The inlay bone graft as a treatment of ununited fractures : a report of fifteen successful cases / Fred H. Albee.

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THE INLAY BONE GRAFT AS A TREATMENT OF UNUNITED FRACTURES. A REPORT OF FIFTEEN SUCCESSFUL CASES.

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This paper is supplemental to the following brief reports appearing in the *Journal of the American Medical Association,* August 3, 1912, page 353; *The Post-Graduate,* November, 1912, Vol. 27, No. 11; and Author's *Stereo-Clinic,* published by The Southworth Co., 1913; and is based upon the results of 15 cases of ununited fractures, and an experience gained from the application of the bone transplant to 205 additional cases of varying character.

I have often said that the Lane plate and other internal metal splints, when applied to ununited fractures of long standing, are a hindrance rather than an advantage in securing bony union. This view has been strengthened by the accumulation of experience.

The indications for treatment in fresh fractures and ununited fractures are entirely different although it is very evident from the discussion of these problems with various men and the large number of failures seen in our clinics, that many practitioners do not appreciate this difference.

In a large percentage of fresh fractures temporary fixation only is necessary to insure union, as the osteogenetic function of the fragments is active and in the presence of accurate apposition union occurs rapidly. The proper application of the Lane plate in suitable cases fulfils all requirements.

In ununited fractures the problem is quite different. We have here in the ends of the fragments a marked diminution or an entire cessation of osteogenetic activity. This cessation of activity is evidenced in the marked sclerosis or eburnation which is always found in ununited fractured ends, often extending back from the seat of fracture, from three-fourths to two inches.

The pathology of this condition of sclerosis is very similar to that found in non-ankylosing osteo-arthritis where there is an over-deposit of calcium salts, and a consequent diminution and degeneration of bone-producing cells. The therapeutic requirements of these pseudoarthroses are fixation, and stimulation of osteogenesis on the part of the fragments, and an osteogenetic scaffold connecting the active bone in each fragment back of the eburnated areas.

The bone graft, when inlaid according to the herein described technique, is the only means of fulfilling these requirements. Two, if not all, of these three essentials are necessary in order to secure union.

The Lane plate furnishes but one of these, viz., temporary fixation, but at the same time it causes absorption and disintegration of bone. The bone transplant not only produces fixation but also stimulates callus-formation and grows bone on its own part.

Abundant evidence has accumulated to prove that something more than fixation is necessary in these conditions. The most favorable cases fo external fixation, such as fractures at the middle third of the tibia, with the fibula intact, have failed to unite in spite of months of effectual splinting and recumbency in bed. Operation showed no

interposition of soft tissues and there was no evident reason for non-union.

Codivilla appreciated the above-mentioned therapeutic requirements and met them partially by spanning the fractured area with a very thin autogenous periosteal graft, which gave a fair percentage of good results. But it was not an ideal procedure in that it did not furnish efficient fixation,

