The gag / by G.H. Colt.

(10)

THE GAG

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THE GAG.[1]

No apology is needed for bringing forward the subject of a mouth-gag designed to suit the needs of the general practitioner, surgeon, dental surgeon, and anæsthetist. If the matter is considered from a scientific point of view the need for a systematic revision of the subject is plain. The number of gags on the market is large, but those which combine in one instrument all the essential, with many of the more special requirements is small; indeed, it may be doubted whether there is a single gag which supplies them all. Many of the gags at present in use have two or even three of the essentials, while they fail in other advantages. The construction of a gag is effected according to a balance struck between many varied factors; the probabilities of use, convenience of construction, and surgical cleanliness have all to be considered. If anyone wishes to test the truth of these statements let him try to choose from a well-stocked surgical instrument maker's shop a gag which will answer all the requirements of the surgeon and anæsthetist, one which he can use with confidence in every case to which he may be called. Let him select the best instrument he can obtain and it is very probable that he will not use it 20 times without finding some material drawback which will oblige him to provide himself with a second or a third pattern. In this manner the present revision of the whole matter arose. The subject is clearly one which demands strict attention to measurement and mechanical detail, combined with a comprehensive view of the requirements to be fulfilled. The instrument is in general use and in some cases its inadequacy may prove fatal, but its efficiency is of

[1] This paper is, by the permission of his son, dedicated to the memory of the late Mr. Alfred Coleman, dental surgeon to the Metropolitan Free Hospital.

such importance to the surgeon and anæsthetist that nothing short of the very best design, materials, construction, and finish should be considered sufficient.

After the matter had been well considered, models and measurements made and experiments conducted, a search through the current English medical literature of the subject was undertaken. It included THE LANCET from 1860 to 1906 inclusive, the *British Medical Journal* from 1860 to 1906 inclusive, the *Medical Times and Gazette* from 1860 to 1885 inclusive (after which year it ceased to appear), and the *Transactions of the Society of Anæsthetists* from 1898 to 1905 inclusive. As the history of the gag may be shortly summed up it is advisable to give the chief references in chronological order with short abstracts of, or quotations from, the subject matter as follows. The most important is the first.

Alfred Coleman, dental surgeon to the Metropolitan Hospital (*Medical Times and Gazette*, 1861, vol. i., p. 105), described "an instrument for keeping the mouth open in operations under chloroform." The instrument is "constructed upon the principle of a pair of forceps, with this difference, however, that the handles do not cross each other at the hinge, so that, by pressing them together, the blades or short extremities are separated. About the hinge the instrument is curved upon itself. Attached to one of the handles is a spring catch, which keeps the blades fixed at any required distance from each other. The extremities of the blades are made broad and covered on their outer surface with vulcanised indiarubber. In using the instrument the handles are opened and the blades brought together, and the latter are introduced between the teeth at the back of the mouth, at the opposite side to that on which any operation is to be performed. The curve of the instrument adapts itself to the cheek and prevents either the handles or blades being in the operator's way. By compressing the handles the blades, and consequently the patient's jaws are separated from each other and by means of the catch can be maintained in the required position at the will of the operator. ..... The instrument is constructed by Messrs. Ferguson and Sons, of Giltspur Street." An illustration of the instrument is given.

Thomas Smith (now Sir Thomas Smith) (Medico-Chirurgical Transactions, vol. li., 1868, p. 79) describes his instrument for use chiefly in the cure of cleft palate as "a species of gag." The instrument has a tongue plate. There is an illustration. No maker's name is given.

Sir William Fergusson (*Brit. Med. Jour.*, April 4th, 1874, p. 437) refers to the last paper and also to Wood's gag as used in 1873. In the same journal on Jan. 1st, 1876, p. 4, he refers to "..... the more simple apparatus, chiefly suggested by my friend Mr. Mason of St. Thomas's ....." as having superseded Smith's and Wood's gags. It was made by Matthews in Carey-street and was about seven inches long. Fergusson mentions that it was convenient to have a smaller size. The present form of curved mouth-shank appeared about this time. Coleman (p. 59) in a letter refers to an addition made to his gag by Professor Humphry, but does not say what it was, and suggests that Mason did

not know of his (Coleman's) previous invention. Mason (p. 117) in a letter says that his gag was made fully five years before and that he is having a modification made by Millikin. Mason states that he was unaware of Coleman's previous invention.

Mason (*Brit. Med. Jour.*, July 7th, 1877, p. 31) states that in 1868–69–70 Messrs. Matthews were making various gags at his suggestion and after numerous failures made a gag which "included the principle upon which the instrument made for Sir William was constructed. I may say that the handles of my original gag are short and that it possesses what I conceive to be an advantage, in that the parts applied to the teeth are provided with a swivel, which makes them fit and fix on the teeth most accurately."

Annandale (*Brit. Med. Jour.*, June 23rd, 1877, p. 795) showed a gag at the meeting of the Medico-Chirurgical Society of Edinburgh on March 7th, 1877. The instrument was a modification of Fergusson's and Hutchinson's, had handles which could be removed, and also a mould for the teeth.

Mason ("On Harelip and Cleft Palate," London, 1877, p. 80) refers to Fergusson's and Coleman's instruments, the latter of which he considers cumbersome. He dates his own gag 1870. The figure shows a gag with a screw adjustment for keeping it open. There is no maker's name given.

Thomas Smith (now Sir Thomas Smith) (THE LANCET, Jan. 8th, 1881, p. 78) ventured to recommend a somewhat novel form of gag. "The instrument is essentially Mr. Rose's double-ended modification of Mr. Coleman's gag to which Messrs. Mayer and Meltzer have adapted an ingenious sliding-ring-catch, to keep it open. To this a tongue plate is now added so that the gag answers almost all the purposes of the more expensive instrument usually employed in operations on the palate."

Rose (THE LANCET, Jan. 15th, 1881, p. 118) wishes to state "in fairness to Messrs. Matthews that they were the first, about three years ago, to construct at my suggestion the double-ended gag *with the sliding ring catch* ....." Rose sent his gag to Messrs. Mayer and Meltzer to be copied.

Messrs. Mayer and Meltzer (THE LANCET, Jan. 22nd, 1881, p. 155) say that Rose's gag was unnecessarily long and likely to be in the way and knocked from between the teeth. "To do away with the likelihood of this occurring we have made the *levers or arms considerably shorter*, and with a larger space between them; this has been found a great advantage, as there is no *loss of power*. This alteration required a different arrangement of the catch ..... To our gag, therefore, we added a series of notches, or hollows, into the catch, thus doing away with any possibility of any slipping ....."

