CHAPTER FIFTEEN

FRACTURES OF THE SHAFT OF THE TIBIA

THE bad results of open reduction and internal fixation of fractures are most commonly seen in fractures of the shaft of the tibia. There are several reasons for this : the tibia is the commonest major long bone to be fractured ; it is very commonly a compound fracture ; it is a fracture which is easily exposed and therefore tempts inexperienced operators ; it is a subcutaneous fracture and after plating is especially prone to defective wound healing accompanied by what in some quarters is euphemistically termed ' drainage.'

We have still a long way to go before the best method of treating a fracture of the shaft of the tibia can be stated with finality. I feel sure that a closed method will eventually prevail, but we need mechanical aids to improve our control of the bone fragments. It is possible time will show that an intramedullary rod, introduced through the tibial tubercle, *without exposing the fracture site*, will be enough to enhance alignment as an adjuvant to closed methods. Used in this simple way the intramedullary rod will not be responsible for immobilisation ; it will merely control alignment and prevent slipping of the reduced fracture.

Most surgeons who practise internal fixation of tibial fractures do so with the idea that accurate coaptation of the fragments, combined with rigid fixation, enhances the ability of the fracture to unite. I have attempted to show in Chapter I that this mechanical approach to fracture healing is out of touch with biological reality.

When viewing the excellent results which are often demonstrated as attributable to the plating of fractures of the tibia we must never forget that the best results of operative treatment are in cases which would also give excellent results by simple plaster fixation. In other words, rapid osseous union after plating the fractured tibia is not a result of the plating but a result of factors resident in the soft tissues associated with that particular fracture.

Example.—Fig. 158 illustrates what might have been shown as an excellent example of the advantages of operative treatment of a fractured tibia. The criticism I wish to make is that the good result should not be credited to the operation. The deformity in the initial radiograph is little more than simple angulation which could have been corrected by manipulation. The anteroposterior radiograph shows that the original deformity was convex at the attachment of the interosseous membrane where an intact periosteal bridge could therefore be predicted. *This prediction is confirmed by the final radiograph which shows plentiful callus at the tibial attachment of the interosseous membrane.* The essential feature which this case illustrates is not the efficacy of internal fixation *per se* but merely that internal fixation has here been used on a case highly favourable

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for normal osseous union under conservative treatment ; it does not indicate that a similar gratifying result would be obtained in a case with gross stripping of all soft tissue attachments as a result of severe initial displacement with overriding of the fragments.

In considering the bad results of plating of fractures of the tibia it is not an exaggeration to say that amputation after one or two years of disability from a fracture of the tibia, can almost always be traced to an injudicious plating operation at the time of the original injury. No fractured tibia, no matter how extensively comminuted, necessitates early amputation by reason of the magnitude of the shattering or loss of bone ; early amputation is invariably a sequel to serious damage to major blood vessels and nerves, to gas gangrene, or to extensive loss

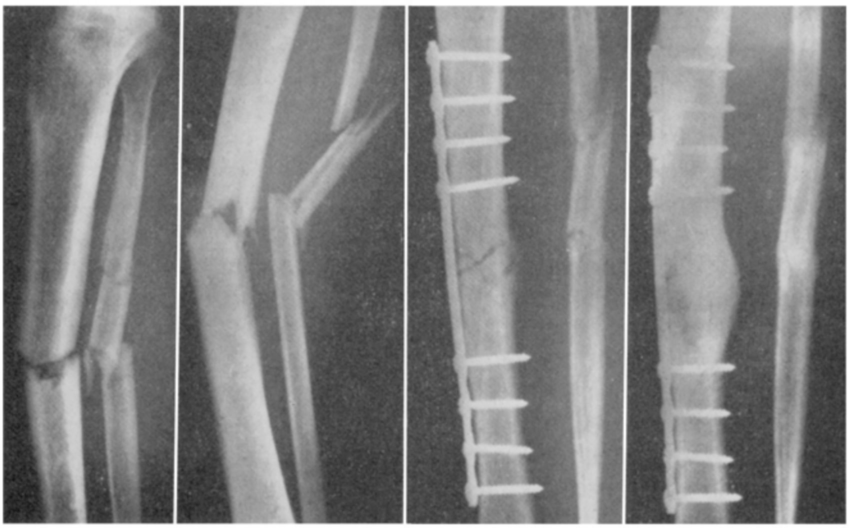

FIG. 158

Successful result of internal fixation but not to be used as a general argument for internal fixation in tibial fractures. Original displacement suggests soft tissue callus pathway probably intact (Group A, Fig. 160, page 210). Union by simple conservative method could be predicted. Note callus bridge at attachment of the interosseous membrane.

of skin. If a patient with extensive comminution of a compound fracture of the tibia survives these initial hazards, osteomyelitis which may follow under conservative treatment is never so profound as to require amputation. Sequestra involving a complete segment of the tibial diaphysis are never encountered after the conservative treatment of the most extensively compound comminuted fractures. The tubular sequestrum in traumatic surgery is invariably the result of infection superimposed on operative interference. Infection demarcates in a permanent fashion the volume of bone rendered ischæmic by the procedure of applying a plate and six screws.

To condemn the plating of fractures of the shaft of the tibia as a maxim in the teaching of safe surgical methods, must not be taken as a total condemnation of this technique. Many exponents of this method can show an impressive series of results, but I believe that this is not so much the result of the method as the result of finely developed clinical perception in the pre-operative selection of cases and in the awareness of threatened post-operative complications for which appropriate avoiding action is promptly taken. In the hands of the unwary this method can lead to disastrous results as indicated in the following example which was perpetrated by a general surgeon who was a competent operator.

FIG. 159
Bad result from internal fixation. Tubular aseptic sequestrum (see text).

Example.—Fig. 159. This example illustrates a disaster of the first magnitude which could not have occurred after conservative treatment. The operator underestimated the significance of the undisplaced crack in the distal fragment; he embarked on what he thought would be a simple plating operation on the main fracture. During the operation the undisplaced crack separated completely, and because the fracture lay too near the ankle a second plate could not be applied. The attempt to insert an oblique screw was futile and the operator, wisely in the circumstances, decided to close the wound with the deliberate intention of applying a cancellous bone graft after two or three months. Unfortunately, when the wound was reopened three months later for the grafting operation it was found that the whole of the middle fragment was completely ischæmic. It was

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so ischæmic that when the plate was removed the proximal end had not even united to the proximal fragment of the tibia though the fracture had been completely immobilised, and had not had any leverage exerted on it. The application of cancellous bone grafts to distal and proximal fractures was not successful and the illustration shows radiological evidence of ischæmia of this tubular fragment. There was never any infection in this case. It is possible that on economic grounds this patient eventually may have to submit to below knee amputation, because even after two years, and after a second cancellous bone graft, there is still no union. Plating this fracture precipitated total ischæmia of the central fragment which would never have happened under conservative treatment.

In condemning the primary operative treatment of fractures of the tibia the crucial argument concerns the evil effects of the open exposure of the fragments which is seen at its worst when a plate is applied to the tibia under the mistaken idea that rigid fixation encourages osseous union. There are, however, other methods of improving the precision of conservative treatment which lie half way between conservative principles and operative. It is possible to stabilise the alignment of fractures of the tibia by the use of an intramedullary nail, even without seeking to produce rigid internal fixation. Intramedullary fixation such as that proposed by Rush can be performed without exposing the fracture or with minimal exposure of the fracture. Used as an adjunct to conservative treatment as a method of giving some precision to the maintenance of alignment, this type of fixation does not offend biological principles. This type of internal fixation need not aspire to rendering external fixation unnecessary. In the subsequent discussion the only form of operative treatment I shall encourage in the treatment of tibial fractures is the stabilisation of alignment by the intramedullary nail, inserted *without exposure of the fracture*, and not demanding a rigid hold of the point of the nail in the distal fragment.

Conservative Treatment and the Phemister Bone Graft

The greatest advance in the treatment of fractures of the shaft of the tibia in the last half century has not been in techniques for the primary treatment of the fresh fracture, but has been in the secondary management of the fracture by the simple sub-periosteal bone graft which was first put on a scientific basis by Phemister (1947). Compared with the importance of this safe and simple method of bone grafting (which I shall describe in detail later) the relative merits of conservative and operative treatment of the initial fracture are almost insignificant.

I will justify this sweeping statement by reference to two special features of the Phemister graft using strips of autogenous iliac bone. Firstly, the resistance to infection shown by this graft and its ability to succeed even in the presence of mild infection are such that it becomes possible to use a bone graft very much earlier than was considered possible in the past. Secondly, the flexibility of the individual strips of cancellous bone renders it possible to apply a graft in the presence of mal-aligned fragments. To use a cortical bone graft, either onlay or inlay, in these circumstances would be courting disaster.

Using the Phemister type of bone graft three months after the injury it becomes possible practically to guarantee osseous union, with all external splintage finally

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abolished, six months after the most severe fracture of the tibia. According to the strategy of using the Phemister graft at three months no attempt is made to adopt radical operative measures for initial treatment in the hope of getting primary union in three months. A more consistent level of success over a large series of cases will be achieved by planning conservatively at the beginning, but being radical in employing a Phemister bone graft as soon as this is first indicated at about three months.

According to these tactics the fractured tibia is treated during the first two or three months with attention devoted primarily to giving time for the revascularisation of the fragments and the avoidance of procedures likely to increase the volume of ischæmic bone already resulting from disruption of the longitudinal circulation in the ends of the fragments. The initial period of delay gives time for the skin and soft parts to recover from the immediate effects of trauma. This emphasis on the nutrition of the soft parts is not only applicable to compound fractures; it is too commonly forgotten that the skin overlying a closed fracture of the tibia is treacherous material through which to operate. The difficulty in wound closure after primary operative treatment of the tibial fractures frequently leads to defective wound healing. Skin which is prone to develop fracture blisters, as is the skin over the subcutaneous border of the tibia, is obviously far removed from normal, and in this respect the tibia is much less suitable for open exposure than are bones which are well covered with muscle. It is sometimes argued that this early involvement of skin in a fractured tibia makes it imperative that open reduction should be performed as early as possible after the injury and before the skin has had time to become œdematous; this recommendation pays no attention to the inevitable behaviour of the skin some days after the wound has been closed and lost from sight under the dressings.

Selection of Type of Treatment

By considering the nature and magnitude of the displacement of the tibial fragments it is possible to select the most appropriate form of treatment for the individual case. The initial radiograph may help in estimating the magnitude of displacement, but most important of all is the clinical examination of the limb with the patient under anæsthesia. It is possible for the initial radiograph to underestimate the magnitude of tearing of the soft parts as a result of the fracture being roughly aligned in the course of first-aid work.

From this assessment two predictions can be made: (1) from the stability of the fracture it can be decided whether it is suitable for the simplest of conservative methods or whether the stability will require to be enhanced by an intramedullary nail, and (2) a prediction can be made regarding the likelihood of delayed union. If from the magnitude of the displacement it is predicted that delayed union is likely to be encountered, strategy must be planned to render the limb in perfect condition for bone grafting should mobility still be present at ten or twelve weeks.