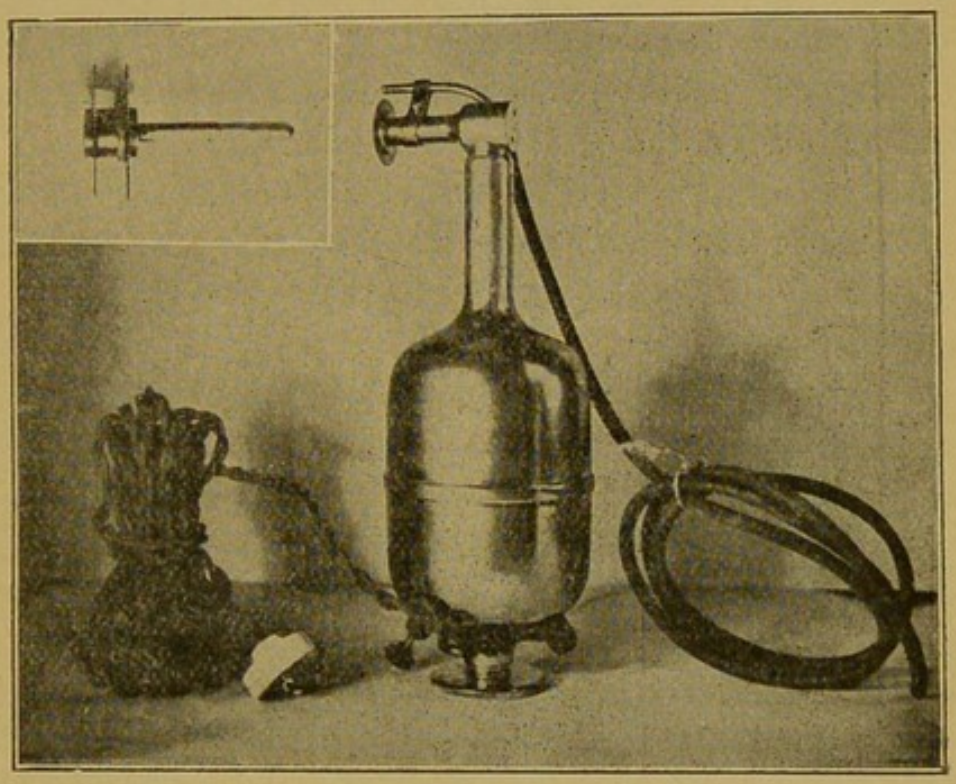

Fig. 1. The Author's modification of the Hartley-Kenyon motor. The right angle arm for saw with gear for reducing speed of saw and the tube, on the left, for constant spray of saline solution on saw from an elevated douche bag are recent and important improvements. The above mentioned twin saw is shown in the left upper corner of the illustration, this can be easily and quickly adjusted into motor in place of single saw already there. For technic of its use see text.

it did not stimulate osteogenesis between the end of the fragments, because it was entirely superficial, and it did not penetrate cortical bone structure. Being extraosseous it therefore furnished an imperfect graft environment.

Murphy has evolved a better method in his use of an intramedullary dowel, which furnishes more

effectual fixation and, being entirely intraosseous, favors stimulation of osteogenesis by better contact of graft to recipient fragments. It is, however, difficult thus to get contact of graft to active bone beyond the sclerosed area, which is most important. It is also difficult of application in small bones, such

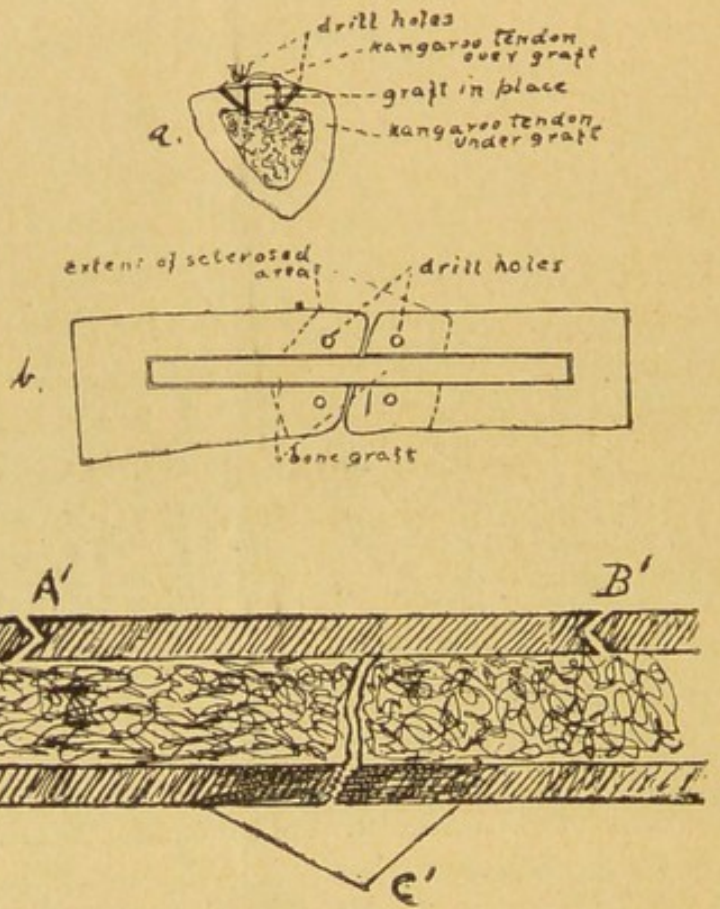

Fig. 2. Diagrams of graft in place in fracture of long bones. a. Is cross section of tibia with graft inlaid into cortex and held in place by kangaroo tendon sutures as described in above text. b. Is longitudinal surface view of graft in place showing location of drill holes for kangaroo sutures. c. Longitudinal sagittal section of bone graft in place. This diagram shows graft spanning the fracture area, also how the tongue and groove ends fit together. a.b. indicates graft. c. indicates fracture with sclerosed bone extending distally from joint of fracture.

as those of the forearm, where the medullary canals are small. As in the case of the intramedullary aluminum splint of Elsberg it is most difficult to secure the necessary lateral fixation in fragments of the ulna and radius, where these bones have been

contractured together during long existing non-union.