Messrs. Matthews in a letter (THE LANCET, Jan. 29th, 1881, p. 193) say: "Will you allow us to state that the 'improved' ring-catch with notches ..... was the original form as made by us for Mr. Rose? The serrations, however, were found to do more harm than good ..... they were therefore abolished, and the requisite fixation secured by 'draw-filing' the opposite surfaces." Messrs. Matthews were the makers of Wood's gag and also of Rose's instrument.

B. Campbell Gowan's gag (THE LANCET, April 19th, 1884, p. 713) is described and figured. "The blades are spread apart by means of two curved ('Archimedian spiral') slots in the disc, which, in their relation to the pins, act as low-pitched inclined planes." Made by A. Konst, Richmond-street, St. Luke's.

Ward Cousins (*Brit. Med. Jour.*, April 2nd, 1887, p. 731) gave a demonstration with a new mouth-gag and snare at a meeting of the South East Hants Medical Society.

Ward Cousins (*Brit. Med. Jour.*, Feb. 18th, 1888, p. 360) describes and illustrates a "New Gag with Throat Guard." The combination of a gag with a throat guard, mouth mirror, and tongue depressor is "especially designed for purposes of dental surgery and for other minor operations on the throat and gums." Manufactured by Messrs. Maw, Son, and Thompson, London.

Montagu Cotterill (THE LANCET, Dec. 1st, 1888, p. 1074) describes and figures a "Gag, Cheek Retractor, and Tongue Depressor." The handles are short and bent outwards. Made by Mr. Gardner, Lothian-street, Edinburgh.

Frederic Hewitt (THE LANCET, Jan. 10th, 1891, p. 81) mentions and figures a "modified Mason's gag, possessing two small tubes for the transmission of chloroform vapour to the back of the mouth. ..... The gag shown has arms sufficiently long to keep the mouth of an edentulous patient well open and the clip arrangement for keeping the arms apart is superior to the ordinary screw, as it is simple to manage and takes but a fraction of a second to adjust." Made by Krohne and Sesemann.

Alexander Morison (*Brit. Med. Jour.*, Feb. 7th, 1891, p. 291) describes and figures a "self-retaining screw gag." The motion is a parallel one and there are bands which encircle the patient's head. Made by Arnold and Sons.

Herbert A. Smith (*Brit. Med. Jour.*, April 14th, 1894, p. 806) describes and figures "a simple gag." Box wood; five inches long; hole in centre for wash-out tube. Designed to go in an antidote case. Made by Arnold and Sons.

F. William Cock (THE LANCET, March 27th, 1897, p. 892, and *Brit. Med. Jour.*, April 17th, 1897, p. 987) describes and figures "An Improved Mouth-Opener and Gag." The chief points are: a rack-catch action with trigger release, and a gutter along the arms of the gag, each being converted into a tube when covered with rubber tubing for the transmission of chloroform vapour. "The advantages of this are that the vapour ways do not increase the bulk and are readily cleaned or cleared, and further being made of solid steel they are not liable to be damaged from an accidental fall, a somewhat frequent occurrence with the metal tubes originally designed for the purpose." He adopts in modified form the suggestion of Mr. W. R. Ackland to set the tooth-plates one behind the other. Made by Down Bros., Limited.

Herbert Snow (THE LANCET, Feb. 6th, 1897, p. 387, and *Brit. Med. Jour.*, Jan. 30th, 1897, p. 276) describes "The 'Mammoth-Tusk' Gag for senile and edentulous jaws." The chief point is a well-marked turn-up on the lingual surface of the teeth when the gag is in position. Made by Weiss. This gag happens to be the first one figured *in the current literature* which shows a spring placed between the handles.

Frederic Hewitt (*Brit. Med. Jour.*, Jan. 15th, 1898, p. 156) describes and figures his metal finger wedge and shield. Made by Messrs. Weiss.

W. R. Ackland (Transactions of the Odontological Society of Great Britain, vol. xxx., 1898, p. 25) at a meeting of the Odontological Society

of Great Britain held on Dec. 6th, 1897, "showed a slight modification he had made in Mason's gag. It consisted of having the jaws side by side instead of one over the other, and so made the wedge going between the teeth much narrower—half the width, in fact—than the ordinary gag. The instruments were made by Messrs. Ash and Son." Cock, in March, 1897, adopts Ackland's suggestion of making the tooth-plates overlap, so that the modification must have become known before this meeting of the society.

Dudley W. Buxton ("Anæsthetics, their Use and Administration," London, third edition, 1900, p. 78) says: "Various forms of gags are in use, the one made for me has special advantages from the facility it offers for rapid removal and replacement. It consists in replacing the screw-fixing arrangement by a ratchet as is seen in the figure." Made by Mayer and Meltzer.

Frederic Hewitt ("Anæsthetics and Their Administration," Ed 2, 1901, p. 321) describes and figures a gag for use on that side of the mouth which is lying against the pillow when, for the purpose of the operation or to allow the blood to run away, the patient's head is turned well over on its side. "A Mason's gag invariably becomes dislodged in these cases by reason of its arms resting upon the pillow." The gag has a parallel screw motion and the tooth plates have a wide turn up on the lingual surface of the teeth. Made by Messrs. Weiss and Son. At the same place Hewitt describes his "chloroform prop."

R. J. Probyn-Williams (*Brit. Med. Jour.*, Sept 7th, 1901, p. 622) describes and figures a modification of Doyen's gag with a wide anæsthetic tube attached. The plates are of soft metal. There is a ratchet and spring. Made by Mayer and Meltzer.

A. de Prenderville (THE LANCET, August 22nd, 1903, p. 535) describes a special form of gag for use during throat and ear operations. Ratchet catch. Wide separation of blades possible. Made by J. H. Montague, 101, New Bond-street, London.

