Bone transplantation as a treatment of Pott's disease, club feet and ununited fractures / by Fred H. Albee.

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BONE TRANSPLANTATION AS A TREATMENT OF POTT'S DISEASE, CLUB FEET AND UNUNITED FRACTURES.

BY FRED H. ALBEE, M.D.

The following is a more extended report of the use and result of bone transplantation in the treatment of Pott's disease of the spine and is based upon fifty-five successful cases. Previous reports have appeared in the *Journal of The American Medical Association* of September 9th, 1911, Vol. VII, pp. 885 and 886 and in the *New York Medical Journal* of March 9th, 1912.

It should be mentioned here, that previous to the adoption of the herein described operation by the writer, a procedure was devised and applied to four cases. It consisted of splitting and breaking the spinous processes, with the approximation of the same. The purpose was to secure bony union between the spinous processes of the involved vertebrae. Early reports of this procedure appeared in the Annual Folder of the American Orthopedic Association of May 15th, 1911, (abstract) and the *Journal of the American Medical Association* of September 9th, 1911.

This osteoplastic method has been entirely given up, in favor of the present one on account of its untrustworthiness in producing a bony bridge and other obvious reasons, stated below.

The writer was induced to undertake this work on the spine, first, because of the inefficiency of the present ambulatory treatment of Pott's disease, especially in the upper dorsal region and second, on account of the excellent operative results obtained in tuberculous joints elsewhere in the body, where bony union with its perfect support and immobilization has caused the tuberculous process to disappear so rapidly, although only a fractional part of the tuberculous tissues were removed. This has been especially exemplified in the author's ankylosing operation on the hip, (see *Surgery, Gynecology and Obstetrics*) March 1910 pages 256-265) when applied to tuberculous ostitis of that joint and also in the erasion of the knee under similar circumstances. This same fact that it is only necessary to secure bony stiffening in tuberculous joints, by operation or otherwise in conjunction with the accepted hygienic treatment, in order to get a rapid disappearance of the tuberculous process has been emphasized very strongly in the recent writings of Ely, from his pathologic studies.

The spine is obviously an ideal location for the operative fixation of one or more tubercular joints because of the large number remaining, that is, the fixation of three or four, or even more of the total twenty-four (24) joints, does not materially affect the function of the spine. To accomplish this, a bone graft long enough to span the number of vertebræ, which are to be fixed, affords the simplest and most trustworthy means. Namely, it produces bony fixation and holds the vertebræ involved in hyper-extension by the splint action of a bone-plate and also by the leverage action of the spinous processes, through the lateral facets serving as a fulcrum. In the latter event the bone graft is acting under the very great mechanical advantage of being pulled upon lengthwise. Thus, preventing flexion of the involved vertebræ or crushing of the bodies, by transferring the superincumbent body weight to the intact lateral masses and by the fixation, above referred to.

The writer feels that too great emphasis cannot be placed upon this mechanical element of crushing of the vertebral bodies in the prolongation of the convalescence of Pott's disease. He also believes, with Ely and others, that bony fixation of tuberculous joints is an absolute panacea. This latter deduction is based upon a fairly extensive experience with fixation operations on the various acute tuberculosis joints, such as hips, knees, etc. In these operations no attempt has been made to remove all tubercular tissue, the only object being to eliminate natures bearer to ankylosis, namely, cartilage etc., and to secure good approximation with as little removal of bone as possible. The results have been very striking. On account of the operative field being in diseased tissues in these various joints, the bony union has been delayed in many cases. In the case of the spinal transplantation, however, the operative field is always in healthy tissues, and bony union in all cases has been, apparently, immediate between the split spinous processes and the bone insert. None of the tuberculous tissue has been removed, neither is all the disease tissues removed in the case of excision of the knee or in the author's arthrodesis of the tubercular hip, nevertheless bony union takes place and all remaining tuberculous tissue disappears.

In reference, to the ultimate fate of auto-transplanted bone into bone there are at present two views. According to Macewen

Kausch, Marchand, Barth, Frankenstein and others bone transplanted into bone persists and lives as such. Others, among whom are Axhausen, Murphy and Steida hold that bone with transplanted in the same individual and in contact with other living bone at one or both ends of the transplanted fragment, always becomes united to the living fragments and acts as a scaffolding for the reproduction of new bone of the same size and shape as the transplanted fragment, if asepsis is attained. It is claimed that, the role the transplant plays is to give mechanical support to the capillaries and blood vessels with their living osteogenetic cells, as they advance from the living bone at both ends of the transplanted fragment, into the Haversian canals, canaliculi and lacunæ of the transplant.

New lamellæ are deposited around the capillaries and these lamellæ fit into and adjust themselves in the graft, so that the bony union is actually formed and mechanical support given long before the transplant loses its splint action and is replaced by new bone or, in other words the bone graft is per se not osteogenetic but osteo-conductive.

Now as far as our purposes are concerned, it is readily seen, that it makes no difference, which of these contentions is true. A permanent supporting bone splint is obtained in either event.

The accepted requirement for a bone graft is that it has contact with a recipient bone on one end. In the case of our transplant there are two bony contacts for each vertebræ into which it is inserted. When inserted into three or four vertebræ, it has six or eight bony contacts. The bed into which a transplant is placed has apparently everything to do with its fate. In reference to this, we quote again from Murphy " Bone with its periosteum transplanted into muscle fat etc., in the same individual, and free from bony contact, practically always dies and is absorbed, except in the case of very young children or infants." It will be seen by this, that grafts placed beside and outside of the spinous processes in the soft tissues, in imitation of Langes metal splints, are not trustworthy.