An illustrative case that will be mentioned later was that of an ununited fracture at the middle of the radius of four years' duration. After four unsuccessful operations, including Lane plating, the radial fragment ends were found closely contractured to the side of the ulna. They were freed with difficulty and held in proper alignment by a long inlay bone graft. On account of the strong tendency of the angulation to relapse the necessary lateral fixation would have been impossible by any intramedullary splint. The problem was easily solved by the leverage action of a long inlay bone graft. It is always difficult to get a tight fit of the intramedullary splint into both fragments. In my experience with the Elsberg intramedullary splint, it was found after operation that in certain cases the splint worked out of one fragment into the other and thus failed to furnish the desired immobilization. This is not so likely to occur in the case of the Murphy intramedullary graft on account of the formation of expected early adhesions.

The technique applied in twelve of my cases, namely, fractures of the tibia, shaft of the femur, radius and humerus, was as follows:

The fractured area was exposed by a generous skin incision. When the fractured bone is superficial, as in the case of the tibia, the incision is made lateral to the intended site of the bone insert. The skin and subcutaneous tissues retracted, the bone ends are developed and freshened with chisel, motor burr or saw, and the sclerosed bone plug is removed from the medullary canal.

If there is overlapping of the fragments the amount of pull required to correct it varies with the

degree of overriding at the site of fracture. In the case of a fractured femur in a muscular man, as much as a 150-pounds pull may be necessary to secure sufficient extension. In this instance, it is far better to set up and adjust a traction pulley apparatus with heavy weights. This provides a constant and uninterrupted pull. If the fragments

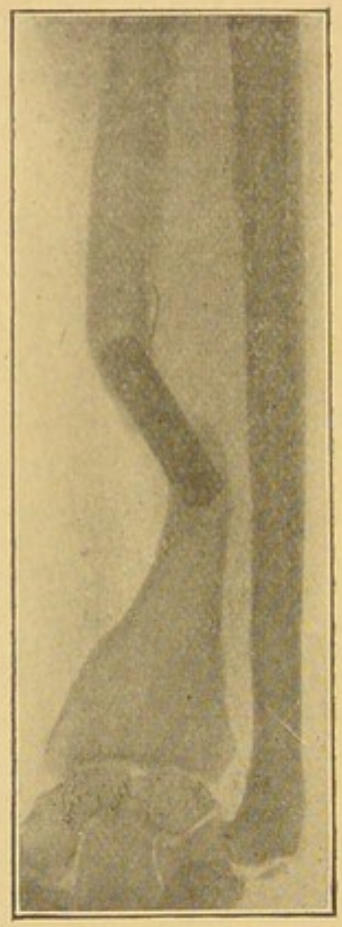

Fig. 3. Case I. Showing conditions after Lane plating. Sagittal view.

still overlap and sufficient extension cannot be made to bring them together, it is necessary to trim off the fragments with motor burr, saw or chisel until good position can be secured. This will produce shortening, but it can not be avoided.

The fragments are now held in good alignment by an assistant. The periosteum is divided with a

knife longitudinally over the bone to be removed in making the gutter for the bone insert. The periosteal flaps are turned back to either side exposing the bone.

Two parallel saw cuts, about 3/8 of an inch apart, are made longitudinally of the fragment ends completely through the bone cortex to the marrow cavity with a motor twin circular saw (see fig. 1). The

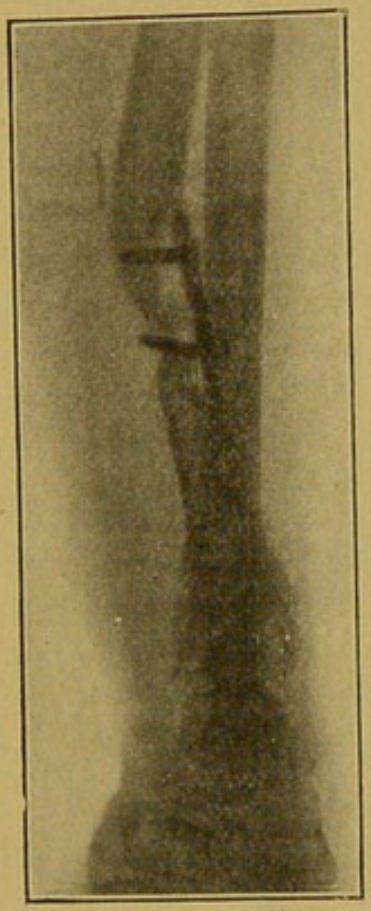

Fig. 4. Case I. After Lane plating. Lateral view.

distance between the saw cuts is arranged by adjusting the distance between the twin saws. These cuts are made from 2½" to 3" into the end of each fragment from the line of fracture, while the fragments are held in good alignment. They should always extend far enough from the line of fracture to reach well into the non-sclerosed, active bone of either fragment. This distance is subject to con-

siderable variation, depending upon the site of fracture and the amount of eburnation present. The distance the twin saws should be apart, i.e., the width of the gutter for the graft, should be from 5/16" to 8/16" according to the size of the bone. The revolving saws are kept constantly bathed in saline solution by a spray connected with a sterile tube to a fountain syringe. This prevents the development of excessive heat from friction, which should be always avoided on account of its devitalizing effect upon peripheral bone cells.

