SOME POINTS ABOUT BONE GRAFTS.

[WITH SPECIAL PLATE.]

BY

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FOUR years of war has provided such a plethora of material for the study of bone-grafting operations that it is possible for surgeons to survey the field from the standpoint of considerable experience. Heretofore discussions about bone grafting have centred mainly round theoretical and academic questions, such as the rôle of the periosteum in the osteogenetic process, and the ultimate fate of the graft in its new position, the all-important clinical standpoint receiving but scant recognition.

So far as the osteogenetic power of periosteum is concerned, the controversy largely appears to hang round the point, What is meant by the periosteum? If merely the fibrous sheath which surrounds bone, then the periosteum is but a limiting and vascularizing membrane; if, on the other hand, the cambium or epiosteum layer lying between periosteum and bone, and rich in osteoblasts, is included as part of the periosteum, then most certainly the periosteum plays an important part in the production of bone. This bone-producing layer, lying between the periosteum and the surface of the bone, clings in children to the periosteum, whereas in adults it appears to belong more properly to the bone, and, in the absence of trauma or inflammation, to be inseparable from it.

If the periosteum is preserved, with its clinging osteoblasts, as in the case of subperiosteal resection of bone in a child, new bone will be formed with mathematical accuracy in every case. In adults subperiosteal resection may or may not be followed by new bone formation, the result apparently depending to a large extent on whether or not the osteoblasts are detached from the bone in the process of separating the periosteum.

From a practical point of view absence of the periosteum from an implanted bone graft probably means slower vascularization and a more prolonged convalescence for the patient. The retention of periosteum with the graft is not essential for success, but appears to play a decided part in the formation of an involucrum of new bone, which is seen with comparative regularity round a graft a few weeks old. Periosteal covered grafts are more permanent, and less likely to be absorbed.

Murphy and others held that the graft was nothing more or less than a scaffold, which is replaced by new bone. When the graft was contacted with living bone, the Haversian vessels permeated the Haversian canals of the graft, and carried with them osteoblasts and osteoclasts. The osteoblasts made good the defects in the graft produced by the activity of the osteoclasts. Thus the osteoblasts produces and inserts a new brick *pari passu* with the demolishing of the old structure by the osteoclasts. That the graft is not a mere scaffolding removed by the action of the osteoclasts and replaced by the activity of the osteoblasts, but is really viable and inherently carries its own osteogenic powers, becomes obvious under certain pathological conditions.

If a fracture occurs, the result of accident, the graft unites by the formation of callus, by a process simulating the repair of normal bone, and if a graft becomes infected, and the infection is not sufficiently severe to kill it outright, then an involucrum and sequestrum may be formed. In other words, almost from the time of insertion, a graft behaves in a manner identical with ordinary bone.

Sir Robert Jones illustrates a case of bone graft introduced to replace a tibia lost from disease. The graft broke near the centre, but subsequent *x*-ray photographs demonstrated a very definite formation of callus at the site of fracture.

Experience teaches many interesting points in connexion with the surgery of bone grafting. Ruin is not inevitable if accidental infection follows the operation, either through error of technique or the result of latent sepsis. A graft will often survive all but the streptococcal and other severe infections, and a bacteriological investigation should be made of the pus, in order to gauge the prognosis. Technique should approach perfection in every surgical operation, but should infection occur, or from the nature of things be inevitable, a bone graft will withstand the assault in a surprising manner, and the end result may be admirable. (Figs. 3 and 4.) In proof of this we have only to watch the completely separated fragments of bone in a compound "ploughed" fracture the result of gunshot wound, and see the fragments not only remaining viable, but rapidly consolidating with the fractured ends during repair. It is not true to suppose that bare bone is of necessity devitalized and will end in sequestration in a septic case, and the same observation applies to a bone graft. Hence the golden rule not to remove loose fragments in the early treatment of septic fractures, nor disturb a bone graft because unexpected infection follows the operation.*

In fifteen cases of Albee's operation for Pott's caries during the last five years the wound twice became infected. In one case, a child seen by Professor Osgood when visiting Dublin, the graft protruded through the lower angle of the wound for some weeks, without any sign of local inflammation in the soft tissues. Eventually the protruding portion was removed with bone pliers, and the skin at once healed across the gap, leaving the main portion of the graft undisturbed. This case recovered rapidly, with the graft firmly consolidated *in situ*.

In the second case, a very thin young adult, a pressure sore developed from insufficient padding of the frame on which the patient was placed after operation. The lower third of the graft became exposed, and the wound suppurated freely. In twelve months' time a sequestrum was thrown off, and the wound healed. *X*-ray photographs showed the graft *in situ* and firmly fixed to the diseased segment of the spine.