The writer wishes to state, here and will refer to it again, that he has become convinced from his experience with the herein reported treatment of Pott's disease and a large amount of animal experimentation, that the exact environment of bone graft, even when it is inserted into or in contact with a recipient bone

or bones, determines whether it is to persist and live as such or whether it is to serve as an osteo-conductive scaffold and slowly become absorbed and replaced by new bone formation. That is, there is a vast difference between the bed of our spinal graft with its numerous bone contacts and ligamentous envelopment, and that of one where the large part of a long bone, such as the humerus or tibia is replaced by a bone transplant, or that of a mildly infected osteomyelitic cavity.

In the first instance the insert is wedged into healthy spinous processes, which are less than three-quarters of an inch apart, in addition to this it is embedded throughout its remaining extent in freshly cut ligamentous tissue. In the last instance, the graft, when supplying six inches or more of the end of a long bone, is embedded throughout its whole length in soft tissues (muscular, adipose or fascial) and has only a bone contact at one end. It is this difference, which determines that the graft shall live in one instance and be osteo-conductive in another.

The author has gathered an abundance of evidence both from animal experimentation and surgical experience, to prove that the spinal transplant, inserted as herein described, persists and lives as such. This evidence consists of microscopic and X-ray examinations of gross specimens, also microscopic examinations of both decalcified and non-decalcified sections. These specimens have been of both surgical and animal experimental origin.

Long grafts with one or two bone contacts are, undoubtedly in most instances, osteo-conductive.

The perfected technique of the operation, herein reported is as follows: With the patient in the ventral position, the spinous processes are reached by a curved incision to one side and the turning up of a skin flap. Care is taken not to incise the supra-spinous ligament (which is the prolongation of the ligamentum nuchae of the neck) to one side. Then with a scalpel the cartilaginous tips of the spinous processes are split in center, also the above mentioned supra-spinous ligament leaving each part of it attached to the halves of the spinous processes. The interspinous ligaments are split into equal parts to a depth of about three-quarter inch, without disturbing their attachments to the spinous process. Very little hemorrhage results, because, only dense ligamentous tissues have been incised. Which is in considerable contrast to the hemorrhage resulting from the separation of the muscles

from the spinous processes in a deeper operation, such as a laminectomy. With a chisel and mallet each process is split longitudinally into equal parts for a depth of about three-quarter inch, care being taken that green stick fractures are produced on one and the same side of all the spinous processes. The unbroken halves preserves, intact, the leverage of these processes. A separation of the tips of the halves of each spinous process produces a wedge shaped cavity, into which the prismatic shaped transplant is later placed. It is important that the spinous processes be split in situ with all the ligamentous and muscular insertions undisturbed, as in this way none of the natural supports of the spine are taken away and the ligaments afford, by means of strong ligatures, an excellent medium for firmly fixing the bone splint in place. A hot saline pack is placed over the back wound until the bone insert is obtained. With the patient still in the ventral position, the leg is flexed on the thigh and an incision over and down to crest of the tibia is made. The fascia and subcutaneous tissues are carefully separated from the periosteum of the anterior—internal flat surface of the tibia. With a sand bag in the popliteal space and behind the leg a prismatic shaped piece of the tibia is removed with a sharp chisel. A motor saw also affords a very rapid and exact method of securing the graft, and has been used in all the later cases. The length of graft varies according to how many vertebræ are to be spanned, its breath from two-thirds to three-quarter inch, according to size of patient, its thickness from one-third to one-half for the same reason. All diseased vertebræ and one healthy one on each side should be included within the insert. The graft is inserted between the halves of the interspinous ligaments and the spinous processes with its edge anterior or innermost. It is held firmly in position by interrupted sutures of heavy or medium kangaroo tendon, which are passed through the supraspinous ligament and the posterior edge of the half of the interspinous ligament on either side near the tip of a spinous process. The suture is brought over the graft posteriorly and into the same ligaments on its other side. The ligaments are then drawn over the insert posteriorly by tense sutures, placed together. If there is a moderate kyphosis of short duration, it is entirely obliterated, any kyphosis of a few years or less duration becomes much diminished, either at the time of operation or the first few weeks after or both.

In three instances tuberculous tissues, with cold abscess formation, were entered in region of the spinous processes. The grafts were inserted as usual and primary union resulted in each case. In several of the later cases where a kyphosis too old or too great, to be entirely corrected has existed and it has been impossible, on account of the angulation of the spine to secure a straight splint, properly, in place in the spinous processes, a very broad bone splint has been taken (in some instances the complete width of the tibia) and than molded with a sharp Rongeur bone forceps, into the segment of a circle. The graft, however, is always straighter than the kyphosis and the spine is straightened and drawn to the bone splint by means of the heavy ligatures. When the deformity has been too great, even for this method the graft has been placed, with its wider diameter in a lateral, rather than anterior posterior plane, and then bent into place between the halves of the spinous processes and held with heavy kangaroo tendon as above indicated. This has been accomplished successfully in children, where grafts of the following dimensions were used $4\frac{1}{2}$ by $\frac{3}{8}$ by $\frac{1}{4}$ inch. In later cases of all ages especially adults, where it is necessary to bend the graft, it has been found, preferable, to saw one-half the way through it, on what is to be its concave side, four to eight times at the place where it is to be bent, (as the carpenter does, when he bends a board). The distance between these saw cuts have varied according to the size of the graft from one-eighth to three-quarters of an inch. The transplants have varied in size from four to seven and one-half inches in length; three-eighths to one-half inch in width; one-fourth to one-half inch in thickness. Care is taken that the insert has some bone marrow. The importance of this has been pointed out by several German investigators. Before placing the transplant in its bed, its periosteum is incised in many places so as to allow the underlying osteogenetic cells exit for proliferation. In adults when we do not wish the bone graft to grow longitudinally the incisions are made lengthwise of the graft. In the case of children they are made crosswise. After pressing the graft in place the dense supraspinous ligament with the posterior part of the halves of the interspinous ligaments are drawn over the graft, with interrupted sutures of heavy kangaroo tendon. It is, thus, firmly embedded under tension in the spinous processes and the dense intraspinous ligaments, and affords immediate and excellent