These are the accounts given in current medical literature during the past 46 years and any omissions are accidental. Other patterns and inventions appear in the catalogues of surgical instrument makers. From the description given by Coleman it is clear that his invention contains the germ of all the essential requirements of the modern gag with the exception of the anæsthetic tube. If he had pursued the question further he would probably have succeeded in making a less cumbersome instrument with the essential points retained and improved. The present representative of Messrs. Ferguson and Sons tells me that the ordinary Mason's or Fergusson's gag was known at St. Bartholomew's Hospital as Coleman's gag until nine or ten years ago. By the courtesy of Mr. Coleman's son I have examined and measured the original instrument. The particulars are as follows. Length over all $7\frac{1}{2}$ inches. Distance of axis of hinge to central point of tooth-plates $1\frac{3}{32}$ inches measured parallel to axis of handles; measured direct,

$1\frac{3}{8}$ inches. Distance of axis of hinge to end of handles $6\frac{1}{4}$ inches. Widest separation of handles $3\frac{1}{2}$ inches. Widest separation of tooth-plates three-quarters of an inch, probably one inch or more if measured with rubber pads. Tooth-plates a square of $\frac{1}{8}$ths of an inch, thin with a rubber pad wired on to the bearing surface. Section of blades D throughout. Width of handles about half an inch, thickness three-eighths of an inch. Handles cross filed. Width at mid-point of shank about a quarter of an inch, thickness one-eighth of an inch. The hinge is situated near the mid-point of the mouth-shank and is the same kind as now employed. The cheek curve is about five-eighths of the circumference of a circle of which the radius is about three-quarters of an inch. Length of spring catch situated at end of handles $2\frac{3}{4}$ inches and its width three-eighths of an inch. Angle between handle and mouth-shank about 170 degrees. Mechanical advantage $\frac{6\frac{1}{4}}{1\frac{3}{32}} = 5\frac{5}{7}$. The chief alterations which have been made in the pattern occur in the size and the shape of the blades, *but no one seems to have made the instrument as a whole a matter of study and measurement since Coleman published his invention.* The introduction of the overlapping tooth-plates, the shape of the mouth shank, the ring clutch, and the anæsthetic tube have been the chief additions to Coleman's invention.

Some patterns of gag are designed for special purposes, for instance, Doyen's gag; others, such as Gowan's, are for general use. Buxton [2] says of the latter instrument: "This gag is as ingenious as it is useful." It is certainly an original departure from the common form and as such is most welcome. As usually made it lacks rigidity and requires two hands to adjust it. It has opposed tooth-plates and the sliding studs are liable to derangement unless the central screw is kept rather tight. All these points could be easily remedied. The advantage of it is that no clutch or ratchet is necessary to keep it open, but in its present form it is not as useful as it is ingenious. Herbert A. Smith's box-wood gag is simple and very useful in hospital practice. On the whole, from the point of view of general utility a modification of Coleman's original pattern is perhaps the best and the following remarks are based on this assumption.

[2] Anæsthetics: their Uses and Administration, by Dudley Wilmot Buxton, third edition, p. 78 (London, 1900).

At the outset it will be convenient to state as briefly as possible the main essential requirements of the modern instrument and to give the reasons for them. In the first place the gag should be capable of opening the mouth as widely as possible and of maintaining it in that position quite motionless without attention from the anæsthetist. Any degree of separation short of this should also be possible. The extremely wide open position sometimes causes respiratory obstruction which, however, can be relieved without diminishing the opening by drawing forward the point of the chin. Since many operations inside the mouth are performed on old and edentulous patients in whom the extra width of separation due to the height of the teeth is absent it follows that a separation of at least two inches between the bearing surfaces of the tooth-plates should be provided. In the second place, the instrument should be capable of introduction during spasm of the muscles which close the jaw in a patient with a perfect set of teeth which articulate properly without damaging them or the gum behind them. The space available between the last molar tooth and the pterygo-mandibular ligament, or the anterior border of a powerfully contracted masseter muscle, is usually too small to admit the tooth-plates of a gag. It follows that the plates should present a narrow end unless a wedge can be used as a preliminary to inserting the gag. As a matter of fact with a skilful anæsthetist the occasion seldom arises for the use of a gag in this manner, but occasionally it is possible to save the life of a patient who would otherwise probably have died from fæcal vomiting during the administration of the anæsthetic. A further inference is that the form of gag with overlapping tooth-plates is most likely to be the best. In the third place, the handles of the instrument should be sufficiently long to give a proper mechanical advantage. They should not be so long as to touch the pillow or rest placed under the patient's head. That is to say, the combined length of the instrument from the tooth-plates to the end of the handles must be such that there is no inconvenience from the handles touching the pillow when the gag is inserted in the mouth of a child with a small head who has to undergo tonsillotomy. This is a very important point. Many gags are made with short handles or with curves in the handles expressly to overcome this difficulty. By shortening the handles the mechanical advantage of the instrument is proportionately diminished and by bending them in either direction towards the axis of the central

joint the combined rigidity of the patient's head and jaw and the gag is much diminished. That is to say, it is easiest of all to "manage a jaw" when the handles of the gag are straight and situated so that their long axis is at right angles to the axis of the tooth-plates. Any form of hinged handle is inadmissible because of the loss in rigidity and for other reasons, such as the liability to bend when not required and the increased difficulty in cleaning. In addition, when the head, for the purpose of the operation and to get rid of the blood, is turned on the side on which the gag is situated, slipping is less likely to occur than when the handles are curved outwards. For this purpose a special gag has been invented.[3] The limit of the combined length from the space between the tooth-plates if these overlap, or from the central axis of both of them if they are of the opposed variety, to the ends of the handles, measured parallel to their axis, is about five and three-quarter inches. As will be seen later, this leaves four inches as the greatest possible length of the handles alone, measured from the pin of the hinge. There are very few cases in which a length of four inches is too great and in these an extra distance from the table of three-eighths of an inch can be gained by moving forward the position of the tooth-plates on the teeth, while still keeping the middle line of the face in the long axis of the body, as, indeed, seems very convenient for the operator. In the fourth place, the gag should not get in the way of the operator's manipulations inside the mouth. Tonsillotomy is easily performed on the side on which the gag is placed provided that the tooth-plates do not project even very slightly beyond the lingual surface of the teeth, and that the gag can be properly locked and left in position without slipping while the anæsthetist places a finger between the instrument and the patient's neck, just behind the angle of the jaw, so as to press the tonsil towards the middle line and at the same time steady its base. The handles of a short-handled gag are generally too long in this respect. These, then, are the main essential points; the others will be mentioned *seriatim* in the course of the rest of the paper.