The reader must not get the impression from this account that I am suggesting that almost all tibiæ should have a Phemister graft at three months. The decision to perform the graft is made on the presence or absence of clinical

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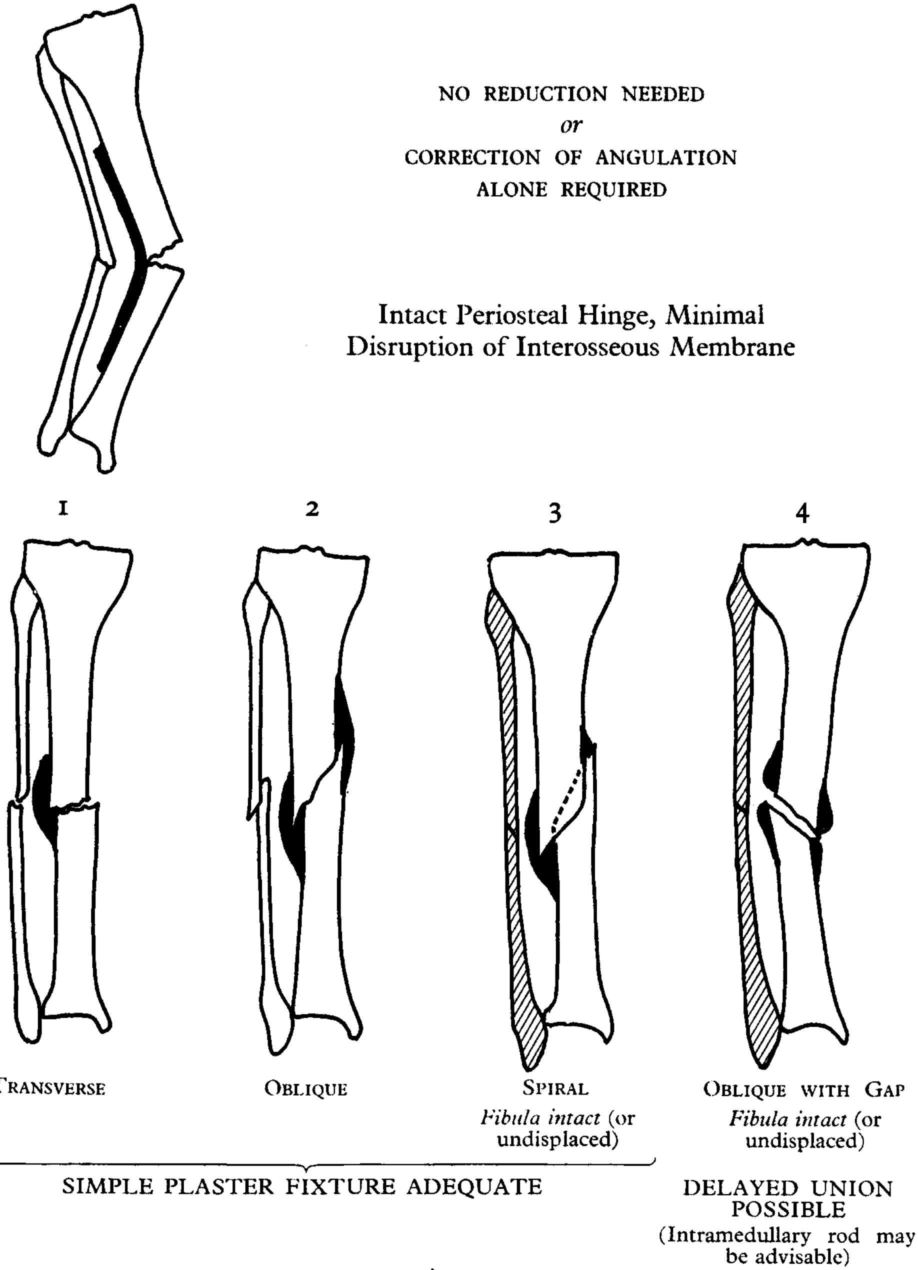
INITIAL DISPLACEMENT MODERATE



A

FIG. 160

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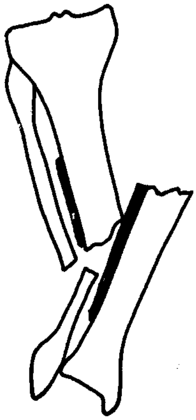
INITIAL DISPLACEMENT SEVERE



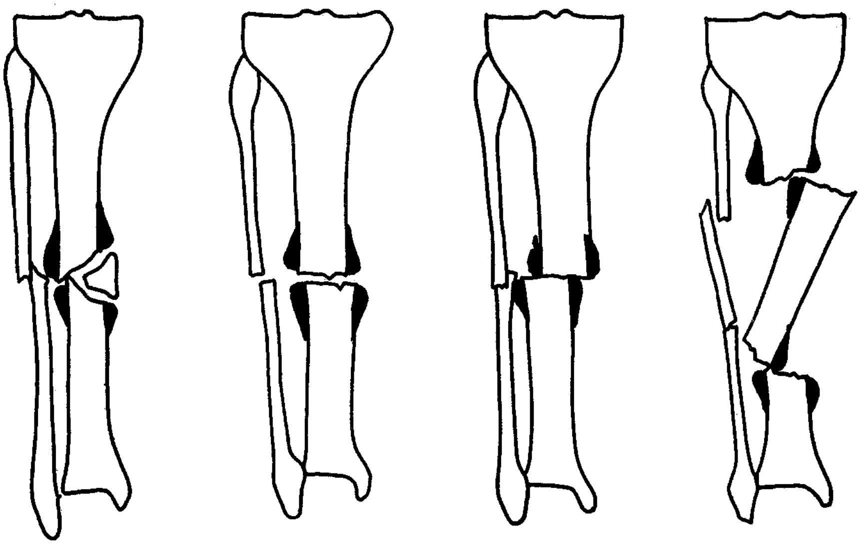
REDUCTION IMPERATIVE—SIMPLE CORRECTION OF ANGULATION NOT ENOUGH

Periosteal Hinge and Interosseous Membrane completely disrupted. Shortening present

Delayed Union very likely
Bone graft to be considered at three months

RADIOGRAPHIC APPEARANCES AFTER MANIPULATIVE REDUCTION

5 6 7 8



Butterfly Comminution	Transverse gapped by Spikes	Transverse without Gap	Double Tibia

McKEE METHOD or
Stabilise with Intramedullary rod as adjuvant to plaster.

AVOID OPERATION
(Graft end which is still mobile after three months)

B

Fig. 160

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union at three months and the majority of fractured tibiæ do not require a bone graft. In the past the commonest error in treatment has been the too long postponement of bone grafting. If postponed too long the condition of *pseudarthrosis* may be established and this condition is more difficult to graft than is a simple case of delayed union. Early bone grafting according to this policy is therefore a form of 'prophylactic grafting.' Though it is possible that more grafts are performed than are absolutely necessary according to this policy, the total time of disability over a large series of several fractured tibiæ will be reduced.

In assessing the original fracture as regards the degree of initial displacement, the essential feature is to decide whether an 'intact soft-tissue hinge' is likely to be present because this favours union by conservative methods. The soft parts most vitally concerned in conducting osseous union across the tibial fragments lie in the interosseous membrane where that structure is attached to the tibia. Callus is seen at this point even when it is absent at other parts of the tibial fracture. It is to be noted that I am using the term 'intact soft-tissue hinge' both in a biological sense, as a pathway capable of conducting osseous union from one fragment to another, as well as in the mechanical sense of a hinge whereby the displaced fragments can be guided into position during manipulative reduction.

Two grades of initial displacement can be distinguished:

1. Displacement nil, or little more than angulation. *In all these cases the fracture can be put into an acceptable position simply by correcting angulation.* Such shortening as there is can be accepted because the fracture is stable at this length and will not shorten further. An intact soft-tissue hinge can usually be predicted on the concave side of the fracture and this will usually be in the region of the interosseous membrane. Union usually offers no problem in this group and sound consolidation under conservative methods will usually be present within three months. The types of cases encountered in this group are indicated in Fig. 160, A.

2. Displacement with overriding. Here the attachments to the interosseous membrane will be ruptured and this important pathway for the bridging of callus from one fragment to the other will be destroyed. Delayed union even after accurate coaptation of the fragments will be likely. Simple correction of angulation is not enough in this type of fracture. The restoration of length and apposition by at least half diameters is essential. Mechanical means must be provided to render the reduced position stable. According to the biological ideas proposed in this work the method required to render the fracture stable against redisplacement need not provide rigid fixation. The types of cases encountered in this group are indicated in Fig. 160, B.

In this second group of fractures of the tibia and fibula the need to prevent redisplacement after reduction is particularly important if the limb is encased in a plaster cast. If a fracture of the tibia and fibula has been reduced by applying traction and a plaster cast, there will be a grave risk of 'plugging' of the venous return inside the plaster if the fracture redisplaces when the traction is removed. Traction lengthens the leg, at the same time making it narrow, and when traction is released the limb will increase in thickness inside the plaster at the same time as it shortens. The vicious circle of venous obstruction which can result from this type of 'plugging' is exceedingly dangerous and especially so if the after-care of these cases has to be entrusted to relatively inexperienced residents during the vital twenty-four hours after reduction. Attempts to assess the circulation by pressing on a toe, to observe the return of blood into the blanched area, are notoriously unreliable and have often given reassurance that the circulation was intact when reassurance was not warranted. It should be emphasised that severe post-operative pain must not be regarded as a normal sequel after the satisfactory reduction and fixation of a fractured tibia. Any patient who is not rendered comfortable by a single dose of morphia after reduction of his fracture may have a serious vascular complication, and this must be diagnosed during the first six or twelve hours after the application of the plaster. The loss of sensation in the toes, and especially loss of active movement of the toes, are both serious signs even in the presence of what may seem to be a good circulation as judged by pressure of the finger on the nail-bed.

Transverse Fractures of the Tibia

The management of transverse fractures of the tibia showing gross initial displacement is a difficult problem. Even if excellent end-to-end reduction is achieved by closed manipulation, the chances of delayed union are still great because this has been decided by the magnitude of the initial displacement. Internal fixation will not enhance the power of union. There is a serious risk of redisplacement if simple plaster fixation is used when the initial displacement has been gross. For this reason it is advisable to consider stabilising the alignment of such a fracture by an intramedullary nail.

Example.—Fig. 161 illustrates this point. The patient was sixty years of age and delayed union was predictable as a result of the magnitude of the original displacement. Predictable also was, or ought to have been, the possibility of redisplacement by treating such a fracture in a simple closed plaster without any additional mechanical assistance. This case should have been supplemented by an intramedullary nail used to stabilise alignment rather than to provide rigid fixation. The patient should be warned as soon as possible after the original injury that an early bone graft will probably be performed in view of the magnitude of the original displacement. If on examining the state of union three months after this injury it is evident that osseous union is present or in progress, the patient will be delighted to learn that no bone graft will be necessary, but if free mobility is present the patient is already adjusted to the idea and the news does not come as a shock.