After the twin saws have travelled the desired length to make the gutter for the graft, the bone fragments between the saw cuts are removed by severing the ends distal from the point of fracture with a narrow osteotome in such a manner as to effect a tongue-and-groove joint with the ends of the graft (see illustration). With motor-driven drill, holes are bored in the cortex on either side of the gutter slanting inward to the marrow cavity. These holes are placed near the line of fracture so as to fix the center of the insert. The ends of graft are secured in position by the above-mentioned tongue-and-groove joint, when feasible, or by additional sutures. This joint is very quickly shaped and the greater the muscular contracture, the more securely is it held in place.

The exact length of the desired insert is obtained by measuring the gutter and transferring this measurement to the exposed antero-internal surface of the opposite tibia. A flexible probe is usually satisfactory for this purpose, a right-angled bend marking the exact measurement.

The wound and gutter are packed with hot saline compresses while the graft is being prepared. The patient remaining in the dorsal position, the graft-

yielding tibia is exposed by an incision over its crest. The overlying structures are retracted, and the size and shape of the graft is outlined in the periosteum by means of the scalpel with the probe measure as a guide. With the twin saws adjusted to the same distance apart as when forming the gutter, bone cuts are made to the marrow cavity

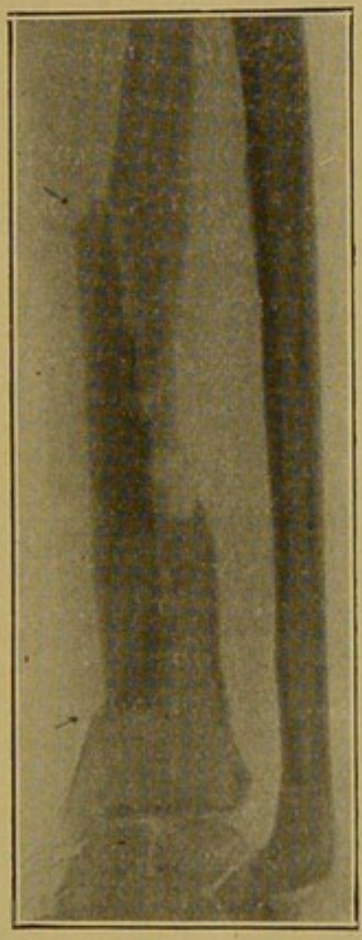

Fig. 5. Case I. Showing bone graft in position and fragments aligned.

along the antero-internal tibial aspect. With a narrow osteotome or small motor-driven saw or burr the graft is now dislodged and the ends grooved with the motor saw to fit the triangular tongue of the gutter ends.

A double strand of heavy kangaroo tendon is passed through the drill holes previously made. One strand in each fragment is now pulled up from the

bottom of the gutter and the graft is placed under them. Traction is now exerted on limb and the graft is forced into position.

A good fit is assured because the same adjustment of twin saws is maintained both in forming the gutter and in removing the graft, and they must be of equal and uniform width throughout their whole extent. Traction is now removed and the elasticity of the soft parts forces the tongue-and-grooved ends into tighter adjustment. The kangaroo fixing sutures are then drawn taught and tied over the graft.

It is readily seen that this not only affords most effectual fixation but also furnishes a most ideal environment for the bone graft. It brings each structural layer of the bone graft into close apposition with its corresponding layer in the recipient fragment, namely, periosteum to periosteum, cortical bone to cortical bone, endosteum to endosteum, and marrow substance to marrow substance. Periosteum, and when possible endosteum and marrow substance, are always included in the graft. We have proved by animal experimentation that this close contact of Haversian systems assures permanent viability at least of a large portion of the insert. The bone which has been removed from the ends of the graft in order to form the above-mentioned grooves and other normal bone fragments are finely chipped with a rongeur and pushed between and placed about the ends of the fragments at the line of fracture wherever possible. These act most effectively as supplementary foci of osteogenesis. MacEwen has well pointed out that the efficacy of a bone graft varies in inverse ratio to its volume. The smaller the graft the greater the relative osteogenesis.

