silver nitrate.

A ligature is occasionally of assistance in turning the edge of the rubber gingivally, particularly if the prepared cavity extends nearly to, or possibly beyond, the mesio-labial and disto-labial angles of the tooth. The silk should be carried through both interproximal spaces, with the loop on the lingual side. The loop should be placed under the lingual jaw of the clamp with a beaver-

Fig. 592.

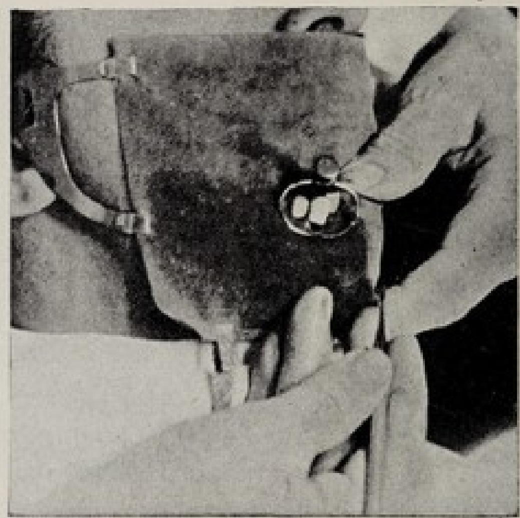


Fig. 593.

tail burnisher and the edge of the rubber should be turned gingivally by making slight tension on the ends which project labially. The ends should be inclined incisally and care should be taken not to cause undue pressure on the attachment of the gingivæ on the mesial and distal sides of the tooth. The ends of the ligature should be left loose; it should not be tied. Then, with the burnisher, each loose end may be gently tucked under the margin of the gingiva along the mesio-labial and disto-labial angles of the tooth.

After this is done, or in case the ligature has not been used, if there is the least leakage of moisture anywhere along the margin of the rubber, the burnisher should be dipped into 95% phenol and then carried along the margin to coagulate the tissue where the leakage occurs.

THE PRIME CLAMP. A new clamp, not yet on the market, has recently been designed by Dr. James M. Prime. It is illustrated in Figures 594 and 595. It is easy to apply, but has not as yet been used sufficiently to justify a statement as to its range of convenient application. It consists of a pair of spring steel jaws, and may be placed in position with the clamp forceps in the same manner as an ordinary rubber dam clamp. See Figure 594. After it has been placed on the tooth, with the lingual jaw close to the gum and the buccal, or labial, jaw as far to the gingival as may be convenient, the bows are blocked in position by packing modeling compound or base-plate gutta-percha under the bows, as illustrated in Figure 595. One may then move the labial jaw as much farther to the gingival as may be desired, by turning the two small bolts on the labial side, with a separator wrench, or any instrument with a round end of proper size. This clamp gives a much broader approach than the Hatch clamp.

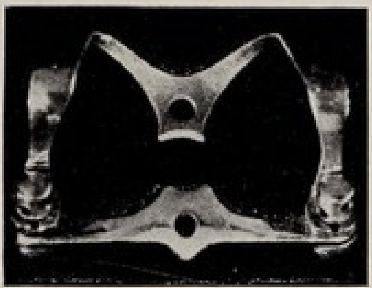


FIG. 594.

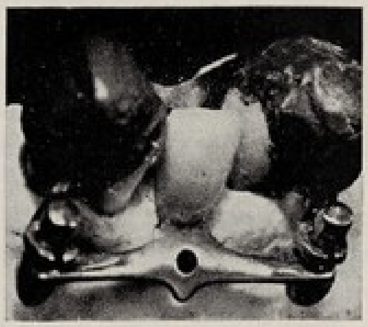


FIG. 595.

In some cases, it is impossible for the most skillful operators to so apply any of these clamps in such manner as to prevent leakage. Then resort must be had to holding the dam in position with an instrument in the hand of an assistant, or in the left hand of the operator while performing the operation with the right hand. The procedure by the operator alone is difficult, but practicable in some cases. The best instrument for this purpose has a slightly curved shank with a broad flat end cut in the form of a fork, or a V-shaped notch.

In preparing for an amalgam restoration in a proximo-occlusal cavity, where the gingival wall is very difficult to reach, the rubber may be forced into position and held with a matrix, or the matrix may be placed first and securely tied and the rubber applied over it. Sometimes a similar device will accomplish the same purpose upon buccal surfaces.

STOPPING LEAKS IN THE RUBBER DAM. If a leak in a rubber dam is discovered before the operation for which it was placed is begun, it will usually be best to remove it and use a new piece of rubber. Occasionally a very small hole or tear may be made

with the jaw of a clamp, or with an instrument and this may not be discovered until an operation is in progress. If the hole is somewhat removed from the tooth being operated on, a considerable pack of cotton or gauze under the rubber may be sufficient. No matter what its position, a small hole may be definitely sealed by dipping a firmly rolled bit of cotton in chloro-percha and placing it in the hole while the rubber is stretched for the moment.

Removal of Ligatures and Rubber Dam.