In treating transverse fractures of the tibia with gross initial displacement the surgeon should be particularly warned of the possibility of delayed union when full diameters apposition has been obtained by closed reduction. I suggest that sometimes an inexperienced surgeon may be so pleased to see full diameter apposition achieved as a result of his closed manipulation that he may overlook the fact that the fracture has been 'gapped open' by spikes which, like the teeth of a gear wheel, may not be completely in register. The bone spikes which gap the fracture open are almost certain to be totally ischæmic. When apposition is only

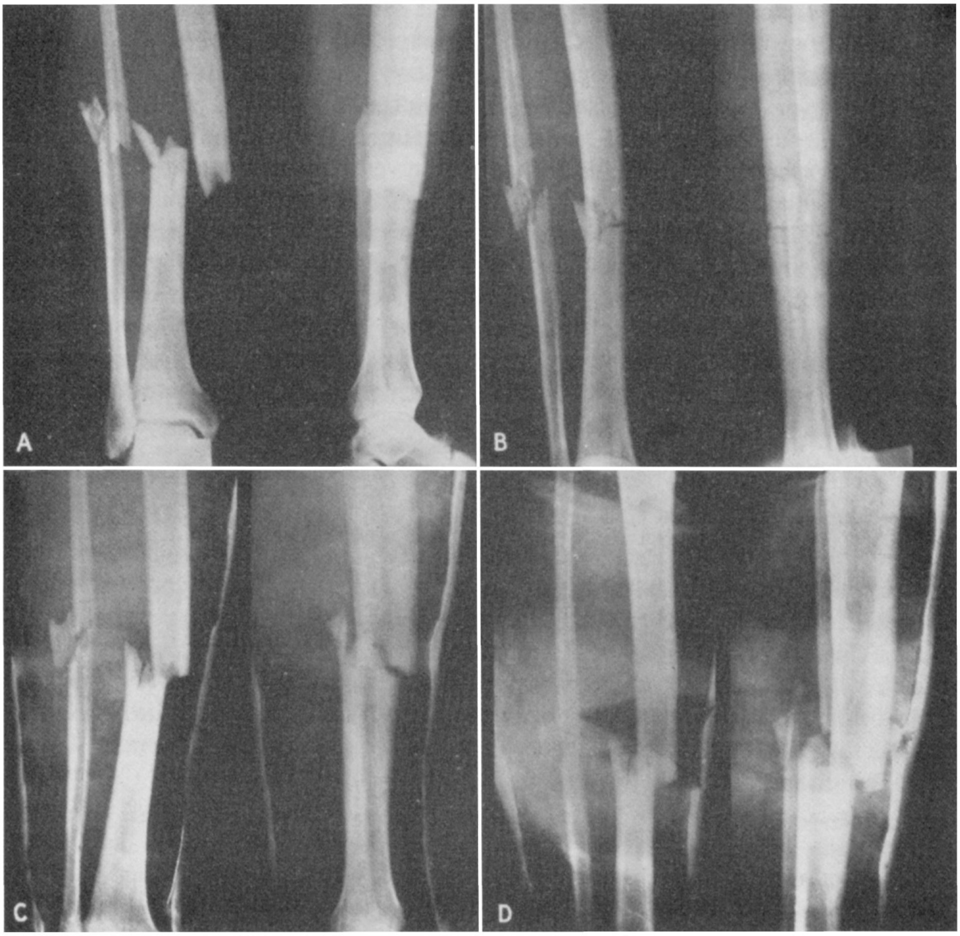

FIG. 161
Example (see text).

FIG. 162
Example of the gapping open of a transverse fracture by a spike (see text).

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by half diameters it is more likely that the fragments will have sunk towards each other more completely.

Example.—Fig. 162. This patient was a man of forty-five years of age with a closed transverse fracture of the tibia and fibula. After manipulative reduction the transverse fracture is seen strutted apart by an unlucky position of the projecting bone spikes. Measured direct on the X-ray film there is a gap of 4 mm. between the bone ends. Eight weeks later there is not the slightest evidence of bridging of the gap which is now reduced to 3 mm. on the X-ray film. Close inspection of the periosteal surfaces of the fragments indicates early periosteal activity and the fibular fracture is already showing good callus. Sixteen weeks after the injury the fracture was still completely mobile. The gap between the bones was now diminished to 1 mm. as the result of weight-bearing in plaster.

This patient was submitted to a bone graft six months after the injury. From the original displacement and the presence of mobility at three months, this patient ought to have had a Phemister graft at three months rather than this should have been delayed to six months.

According to the biological principles advocated in this work open reduction of this fracture with accurate coaptation of these bone spikes would not have enhanced the power of osseous union.

The correct strategy in this case would have been to plan treatment with a view to grafting early because the surgeon could have been forewarned by examining under anæsthesia the magnitude of displacement of the original fracture.

In considering the role of intramedullary fixation in a case such as the foregoing, it must be emphasised that the absence of rigid internal fixation is not a disadvantage in this technique. If osseous union is not in the process of development three months after the injury it is better for this to be revealed by clinical examination of the fracture than to have it masked by the internal fixation which may render the tibia ' plate-solid ' and delay the diagnosis of defective consolidation until failure splint of the internal brings this to light at a much later date.

The Butterfly or Wedge-shaped Fragment

One of the most treacherous tibial fractures which may invite the unwary surgeon to operate is that in which one main fragment is roughly transverse and the other is oblique, as the result of the separation of a wedge-shaped (butterfly) fragment. The danger in this fracture lies in the fact that the wedge-shaped fragment cannot take an active part in union, because its longitudinal Haversian circulation must be seriously interrupted, and operative intervention will render it even more completely ischæmic. If in our mental image we exclude the butterfly fragment from the active process of union, we see that after reduction the main tibial fragments are in contact only at one small point, at the summit of two spikes, and that the greater part of the fracture is a ' gap ' bridged only by the metallic fixation (Fig. 163). The two main fragments demand that they be approximated towards each other and, if possible, that one spike should fit inside the medullary canal of the other. Moreover, being a comminuted fracture it is devoid of the potential stability which is produced by the interlocking of non-comminuted

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fractures in the reduced position, and the metallic splint used for the internal fixation of this type of fracture will be directly exposed to all the deforming forces without any protection or reinforcement from the bones themselves (as can happen to some extent in transverse fractures), and it is likely that failure of the fixation will occur.

The conservative treatment in this type of case can be reinforced by an intra-

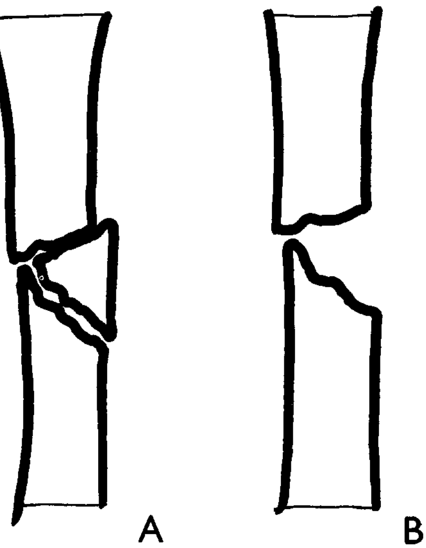

FIG. 163

Diagram to illustrate idea that 'butter-fly' fragment, A, plays only passive role in osseous union (especially if devitalised by open operation). Biological state of such a fracture is as if fragment was absent, B.

medullary nail to hold alignment provided that this is inserted without exposing the fracture site.

Oblique Fractures of the Tibia with Intact Fibula

When this type of fracture is first seen it often seems so innocent that it is frequently put into a plaster cast without anæsthesia. Reduction is often considered unnecessary because the displacement appears so slight; and an anæsthetic is not needed during application of the cast because the intact fibula offers splintage. This fracture is a frequent source of delayed union and is the solitary exception to the general rule that delayed union is most frequent after gross initial deformity.

The strutting action of the intact fibula causes the tibial fragments to 'float' near each other so that they frequently separate in a lateral direction. If several films are taken with the leg in different degrees of rotation a clear gap may be demonstrated between the tibial fragments (Figs. 164 and 165). This gap is accentuated by the tendency for the tibia to angulate towards the intact fibula. These remarks apply with almost equal force when the fibula is fractured but undisplaced.

Delayed union in this type of fracture is often quoted against the argument that the magnitude of the initial displacement governs the speed of union. It is

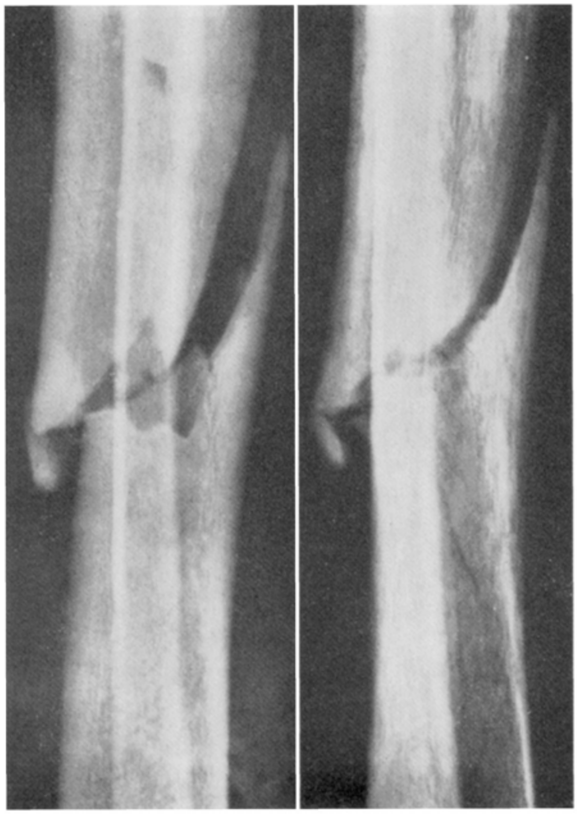

FIG. 164
Example of fracture with gap held open by an intact fibula which proceeded to delayed union.

probable that the flexibility of the fibula, and the flexibility of the upper and lower tibio-fibular joints, masks the fact that at the moment of injury this tibial fracture might have been grossly displaced with extensive separation of the fragments from the interosseous membrane, and disruption therefore of the natural pathway for callus.

Oblique fractures are unsuitable for fixation by a transverse screw. The fragments have to be denuded fairly completely in order to obtain a 'hair-line' fit of the fragments, and the strength of the fixation is poor in resisting movement in the plane of the fracture.

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Spiral Fractures

It is necessary to emphasise that *spiral* fractures of the tibia, even if associated with an intact fibula, almost never show non-union. If a fracture is truly spiral it will be impossible (by definition) for a clear gap to be seen through the fracture by any orientation of the radiograph. The displacement of a true spiral fracture, especially if there is a trace of shortening, produces some degree of interlocking

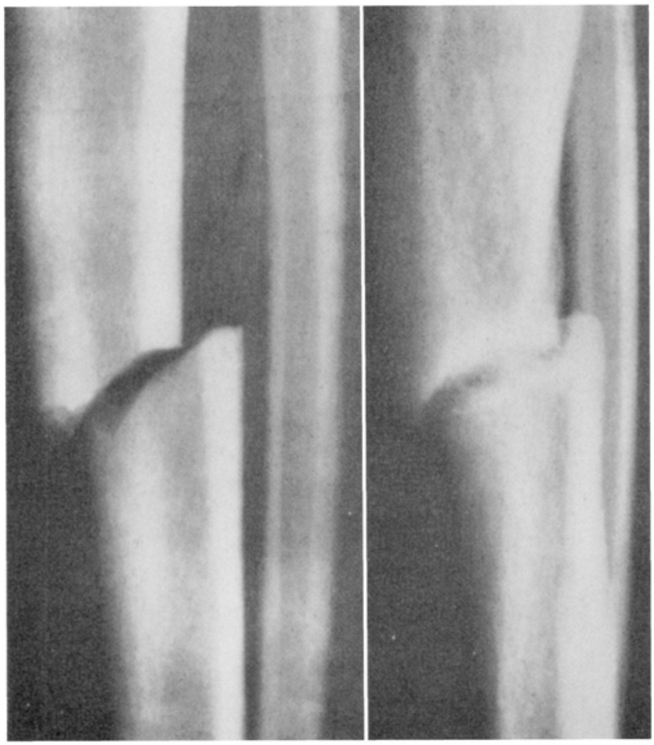

FIG. 165
Example of fracture with gap held open by an intact fibula which proceeded to non-union.

of the fragments, with ideal contact of periosteal and endosteal surfaces, and there is never much tendency for a spiral fracture to angulate towards the fibula and so to open a clear gap by lateral displacement.

