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SPLINT GRAFTS IN THE TREATMENT OF DELAYED AND NON-UNION OF FRACTURES¹

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FOR a long time after the introduction of free tissue transplantation, the skin graft was about the only type of graft that was of any practical importance. Within the last 25 years there has been a steady increase in the use of bone as a free transplant and now it ranks at least equal with skin as a therapeutic agent. Its greatest usefulness has been in the field of ununited fractures where treatment by bone transplantation has become almost a routine procedure. This advance has been due both to improvements in operative technique and to a better understanding of the behavior of bone grafts under various environments. Developments in technique have led to the use of complex operative procedures consisting of resection of fragment ends, correction of alignment and position of fragments, and the use of a bone graft, for the purposes of bridging the fracture line, internal fixation of fragments, and osteogenesis. On

¹The Fracture Oration presented before the Clinical Congress of the American College of Surgeons, Philadelphia, October 13-17, 1930.

the whole these operative procedures have given better results than the earlier and cruder ones although the complicated operations are not entirely free from drawbacks.

As to the behavior of bone in different environments, it has been demonstrated that osseous tissue, regardless of the portion of the bone in which it is located, behaves the same in its reparative response to injury and loss of substance. Thus, the endosteal surface of a whole thickness graft or the inner surface of an osteoperiosteal or sliver graft will unite with the periosteal surface of the shaft when made to bridge the fracture line just as readily as an inlay graft will unite with the cortex when embedded in it. In other words, it is not necessary to bring periosteal side in line with periosteal side and endosteal side with endosteal side in order to obtain bone repair. It has also been observed that once a bony bridge is established across a portion of a fracture line, the remaining intermediary callus will almost always ossify, provided the fracture is adequately immobilized and protected from weight bearing. Also, it has been established that bone taken from the neighborhood of an ununited fracture which has led to atrophy is usually not as satisfactory material for bone grafting as healthy bone taken from another part of the body.

In general, ununited fractures have been treated by three types of bone grafts, namely, intramedullary, inlay, and onlay or splint grafts. Simple intramedullary bone grafts for cases of non-union have justly been largely abandoned because of the frequency with

which non-union persists. However, the little used sliding graft of Høglund affords a reliable method of treating fresh fractures and early delayed union that require operation because of displacement. A graft is cut from the cortex of the longer fragment beginning 1 to 2 centimeters from the fracture and of a breadth that will fit snugly in the medullary cavity. It is introduced into the medullary cavity of that fragment at the fracture end. The fragments are then aligned and the bone graft driven outward by hammering on a chisel placed at a right angle on its end through the window until roughly one-half of it rests in the medullary cavity of one fragment and the other half in the other. The collar of cortex left at the end of the fragment prevents the ends from becoming displaced. Its use is illustrated by the case shown in Figure 1. *A*, Shows a fracture of radius and ulna of 2 months' duration with delayed union because of malposition; *B*, shows the condition 2 months and *C*, 2 years after open reduction and fixation by intramedullary bone grafts cut from the upper fragments, by the Høglund technique. However, I warn against its use in frank non-union as I have had some failures in such cases.

Inlay grafts when well used have been found to give successful results in a high percentage of cases. Albee, who implants either a rectangular or a double wedge-end inlay into a cortical slot sawed into the side of the fragments, recently reported bony union in 89 per cent of 754 cases operated on. However, he often adds sliver grafts laid exter-

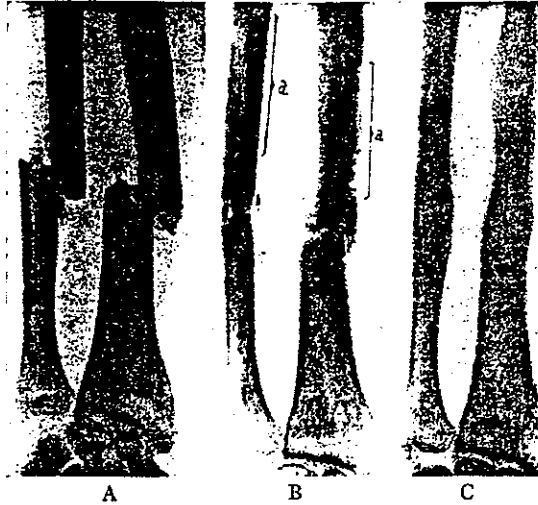


Fig. 1. A, Displacement and delayed union 2 months after fracture. B, Two months after Hohlund sliding grafts cut from *a*. C, Result 2 years after injury.

nally across the fracture line which aid much in the success of the operation. A drawback to the rectangular inlay graft is that it sometimes becomes displaced from its bed or fractures because of its small size, resulting in continued non-union. A heavier and more stable inlay is obtained in case of ununited fractures of large bones, particularly humerus, by a graft cut from the anterior surface and crest of the tibia which, when implanted on edge, is broad enough to fill not only the window cut in the cortex but to extend across the medullary canal. It should fit very tightly in the cortical slot and should be further immobilized by kangaroo tendon passed through holes drilled in graft and fragments.