fixation of those vertebræ involved, even before union takes place. The immediate fixation thus obtained must be far more perfect than that secured by any external orthopedic means, as plaster jackets, etc. This has been especially confirmed by the immediate disappearance of pain in adults and pain and night cries in children, (*i.e.* within a few days.) The environment of the spinal insert thus placed is most favorable, it is not only wedged into well nourished healthy spinous processes, which are less than three-quarter inch apart, but is also surrounded throughout its whole extent by ligamentous tissue, which is normally attached to bone. The conditions are very favorable to a rapid establishment of an Haversian blood supply from the spinous processes to graft. The writer believes that the fact that his spinal grafts have showed no evidence of disintegration or absorption, is explained in this way. In four cases, where the kyphosis was very marked and angular, green stick fractures of both halves of the prominent spinous process were produced (by help of osteotomy) and about one-third to two-thirds of their tips turned in laterally and sutured in contact with posterior surface of transplant. Thus producing additional bone contacts for graft and reducing the kyphosis by so much.

On August 5th, 1912 at Bellevue Hospital a spinal graft which had been inserted, seven (7) weeks before, was cut down upon and carefully examined. The case was that of a child who had a large kyphosis and the graft had been bent into place under considerable tension. Although the spinal deformity had become straightened a good deal at the operation and from the constant tension of the bent bone plate afterwards (as of a bow) the upper end of the graft had become disengaged from the tips of the spinous processes and had sprung posteriorly into the soft tissues.

The graft was firmly united to all the spinous processes with which it was in contact. There had been a large amount of new bone formation about the graft and tips of the spinous processes. The graft had become increased in its diameter between the spinous processes with which it had become united. The projecting ends had increased but slightly. Careful inspection failed to find any evidence of bone degeneration or absorption. About one-half inch of its upper end was removed with bone forceps. The cut end of the transplant bled uniformly through-

cut its whole diameter. The graft was then partially cut with a chisel obliquely through, on its posterior aspect, about one inch from each end. The tips of the spinous processes beneath were split and the ends of the graft forced into them by producing green stick fractures of the graft when it had previously been cut, and secured with interrupted sutures of medium kangaroo tendon. The important feature of the event was that the graft presented every evidence of healthy live bone and bled whenever cut. A miscroscopical examination has shown healthy bone throughout the diameter of the transplant. No dead or degenerated bone cells could be found. Up to date fifty-five cases have been operated. They have varied in ages from two to fifty-one years of age and have all been cases with acute symptoms. In fact, some of the cases have been very acute. One great surprise has been the large amount of recession of the deformity secured by the straightening effect of the bone splint sutured in place under tension. The elasticity of the tissues, held by the sutures, and the straightening effect of the graft, bent under tension, has been undoubtedly largely responsible for the additional kyphotic recession, occurring after the operation.

Thirty-four of which have been in the dorsal region, nineteen in the lumbar region and two in the cervical region. The results have been nothing short of remarkable.

No plaster of Paris jackets, whatever, have been used in the post-operative treatment. A spinal brace was used in a case of an adult, an early case who went back to work as a carpenter seven weeks after the operation. The postoperative treatment has been the recumbent position on a narrow gas pipe frame or a fracture bed for five to twelve weeks. After this, they have walked about without apparatus. Three cases, two children and one adult, we have gotten up at the end of five weeks, although they were acute cases. They have been free from all symptoms up to ten months.

The relief of pain and all symptoms of acute disease has disappeared within a few days. All the adults of which, there has been five, have been most appreciative, on account of the immediate relief of pain and all other symptoms. All pain has disappeared, in every case, not later then the third day after operation. The rapid improvement in the general condition

has been very striking. Four of the cases were complicated by complete paraplegia. One child of four years was referred by Dr. Swift of the Pediatric Clinic, Cornell Dispensary. This child had incontinence of urine and feces and was operated at Bellevue Hospital. In five months from the time of operation this child was walking and did not even have increase knee jerks. The paraplegia of the remaining three cases cleared up in each incidence in less than six months.

There has been no shock of consequence in any of the cases. Every wound has healed by primary union. There has been no mortality. One wound broke down, superficially, two weeks after the operation and after primary union seemed satisfactory. It seems likely that there would be some trouble with the insert, but the wound finally healed, kindly. It has been fifteen months now since the early cases were operated. Most of the cases have been operated in the following hospitals, Sea Breeze, Bellevue, Roosevelt, Post-Graduate and Mary Fletcher Hospital (University of Vermont). Sixteen of the cases were operated at Sea Breeze Hospital, where they had all the advantages of a seaside fresh air hospital. One great advantage of this treatment is that the children are able to go in bathing soon after the operation, (*i.e.* in six or seven weeks).