The Unreliability of the Transverse Screw

It is often tempting to coapt the fragments of an oblique or spiral fracture of the tibia by one or two transverse screws transfixing the fragments. Though at one time a keen exponent of this method, I am now reluctantly forced to advise caution in its use and to recommend that only one screw should be used (for coaptation not fixation), periosteum should be disturbed as little as possible, and plaster fixation should be used thereafter as for closed treatment. The depression

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of biological activity in a healing fracture as a result of operative exposure of the fracture has been mentioned in Chapter I (pp. 21-27), and the mechanical strength of this method of fixation is not enough to withstand the strain over the prolonged period of time to which it is exposed as a result of the artificially delayed process of union (Fig. 26, p. 25).

An example of the harmful effect of three screws traversing the bone ends actually involved in a fracture is seen in Fig. 166. At operation, undertaken because the fracture was completely mobile four months later, the bone ends were visibly ischæmic for a distance of nearly 1 cm. on each side of the fracture.

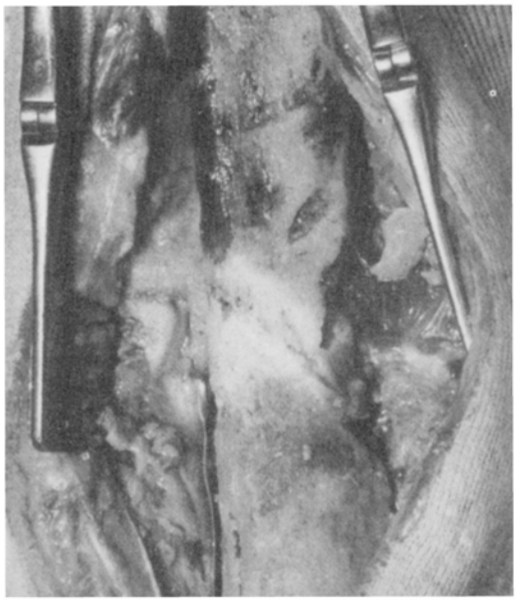

FIG. 166

Un-united fracture of the tibia, short oblique, four months after insertion of three transverse screws. Note dead white bone ends adjacent to the line of the fracture.

The insertion of screws and the stripping of periosteum accentuates a state of affairs already existing to some degree after any fracture of a long bone.

It is not commonly realised that the use of *two* screws across an *oblique* fracture does not produce such sound mechanical fixation as *one* screw on a *spiral* fracture. When a *spiral* fracture has been accurately coapted it becomes locked under light pressure and thereafter can resist quite powerful stresses in a variety of directions. The total strength of this junction is largely due to the locking of the spiral bone fragments and the screw is shielded from most of the external forces exerted on the tibia. The *oblique* fracture, however, unlike the spiral fracture, occupies only a single plane, and therefore it has no locking potential and has no inherent stability against motion in that plane. The truth of this statement can easily be tested experimentally. Oblique fractures therefore expose the screws to extreme strains because the fixation is entirely dependent on the strength of the screws. There is evidence also that two or three transverse screws can devitalise the oblique fragment if separated by less than about 1 cm. from each other, and thus increased mechanical fixation may have the disastrous effect of causing widespread bone death.

It is an ironical fact that it is the oblique fracture of the tibia which most often invites operative coaptation (when in combination with an intact fibula), whereas the spiral fracture of the tibia, which is mechanically suitable for a transverse screw, never needs to be operated on because it never presents a gap.

Only too often a fracture which is regarded as a simple spiral at operation will be found to be comminuted as a result of a minute crack which was not detected in the original radiograph. It is foolish to persist with attempts to insert several transverse screws in these cases.

It should be unnecessary to remind the reader that if a transverse screw is to be applied to one of these fractures the screw hole in the superficial cortex (*i.e.*, that which will eventually be in contact with the head of the screw) should be larger than the outside diameter of the screw thread, and that only the deep cortex, which receives the point of the screw, should be drilled to ' tapping size.' Failure to observe this technical point is a common source of trouble, but I have seen failures in the treatment of oblique fractures with a transverse screw even when this detail has been carefully observed (as in the case illustrated in Fig. 26, p. 25).

Double Fractures of the Tibia

The ' double ' fracture of the tibia, in which there is a large central fragment comprising practically the whole of the middle third, should never be treated by open operation (Fig. 167, A). The danger of converting the whole of the central fragment into a dead tubular sequestrum by operative interference is too great to be worth the risk. It is worth emphasising that large pieces of the tibia which can be seen to be dead when exposed during bone-grafting operations do not reveal themselves by increased density on the radiograph (Compere, 1949).

The safest way of handling these double fractures is by conservative treatment followed three months later by a planned bone graft (predicted to the patient). The leg can be kept at adequate length (*i.e.*, encouraging a little shortening) in a simple plaster cast without traction. After three months one end of the large central fragment (usually proximal) will be clinically united while the other end will be mobile. A graft of iliac bone (p. 248) can now be applied to the un-united fracture and a further three months of plaster fixation will see the successful conclusion of a very difficult problem in a total period of disability of no more than six to nine months. It is unnecessary to consider the position of the central fragment, because the alignment of proximal and distal fragments in relation to their associated joints is easily controlled, and if gross deformity is accepted the opportunity can be taken at the time of bone grafting to reduce the size of any ugly bony prominence by shaving it away. The serious danger of prolonged invalidism —and even amputation—which can follow injudicious handling of this very difficult fracture cannot be over-emphasised. An example of this fracture treated

A

B

FIG. 167

Double fracture of tibia. Internal fixation gave good radiological result, B, but fixation had to be reinforced by plaster and the distal fracture developed non-union. It would have been better to have used the conservative method and accept the original deformity (see text).

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by the intramedullary nail is shown in Fig. 167, B; but after a very difficult operation, where the threat of infection as a result of prolonged handling of the tissues was only avoided by good luck, non-union still developed in the distal fracture and needed bone grafting. The patient was therefore no better off than if he had been treated conservatively from the start, and it was necessary to use a plaster because the intramedullary nail did not completely immobilise the fragments against rotation.

Cosmetic Factors in Conservative Treatment

It is sometimes forgotten that the final appearance of a leg after a fracture of the shafts of the tibia and fibula can usually be judged from the external appearance

FIG. 168
Extreme example of deformity not suspected by external inspection of leg. Patient was a heavily built man. Union first detected six weeks after fracture.

of the limb when the plaster is about to be applied. The stark simplicity of this recommendation can be appreciated when one realises that this approach is almost a return to the methods of the Middle Ages. A gross example, which I do not suggest should be copied, is illustrated in Fig 168; this degree of displacement would never have been suspected by external inspection of the leg one year later

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and this carries with it an important lesson. There is a danger in being satisfied by the radiograph, as a criterion of parallel alignment, if the surgeon does not take care also to *look at the shape of the leg with his naked eyes*. This paradox is encountered if the surgeon is about to accept the position of a fracture where the proximal fragment is lying, as it most often does, more medial than the distal fragment (Fig. 169). If the distal fragment is aligned in strict radiological parallelism with the proximal fragment a visible prominence may be caused on the subcutaneous border of the tibia. A slight valgus deformity in such a case will make this prominence even more ugly. On the other hand, and this is the point I wish to emphasise, a slight varus deformity, deliberately introduced by the surgeon, will conceal such a bony boss (Fig. 170). Other examples of this are indicated in Figs. 171 and 172. The amount of varus required is nothing more than is needed to bring the centre of the ankle joint back into the line of the axis of the proximal fragment. Insistence on strict radiological parallelism will place the centre of the ankle joint lateral to the natural axis of weight-bearing.

FIG. 169

Bony prominence on subcutaneous surface of tibia, caused by proximal fragment, is made cosmetically more objectionable by slight valgus deformity of distal fragment.

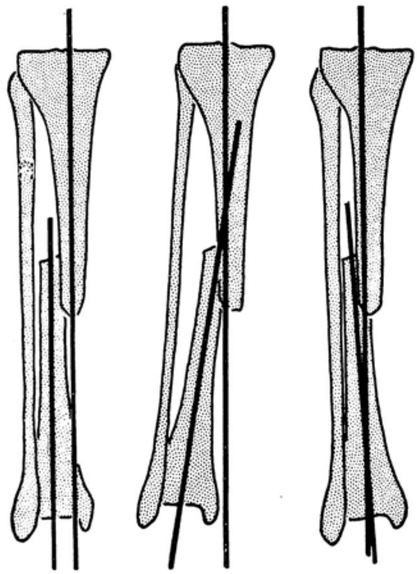

FIG. 170

Showing how classical advice to align tibial fragments in exact parallelism is neither cosmetically nor physiologically sound if the fragments have some lateral displacement. Valgus deformity is always cosmetically objectionable; but a trace of varus deformity will conceal a bony prominence and bring centre of ankle joint back into line of weight-bearing.

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FIG. 171

Excessive *varus* angulation yet external deformity was not particularly noticeable. Axis of proximal fragment in line with tibiofibular joint, whereas it should lie near centre of talus.

The statement which one routinely hears that an angulation as small as 5 degrees will inevitably cause late traumatic arthritis of the ankle joint is not supported by the facts. I cannot recall an example after a fracture involving only the shaft of the tibia, though it is of course common when the ankle joint itself has been directly involved in a fracture.

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FIG. 172
This trivial amount of *valgus* angulation was cosmetically objectionable, because it destroyed the concave profile of the subcutaneous surface of the tibia.

TECHNIQUE OF CONSERVATIVE TREATMENT

1. Simple Plaster Fixation

The fractures of the tibia chosen for this type of treatment will be judged from the magnitude of the original displacement and will fall into the categories shown diagrammatically in Fig. 160, A.

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It is to be noted that the only exception to simple plaster fixation in this group of relatively undisplaced fractures is the oblique fracture of the tibia associated with the intact fibula. I suggest that this type of case should be submitted to intramedullary nailing if the displacement is severe. This point should be judged under general anæsthesia rather than from simple inspection of X-ray which may minimise the problem. If on testing under anæsthesia the fracture is not

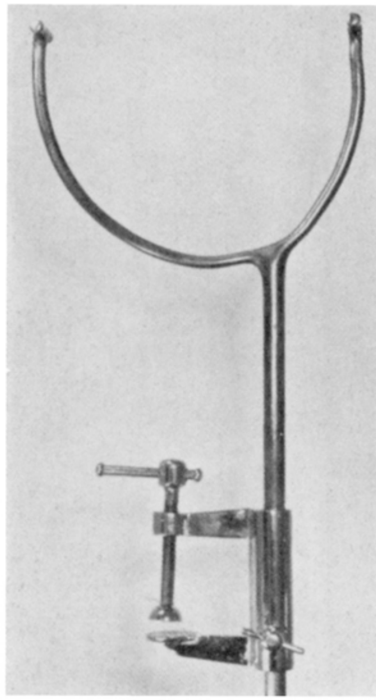

FIG. 173
Simple support for knee which can be attached to any table. Bandage is passed across the open end of the U which is then placed behind the knee.

unstable and is no worse than would seem to be apparent from the X-ray, it is probably unnecessary to use internal fixation.

Having decided from the original displacement that the stability of a fracture against further shortening renders it suitable for simple plaster fixation, to hold a manual reduction while applying a long leg plaster in one stage is a very difficult matter. I have found the following technique better than the alternative of applying first a below-knee plaster, with the knee flexed, and later completing the plaster above the knee.