Figure 2 shows a non-union of the humerus of 1½ years' duration, which was repaired in this way. *A*, Shows the condition before operation; *B*, the graft in position 10 days after operation; and *C*, the bony union 7 months later. An additional means of anchorage of such a graft is to make it 2 centimeters longer than the slot cut in the cortex and prepare a shoulder at either end, which is sunk into the medullary cavity of the fragments as shown in Figure 3.

The onlay or splint graft is applied externally to the bare surface of the fragments. It has been most extensively employed for fixation, bridging, and osteogenesis. Its use in this way is best exemplified by the operation of Henderson (3) in which a strong, whole thickness transplant is applied to a flattened surface of the fragments and fixed by means of beef bone screws. Additional unfixed grafts in the form of splinters and cancellous bone may be laid along the surface across the fracture line. The results have been at least as satisfactory as those reported for any other method of bone grafting for ununited fractures.

The objection to these more complex operations is that the amount of traumatism, the technical difficulties, hæmorrhage, general reaction, and risk of infection are sometimes greater than in more simple procedures, and occasionally give rise to serious trouble. However, the advantages so far outweigh the disadvantages in cases in which realignment, approximation, and fixation of fragments are necessary that one of the procedures should routinely be employed.

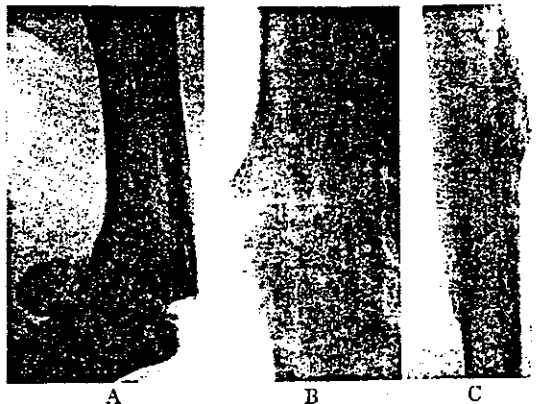


Fig. 2. A, Non-union of humerus of 18 months' duration. B, Ten days after resection and fixation by heavy graft inlaid on edge. C, (Print reversed.) Result after 7 months.

SIMPLE SPLINT GRAFTS

I want to consider a group of cases in which a more simple onlay or splinting operation may be performed that yields better results than the complex procedures. There is a group of cases of delayed or non-union in which both alignment and approximation of fragments are so satisfactory that if bony union could be obtained without altering them it would give an acceptable clinical result. In such cases it is possible to apply grafts that are intended to serve not for immediate fixation but only as bridges and as a source of osteogenesis leaving fixation to pre-existing callus, to an associated splint bone, or to external appliances.

Delangeniére introduced osteoperiosteal grafts for the treatment of such cases. The

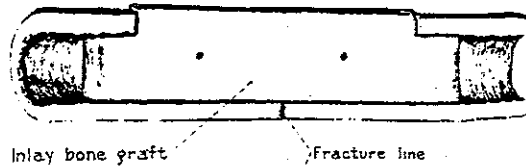


Fig. 3. Method of fixation of heavy inlay graft inserted on edge.

seat of fracture is exposed and the surrounding periosteum and soft parts reflected from the entire circumference of the fragment ends. Three to six osteoperiosteal strips 3 to 5 centimeters in length are chiselled off of the tibia and laid along the surface of the fragments. The intermediary callus may be partly or wholly gouged out or it may be left undisturbed according to the case. The soft parts which are then sutured hold the grafts in contact with the surface of the bone. A period of immobilization follows. The operation is quickly and easily performed and is less likely to stir up latent infection or give rise to new infection than the more traumatizing ones in which a fixation graft is employed. It leads to bony union in a large percentage of cases.

In certain other cases one or sometimes two large whole thickness splint grafts applied to one side of the fracture offer a better method of treatment than do osteoperiosteal grafts. A strong bony bridge established by bony union of the graft to the two fragments is more likely to be followed by ossification of the intermediary callus than is a weaker bony bridge furnished by osteoperiosteal grafts; also, bony union takes place more rapidly.