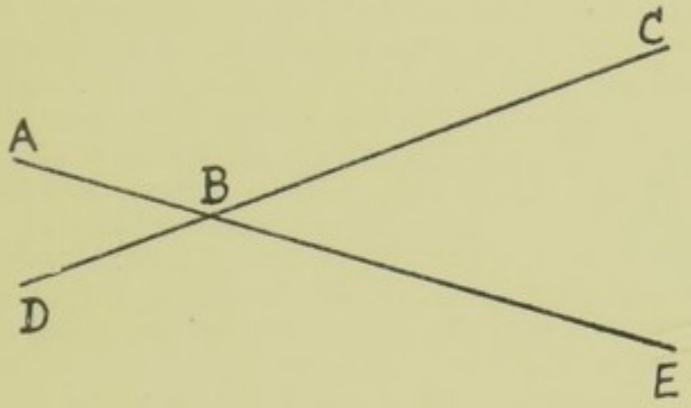
The questions of mechanical advantage and of the separation of the tooth-plates are best considered together, because the factors in each are to a large extent adverse. To aid the

[3] Anæsthetics and their Administration, by Frederic W. Hewitt, second edition, p. 321 (London, 1901).

solution of the problem consider Fig. 1. The figure is a diagram of the common form of gag but it is only a diagram. As such it has its uses, but it is impossible to calculate from it the correct measurements of an instrument without having a model to make measurements on.

AB and DB represent the tooth-plates and mouth-shanks, CB and EB the handles. The angles ABC and DBE are constant and equal in any particular case, each representing a rigid system and forming a lever of the first order, the

FIG. 1.



power being at C and E, the weight or resistance to be overcome at A and D and the fulcrum at B, where the two systems are hinged. Assume for clearness that AB = DB and CB = EB. The mechanical advantage is a number and represents approximately the result of dividing the distance CB by the distance AB. In actual fact when AB and DB come together it is $\frac{CB \cos \frac{1}{2} CBE}{AB}$ or $\frac{CB \sin \frac{1}{2} ABC}{AB}$, whereas when CB and EB come together it is $\frac{CB}{AB \cos \frac{1}{2} ABD}$ or $\frac{CB}{AB \sin \frac{1}{2} ABC}$ and between these two conditions it has an intermediate value. It is unfortunate that the mechanical advantage is least when AB and DB are close together, that is to say, when the patient's jaws are closed, but the mechanical difficulties which would have to be overcome to reverse this result would be completely out of place in a surgical instrument. In a well-contrived gag the mechanical advantage measured merely by dividing one distance by the other works out at about two and one-third. It is greater in proportion

to the length of the handles measured from the pin of the central hinge and it is greater as the inverse distance of the central point of the tooth-plates from the same spot, measured at right angles to the axis of motion of the hinge. That is to say, the longer this last distance the less, other things being equal, is the mechanical advantage. When the tooth-plates are of the overlapping variety the mean distance between the central axis of each of them is taken as the line to measure from. In many gags with short handles the ratio representing the mechanical advantage is as small as 1 or even less than 1. In some with relatively long unwieldy handles it is little more than $1\frac{1}{2}$, owing to the disproportionate distance of the tooth-plates from the central pin. In very few gags is the mechanical advantage equal to or greater than $2\frac{1}{2}$ and in these the result is often attained by sacrificing some other important advantage. From practical experience a mechanical advantage of between $2\frac{1}{3}$ and $2\frac{1}{2}$ is sufficient to enable the anæsthetist to overcome any muscular contraction he is likely to encounter.

Now consider the question of the separation of the tooth-plates when the handles are closed. This varies directly as the distances AB and DB and with cos $\frac{1}{2}$ ABC being equal to AB cos $\frac{1}{2}$ ABC + DB cos $\frac{1}{2}$ DBE = 2 AB cos $\frac{1}{2}$ ABC. Increase the angle ABC and the separation between A and D when C meets E is decreased. Decrease the angle and the separation is increased. Here, then, are two factors adverse to each other and each adverse to the attainment of a good mechanical advantage. The mechanical advantage varies inversely as the length AB, whereas the separation varies directly as this length. It is impossible, therefore, to have the maximum and best of each in one instrument and a suitable mean must be taken according to the requirements. A mechanical advantage of about two and one-third and a separation of at least two inches seem to be most suitable. The decrease of the angle ABC is adverse to a good mechanical advantage, because cos $\frac{1}{2}$ CBE (= sin $\frac{1}{2}$ ABC) decreases at the same time. In practice this has an effect which may be stated as follows. The force for opening the gag is applied by approximating the thumb and fingers of the anæsthetist's hand applied on the outer surface of the handles. Some part of the palm is also used and in some cases the chief force is applied through the palmar surfaces of the distal phalanges of the thumb and little finger. These forces may or may not be normal to the axis of the handles. The

direction in which the force is applied is probably altered continuously throughout the movement of separation by the contraction of the intrinsic muscles of the palm, just as the intrinsic muscles of the sole of the foot are said to alter the transmission of the weight of the body when walking barefooted on uneven ground. If the angle ABC is made more acute the separation between the ends of the handles when the tooth-plates are closed for insertion becomes abnormally wide. The angle CBE is, in fact, increased out of proportion to convenience. When the length BC remains constant this results in the separation of the handles being so wide that the span of the anæsthetist's hand is unable to traverse the distance comfortably and he cannot obtain a good grip of the instrument. A further consequence is that the force is applied to the handles at a more acute angle and that its available component is less. Increase the thickness of the handles and the span necessary to encompass them is also increased. Increase the length and the same is true. Decrease the thickness and length and a relatively smaller angle ABC may be adopted with slightly increased width of separation between the tooth-plates but with decreased mechanical advantage. Here, then, it is necessary to strike a suitable balance between adverse factors and in the construction of the gag attention to measurement and detail is in this respect of the utmost importance.

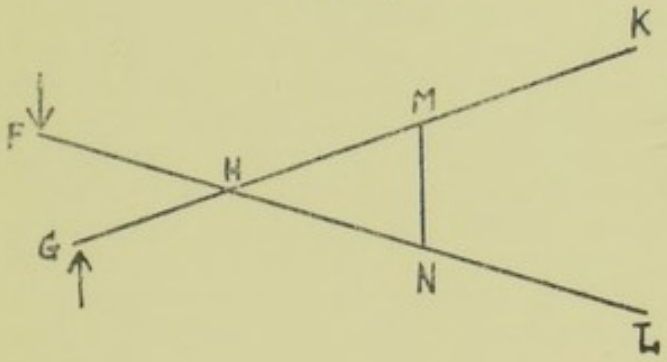
Whatever the surface of the handles is like the tendency to slip in the hand is very slight. Corrugations and flutings are unnecessary and their sharpness may cause inconvenience or even injure the anæsthetist's hand if much spasm of the masseter muscle has to be overcome, as is sometimes the case. The surface of some corrugated handles is not easy to clean and all the indications, such as they are, are against any but a plain smooth handle. That each should be forged in continuity with the rest of the blade goes without saying but it is doubtful if it is necessary to make them as heavy and strong as is usually done. The handle as such can, in fact, be a mere shell of steel, at most one-sixteenth of an inch thick, and will then be amply strong enough to withstand the strongest pressure to which it will ever be subjected. Hollowing out the handles helps to throw the centre of gravity of the gag towards the axis of the hinge and this greatly increases the ease with which the instrument is manipulated. If the handle is too narrow the palm of the anæsthetist's hand is liable to be injured. Judging by experi-

ence the handle should be at least an inch wide and when closed the two handles together should be about an inch thick. Some prefer a greater thickness than this ; but as has been mentioned this entails a corresponding loss in mechanical advantage and convenience of manipulation when the handles are open to their greatest extent.