It is essential to have a fixed support for the knee rather than to expect an assistant to hold it manually. The device which I have adapted from the Putti orthopædic table (Figs. 173, 174, A, B, C) has proved useful. The knee is supported

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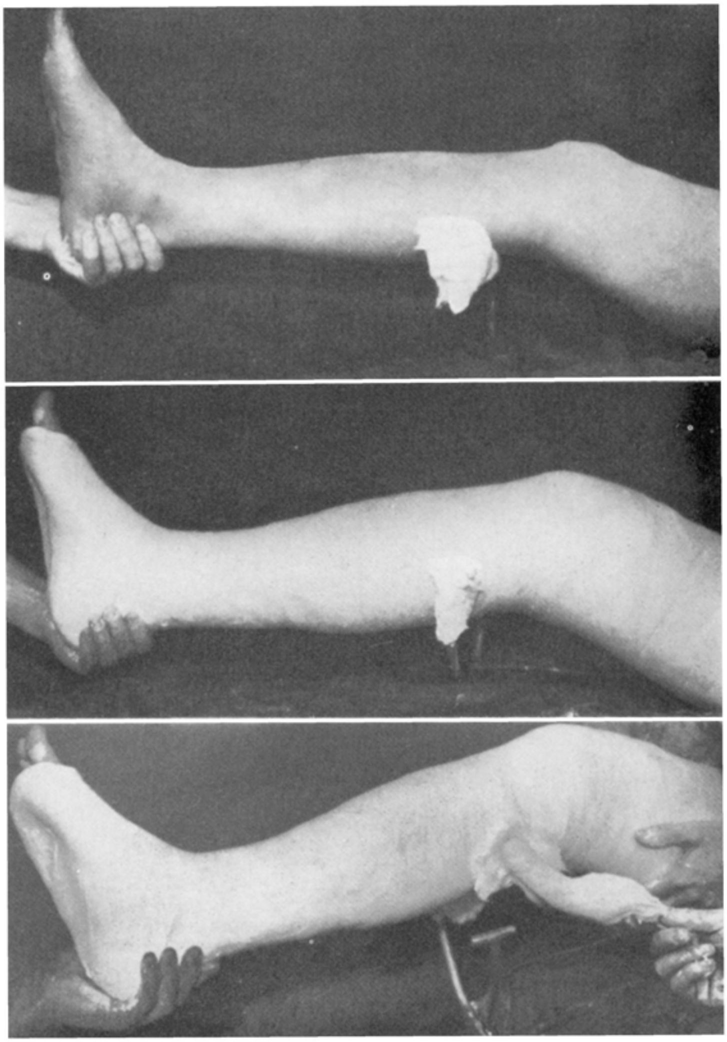
on a flannel bandage tied across the free ends of the support and, in order to extract it easily when the plaster has set, it is liberally covered in a tube of wool which is left behind in the plaster.



A

B

C

FIG. 174
Use of knee support.
A, Wool-covered support in position.
B, Plaster applied.
C, Support being extracted after being cut.

It must be emphasised that there is a very serious danger of obstructing the popliteal vessels by this support if the operator does not understand the method of extracting it as soon as the plaster has hardened. The tubular covering of wool

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is applied to prevent the flannel bandage adhering to the plaster and remaining inside the cast as a constricting ridge.

A technical detail is illustrated in Fig. 175: it will sometimes be found that if the knee support is placed directly behind the popliteal fossa the upper fragment will sag into posterior angulation (Fig. 175, A); to overcome this the knee support should be placed behind the upper quarter of the tibia. In order to encourage the

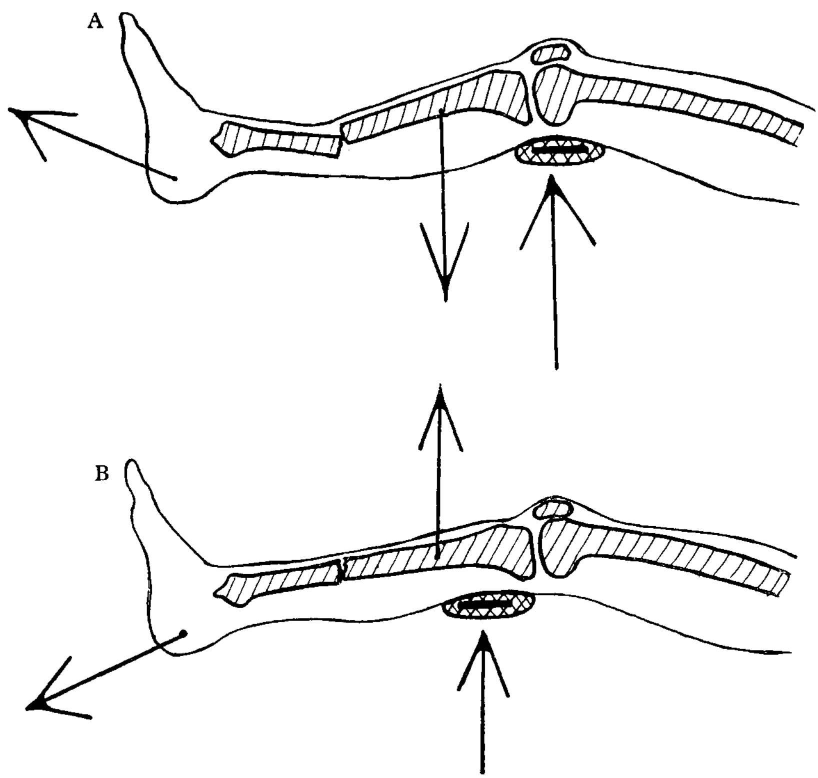


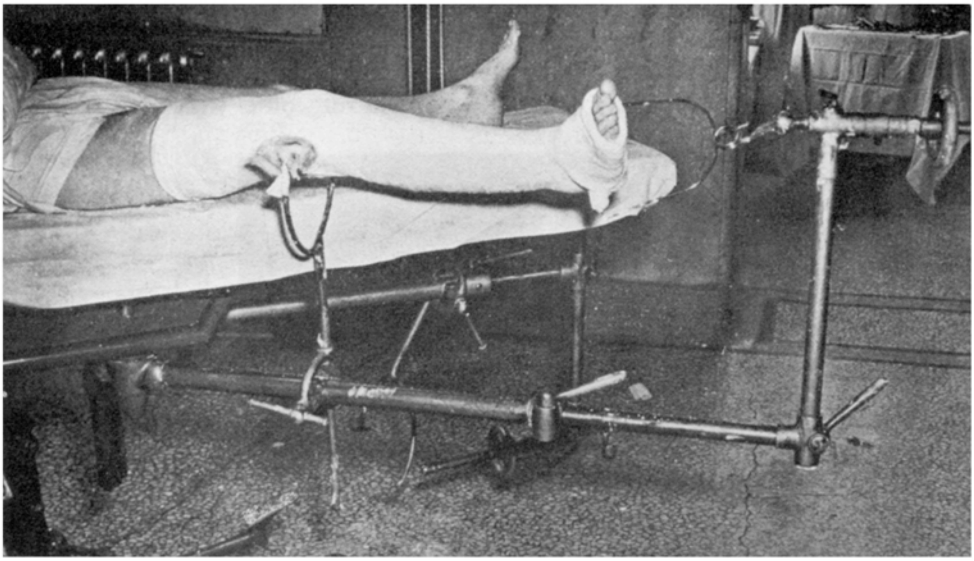
FIG. 175

Diagram explaining necessity, in some cases, for supporting tibia behind upper quarter rather than behind the knee joint, to hold forward proximal fragment and prevent backward angulation.

normal tendency to a concave curvature on the subcutaneous border of the tibia, the best position for the leg is rolled outwards in slight external rotation (Figs. 174, C, and 176).

The plaster should be padded with an even layer of wool $\frac{1}{2}$ inch thick, placed over stockinet, and the plaster bandages applied with firm tension to compress the wool and enhance fixation.

At this initial stage under anæsthesia the foot should be brought up to the right angle, though an exact plantigrade position should not be too much of a fetish if thereby posterior displacement of the fracture is invoked. If the foot cannot



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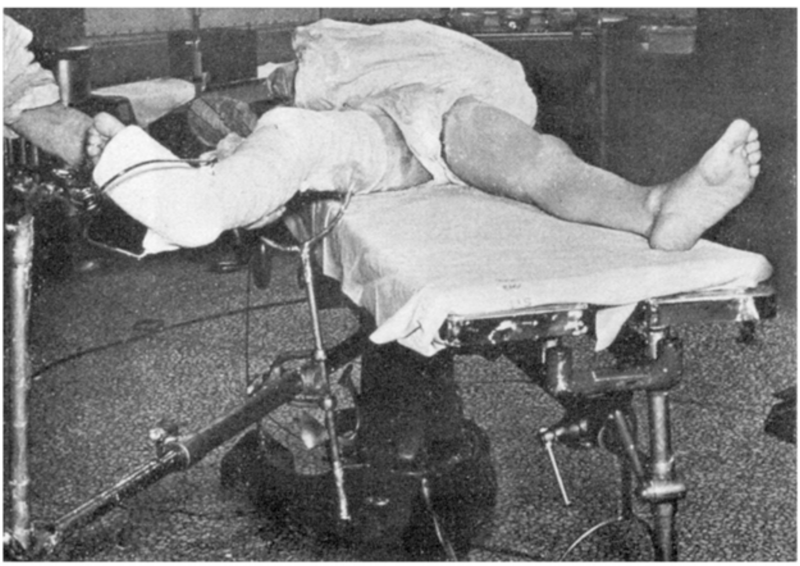

FIG. 176
Alternative arrangement using temporary skeletal traction on the heel. Note the external rotation which converts undesirable tendency to backward angulation into desirable position of varus bowing.

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easily be brought up to the right angles by gentle upward pressure on the sole of the forefoot, this must be combined with manual traction to the heel; this combination of traction on the heel and upward pressure on the forefoot is better than powerful forcing of the forefoot dorsally, which tends to cause backward angulation of the fracture. The best stance for the surgeon is with the sole of the

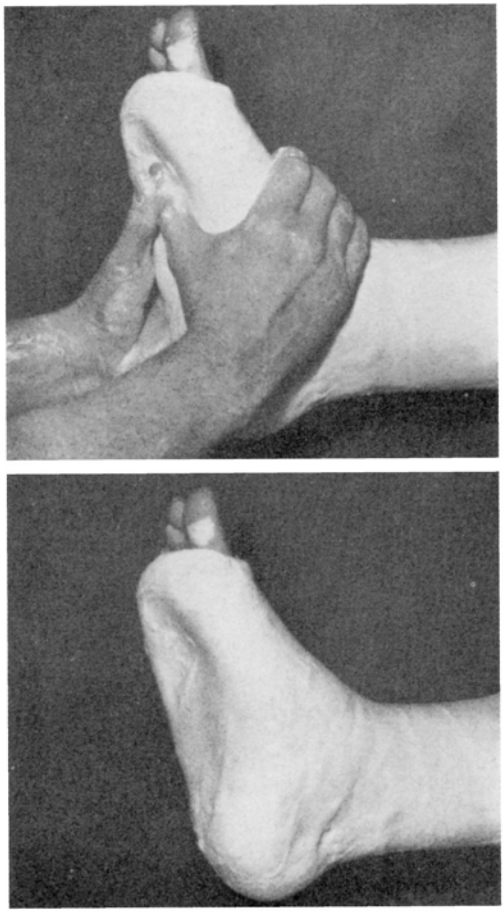

FIG. 177
Moulding sole of plaster to restore transverse metatarsal arch.

patient's forefoot resting on the operator's epigastrium while the heel is pulled down with one hand.

If, when the plaster is complete, the foot should be in some equinus, I strongly recommend that when the plaster is to be changed at six weeks, in preparation for walking, it should be done *under full anæsthesia*, because without anæsthesia it is never possible to bring the foot to the right angle no matter how the patient tries to co-operate.