Too much cannot be said of the importance of this kind of treatment after the operation.

From the clinical course of all these cases and frequent X-ray examination by two planes, it seems very certain that all the inserts have become united into the spinous processes. The X-ray also shows a bone proliferation about the graft and tips of spinous processes and an increase in the diameter, in most of the cases, of the transplant itself. The vertebral bodies after several months become dense and the bone detail clearer and sharper in outline.

Fifteen dogs have been operated on at the Loomis Laboratory, Cornell University Medical College. A duplicate of the above operation and other procedure for producing a bony union between the vertebræ have been carried out. The bone graft has never failed to produce bony union between spinous processes, in the presence of asepsis. Although the postoperative conditions have been most unfavorable. No attempt having been made to fix or immobilize the dog's spine by splints or

plaster of Paris. The transplants have been inserted and the dogs have been put back into their cages to move as much as they choose, nevertheless, autopsies have demonstrated the firm bone-bridge between the spinous processes. In other cases, grafts taken from other dogs ulnæ both young and old, have been kept in salt solution or Ringier's solution in an ordinary ice box up to periods of four days with equally as good results. Three of these dogs, which were operated the first of December 1911, were autopsied May 25th, 1912 in order to present a bone bridge of six months' duration.

In these older cases the bone graft has lost its identity and the bridge of bone looks as if it was a part of the spinous processes. They are larger in diameter, in most cases, then the original graft. A careful microscopical study of specimens, six weeks and six months after transplantation, has been made by Dr. Ferguson, Professor of Histology at Cornell University Medical College and myself. No dead bone, whatever, could be found. The blood supply extending from spinous process into the graft in each instance was most profuse. There was every evidence of a proliferation of bone from the graft extending into the spinous process. There was no cartilage cells whatever. The bone union was complete even in the six weeks' specimens. The specimens were examined carefully, both by the X-ray and by the microscope. The microscopical preparations were both sections of decalcified specimens and ground sections not decalcified. Under the same unfavorable conditions all attempts, in dogs up to the present time, to produce by fracturing and bending down the spinous processes or by placing strips of periosteum between the spinous processes, have failed to produce a bony bridge.

SUMMARY (POTT'S DISEASE).

1. The operative procedure is superficial and confined to bone and ligamentous structures, therefore, it is of short duration, usually taking from fifteen to thirty minutes, and is associated with a minimum amount of shock and hemorrhage.

2. No normal anatomical structure or support of the spine is severed or destroyed. The full leverage of the spinous processes, which is the only physiological means of holding the spine in hyper-extension is preserved and taken advantage of, thus preventing kyphotic deformity. It should be noted, in this