The fact that the tooth-plates should overlap when they are closed for insertion adds again to the difficulty of solving the problem. The various forms of tooth-plate may be classed in two main groups. In one group the plates are opposed to each other, in the other group they overlap and their planes come approximately into one plane. In the first group the width of material, rubber included, which has to be inserted between the teeth is something between a quarter and five-eighths of an inch, and is often a little greater than this at the ends, because they are turned away from each other so as to aid in preventing the tooth-plates from slipping out sideways. Such tooth-plates are only introduced with difficulty, even in the absence of contraction of the muscles of the jaw, when the teeth are perfect and often also when they are imperfect. If inserted in a hurry a valuable crown has sometimes been unseated or other damage caused. The opposed tooth-plates have this advantage, however, that their thickness is so much extra distance added to the required degree of separation, and this aids the designer in increasing the angle between the handles and the mouth shanks. This indirectly aids the other factors which make for increased leverage. In the second group the tooth-plates overlap. This arrangement gives great ease in introduction but has two disadvantages. First and foremost it causes the gag to slip, and secondly, there is a corresponding decrease in the desired separation of the plates. It is to the first point that attention is here directed because obviously if this tendency to slip—which has been noticed by very many different observers—can be overcome in a sufficiently simple manner the advantages of the overlapping tooth-plates will far outweigh the disadvantages. Consider a second diagram (Fig. 2) similar to the first, only that the gag is supposed to be held rigidly half open and the lengths of the mouth-shanks FH and GH are unequal, FH being the longer of the two. Pressure is made on the tooth-plates F and G in the direction of the arrows. These forces are approximately equal. Let no force other than the restraining force of the clutch MN act on the handles, and this force is intrinsic. It is clear that if the system is left free to move it will do so, because the leverage of the force acting at F is greater

than that acting at G by an amount depending on the lengths of FH and GH. In other words, FH will be tilted downwards and the system will rotate. The actual point about which rotation occurs is a mathematical matter and requires other specifications for its solution, but in practice rotation occurs about that tooth-plate which is in contact with a fixed point—viz., the upper jaw ; as anyone may verify by observation. Let a gag with overlapping tooth-plates be arranged half open with the plates between the jaws of a parallel vice and gradually tighten the vice. A lithotrite is convenient for the purpose. Rotation occurs as described. In the mouth the teeth, of course, do not open in a parallel manner, but as will be explained later the conditions hold approximately. When the gag is inserted on the left side of the mouth and the tooth-plate which is more distant from the hinge

FIG. 2.



impinges on the lower set of teeth the handles of the gag are found to rotate downwards and forwards towards the chin. When the same gag is on the right side the handles are found to rotate upwards and forwards towards the occiput. Since the centre of rotation is the upper jaw and since the gag is most frequently used on the left side the more distant tooth-plate should be on the lower blade, because the radius of rotation will then be as small as possible. This, however, is a minor consideration. The conditions are those of unstable equilibrium and the rotation tends to increase. As a matter of trial no mere forcible control of the movement of the handles is sufficient to prevent the relative arrangement of tooth-plates and jaws from becoming altered. It is an interesting and very useful fact that in a great number of skulls the distance between the centre of the mandibular foramen, through

which the axis of movement of the lower jaw passes, and the space between the first and second molar teeth on the same side, which is the place where the tooth-plates most frequently take their bearings, is one and five-eighths inches. If in the gag the mean distance of the tooth-plate from the axis of the hinge is also one and five-eighths inches, the axis of movement of the jaw will coincide with the axis of the hinge of the gag and the space between the first and second molar teeth in the lower jaw will open along the circumference of a circle drawn between the overlapping tooth-plates about the axis of the hinge as a centre. In other words, the resistance offered by the teeth will be transmitted to the tooth-plates in a direction normal to their bearing surfaces throughout the entire movement of opening the jaw. In the gag to be described a distance of one and five-eighths inches was selected by trial as a suitable distance before this observation on the skull was made and, indeed, for other reasons. When considering this part of the problem it at once became apparent that the tendency to rotation and slipping could be abolished by altering the set of the bearing surfaces of the tooth-plates in a certain manner. Imagine the gag hung up half open with the handles dependent vertically and look at the ends of the tooth-plates. Imagine the plates to be twisted on the shank so that the bearing surfaces lie in two parallel planes and at right angles to the line joining their central points. The correct twist is for both plates to move anti-clockwise through a considerable angle, but in the practical application the best solution is obtained by twisting the right plate anti-clockwise and the left clockwise. The twisting of the right or far plate is greater than that of the left or near plate in order to compensate for the necessity of having an appreciable gap between them when they are closed. This solution was found out experimentally, but I am told on good authority that the theoretical consideration underlying it is correct. The tendency to rotation and slipping was found to be enormously minimised, but not quite abolished, by adopting this twisted position of the tooth-plates on the shanks. As a matter of experiment, slipping also depends on the particular conformation of the articular surfaces of the teeth between which the tooth-plates are inserted. On this conformation depend the directions in which the resistances are transmitted to the plates, and according to the directions so are the resolved components of the forces helpful or adverse to the prevention of

slipping. It was found that when the plates had been twisted as described their introduction between the teeth was not so easy as before. If the main part of the bearing surfaces had the required twist that would be sufficient. The ends of the tooth-plates were therefore twisted back again into their old position in one plane when the plates were closed. Made in this way the ends of the plates present a wedge and their introduction is easy. Exact counterbalance of the pressures is only obtained in the half-open position. As already mentioned, the fact that the distance between the axis of rotation of the lower jaw and the space between the first and second molar teeth on the same side is approximately equal to the distance between the mean axis of the tooth-plates and the axis of the hinge of the gag is largely in favour of the balance holding with the jaw open in any other position. The whole matter is of necessity a mechanical patch up; but it is a good one. Hence it is possible to retain the overlapping tooth-plates with their ease of introduction and to abolish almost entirely the tendency to rotation and slipping. Nothing is easier than to prevent a gag from slipping when suitable teeth are absent or when one or two teeth only are present in the right situations, but this is not the object at all. Slipping should be prevented from occurring when the teeth are perfect.