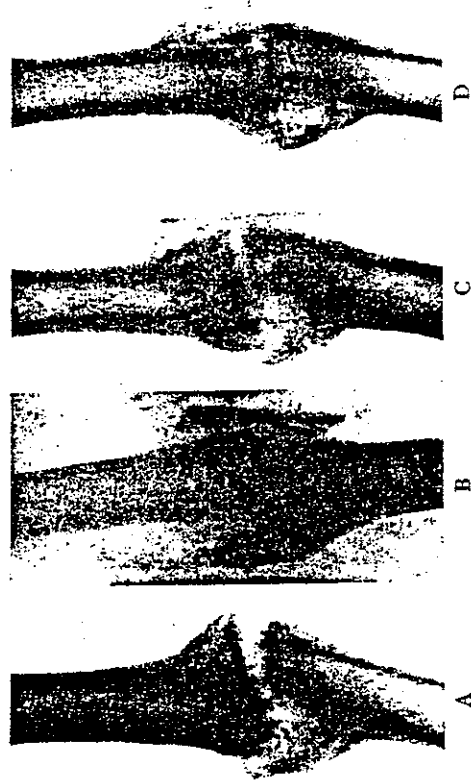


Fig. 4. A, Non-union of 13 months' duration. B, Two grafts laid across fracture line. C, Fusion of grafts with fragments and extensive ossification of intermediary callus 3 months after operation. D, Bony union complete 7 1/2 months after operation.

This is well illustrated by Figure 4, in which a non-union of the femur of 13 months' duration in a man, aged 43 years, was operated on by Dr. G. M. Curtis. Delivery and resection of the fragment ends with fixation by means of an inlay or onlay graft would have meant a big operation with its concurrent risks. The fracture was exposed laterally and two whole thickness grafts from the tibia were made to bridge it, one posteriorly and the other laterally after the exuberant bone was chiselled off. The intermediary callus was not disturbed and the grafts were held in place by the sutured soft parts. A body and leg cast was worn for 2 months during which time bony union between grafts and fragment ends was established. This was followed by rapid ossification of the intermediary callus. The patient was walking on the limb without assistance at the end of 4 months.

In some cases of non-union of infected fractures, the infection persists along only one side of the bone. A whole thickness splint graft may be inserted along the opposite side soon after the infection has healed, thereby saving much time, since any other type of operation would necessitate entrance of the recently infected field and could not be done safely until several months later.

Figure 5 illustrates the case of a male, aged 23 years, who had an infected ununited fracture of the tibia which resulted in sequestration of a portion of the anterior cortex of the lower fragment. This was removed at the end of 7 months. Three weeks later the anterior sinus leading to the seat of fracture

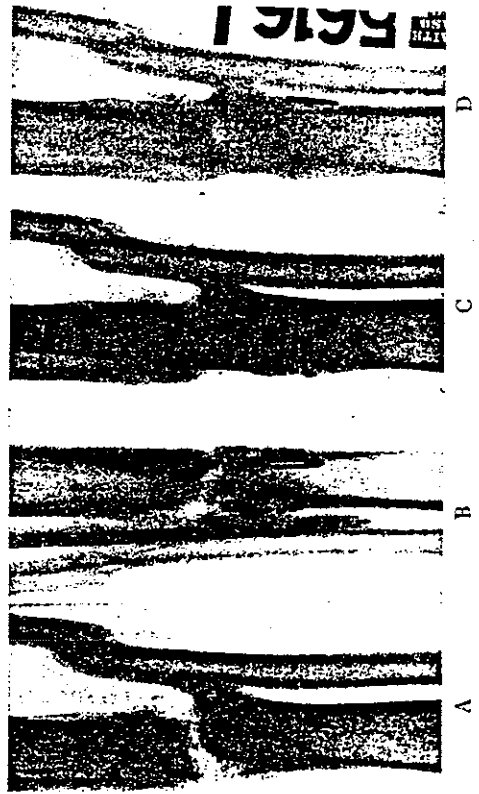


Fig. 5. A, Non-union of infected fracture of tibia. Sinus recently healed. B and C, Bony union after insertion of heavy splint graft to side of tibia opposite point of infection. D, Further consolidation 5 months after C.

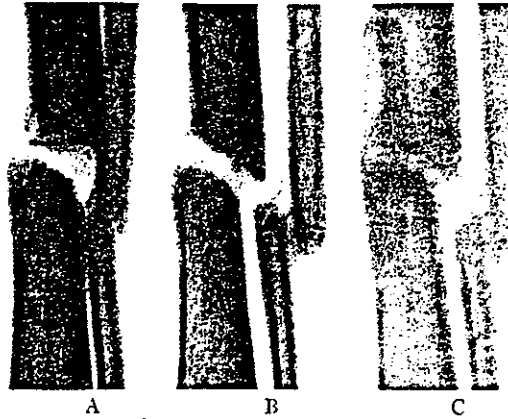


Fig. 6. A, Defect in tibia 10 days after removal of sequestra in infected compound fracture of $5\frac{1}{2}$ months' duration. B, Non-union of tibia $2\frac{1}{2}$ months after jamming ends together following refracturing of fibula. C, Two and one-half months later tibia still ununited. A heavy splint graft was introduced. This figure shows union 2 months later.

had healed. Through a posteromesial incision, a heavy whole thickness bone graft was then applied along the posterior side of the tibia with its periosteal side outward. A cast was applied for $2\frac{3}{4}$ months at the end of which time there was bony union between the graft and the fragments and the intermediary callus of the fracture was ossified. Walking was then resumed and further solidification of the fracture followed.