When the operation is completed, great care should be taken to remove all ligatures before removing the rubber, for if the rubber is pulled away with a ligature on, a ring of rubber will sometimes be torn away and remain around the neck of the tooth unobserved and do great damage before the cause is discovered. Each ligature should be cut and removed. A gold finishing knife, Figure 424, is very convenient for this purpose. If the ligature had been tied, the knot may be grasped with a pair of pliers to remove the piece that is wrapped around the tooth. In removing the rubber dam, it should be stretched to the labial or buccal and each septum should be cut with a small pair of blunt-end scissors. The crown and collar scissors are best for this. After the rubber is removed, it should be examined carefully to see if any part has been torn away and possibly left between the teeth. The best way to do this, is to hold it up to the light to see that it is all there. This will avoid the danger of leaving bits of rubber under the margins of the gingivae. Finally, when the rubber has been removed, the gums should be well kneaded with the fingers and flooded with warm water from the syringe. The gums will have been compressed and the circulation interfered with, and this will clean the parts and start the blood into full activity, thus preventing the soreness that will sometimes follow if this is neglected.

PACKING THE MOUTH.

In selected cases, a particular region of the mouth may be kept free from saliva for a brief period by the use of rolls of gauze or cotton. However, consideration must be given to the moisture from the breath, which may prevent one from maintaining a dry field, unless the patient breathes through the nose. As a rule the saliva ejector will aid by carrying away saliva that may accumulate in the floor of the mouth; it will also prevent the patient from closing the mouth, and the tongue will usually be held well back in the mouth while the ejector is in place. The technic of packing is different for various locations.

By such means, it is less difficult to maintain dryness of the upper than the lower teeth, and the upper anterior teeth may be kept dry with greater certainty than the upper posterior teeth. The lower molars are usually the most difficult. The flow of saliva in some mouths is much greater than in others, due to any of

several causes. Young children have difficulty in cooperating by keeping the tongue, cheeks and jaws at rest, as do many persons of mature age. Some persons gag very readily if anything is placed far back in the mouth; others breathe through the nose with difficulty. These and other obstacles, such as the nature of the operation and the time it will likely require, must be given consideration in each case.

The dentist will oftentimes need both hands free for some other purpose and must therefore, if operating without an assistant, depend on the thoroughness of the packing and the cooperation of the patient, to maintain dryness of the field while he is otherwise occupied. Certainly the dentist who employs an assistant will less often fail to keep the field dry. For some operations, the assistant will attend to the patient, holding the packing in place while the dentist performs the operation; in others, the dentist will look after the mouth while the assistant prepares a mix of cement or performs some other service. First one, then the other, may be watchful of the packing, to be certain that the field is dry. It is always necessary to use cotton and usually air to dry the field after the mouth is packed, and often desirable to repeat this procedure at the last moment before the performance of the particular procedure for which dryness is necessary.

Before packing the mouth, everything should be in readiness for the operation so that there will be no unnecessary delay in its performance. The saliva ejector should be tested to be certain that it is in good order, and several extra gauze or cotton rolls should be laid on the tray for replacing rolls which become moist with absorbed saliva. Whatever aids are desirable for holding the gauze should be tried, if necessary, to be certain they are suited for the purpose.

The rolls may be of gauze, cotton encased in gauze, or any absorbent material, and should be of several sizes—¼, ⅜ and ½ inches in diameter, and about two and a half inches long. For young children, they may be cut as much shorter as may be desired.

For the region of the upper anterior teeth, a roll of gauze or cotton placed under the lip, and the saliva ejector to drain saliva from the mouth, are all that are usually required. The gauze should be so placed that it will remain high up against the tissues at the junction of the gum and lip, and not be dislodged by movements of the lip. To accomplish this, the lip should be drawn a little outward from the teeth and the gauze roll should be rotated into position. As the gauze is carried upward, the rotation should be in such direction that the surface against the gum is being turned upward, while the surface against the lip is being turned downward. This prevents a fold of the mucous membrane of the lip from being formed above the gauze, as is likely to occur if the gauze is placed without rotating it. Such a fold places the mucous membrane of the lip on tension and it pulls the gauze away from

the desired position. The area is dried with cotton and air after the gauze and ejector are in place.

For the upper posterior teeth the procedure is the same, except that the gauze is rotated into place opposite the molars and should cover the orifice of Stenson's duct. In this position the gauze is likely to become saturated with saliva within a short time and another roll must be substituted. It will often be helpful, particularly if operating without an assistant, to use a rubber dam clamp with flanges on the buccal and lingual sides, designed to hold a roll of gauze in place. In this position the gauze would be used only on the buccal side, but the lingual flange might be helpful in keeping the tongue away from the operating field.

For the lower anterior teeth, one roll of gauze should be placed to the lingual, well under the tongue, another should be rotated into position under the lower lip. If the saliva flows copiously, it may be desirable to place two more gauze rolls, one on either side to the buccal of the upper molars, to absorb the discharge of Stenson's ducts. The saliva ejector should also be used.

For the lower posterior teeth, at least three rolls of gauze should be used; one to the buccal of the upper molars, one to the buccal of the lower molars, and one, usually of larger diameter, to the lingual of the lower molars, under the tongue. The roll may be most conveniently placed under the tongue either by asking the patient to lift the tongue, or by carrying the first finger of the left hand under the tongue rather far back on the desired side, and then placing the roll under the finger as it is lifted. The saliva ejector should be placed near the front of the mouth on the opposite side. A flanged clamp, placed on the most convenient lower molar, may be helpful in holding both rolls of gauze in place, also in keeping the tongue away. A special device is made for holding the gauze rolls to maintain dryness in the lower molar region. It consists of a narrow arm to hold the gauze to the buccal and a much wider arm or plate to hold the gauze to the lingual of the teeth and also serve as a tongue depressor. It is held in position with a spring controlled clamp which fits under the chin.

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