The site of the fracture is covered with the periosteal flaps which were reflected to expose the bone to be removed. This gives two layers of periosteum covering the transplanted fragment. The overlying tissues and skin are closed without drainage. The leg wound is closed in a similar way except that the

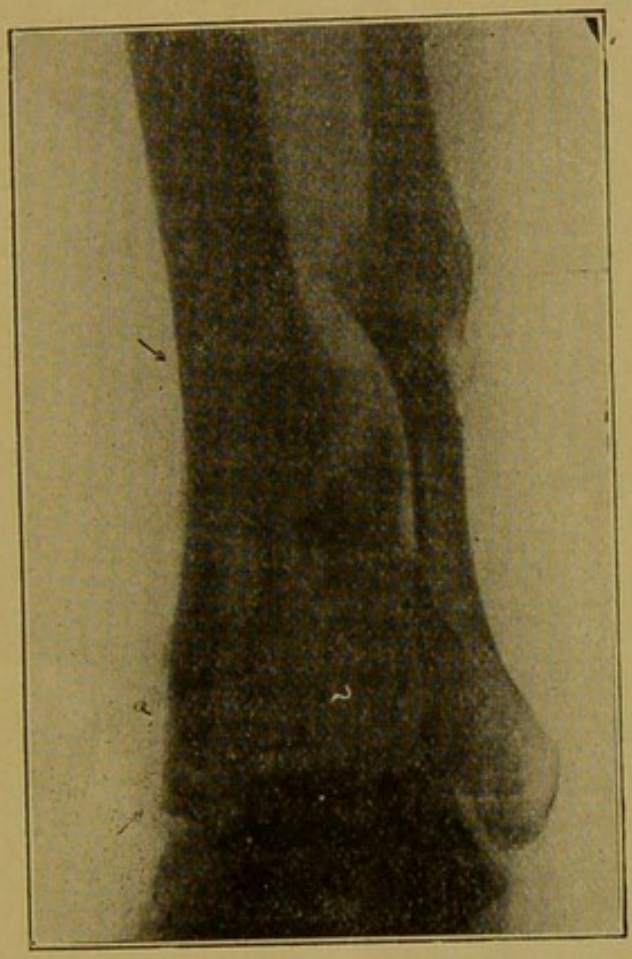

Fig. 6. Four months after operation. Ununited fracture of tibia and fibula of one and one-half years' duration. Middle aged women of 250 pounds. Fracture of extreme lower end of tibia within ¾ inch from tip of internal malleolus with marked displacement backward of foot. A. indicates old point of fracture. Replacement difficult. An inlay graft about three inches long spanning the fracture was placed reaching to the tip of the internal malleolus and held in position. The mechanical action of the inlay graft placed into the inner aspect of the tibia held the reduced fragments perfectly, although there was a strong tendency to the recurrence of the old displacement. The fact of the loss of definite outline of the graft is due to the thorough fusing of it with the tibia.

adjacent muscles are drawn into the cavity from which the graft was taken. Splints are applied and not removed before five weeks.

Illustrative Cases.

Case I, M.S.—Female, 45 years old, always healthy. Four years previously she fell, fracturing the right radius at the junction of the middle and distal thirds, the ulna remaining intact. Fragments reduced under ether. No union occurring in eight weeks, fracture was cut down upon and muscle freed from the bone ends. Good apposition was