The first thought of the surgeon must be how to fix the graft in its new bed and by what method the limb is to be immobilized immediately after operation. A small amount of movement does not delay union in a simple fracture, as evidenced by the rapid repair of a broken rib or jaw, but the slightest mobility in a bone graft may make all the difference between success and failure.

In planning the line of the incision there will be no difficulty in dealing with easily accessible bones, such as the ulna and tibia, but in the case of the humerus and radius real respect must be paid to anatomical structures. Cases operated on previously, and exhibiting many scars, require ingenuity in planning the operation, so as to avoid, *inter alia*, the musculo-spiral and posterior interosseous nerves. The best plan is to expose the bone in its most easily accessible portion and then to extend the dissection by keeping under the periosteum, or as close to the bone as possible. The less the muscular attachments are interfered with the more rapidly will the osteogenetic process be established. Ruthless stripping of the bone must be avoided.

In old ununited fractures the difficulty at once arises of how to prepare a bed for the graft in the presence of, perhaps, two or three inches of sclerosed avascular bone. Complete resection often cannot be done without undue sacrifice of length of the limb. In such cases reliance may be placed on a long stout graft extending for a considerable distance above and below the sclerosed area, and an attempt made to create new vascular channels by drilling holes and reaming out a new medullary cavity before placing the graft in position. (Fig. 7.)

A long stout inlay graft is most likely to succeed, but it should be remembered that the recipient bone in the critical area—that is, the region of the fracture—is unsuitable soil; osteogenesis and thickening of the graft may fail, and the solution of continuity reappear on absorption of the graft many months after operation. Radical shortening of the bone is the only remedy if grafting fails, and in the case of the humerus gives a good functional result. The operation should for choice take the form of "the step" coaptation recommended by Hey Groves.

In old cases a sliding graft, taken from above or below the site of fracture, must not be used; the lower or upper end of a graft so taken would consist of sclerosed bone, avascular and devitalized by prolonged inflammatory changes. Sliding grafts should be reserved to bridge a fracture in recent simple cases, and even then should be

* The practice of Leriche and others of freely removing loose fragments subperiosteally in early cases is to be condemned in view of late results, unless the method is limited to those violently septic cases which would end in amputation without drastic sacrifice of the injured bone.

sparingly employed: they are frequently too short and insecure.

The intramedullary peg is condemned by many, but it provides the simplest form of bone graft, and in the late J. B. Murphy's hands it gave excellent results, the peg becoming firmly incorporated with the bone into which it was inserted. In one of my cases, an ununited fracture of the humerus of eight years' standing, the upper portion of the peg failed to unite, and gradually formed a species of ball-and-socket joint within the medullary cavity, but there was firm incorporation of the lower end of the graft with the recipient bone. At a second operation, three months afterwards, it was found impossible to remove this portion of the graft without the free use of the chisel.

There is one obvious difficulty in the introduction of a peg graft, for if half be driven into the medullary cavity of one fragment it is impossible to complete the introduction of the other without undue traction of the limb. To overcome this difficulty, the end of the graft which protrudes from the medullary cavity of one fragment should be laid in a groove cut in the other during traction of the limb. When the traction is relaxed the end of the peg glides past the groove into position. The alignment is of necessity perfect.

It must be remembered that overstrenuous traction of the arm in a case of ununited fracture of the humerus will produce transient musculo-spiral paralysis, and give rise to anxiety for two or three months. The peg graft is admirable if it were not for the real danger of fracture during convalescence. (Fig. 6.) This accident has occurred over and over again notwithstanding the greatest care in applying splints and plaster dressings. Owing to this liability to fracture, the use of a peg graft may with advantage be confined to cases of fracture or defect in the bones of the forearm (Figs. 1 and 2), and more stable lateral inlay grafts be reserved for the repair of the femur and humerus.

Injury to the radius or ulna is followed often by pronation deformity, the correction of which is an important part of the preliminary treatment. An intramedullary peg in the radius will not be disturbed by the coaxing of the lower fragments into a supinated position, although, whenever possible, every deformity should be corrected before operation is undertaken. When an inlay graft is employed it is a simple matter to lay the upper end in a groove of the proper dimensions and then push it for a short distance into the medullary cavity above; but in this case the lower end may tend to spring away from the lower fragment, and some means must be adopted for its fixation. Surrounding the bone by two or three heavy catgut ligatures tightly tied round the graft suffices in most cases, provided the rigid fixation of the limb is afterwards ensured.