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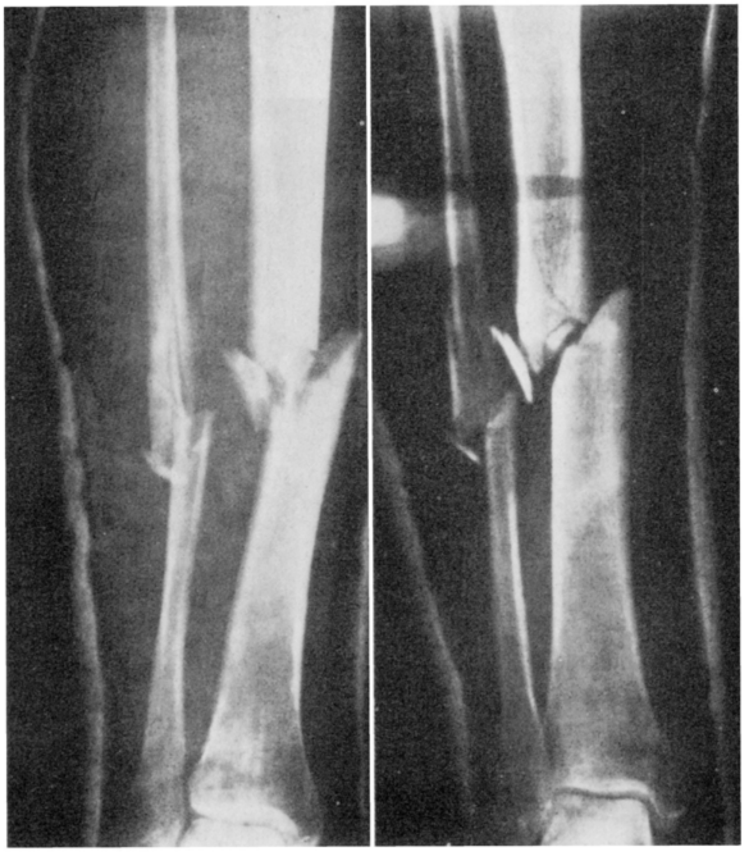
The transverse metatarsal arch should be moulded into the sole of the plaster as the last stage after the main body has set (Fig. 177).

Wedging the Plaster

The judicious use of intramedullary nailing in difficult fractures of the tibia will reduce the necessity for wedging of plasters, but there will always be a place



A B

FIG. 178

Wedging plaster by *opening concave* side can distract and displace a fracture. This case developed non-union, as might have been predicted from the gap.

for this procedure which should be regarded as an unfortunate necessity rather than a procedure of choice. If the radiograph shows some residual angulation, this can be corrected by wedging.

The common and easy method of wedging a plaster, by cutting it on the side to be made convex and strutting open the saw cut with blocks of wood, may have deleterious effects by distracting the tibial fragments (Fig. 178). I have the impression that the tibiæ which present with delayed union show an unusually high proportion which have been wedged in the course of their early treatment.

The truth of the matter is that cases such as that illustrated in Fig. 178 proceed to delayed union as a result of the magnitude of the initial displacement rather than as a result of the wedging.

The best method of wedging is to close the plaster on the side to be made concave. There is here a danger that the skin may be pinched in the gap if a narrow wedge is removed, and it is much better therefore to cut a large window in the convex side so large that it is still widely open when the wedging has been completed. The plaster can then be completed without pinching the soft parts (Fig. 179).

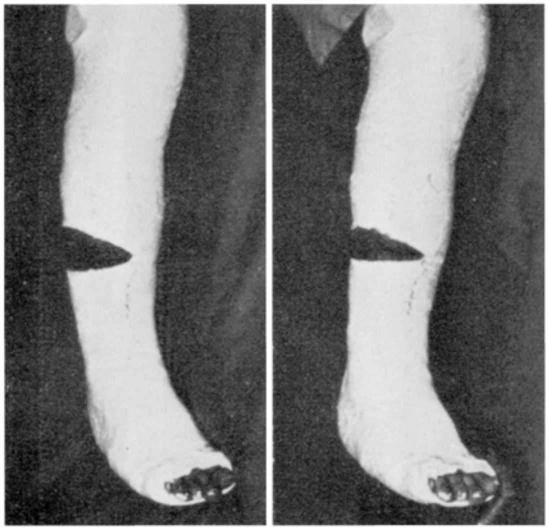


FIG. 179

Wedging plaster by *closing convex* side of deformity. Necessary to remove a wide wedge so that it is not completely closed at the end of wedging and so cannot pinch soft tissues.

All wedging should be finished within the first two or three days after reduction, and the first plaster should then be left untouched for six to eight weeks.

2. Unstable Fractures and Conservative Treatment

The fractures in this category are shown diagrammatically in Fig. 160, B. *The tactics in handling this type of fracture are to avoid major primary operations and concentrate on the possibility of an early Phemister bone graft if mobility is detected three months after the injury.*

These fractures are unsuitable for simple plaster fixation, as after reduction and traction the possibility of slipping is very great.

These cases can be treated by skeletal traction according to McKee's method outlined on page 235. By this technique the alignment is held for four to six weeks and a plaster cast then applied when shrinking of the soft parts has become maximal, and when redisplacement of the fragments is unlikely. Six weeks later the plaster is removed and the condition of union estimated clinically with a view to proceeding immediately with a Phemister bone graft.

Intramedullary Stabilisation

In this category of unstable fracture with gross initial displacement the idea of an intramedullary nail of the Rush type is very attractive if it can be inserted *without opening the fracture*.

After insertion of the nail the fracture is managed as for conservative methods in a long-leg plaster for three months and the condition of union at the end of this time is assessed with a view to immediate Phemister bone grafting without further delay. In inserting the intramedullary nail it is important to have strong skeletal traction to align the fragments by a screw traction device such as the Watson-Jones screw tractor which is used with the knee flexed to 90 degrees over the edge of the table.

Compound Fractures of the Tibia

In the common type of compound fractures of the tibia, where a small wound is present as a result of the bone penetrating the skin from within, the treatment is identical with that for a closed fracture if the skin is clean and no more than about six hours have elapsed since the injury.

When a compound comminuted fracture of the tibia and fibula is complicated by extensive loss of soft parts and skin, the problem is much more difficult. The treatment of this type of injury by a simple plaster technique is unsatisfactory because some infection is unavoidable and venous obstruction due to 'plugging' of the leg inside a plaster cast, in the absence of traction, can have a disastrous effect on the healing of slightly infected wounds.

It has been argued that the immobilisation of bone fragments is more essential in an open fracture than in a closed fracture, because if the fragments are allowed to continue in free mobility it is possible that bacterial contamination may proliferate and a more extensive infection occur than if the fragments were not in relative motion. With this object in mind there are some surgeons who apply plates and screws to compound fractures of the tibia, especially with skin loss, because the internal fixation facilitates an immediate cross-leg skin graft to obtain bone cover. It is argued that if infection should occur it will be nothing more serious than a mild local infection around the plate, which eventually subsides when union at a later date permits the plate to be removed. Remarkable successes have certainly been recorded by this technique since the advent of antibiotics, but we must not forget the cases where operative intervention in these circumstances has been the deciding factor in precipitating complete ischæmia of full-diameter sections of the tibial graft, necessitating amputation one or two years later after prolonged disability. I have already mentioned that late amputation as a result of osteomyelitis does not happen when a fracture has been treated conservatively at the outset.

It is possible that there may be a revival of interest in external skeletal fixation in a restricted field of application to compound fractures of the tibia necessitating

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skin cover. In this technique the proximal and distal fragments are transfixed, through healthy skin and at some distance from the fracture, by 'half-pin units' which are then connected together by a rigid external steel bar as in the Stader splint (Fig. 180). Unfortunately when this method was practised in the U.S.A. and Canada during the Second World War it was grossly abused and is now in disrepute. Nevertheless the principle of this method offers the best theoretical conditions for an open fracture of the tibia to heal without bone infection. External skeletal fixation should be restricted exclusively to the treatment of fractures of the tibia and fibula and should not be used for any other bone. The bad reputation which this splint has acquired is the result of its abuse. The transfixion pins should never penetrate muscle, because the movement of muscle round the nails, which occurs if associated joints are exercised, will induce infection. The patient should never be expected to become ambulant with external skeletal fixation *in situ*. The patient should not be allowed to hold the limb dependent and engorged

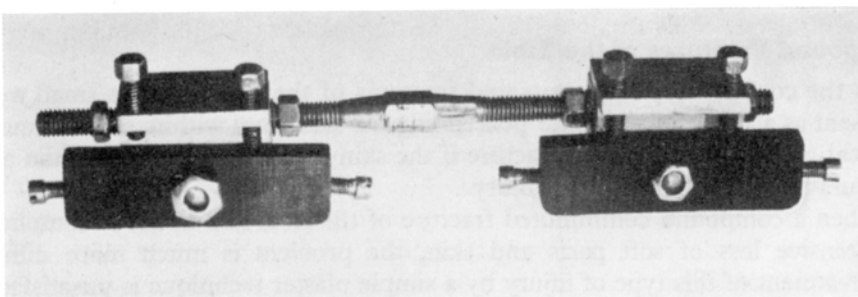

FIG. 180
Stader splint. See text.

with blood for long periods of time. The external skeletal fixation should be removed as soon as the condition of the compound fracture permits and should not be retained *in situ* for months in the hope of union occurring.

In a series of animal experiments undertaken to compare the rate of union after different forms of mechanical fixation, Hey Groves (1921) came to the conclusion that external skeletal fixation gave the best callus formation of any method he had tried. In this comparison he used plates of various sizes with different forms of attachment, such as screws and 'split-pins,' and also intramedullary fixation. To quote Hey Groves:

> 'There can be no doubt, as far as the evidence of these experiments goes, that this method of indirect fixation of the fracture gives a more perfect union of the bones than any direct method that I have performed.'

Skeletal Traction

A popular method of handling severe fractures of the tibia and fibula is to apply skeletal traction to the lower end of the tibia or os calcis, and nurse the limb on a Braun splint. Usually the alignment of the limb is reinforced by the application of a below-knee plaster.

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This method lacks precision in that the proximal fragment is not controlled, and if there has been extensive damage to soft parts, weight-traction of 10 lb. may produce considerable distraction of the fragments. If it is considered necessary to reinforce the fixation with a below-knee plaster, this has the disadvantage of rendering the wound inaccessible. The method of external skeletal fixation which I have found best (McKee's method) uses a bent Thomas splint to replace the Braun splint, and the proximal fragment is held to the splint by means of a second nail. In this method fixed traction is used so that the length of the tibia can be set at whatever length the surgeon wishes.

In this method it is unnecessary to use plaster and the leg is supported with flannel slings and the wound can be dressed and skin grafted by Thiersch or pinch grafts at any time in the subsequent course of healing.

I consider this method is preferable to the simple technique of incorporating transfixion nails in plaster. A single Steinmann nail in the proximal and in the distal fragments in combination with a plaster cast is not enough to control angulation in two planes, but in combination with a Thomas splint there are facilities for readjusting the alignment in stages subsequent to the original reduction.

By concentrating on procedures to obtain skin closure, while holding the fracture in acceptable position, it is almost always possible to get the soft parts healed and dry and in a state suitable for grafting by the Phemister technique in the most severe of compound fractures of the tibia before three months have elapsed.

The compound tibia is held with skeletal fixation on the splint with the patient in bed for an initial period of four to six weeks, and thereafter a long leg plaster is applied and the nails are removed.