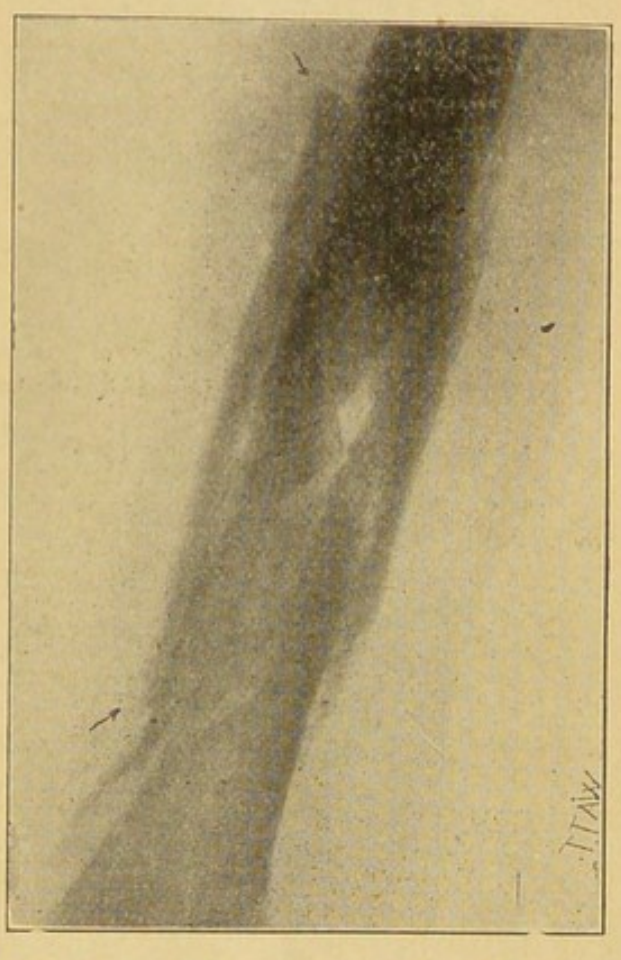

Fig. 7. Comminuted fracture of lower end of femur. No union or callus formation after 69 days of fixation treatment in bed. Bone graft inserted, resulting in firm union in five weeks. There was loss of bone substance for about two inches and the graft was placed so as to span this distance, thus preserving nearly the full length of the leg. Upper arrow points to end of graft and to proliferating bone originating both from graft and the recipient fragment, on account of the necessity of the graft being so large in diameter it was not inlaid level with the periosteum.

secured but no union followed. A second open operation was performed and the fragments nailed together. Again no union resulted. At a third open operation the fragments were wired, but again

no union followed. Two years after the fracture, at a fourth operation, Lane plates were applied, and this also was followed by non-union. Two years later, four years after the fracture, the patient in desperation consulted me to determine whether something further could not be done, for her arm was both painful and useless.

November 7, 1913, the fracture was cut down

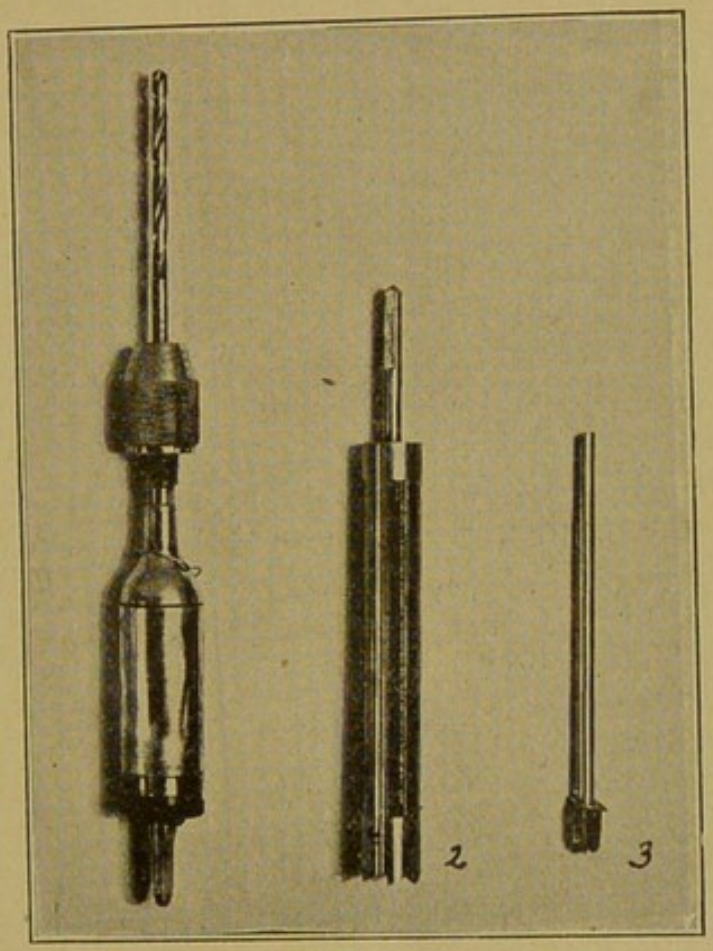

Fig. 8. 1. Is chuck holding small drill. 2. Is Author's dowelling instrument for turning out a perfectly round dowel for ununited fractures of the neck of the temur. This instrument is placed into the motor in place of the saw and while revolving very rapidly a graft (taken from the crest of the tibia by means of the motor saw) is pushed into it, thus being made perfectly round. The cutter at the lower end of the instrument can be changed for a smaller one for turning out pegs or nail grafts which are used in place of metal ones. 3. Is the Author's large motor burr drill for drilling the neck of the femur for the dowel graft. The dowel made by dowelling instrument No. 2 fits tightly into the hole made by this drill.

upon and the Lane plate was found loose in the peri-osseous tissues. The tips of the screws were found in large circular cavities in the bone from which they had loosened. There was a depression

in the side of the fragment ends where the metal plate had caused an absorption of bone. The radial fragments, as shown in figures 3 and 4, were much shortened from the previous operations and the metal contact, and badly angulated towards the ulna. Their ends were made fresh and with much difficulty their alignment was corrected. This caused the fragments to retract from each other about an inch. The periosteum on the outer side of each fragment was incised distally from the fracture for two and one-half inches and retracted, exposing the bone.