By some, reliance is placed on the rigid fixation of the graft *in situ* by mechanical aids, and early movements of the limb encouraged to stimulate the activities of the bone (so well seen in children) according to Wolff's law. By others the graft is so arranged that success entirely depends on the fixity supplied by the splint or plaster cast, and no movement is allowed for at least three months. All are agreed that unless the graft lies in its bed incapable of movement the operation is certain to fail.

In the hands of Lane, Hey Groves, and others, as might be expected, excellent results follow the use of plates, bolts, and screws in combination with grafts. This procedure, however, prolongs and complicates the operation, and I am frankly afraid of disappointments in attempting too much. Bone nails can be readily made with the lathe and appliances provided with the Albee electro-motor saw, and the graft can be thus secured in position. It is fascinating but tedious work. I have twice fixed the graft successfully with a series of bone nails, but the operation appeared to me to be unduly prolonged. By making the graft a tight fit for the groove and hammering it into position reasonable fixation can also be secured.

In all my cases (except two) the graft, consisting of periosteum, compact bone, endosteum, and marrow, was taken in the orthodox manner from the subcutaneous surface of the tibia by means of Albee's twin electro-motor saw. In the two cases—one a congenital dislocation of the hip, and the other caries of the spine with much deformity—a rib transplant was found most suitable in size and shape.

A note of warning is necessary regarding fracture of the tibia from which a graft has been taken. This may occur some months after operation. As a precautionary measure a light plaster casing should be employed, and the use of crutches encouraged until strength of the leg is assured.

Hey Groves expresses the thought of most workers in this branch of surgery when he states that his "feelings are those of disappointment and hope—disappointment that the proportion of successes has been so small, and hope that by the experience gained one may be able to avoid causes of failure, which are seen to be so obvious, and therefore so possible of evasion."

From the above remarks, based on a study of thirty cases, it may be concluded that—

1. Whatever the histological rôle the clinical usefulness of a bone graft is not affected.

2. The final success of bone grafting in cases in which a gap is bridged depends upon the operation of Wolff's law (Fig. 5)—that is, the graft, stimulated by strains and stresses, changes its internal architecture and external conformation until the required strength is attained. In other words, "the amount of growth in a bone depends on the need for it" (Murphy).

3. The periosteum should be left on the graft, because, although not essential, it is the medium through which new blood vessels enter the graft and the surrounding structures. Furthermore, in removing the periosteum superficial layers of osteoblasts may be sacrificed. A periosteum covered graft is less likely to become rapidly absorbed.

4. To provide the necessary strains and stresses it is advisable to allow the graft to functionate as early as possible, but in most cases preliminary fixation for three months is essential.

5. In old ununited fractures with false joints the bone in the critical area (near the site of fracture) is sclerosed and avascular, and makes an unsuitable soil for that portion of the graft in contact with this area. Growth in the graft is impeded by the surrounding sclerosis. Dense sclerotic bone has no osteogenetic power.

6. In such cases a periosteal covered graft, instead of exhibiting osteogenetic powers and responding to Wolff's law, may become attenuated and absorbed or break in the critical area five or six months after operation.

7. In the same class of case very prolonged fixation is particularly unfavourable to osteogenesis, to the establishment of blood supply, and bony union. Early movements and the bearing of mechanical stress and strain, on the other hand, may lead to yielding of the graft and failure. The problem is a difficult one in the case of the humerus or femur, where strength is essential from the commencement of treatment, but may be solved by wide resection of the sclerosed bone, and resignation on the part of the patient to a short limb.

8. But for slightly slower osteogenetic powers, and a real tendency to fracture, the intramedullary peg is effective. This method of bone grafting is satisfactory in the case of the radius and the ulna.

9. In the case of the humerus and femur, long stout inlay grafts give the best results. Sliding grafts should only be employed in simple and fresh cases.

10. The bone graft has inherent bacteria-resisting properties.

11. Absolute fixation of the graft in its bed, either as part of the operation, or afterwards, by splints or plaster, is essential to success.

12. Bone grafting for spinal caries is followed by more uniformly successful results than is seen elsewhere. This is to be expected, since both the graft and the recipient bed (in the region of the spinous processes) consist of healthy bone.

13. As in the operation of tendon transplantation and nerve suture, the operation of bone grafting should be preceded by correction of any existing deformity and by the freeing of adhesions in neighbouring tendons and joints.

ON the initiative of Professor Carlo Besta, director of a neurological centre in Milan, an institute for sufferers from wounds of the brain is to be established in that city. Already £7,200 has been subscribed for the purpose.