Details of Technique. McKee's Method.

A new Thomas splint is chosen with a ring of suitable diameter to fit the opposite groin. The splint is bent 30 degrees at the point which will correspond with the level of the knee. This is easily done by bending over the edge of a table.

The patient is anæsthetised and the skin cleansed with soap and water, etc., prior to surgical debridement of the wound. Having surgically cleansed the wound, the leg can be draped in sterile towels while the Thomas splint is threaded over the limb and while the Steinmann nails are being inserted. It is unnecessary to insist on very strict asepsis during this phase of the procedure as the nails can be inserted by no-touch technique. The side bars of the Thomas splint can be sterilised by antiseptic means such as wiping down with a suitable antiseptic solution.

The first Steinmann nail is inserted into the proximal fragment at the level of the tibial tubercle and every care should be taken to see that this is transverse to the long axis of the proximal fragment.

The second Steinmann nail is now passed through the os calcis. This must be done below the side bars of the splint with an assistant holding the splint upwards.

The proximal Steinmann nail is now clamped to the side bars of the splint

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using the McKee clamps (Fig. 181) in a position which brings the ring of the splint in comfortable relationship with the groin.

McKee clamps are now threaded over the distal nail which is loosely clamped to the side bars *underneath* the splint (Fig. 182).

Powerful traction is applied to the distal nail with the surgeon standing so that the foot of the splint is against his body (Fig. 183). The distal McKee clamps are now tightened and the position of the fracture under powerful traction is assessed. At this point the splint can be draped with sterile towels and the fracture and wounds exposed. Direct inspection of the fragments can be carried out, and the effect of reducing the traction from the distal nail can be examined. The object is to find the minimum amount of traction which will hold the fragments in stable alignment.

In the case of closed fractures radiographic control will help in the final adjustment of the reduction.

When the position of the fracture is regarded as satisfactory, dressings are applied to the wound and flannel slings placed under the calf to check posterior sagging.

It is finally necessary to support the forefoot to prevent a cavus deformity taking place at the midtarsal joint. This can be done by means of a plaster slab which can be bandaged to the side bars of the splint with a figure-of-eight bandage.

Post-operative Management

The patient can be nursed in bed with a rigid support to hold the heel clear of the bed (Fig. 192, B, p. 243) or preferably the splint can be counterpoised from a Balkan beam (Fig. 192, C, p. 243).

After three or four weeks there may be considerable shrinkage in volume of the soft parts, especially if the leg originally was grossly swollen with effused blood. It may be necessary to re-tighten the slings if shrinkage of the leg has permitted posterior bowing to occur.

Throughout the four weeks X-ray checks should be made from time to time with a view to readjusting the first alignment of the fracture if necessary, and for this purpose short anæsthetics may be needed.

Application of the Final Cast

After four to six weeks the fracture will be sufficiently sticky to permit it being held in a long leg cast without the transfixion nails. This can be done without anæsthesia by applying wet plaster slabs to the front and back of the leg and thigh and bandaging into position with gauze bandages while the limb is still held in the splint. When these plaster slabs have hardened the splint can be removed and the slabs converted into a complete cast after removing the splint.

Special Details

Two special details in the handling of severe compound fractures of the tibia by this method need emphasis: (1) Landmarks for inserting the nail in the os calcis. It is important to avoid transfixing the subastragaloid joint with the distal

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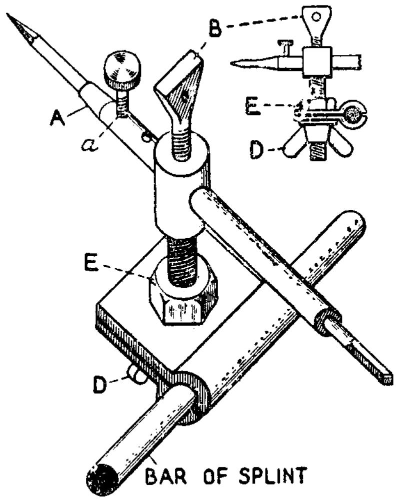

FIG. 181
McKee clamp for holding Steinmann nail to the side bars of the Thomas splint.

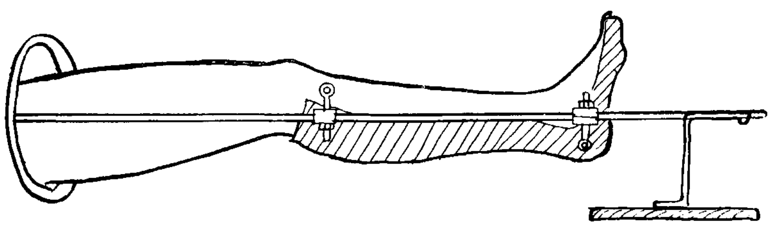

FIG. 182
McKee clamps on Thomas splint with plaster slab to reinforce fixation against movement in a sagittal plane.

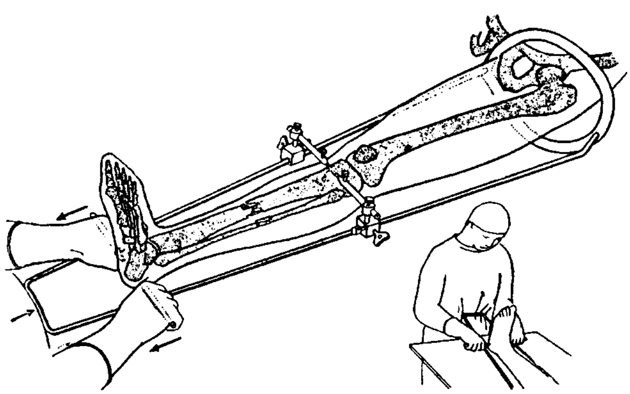

FIG. 183
Reduction of the fracture by traction. It must be emphasised that once reduction is secured traction is removed; the nails are left in position only to enhance fixation *not* to maintain traction.

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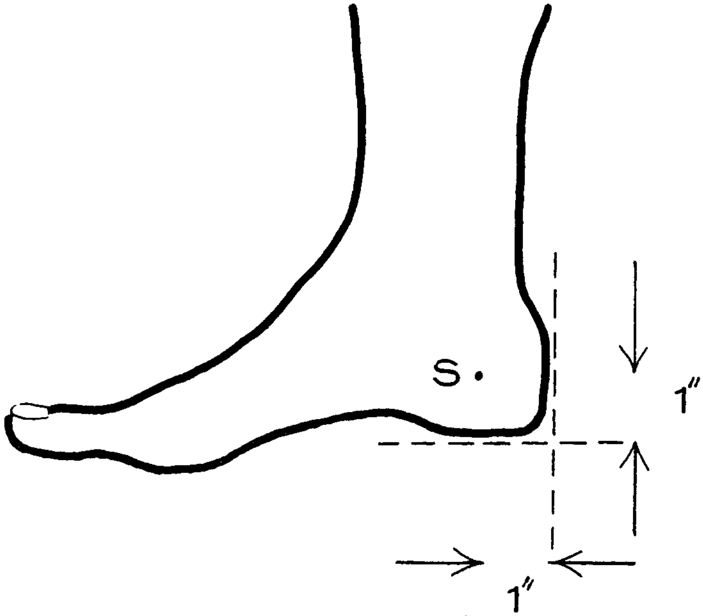

FIG. 184

Landmarks for avoiding transfixion of the subtaloid joint when inserting a nail through the os calcis. Measurements are estimated from the profile of the skin of the heel, as seen in side view.

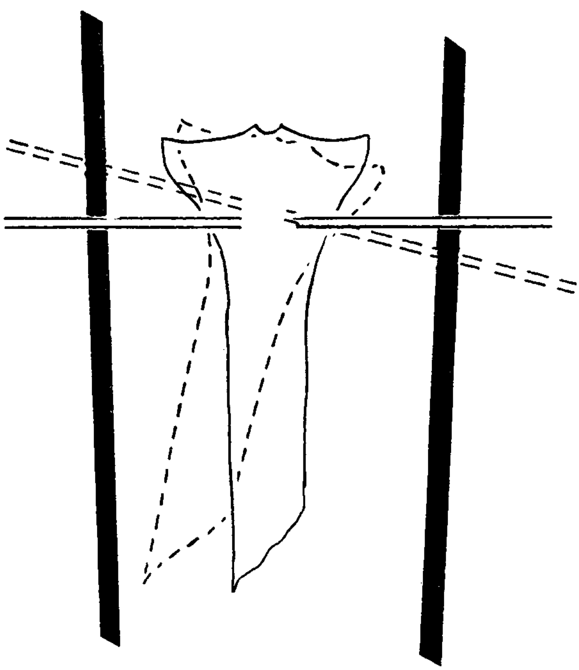

FIG. 185

Controlling varus and valgus alignment of the proximal tibial fragment in McKee's method by altering the level of attachment of the clamps on the side bars of the splint.

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nail. The best landmark is a point 1 inch above and in front of the profile of the heel (Fig. 184). In order to avoid an erroneous position of rotation of the foot when this nail is clamped to the side bars of the splint, it is important that the assistant should hold the foot vertical while the surgeon is inserting the Steinmann nail and taking care to keep the nail horizontal.

(2) Control of the proximal fragment. In controlling the alignment of the fractured tibia the distal fragment aligns itself with the axis of the splint and cannot be directly controlled because it is mobile on the ankle joint. The proximal fragment must be aligned by controlling its direction in the following way : *Valgus and varus angulation* is controlled by altering the level of attachment of the outer ends of this nail to the side bars of the splint. Thus by moving the lateral clamp proximally and the medial clamp distally, the proximal fragment will be directed in a valgus direction and vice versa (Fig. 185).

Forward and backward angulation is controlled by raising or lowering the knee and lower third of the thigh in relation to the Thomas splint. By means of a flannel sling and pad under the lower third of the thigh the proximal tibial fragment can be directed backwards by elevating the knee and forwards by allowing the knee to sag.

An extreme example of the salvage of a ' de-gloved ' leg, associated with a transverse fracture of the tibia and fibula, is illustrated in Fig. 186. The patient was a youth of twenty who had been run over by a bus and the opposite leg had evidence of threatened circulatory damage due to crushing of the calf muscles. This rendered it more than ever imperative that some attempt should be made to save the de-gloved leg. Even a below-knee amputation would not have been an immediate solution of the problem because it would have left a stump requiring a skin graft.

Having removed crushed muscles, cleaned the flap and removed fat, the skin was loosely sutured back in position and the whole limb splinted in the McKee apparatus. It was nursed with the skin exposed to the air and the limb supported in slings from behind. The skin flap died *in toto*, but by permitting it to become dry by exposure to the air no spreading infection developed. After three weeks the whole skin flap was black and hard. There was sensation in the foot and a good circulation, and the fracture was in good position.

Under anæsthesia the dry, black, skin cover was stripped away to leave a clean granulating surface covering all the muscles (Fig. 187). Postage stamp skin grafts were then applied at intervals of one week and the leg was nursed by exposure to the air under a protective cradle (Fig. 188).

The final state of healing of the leg is indicated in Figs. 189 and 190. The foot became grossly deformed because the forefoot had been permitted to fall into equinus (the extensor muscles having been largely removed at the time of the debridement) but this was later corrected by a wedge tarsectomy. The knee recovered a range of motion of 70 degrees. The opposite leg developed a Volkmann contracture of the calf, for which operations were necessary to correct the equinus deformity.

It is difficult to think of any other method by which such a limb could have been treated.