By means of the motor saw and osteotome a gutter was made in the fragments according to the above-described technique, about 3/16 of an inch wide, and three and one-half inches long.

With the motor saw a graft 3½ x 7/16 x 3/16 inches was removed from the anterior internal aspect of the tibia and trimmed with the saw so that it fitted tightly into the gutters in each fragment. The strong tendency of the angular deformity to relapse was prevented, and the fragments were held very securely by the heavy kangaroo bone suture previously described. A plaster of Paris cast was applied and upon its removal, five weeks later, firm union of the fragments had occurred in good position (see fig. 6).

Case II, H. C.—Male, 28 years old, in an automobile accident in Scotland April 5, 1911, sustained a fracture at the middle-third of the right tibia and fibula. The fracture was reduced and placed in a plaster of Paris splint. Seven weeks later no union had occurred and Bier's hyperemia was applied for four months at a hospital in Scotland. No union resulted. One year after the fracture, with non-union, I cut down on the tibia and inlaid a graft five inches long according to the above-described technique. It was not deemed necessary to disturb the fibula. In five weeks firm union had occurred. Excellent function existed twenty months after the operation.

In cases of non-union and certain fresh fractures

of the vertebrae when displacement and cord pressure have not occurred, the bone graft as applied by me in Pott's disease is applicable for support and fixation (*Journal A. M. A.*, April 5, 1913; *New York Medical Journal*, March 9, 1912; *The Post-Graduate*, November, 1912.)

An illustrative case is that of a young woman referred by Dr. E. H. Johnson of Naugatuck, Conn.

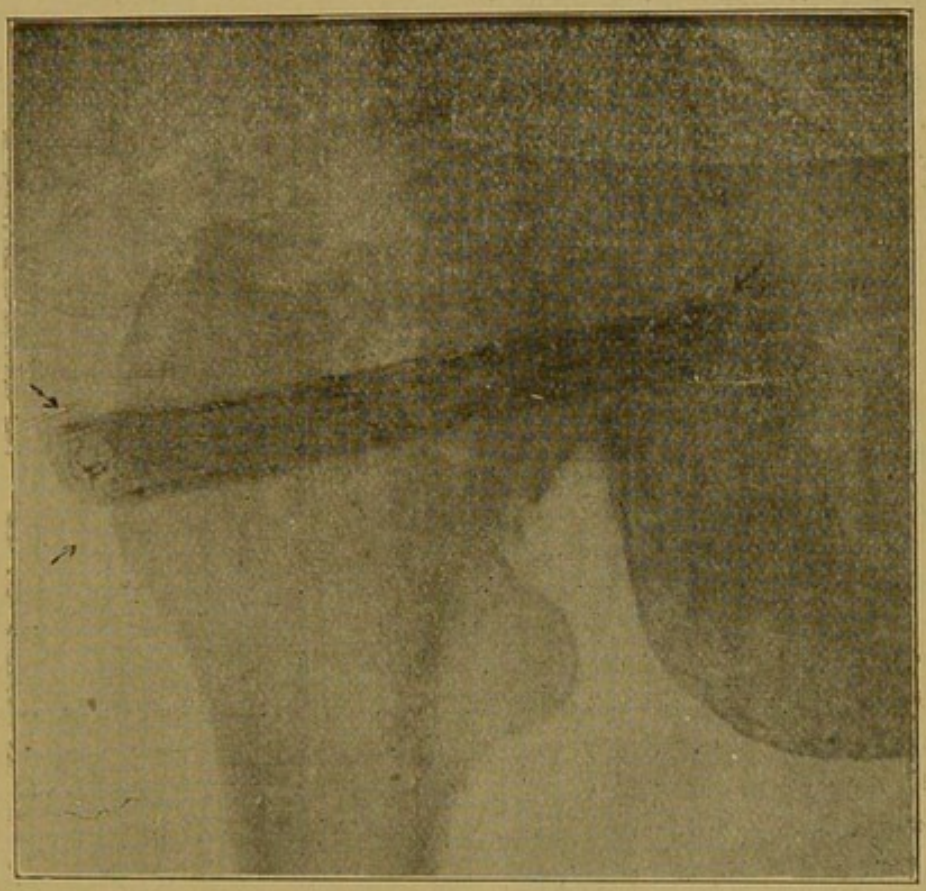

Fig. 9. For further description of this case see text of the above mentioned ununited fracture of neck of femur in women 60. Arrow points to dowel graft from other tibia. (See fig.) Author's dowelling instrument. Firm union resulted. Lower arrow points to large amount of new bone proliferating from end of graft and extending into soft tissues.