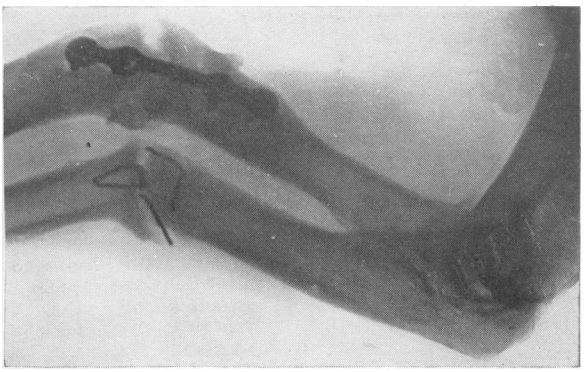

FIG. 1.—Bones of forearm on admission. Great angular deformity and shortening.

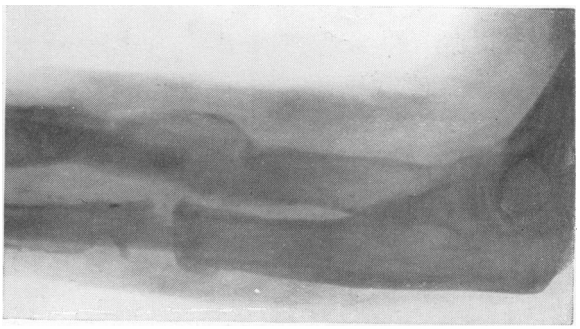

FIG. 2.—Showing reconstruction of the forearm shown in Fig. 1 by resection of bone, plate, and wires *en bloc*, and bridging of gaps with intramedullary pegs. The radial peg increased in diameter to size of normal radius after six months.

FIG. 3.—Gunshot wound of lower end of humerus before operation. Temporary musculo-spiral paralysis disappeared *pari passu* with the healing of the wound three months after injury.

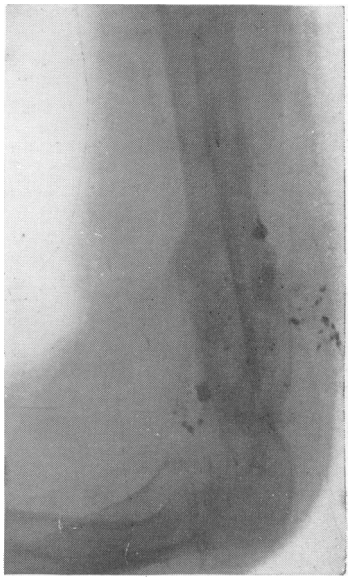

FIG. 4.—After operation. The introduction of a peg graft four months after healing was followed by lighting up of latent sepsis in the old wound. The graft survived, firm union followed, with full movements at the elbow-joint.

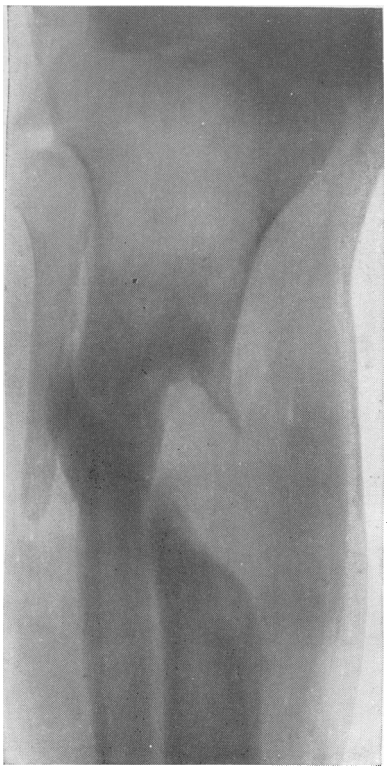

FIG. 5.—Union of fibula and tibia. Note thickening of fibula, the result of weight bearing. Good functional result.

FIG. 6.—Illustrating fracture of peg graft in old fracture of humerus. These cases should be treated by shortening and inlay grafts or the step operation.

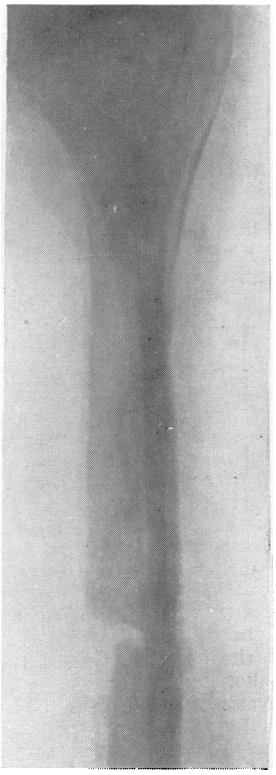

FIG. 7.—Long inlay graft in an ununited fracture of the humerus of eight years' standing. Six months after operation there was absorption of the graft in the "critical area" and failure of union.