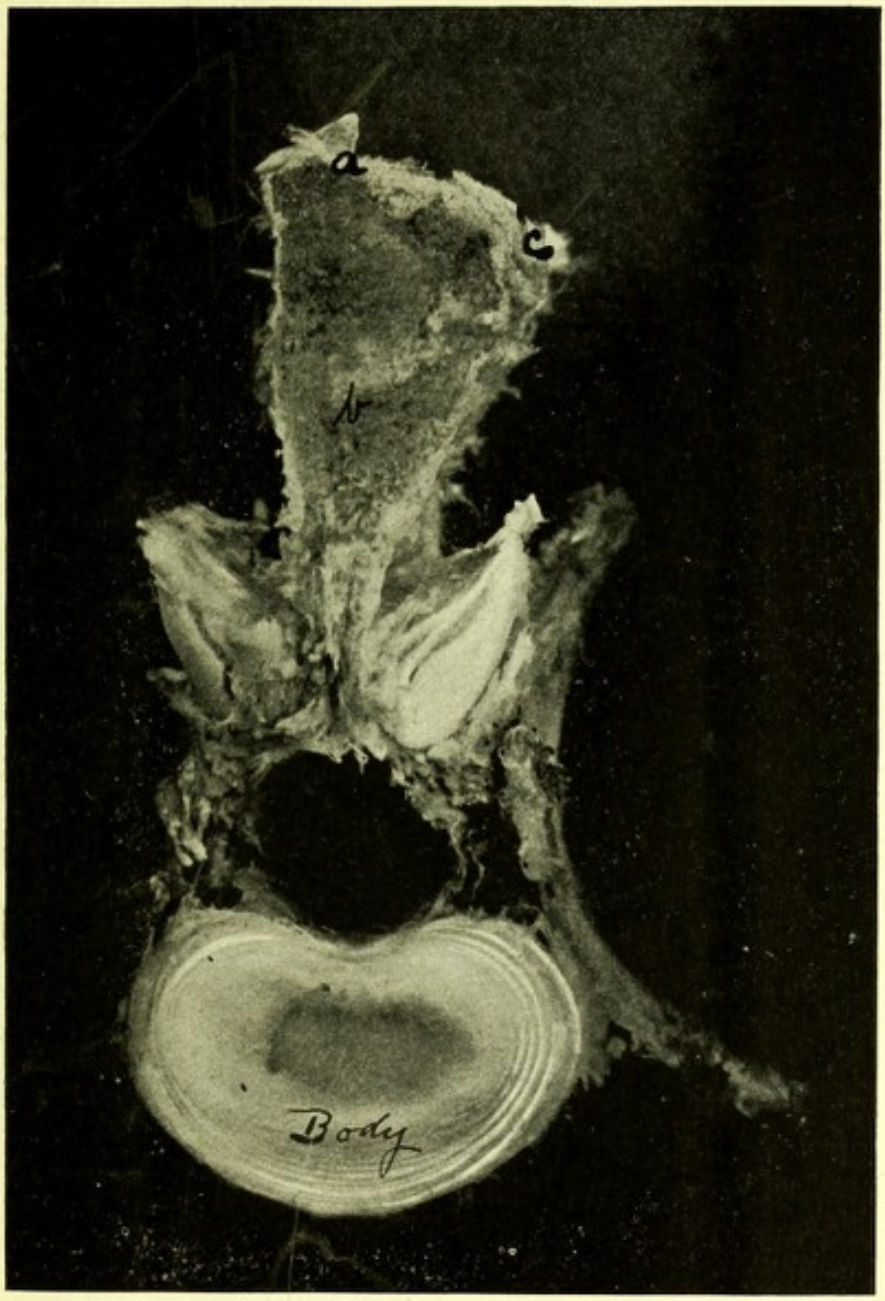

FIG. 1.—View of a dog's vertebra, into the spinous process of which a portion of his ulna, had been ingrafted six months before. A, b, and c indicate the outlines of the graft, which has become firmly grown into the split spinous process. Fig. 2 is a microphotograph of a section of graft grown into the spinous process at this point.

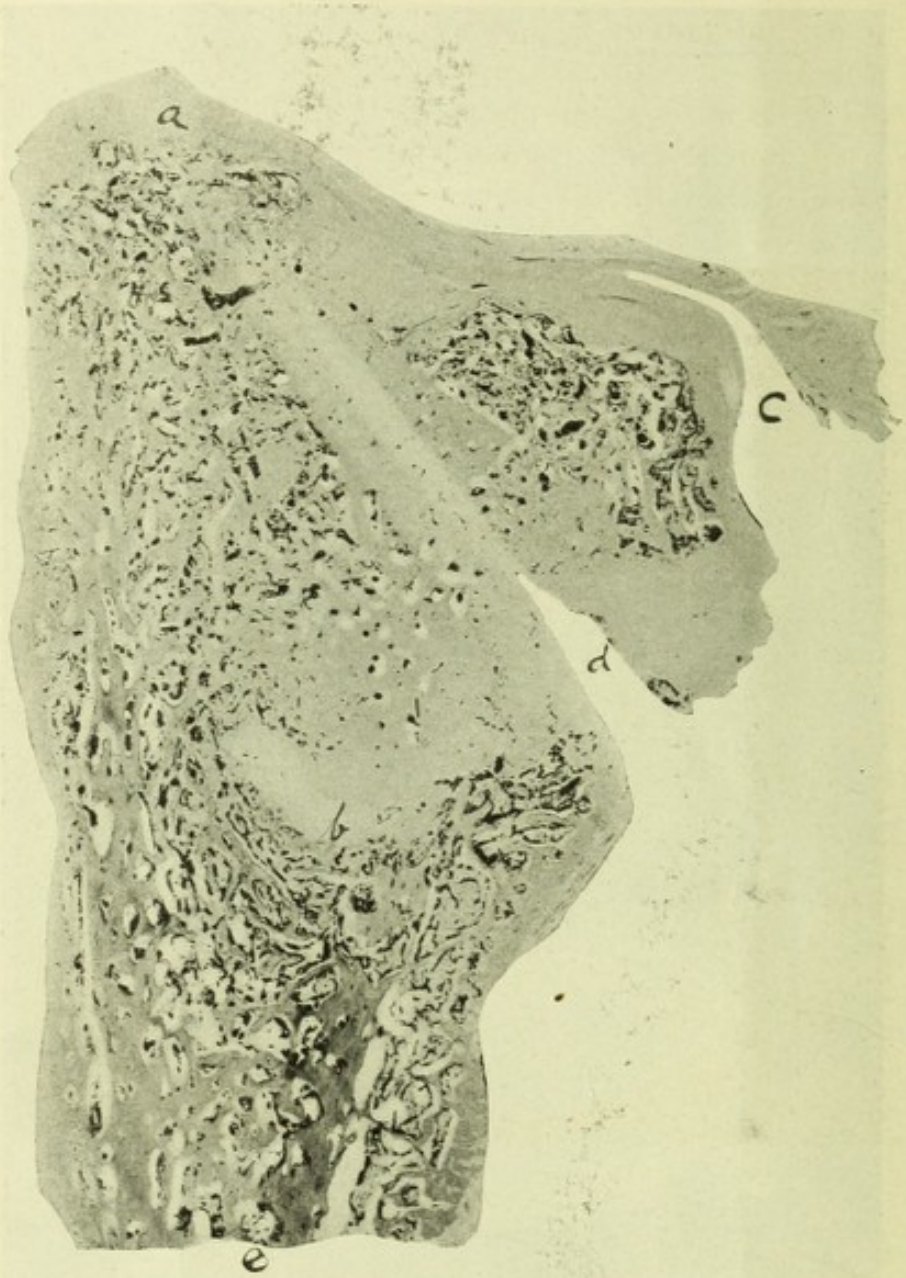

FIG. 2.—Dog specimen. Six months after a portion of same animals ulna had been grafted into spinous processes. Microphotograph of a decalcified section through long axis of spinous process with cross section of the grown-in graft. A careful microscopical study of these sections and all others have failed to disclose dead bone cells. A, b, and c are placed at the corners of the graft. (d. is a microtome artefact.) e. is base of spinous process.

connection, that the nearer the bone transplant is to the tips of the spinous processes (or the more superficial) the greater mechanical advantage is derived.