She sustained, in a railroad accident, a horizontal fracture through the middle of the body of the eleventh dorsal vertebra. Plaster of Paris jackets were worn continuously for one year, at the end of which time support was so necessary that whenever the casts became soft the patient complained of pain and lack of support and asked for a fresh

jacket. The tips of the 10th, 11th and 12th spinous processes were exposed through a circular incision to the right, turning up the flap of skin and subcutaneous tissues. These spinous processes were split *en masse* with the attached supra- and interspinous ligaments, with a scalpel, thin chisel and mallet. A graft of sufficient length was removed from the crest of the right tibia and inserted in the cleft. The split ligaments, with the imbedded fragments of the spinous processes, were drawn over it by means of interrupted sutures of medium sized kangaroo tendon. The patient was kept on a fracture bed for five weeks. The support from the graft thus imbedded gave immediate relief although no plaster of Paris jacket was applied. At this writing, one year later, there is no evidence of pain or lack of support.

In cases of ununited fracture of the neck of the femur the bone graft is even more necessary than in the shafts of long bones, for here the mechanics, blood supply, and osteogenetic conditions are much more unfavorable to union.

This is exemplified by the case of a young woman who received a fracture of the neck of the femur and four months later non-union was evident. The pseudo-arthrosis was cut down upon, the ends of the fragments were freshened and the fragments were held together by a long square tin-plated spike driven through the great trochanter and neck into the head. A long plaster of Paris spica was worn for ten weeks. Primary union of the soft tissues resulted. Much bone absorption about the spike occurred, and non-union resulted.

The above experience, among others, has induced me to evolve the following technique for the use of the bone graft in place of the metal spike:

Illustrative case. Female, 60 years old. Non-union of the neck of the femur of five months duration. The point of fracture was reached through an anterior incision from the anterior spine of the ilium downward for five inches. The ends of the

fragments were freshened by chisel and sharp curette. A point just below the great trochanter was reached by a short lateral incision.

The proper location through the center of the neck and the direction of drill hole for the graft were determined by thrusting a small hand drill through the great trochanter obliquely upward through the center of the neck and into the center of the fractured end of the capital fragment, as felt or seen through the anterior incision. This may necessitate the withdrawal and reinsertion of the drill. When the proper location and direction for the drill hole was determined the large motor-driven drill was pushed inward along the direction previously determined, through the center of the neck and well into the head. This drill, made after my directions, produced a hole 6/16″ in diameter. The drill was then disengaged from the motor and left in to hold the fragments in apposition while the bone graft was being removed from the crest of the opposite tibia.

This graft was removed by the motor saw and was about four inches long by 6/16 to 7/16 inches in cross-section. My dowelling instrument, which turns out a dowel of proper size to fit the drill hole, was then adjusted into the motor (see fig. 6).

While the motor was held by an assistant, I fed the graft slowly into the doweling instrument. This was done with comparative speed and assured a perfect fit. This strong graft was driven into place by a metal mallet. The operative technique was precisely the same as when the metal spike is used. The skin was closed without drainage. In six weeks there was firm union. Six months after operation the patient walked about without pain and with perfect function.

Summary.

The bone graft as applied in the fifteen cases of pseudo-arthrosis herein mentioned, has given 100% of bony unions.

On account of the eburnation which always exists

in the ends of fragments in cases of pseudo-arthrosis, it is essential to use healthy bone from elsewhere in the body, as the tibia.

In cases of fresh fracture, however, the bone being normal, material can be taken from the fragments themselves and used to advantage. This is best done by making the saw cuts in one fragment just double the length of the other and transposing the two strips of bone removed.

This as well as other similar technique would be impossible without resorting to the motor saw. The proper use of the motor saw, by shortening the time of operation, lessening the traumatism, and affording a means for accurately shaping the bone grafts and their beds, has opened up a very wide field of application hitherto impossible of development. There are many technical difficulties in connection with bone work which could never be overcome except for the assistance of the motor saw and its various adjustable attachments.

In the repair of deformity and the result of traumatism of the skeleton the advantage of the use of its own material and of the avoidance of the former seemingly necessary foreign substances has been clearly demonstrated. Metal introduced into the tissues is in most respects the direct antithesis of the bone graft. It favors infection, absorption and disintegration of tissue.

The bone graft being living tissue has certain germ-resisting properties. It immediately becomes adherent and fixed to the contacting tissues. It not only stimulates the bone with which it is contacted to increased osteogenesis but it proliferates bone on its own initiative.

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