The other factors that affect the size of the plates are as follows. The width should be sufficiently great so that the teeth may not be injured or separated from their fellows in the same row; it should also be small enough to enable advantage to be taken of the gap left by a missing tooth. When in position the plates should not project beyond the lingual surface of the teeth, or, at any rate, not so as to impede the introduction or rotation of a tonsillotome. A projection of an eighth of an inch is too much. The edges and angles of the plates should be well-rounded off so that the gums of an edentulous patient may not be injured. Some are corrugated or cross cut on the bearing surface to prevent slipping but with doubtful success, and as regards rust and wear this arrangement is decidedly inferior. It is well known that the accumulation of moisture between the rubber covers and the plating aids the oxidation of the latter. Anything which increases the collection of moisture or presents a roughened surface is inferior and also hinders cleaning. After a gag fitted with rubbers has been boiled the formation of a black film of nickel sulphide is often very marked and in a few weeks the tooth-plates are sometimes nearly rusted through. The experiments with different kinds of metal plated on have

not yielded a satisfactory solution of the problem. Again, it is unsatisfactory to divide one of the tooth-plates into two and cause the other to enter the gap so formed. Such an arrangement does to a small extent tend to prevent slipping, but the wear and tear combined with oxidation soon result in the arrangement being out of repair. A similar remark applies to the addition of two small wedges of metal placed at the ends of the opposed tooth-plates. By connecting each of these pieces of metal with a small lever and letting the levers into slots cut in the plates it is possible to arrange so that the end pieces which form a wedge turn up and down automatically by the pressure of the teeth and lie against their lingual surfaces. This appeared good at first sight, but on trial it was clear that the arrangement would wear out in a week. The extra complication is out of proportion to the desired result. A similar remark applies to a swivel fixed between the tooth-plate and the shank.

For covering the plates rubber holds its own as regards cleanliness, convenience, and ease of introduction into the mouth. It is more satisfactory to have the distal ends of the rubbers closed, so as to prevent them from rucking up, but it is doubtful whether the section of the tubing should be oval instead of circular, first because the fitting on the shank would be imperfect and secondly because the rubbers would not be adaptable to any gag now in use. Neither need one side be thicker than the other. All these details would give more trouble in constructing the mould for the rubbers than they are worth in practice.

The selection of the best variety of clutch is a difficult matter. The ordinary screw pattern is good but has two disadvantages. In the first place it requires the use of a second hand to manipulate it, especially when it sticks ; and in the second place it involves making a slot in one handle and some kind of attachment to the other, and both of these are difficult to clean. Some anæsthetists also find that occasionally the skin between the thumb and index finger gets nipped between the handle of the gag and the fly-screw. The same remarks apply to the familiar spring ratchet. This ratchet arrangement, especially when new, has a very inconvenient way of sticking just when one requires to release it, and as the movement must usually be performed quickly during the operation of tonsillotomy the objection to a ratchet catch is well founded. One cannot, of course, say that all such ratchets stick but of those examined to determine this point most were unsatisfactory. There is one good pattern of

ratchet release which enables the ratchet to be freed by merely pressing a small stud on one of the handles. It answers well and can be used with one hand but it can only be operated from one side of the handles and when the gag is used with this side underneath there is slight difficulty. Sometimes, too, the stud is pressed inadvertently. The arrangement is difficult to clean and liable to rust and get out of order. On the whole, the most suitable variety of clutch is the oblong form which encircles the two handles like a ring, can be moved along them, and engages a set of relatively fine serrations on their outer and opposite surfaces by means of two internal knife-edges situated parallel to each other at opposite ends of the oblong. This clutch if constructed on scientific lines is wonderfully efficient. In the first place, it is the one form of clutch that can, together with the gag, be operated with only one hand. By using the forefinger, or the first and second fingers, of the hand which holds the gag this clutch is under complete control. This fact makes it superior to every other kind. The serrations being superficial, straight, and easy of access are correspondingly easy to clean. To be efficient the clutch should be made on these lines. First as to the main essential, the distance between the knife edges. Let the handles of the gag be closed, measure the greatest distance transversely across the sloping serrated surfaces at or near the palmar portion of the handles, add one-sixteenth of an inch to give slight play and allow for releasing the clutch, and the total represents the required distance between the knife-edges. These should present relatively small, acute angles, so that the actual knife-edges may engage with the troughs of the serrations. The sides of the clutch should fit closely and not allow it to wobble. All the outside angles and edges should be very carefully and thoroughly rounded off, especially those towards the patient, or else the clutch may scratch the face. There should be a projection on the side remote from the face for the fingers of the anæsthetist's hand, so that he can move the clutch easily. This projection must not be too pronounced, or it will get in the way of the anæsthetic tube to be described later. The whole clutch should be cut out of one piece of steel and not be built up of several pieces screwed together. By making it in one piece greater strength and cleanliness are insured and it is less likely to get out of order. There is no difficulty in placing it in position before adjusting the central screw at the hinge. The serrations which engage the knife-edges should be

deeply and sharply cut, at any rate near the hinge, with the concavities of the serrations directed towards the ends of the handles. Near the rest of the handles the concavities are directed towards the hinge or the serrations are made finer. This arrangement greatly facilitates keeping the gag only slightly open, that is to say, with the tooth-plates only slightly separated, and prevents the clutch from sticking when situated far from the hinge. The possibility of maintaining the gag open in all positions depends mainly on having a correct slope to the serrated portion of the handle. By trial one finds that the transverse distance across the distal part should bear to a similar measurement near the hinge a ratio of about 7 to 4 and that the length of the serrated part should be one and a quarter inches. When constructed in this manner this kind of clutch is one of the simplest and most efficient pieces of practical mechanism known to surgery. It is easily cleaned. Like any other device, its use has to be learnt. It is not uncommon to see a novice throw down an instrument fitted with this kind of clutch because he fails to unlock it, having forgotten that the only way to release it in the first instance is to press the handles slightly together and so open the patient's mouth a little wider. When the gag is to be used for a case of operation on the nose and throat of short duration it is almost better to unscrew the pin of the hinge and remove the clutch altogether, but a good deal depends on the ways of the operator. Personally, I only use the gag with the clutch attached in a case of prolonged operation on the nose or mouth. At all other times I use the gag without the clutch.