3. The bone splint insert, as described, gives firm fixation the moment it is sutured in place and affords even before bony union far more efficient immobilization than any external brace or plaster of Paris jacket can possibly supply.

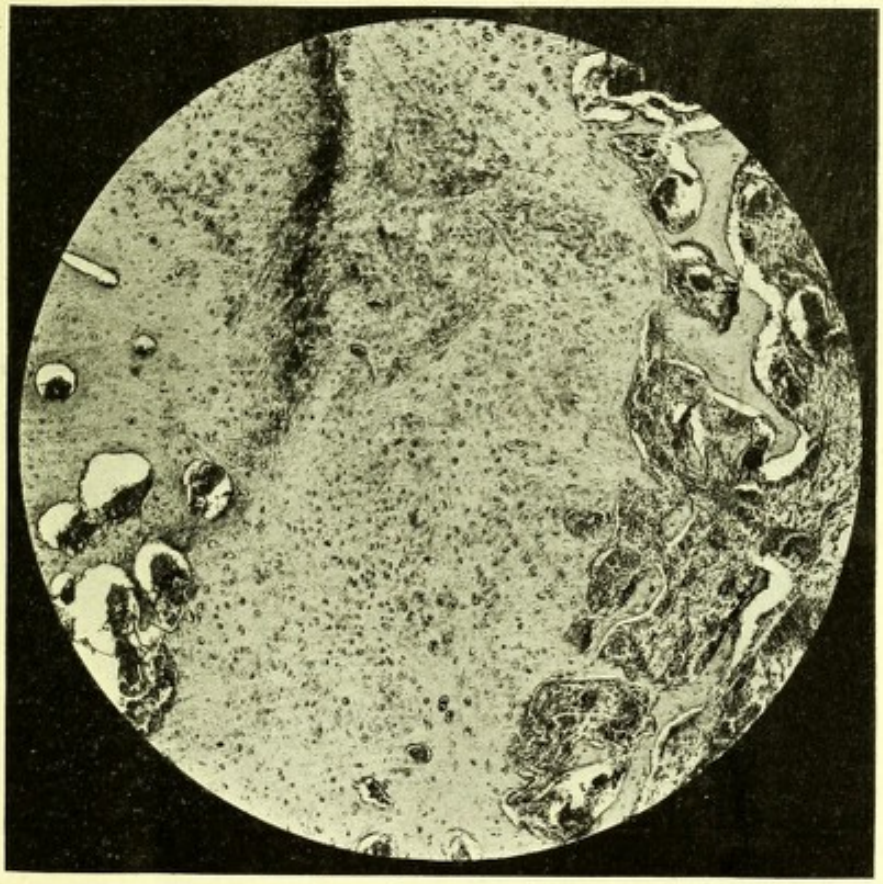

FIG. 3.—High power microphotograph of junction of graft and spinous process in a case of six months. No dead bone cells could be found in these specimens.

4. On account of the fixation being applied internally and directly to the vertebræ involved and those only, the function of the rest of the spine and respiration is not interferred with. Long confinement on a frame or in a plaster of Paris jacket or spinal brace is no longer necessary.

5. The bed, into which the bone insert is placed, is of an ideal nature, for a bone graft, as it is composed of freshly severed

ligamentous and bone structures. It is claimed that one bony contact, of recipient bone to graft, is sufficient for the establishment of a proper blood supply for the latter. In the case of our graft, there are two bony contacts for each spinous process involved, and they are only the distance of the interspinous space apart. In this environment the bone graft lives and persists as such.