Figure 6 illustrates the case of a male, aged 28 years, who had an ununited infected fracture of the tibia of $5\frac{1}{2}$ months' duration with sequestration of 1 centimeter of the upper fragment leaving a defect in the bone after sequestrectomy 10 days before, A. A sinus

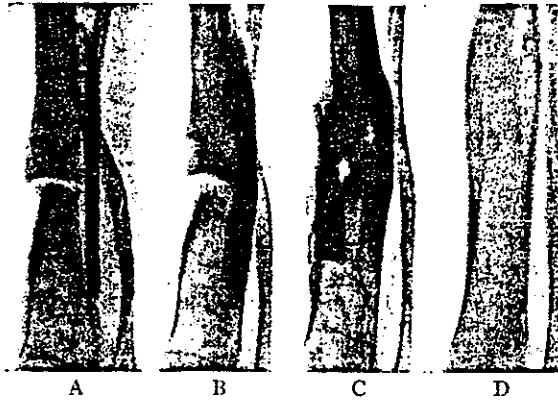


Fig. 7. A, Congenital pseudarthrosis of tibia. Shows union between graft and fragments 4 months after operation. B, Shows intermediary callus unossified 13 months after operation. Graft fractured at seat of old fracture line. C, Bony union 8 months after application of two whole thickness splint grafts, mesially. D, Shows result 3½ years after last operation.

led to the posterolateral part of the defect. At operation the fracture line was exposed through a short transverse incision, and the end of each fragment freshened without separating soft parts from its sides. The fibula was then refractured and the ends of the tibia were jammed together, the fibular fragments overriding. A cast was applied and the wound in the soft parts healed promptly. The fibula united, but the tibia still showed an incompletely ossified callus at the end of 5 months. A whole thickness bone graft was then inserted opposite the old field of infection. The wound healed without infection and there was prompt bony union of the graft with fragments and of the fragments with

each other so that after 2 months the patient was able to walk on the limb.

There is a further group of ununited fractures either congenital or acquired occurring in children, the most important being congenital pseudarthrosis of the tibia in which there is likely to be failure of bony union after repair by use of the ordinary methods as shown by the report of Henderson (4). In such cases the application of two or more additional encircling whole thickness splint grafts may lead to bony union which remains permanent.

A girl, aged 8 years, had had four previous operations for congenital pseudarthrosis of the lower third of the left tibia without success. The fragments were freed, aligned, and fixed by a broad graft from the other tibia applied laterally and anchored by encircling kangaroo tendon ligatures. Figure 7 shows the bony union between fragment ends and the transplant when the cast was removed at the end of 4 months. There was no ossification of the intermediary callus. At the end of 13 months of cast treatment, the intermediary callus was still ununited although the transplant had undergone some hypertrophy. Walking at that time resulted in fracture of the transplant. Two broad, whole thickness grafts 3 inches long were then cut from the regenerated right tibia and laid along the anteromesial and posteromesial sides of the fragments without interference with the intermediary callus. They fused with the fragments and the intermediary callus ossified as shown in Figure 7C. The pa-

tient walked on the limb after that and Figure 7D shows the appearance of the bones 3 years and 2 months after the last operation.

As to the results with the use of the splint graft in non-union without fixation to the fragment, the osteoperiosteal graft has been used alone in 13 cases and the whole thickness graft in 11 cases. Bony union has been secured in every instance. If the cases were to be done over the whole thickness splint graft would be used in some of those treated with the osteoperiosteal graft because of its simplicity and of the greater rapidity with which bony union follows.

SUMMARY

Ununited fractures in which there is little or no displacement or angulation of fragments may be treated satisfactorily by the simple application of whole thickness splint grafts or in some cases of osteoperiosteal grafts to the fragment surfaces bridging the fracture line and held in place by the sutured soft parts. Intramedullary grafts are unsuited for cases of non-union but the Hohlund sliding graft may be used in fresh fractures and in delayed union where marked displacement of fragments is the indication for operation. A broad inlay graft which is turned on edge and made to fill both medullary cavity and slot cut in cortex affords a suitable method of treatment of some cases of non-union of large bones.

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