The curve and the length of the mouth-shanks are relatively minor considerations. The chief object is to obtain a curve which will give plenty of room for almost any cheek and a length which will not unduly stretch the cheeks when the mouth is fully open, for this makes them rigid and greatly impedes the examination or operation. The shank should be out of the way of the operator's knuckles when he is examining the post-nasal space. The curve should fit the cheek fairly closely and allow the rest of the instrument to be not too far removed from the neck and face. This also allows a face-piece to be applied without having to remove the gag. The tooth-plates should overlap. Should the two shanks be parallel curves and then diverge to the plates or should one curve lie in the concavity of the other? The answer depends on the magni-

tude of the curves. If they are relatively large one may be made to lie in the concavity of the other and a distance equal to the diameter of one of them is abolished as regards stretching the cheeks, while there is still room for the cheek in the concavity of the smaller of the two curves. If, however, the curves are relatively small this arrangement is impossible, because there is insufficient room for the average cheek, and the first arrangement of parallel curves has to be adopted. In the gag described later the shanks are parallel, two and three-eighths inches long, and the mean radius of the curve is half an inch. These measurements are averages struck from observations made in a large number of cases. The smallest diameter of the shanks is one-eighth of an inch. Although a more slender shank does not break a certain amount of rigidity is sacrificed if a smaller measurement is adopted. The pattern of shank which is oval in cross section is employed. The junction of the shank and tooth-plate should be kinked outwards a little, or the shank here should be straight and at right angles to the plate, because this makes the shank lie better in the space between the cheek and the gum, brings more of the distal part of the shank nearer the outer surface of the gum, and insures a greater rigidity. It is, however, a small matter. There should be plenty of clearance between the tooth-plates and also between the distal part of the shanks so as to allow perfect overlapping when they are covered with rubber of a suitable thickness, but any separation here unfortunately favours slipping in the mouth. A distance of one-sixteenth of an inch is suitable.

Should there be a spring or should there not? The use of the spring is to bring the tooth-plates well together, if necessary quickly. Hewitt[4] therefore advocates a strong spring. The disadvantage is that a spring takes up room and prevents the attainment of a wide separation between the tooth-plates. This difficulty may easily be overcome. A spring is liable to rust and hold the dirt in its angle of attachment and sometimes it goes wrong. The tooth-plates can be easily brought together without it. When changing the gag from one side to the other rapidly, as, for instance, during tonsillotomy, it is easy to prevent the tooth-plates from becoming separated simply by rotating the whole instrument forward and to the right or the left as the case

[4] Op. cit., p. 198.

may be about the tooth-plates as a centre, though moving them at the same time across between the front teeth to the opposite side. The movement is hard to describe and easy to execute. It is effectual and does no harm. When preparing for an anæsthetic, especially one in which fæcal vomiting is likely to occur, the gag is placed near at hand with the tooth-plates closed and ready for use. The gag in any case is held for insertion with the curve of the mouth shank in the concavity of the anæsthetist's forefinger, the tooth-plates being closed, and in this way is easily inserted. On the whole, therefore, the presence of a spring in a gag is an unnecessary complication and it has been discarded in my own model. The hinge should work loosely but not allow any lateral wobble. The circular "box" pattern is the best to employ. The central screw should project a short distance above the level of the rest of the metal here and so prevent the clutch from slipping over the mouth shanks. If a spring is considered essential it could be contained within the box joint.

The consideration of the choice of an anæsthetic tube need not be lengthy. If possible it should be so designed that it is not a permanent attachment to the gag, because the cases in which it is required make up only a small percentage of the total number of cases in which a gag is used and it is therefore liable to be in the way when not in use and so get broken. One should be able to alter the position of the tube relatively to both the gag and the mouth. A rigid tube brazed on the mouth-shank has the great disadvantage that the chloroform vapour always impinges on the same part of the mouth and occasionally produces soreness and ulceration of the mucous membrane or perhaps impairs healing after an operation for cleft palate. The last point, however, is difficult to be sure about. The difficulty of directing the vapour with this tube is great and in the case of a patient who needs a relatively large amount to keep him anæsthetised this is of importance. A small amount of chloroform vapour properly directed is equal in effect to a larger quantity improperly directed and is far less unpleasant for the operator and anæsthetist. The objection to a flexible tube is that it often becomes kinked and occasionally staved in. If made of tubing of small diameter kinking is easy to prevent by holding the tubing in a certain manner when bending it It should be held between the first finger and thumb of each hand with the thumbs nearest the body and close to each other and bent along the palmar surface of the pad of the distal

phalanges of the thumbs which should be pressed at the same time away from the body. The anæsthetic tube then should be capable of attachment to the frame of the gag in a simple manner and in a suitable position and should be capable of rotation so that the direction of the stream of vapour may be altered at will. The attachment should be firm and the tube should not be liable to move unless altered by the anæsthetist. The nearest approach to these requirements is the attachment devised by Mr. Cock [5] but the slot is difficult to clean and the tube would require a swivel attachment for its rotation. All these points may be attained in a much more simple way. Let a series of small, slightly conical holes be drilled along the sides of the handles and mouth-shank of one blade. The axis of each hole is parallel to the screw of the hinge of the gag and their wider openings are situated on the outer surface of the blade. The holes are small and do not materially weaken the handle and they are carried right through it so that they do not become stopped up and can be readily cleaned. For convenience they are situated on the lower blade when the gag is on the left side. This point is perhaps a matter of opinion. The anæsthetic tube is fixed to a brass nipple bent at a right angle and the joint between the two is a tapered joint of soft solder. This is a practical point. Most tubes kink and break at this joint, but with a tapered joint the transition from the rigid nipple to the flexible tube is gradual and the liability to break is much diminished. The nipple has a steel spike at the side, coned to fit the holes, and by inserting the spike in a convenient hole and pressing it home with a screwlike motion the anæsthetic tube is fixed firmly in the required position and needs very little extra adjustment. A foot-bellows for working the Junker's inhaler has been recommended, but I have been unable to find the description. It is a simple thing to lengthen the tube and to put the india-rubber ball on the floor and tread on it. If the ball is tied by either pole to the upper surface of a piece of sheet lead, two and a half inches square and one-eighth of an inch thick, this completely prevents its rolling or slipping away. Perhaps a slight improvement would be to make the bellows flat instead of round, but this would be an unnecessary expense and the other plan is applicable to any ball at a cost of 3*d*. and answers admirably. It certainly is an enormous

[5] Surgical Instruments, standard edition, 1906, p. 1102, Down Bros., Limited.

advantage to be able to work the pumping arrangement with the foot, because when the gag is satisfactory the whole combination gives the anæsthetist two hands free with which to assist or sponge the throat and his position behind the head is one of great convenience. In any prolonged operation on the nose or throat this extra gain is enormous.