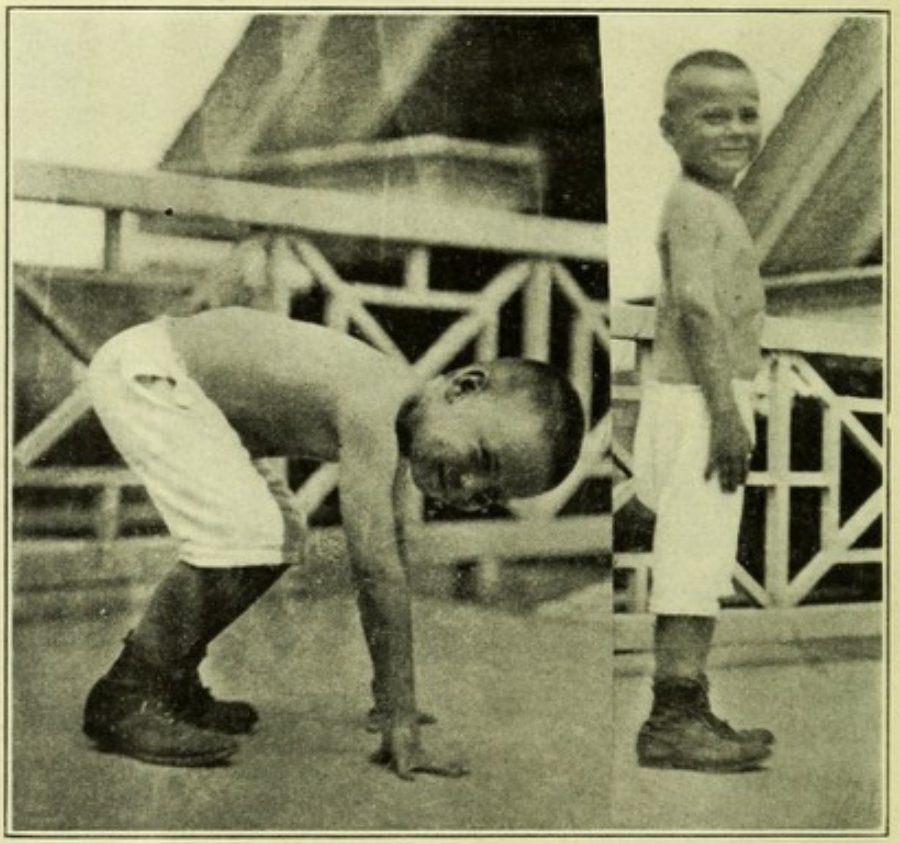

FIG. 4.—This boy, a very acute case of Pott's Disease, was operated on at Post-Graduate Hospital over sixteen months ago. No plaster jacket or brace was used. These photographs show him as he is now and the flexibility of his spine above and below the graft.

6. As stated above the field of operation is superficial and distal from the neural arches, therefore, there is no danger of encroachment upon the spinal canal by over growth of bone or infection, which might arise from operative trauma.

7. If bone union of graft to spinous processes should not, by chance occur, the same mechanical effect of the splint action of the bone transplant and the leverage of the spinous processes, above

referred to, would still be obtained in a large degree, account of the insert being imbedded in the spinous processes and the dense ligamentous structures attached to the spinous processes.

8. The post-operative treatment is simple in character and of short duration. It consists of dorsal recumbency on a gas pipe frame or a firm mattress with a board under it, in the region where the kyphosis comes (fracture bed) for a period of five or twelve weeks. At the end of this time, bony union has taken

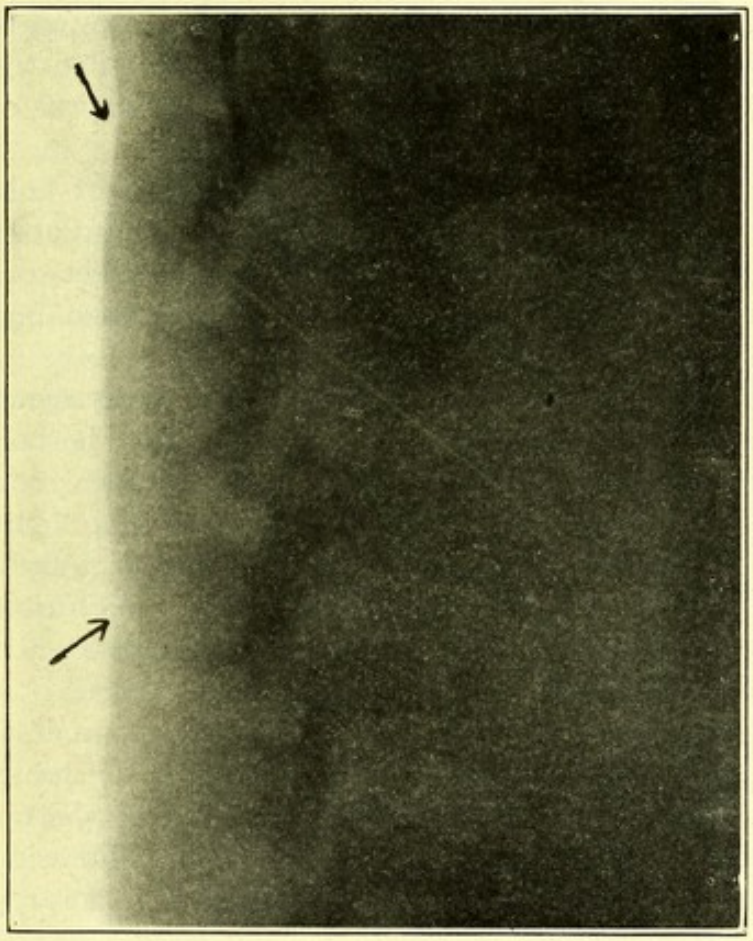

FIG. 5.—This is a skiagram (lateral view) of an acute case of lumbar Pott's Disease sixteen months after operation. The arrow indicates the graft grown into the spinous processes.

place between bone splint and vertebræ and no further supportive or immobilization treatment by plaster of Paris jackets, braces, etc., is necessary.

9. A continuous bridge of bone with periosteum and endosteum is furnished, spanning the entire number of vertebræ, which are

desired to be immobilized and, therefore, should be under the influence of Wolff's anatomic law and become greater in diameter and length as the parts develop. In other words it is an imitation of Nature's success. In dogs this bone transplant loses its identity in four to five months and becomes continuous and homogenous with the spinous process into which it was placed, and apparently innervated by the same trophic nerves.

10. Disease tissues are not entered. The field of operation is, entirely, in healthy tissues, therefore, primary union can be expected.

11. The procedure is not a formidable one. The technique is very simple. In three cases the operating time was not over fifteen minutes.

12. Metal splints placed into or on bone will not hold stress for any length of time, because of bone atrophy and absorption, which takes place, very early, wherever contact between metal and bones occurs. Therefore, the advantages of a bone graft over metal is apparent.

13. When possible, a recession of the kyphosis by recumbency on a convex gas pipe frame should be secured. The bone graft offers great promise of holding permanently the corrcetion obtained, whereas, without this artificial bone support there is a great tendency to a relapse of the deformity, when ambulatory treatment is later resumed, on account of the inhibition of the tuberculous bacillus to the rapid new bone formation between the diseased vertebræ.