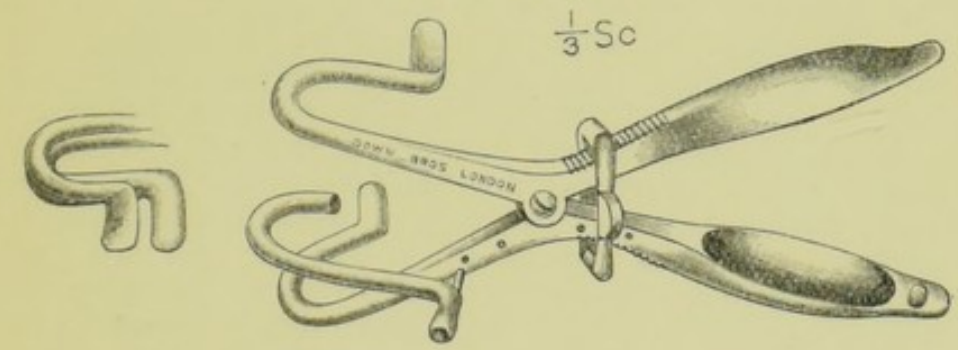
The matters discussed above are the chief ones which relate to the principles of construction of a gag. It remains to describe very shortly and illustrate the instrument which I have had made, and which fulfils all the specified requirements. The illustration gives a good general idea of the whole instrument, but the little points which so materially help towards perfection cannot be shown in a drawing. The instrument is the simplest possible in the circumstances, and Messrs. Down Brothers, Limited, are the authorised makers. The chief measurements are as follows :—

Length over all	6¼ inches.
Mean axis between tooth-plates to axis of hinge ...	1⅝ ,,
Axis of hinge to end of handles	4 ,,
Mechanical advantage approximately	2 6/13 ,,
Widest separation of tooth-plates measured across mid-points	2 ,,
Widest separation of ends of handles	4¾ ,,
Angle between handles and mouth-shanks	142 degrees.
Width of handles	1 inch.
Thickness when closed	1/8 ,,
Length of serrated portion	1¼ inches.
Widths across serrated portion	½ and 1/8 inch.
Thickness of serrated portion	¼ ,,
Lengths of tooth-plates measured from heel of shank	⅝ and ½ ,,
Width of tooth-plates	¼ ,,
Internal diameter of anæsthetic tube	⅛ ,,
The gag when finished usually weighs about	4½ ounces.

The instrument is made of well-hammered, mild, cast steel. The handles are mere shells of steel one-sixteenth of an inch thick. Their inner edges are well rounded off, so that should the palm of the anæsthetist's hand get nipped it may slip out of danger. There is also a stop well rounded off to help to prevent nipping. It is situated near the end of the handles, so that no strain shall be thrown on the hinge, and its oblong shape also obviates any lateral strain on this important part. There is a slight smooth scollop on the outer

surface of each handle at the end. This greatly aids opening the gag in a difficult case. The scollops are intended for the anæsthetist's thumb and little finger. Apart from this the palmar part of the handle is quite straight, convex, and smooth, and narrower at the ends than towards the hinge. The nickel plating is left dull, so as not to be so slippery when wet. The clutch and the sloping serrated part on the handles are made on the lines already mentioned and will keep the gag open in any position. The overlapping tooth-plates, similarly, are designed to prevent slipping and allow an easy introduction but owing to the fact that their length has been cut down to a minimum they have to be placed in position with more than usual care. Their bearing surfaces are twisted in the manner described and are left smooth. The chief parts of the surfaces are at right angles to a line joining their mid-points when separated to the

FIG. 3.



extent of one and a quarter inches. Their outer surfaces and ends are sloped to aid the formation of the wedge as described. The rubber covers have one end closed and are made circular in transverse section. At the open end the thickness of the rubber is graduated, so that the ending is not abrupt. The rubbers should be removed to prevent corrosion when the gag is not in use or is being boiled. The anæsthetic tube is attached as described. The attachment of this tube and its tapered joint, the special setting of the tooth-plates, the addition of the projection to the clutch, the stop to prevent nipping, the rubber caps with closed ends, and the shape and width of the handles might be regarded as new features. What really is new is a scientific adjustment of the measurements of the various items in the whole instrument, effected according to the uses to which it is likely to be put and their prob-

abilities of occurrence. The instructions have been carried out by the makers of the instrument with the greatest care and they will insure by means of templets and bosses that the manufactured article is always an exact replica of the approved model. They will also supply the gag without the clutch or anæsthetic tube as may be required.

The fitting and measurements for the experimental model were made in 500 jaws and the model was actually used in 220 cases, of which 160 were cases of operation on the nose and throat. By reason of its easy introduction and relatively large mechanical advantage it probably saved three lives in this series of 220 cases taken in a series of 1000 consecutive administrations. The three patients had fæcal vomiting during the early stages of chloroform anæsthesia in spite of a specially slow administration designed to prevent the occurrence of vomiting. Now in such case it is well-known that if the mouth can be opened quickly, the head turned on one side, the tongue controlled, and the vomit sponged quickly away the patient may recover and a calamity be averted. Usually the patient dies about three breaths after the regurgitation. Apparently the slight extra strain from vomiting followed by slight respiratory obstruction and possibly a rise of the intra-thoracic blood pressure are sufficient to cause an already exhausted heart to stop at once in diastole. It is needless to discuss the matter because no one can ever say absolutely that a patient who recovers would have died unless such and such a thing had been done, but the impression left is that these patients would have died had not prompt remedial measures been taken.

The final instrument may perhaps be shown to be imperfect. This is inevitable in the evolution of a universal pattern of instrument for use in many different varieties of circumstances ; but it is an attempt in the right direction and as such I venture to bring it before the profession. Liston[6] once advised his pupils at the North London Hospital "always to use their fingers, if possible, in preference to instruments, many of which were invented only for those whose fingers were useless. He [Liston] had endeavoured all his life to simplify modern *treatment, apparatus, and operations.*" To a great extent this holds true with respect to the gag. For special purposes the case is met by manual dexterity rather than by mechanical modifications of the instrument.

[6] THE LANCET, Jan. 17th, 1835, p. 598.