14. One of the most gratifying features of this mode of treatment has been the large amount of correction of the kyphotic deformity, which has been possible to obtain at the operation and during the first few days after, especially in early cases with angular deformities the kyphotic recession has resulted from the straightening effect of the bone transplant sutured under lateral tension into the dense inter- and supraspinous ligaments and the spinous processes.

15. Perfect immobilization and support of the involved vertebræ in the respiratory area of the spine is secured. Which is an impossibility by any external, mechanical device or treatment, on account of the constant respiratory movement of the ribs and attached vertebræ. This motion of the diseased vertebræ upon each other has been especially noticeable when the spinous

processes are cut down upon. It, necessarily, entirely ceases as soon as the bone splint, is fixed in place.

In cases of congenital club-foot in older children, over three or four years old, where adduction of the front part of the foot predominates, a wedge of bone, taken usually from the upper end of the tibia of the other leg, has been ingrafted into the scaphoid, in several cases with most gratifying results. It should be noted that the scaphoid bone extends about half way through the skeleton of the foot from inside outward. To its outer side is attached an inter osseous ligament and there is no articulation here, with the cuboid. Therefore when the scaphoid is split vertically into an anterior and posterior portion no joint is entered and the foot is unfolded and straightened by a separation of the scaphoidal fragments and the formation of a wedge-shape cavity between them.

The ease with which markedly adducted feet are straightened after this osteotomy, has been very gratifying. A wedge consisting of the full thickness of cortex and some marrow, with a broader base than that of the cavity in the scaphoid is removed from the crest of the other tibia, high up with a motor saw. Before it is disengaged from the tibia the cortex of the wedge is drilled obliquely.

The foot is then held well corrected and this bone wedge is forced into place. This separates the scaphoidal fragments still more. The wedge is then held in position by a suture of medium kangaroo tendon passed through the inner edges of the portion of the scaphoid and the hole drilled in the wedge, also by suturing fascia about it. In this way the inner side of the skeleton of the foot which was shorter than the outer side, has been made of equal length, or in other words the foot has been propped in the correct position by a rigid bone graft. Thus a relapse should be very unlikely and the long continuance of braces is not necessary as it is, many times, after correction, following soft tissues operations, as the Phelps operation.

The same procedure with or without the insertion of silk ligaments has been practiced on acquired deformities of a similar nature, from infantile paralysis etc. An example is an adducted foot in varus from a paralysis of the peroneus longus and brevis muscles. These muscles are strong abductors of the front of foot and elevators of its outer edge. Therefore the foot

becomes adducted in the varus position and is difficult to control by braces. The astragulo-scaphoid joint is hypermobile.

A bone wedge placed between the head of the astragalus and the scaphoid after the cartilage has been removed from each of these joint surfaces, not only props the foot in a corrected position as to its adduction, but acts as an arthrodesis of this joint, thus producing needed stability. To hold the outer edge of the foot up or to correct the varus resulting from the paralysis of the peronei, a strong braided silk ligament is placed under tension between the external malleolus and the posterior upper surface of the cuboid. The silk is fixed into the bone substance by drilling. The knots are prevented from untying by action of tissues, by tying each half knot with small silk. In this way the proper balance of the foot and limb is restored by a remodeling the skeleton of the foot, and braces, which would otherwise be necessary, are dispensed with.

The bone graft, also offers an ideal treatment for ununited fractures of pseudarthrosis. In this condition we have appearing early, a marked sclerosis of the ends of the fragments, due to an over deposit of bone salts and an equal diminution of the bone cells. In these cases freshening of the ends of the fragments and the application of the Lane plate has not been trustworthy, because of the above mentioned bone sclerosis and lack of active osteogenesis. In reference to this, Martin has well stated in *Surgery, Gynecology and Obstetrics*, Sept., 1912. "There is a too broadly accepted belief, to the effect, that if a fracture be exposed, neatly apposed, plated, properly splinted and the wound remains clean, the union of that fracture is assured. This is not true. As a rule the presence of a plate (Lane plate) in place of stimulating osteogenesis between the broken bone ends retards it."

In many cases of long standing pseudarthroses there is a perfect apposition of the fragments, and the point of fracture may be in the center of the tibia, where very perfect fixation can be obtained by external splints. Still no union takes place. It is obvious that the situation cannot be much improved upon, by open operation and the application of Lane plate. The thing, that is needed, above all others, is an added osteogenetic force. This is best supplied, as well as perfect internal fixation, by the bone graft inserted in the following way.

The point of fraction is reached by a long incision. The tissues are separated from the side of the fragment where the graft is to be placed for about two to three inches each side of the point of fracture. The bone ends are then freshened with chisel and mallet or motor saw. They are then well approximated with fragments in good alignment. The bone cortex where the graft is to be placed is then sawed through to the marrow, by two parallel cuts from $\frac{3}{8}$ to $\frac{1}{2}$ inch apart, extending into each fragment for $2\frac{1}{2}$ to 3 inches from point of fracture. These strips of bone are then removed with a narrow chisel and mallet. Thus producing a long mortice extending into each fragment. A strip of bone of proper length taken from the crest of the tibia, with a motor saw, is then inlaid (as a cabinet maker inlays a piece of wood.) This bone gratt should always extend beyond the sclerosed ends, into healthy vascular bone in each fragment. The insert is held in place by kangaroo tendon placed in drill holes in the recipient bone on each side and brought over graft and tied. This procedure has produced bony union all of the four cases operated upon. In one case the pseudarthrosis had existed ten and one-half months.