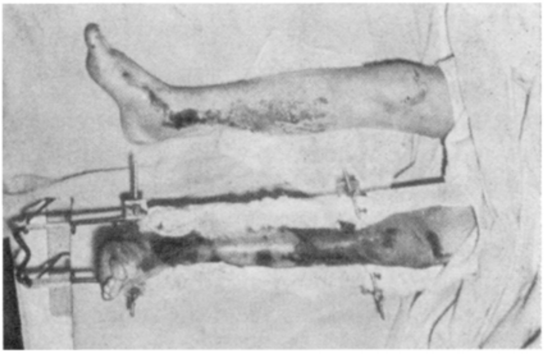

Fig. 186

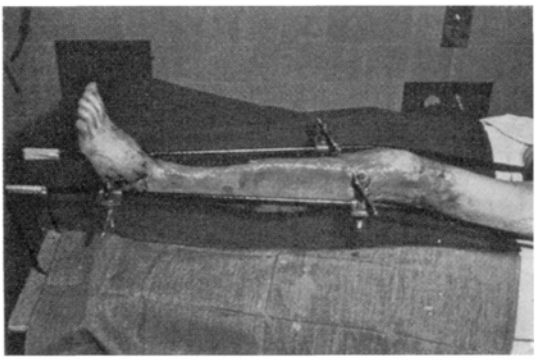

Fig. 187

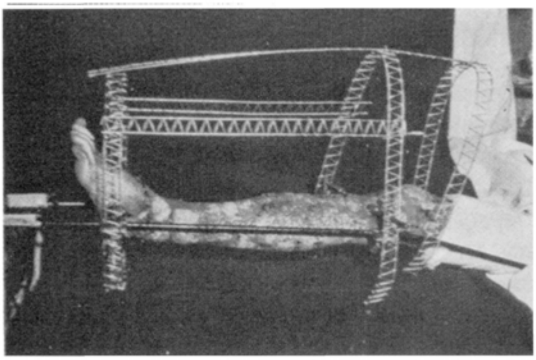

Fig. 188

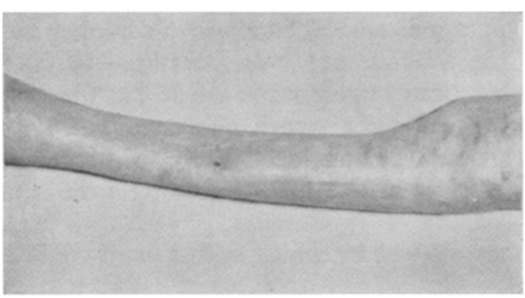

Fig. 189

Fig. 186—'De-gloved' left leg, with fracture of shaft of the tibia, treated by exposure to air in McKee's method.

Fig. 187—Same case about one month later when dead skin separated, leaving a granulating surface.

Fig. 188—First stage of skin-grafting by 'postage stamp' grafts. Note framework to permit leg to be nursed without dressings and with exposure to air continuously.

Fig. 189—State of healing of the grafts after six months.

Fig. 190—Result two years later.

Fig. 190

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Common Causes of Failure

While the McKee method of treating severe fractures of the tibia enables the position of the fragments to be controlled better than any other simple method, the technique still requires considerable skill and very careful observation. I have noticed from the work of my assistants that failure to get the best out of this method can usually be traced to one or other of the following facts :

1. Failure to control the position by failing to inspect the external contour of the limb.

2. Failure to inspect the contour of the limb as the result of covering the leg in plaster or bandages and failing to remove these for inspection during the first three weeks. It is possible to have an acceptable radiological picture with one tibial fragment pressing up through the skin ; what originally was a closed fracture may become compound with an ugly bony projection at the level of the fracture.

3. Failure to readjust the fragments, under anæsthesia, on one or two occasions during the first two weeks after the injury. There is a tendency to hope that the fragments will stay in perfect position without touching the apparatus after the primary treatment. The control of the fragments in this method is not complete, but the method has the advantage over other simple methods that it is possible to make minor adjustments without completely disturbing the fracture.

4. Failure to realise that the position of the proximal fragment is to some extent controlled by support under the lower end of the thigh.

Skeletal Traction : Os Calcis versus Tibia

In McKee's method traction applied through the os calcis is much better than traction through the lower end of the tibia. In passing a Steinmann nail through the lower end of the tibia the surgeon may have the misfortune of splitting the tibia if he chooses too high a level above the expanded lower end. If the nail is passed through the lower end of the tibia, on applying traction the bones will pull apart and yet continually return to their displaced position on removing the traction. This is caused by the tension of the posterior calf muscles and particularly those inserted into the tendo Achillis. If skeletal traction is applied to the lower end of the tibia the fragments will lift away from each other rather like the opening of the Tower Bridge (Fig. 191). The posterior muscles are not elongated by the traction force when it acts in the axis of the tibia. If the skeletal traction is applied to the os calcis the traction force acts directly in the axis of the calf muscles and, as these are the primary cause of the shortening, the fragments of the tibia will float into alignment.

Fracture of the Tibia associated with Fractures of the Femur

When both the tibia and the femur are fractured the problem is simplified by using internal fixation of one or other bone. If one of these bones is severely comminuted then the other will be chosen for internal fixation. The case illustrated in Fig. 192 had an extremely comminuted fracture of the lower third of the femur combined with a comminuted fracture of the tibia in which it was considered

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that internal fixation was unsuitable for both fractures. The McKee method of external skeletal fixation offered a useful solution to this problem.

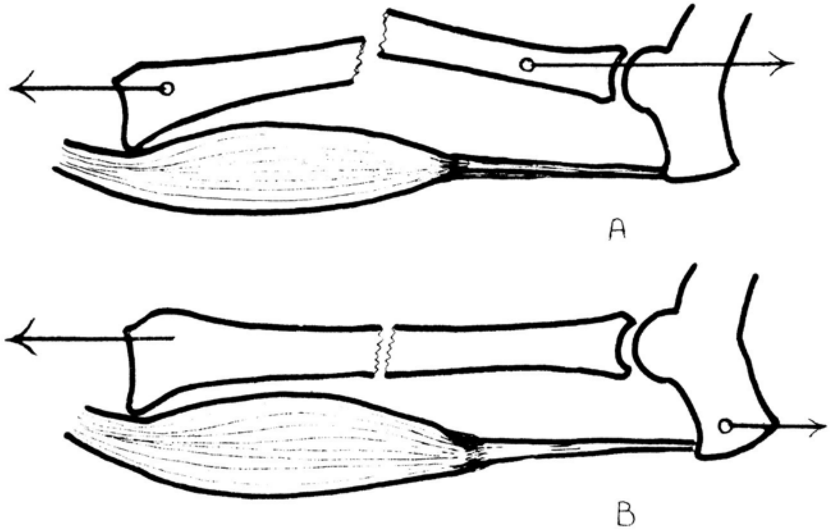
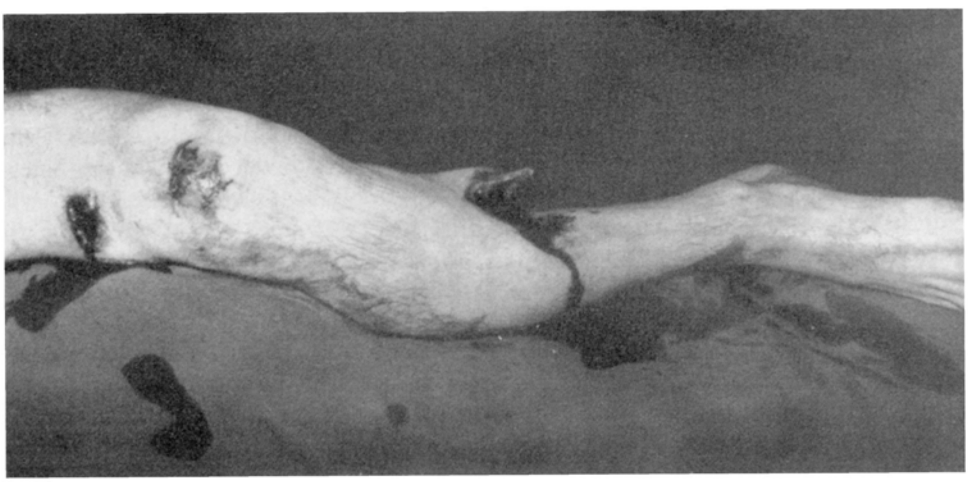


FIG. 191

Traction through the os calcis produces better alignment of tibial fractures than does traction to the lower end of the tibia.

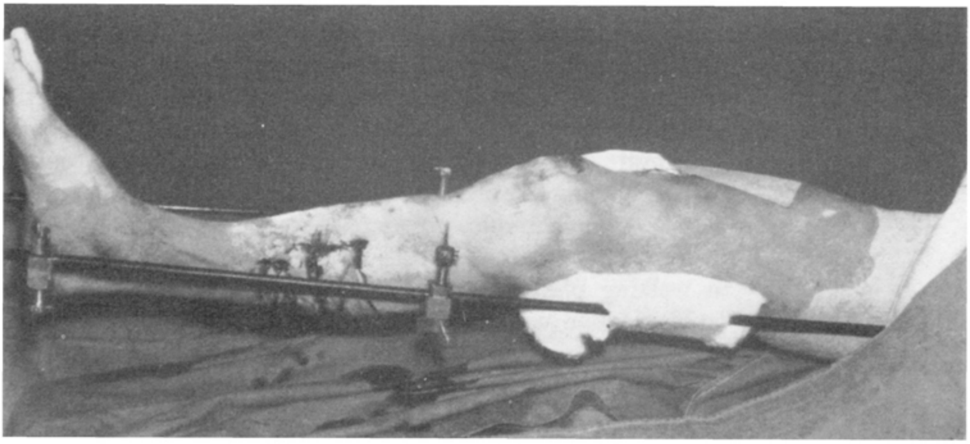


A

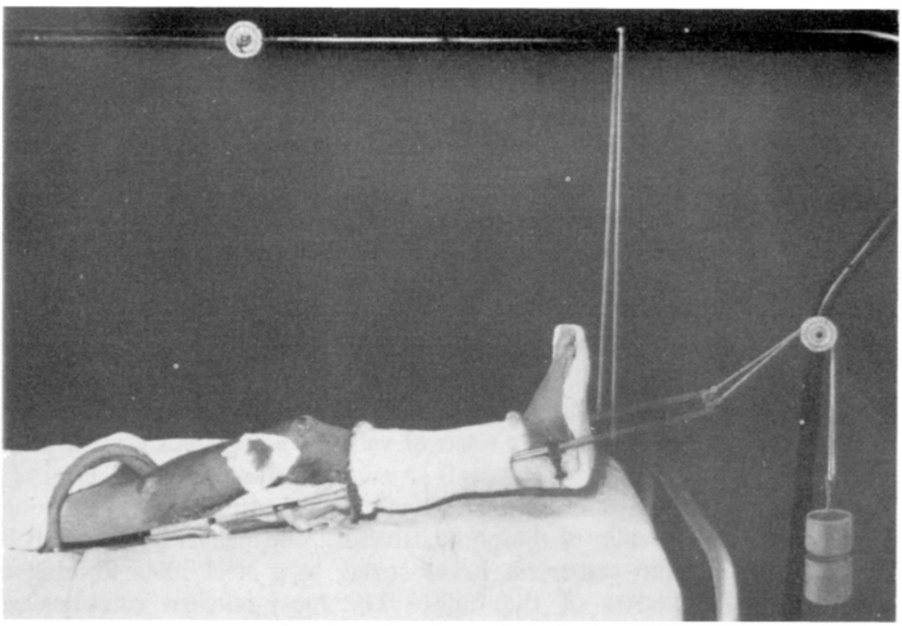
FIG. 192

Example of compound comminuted fractures of the lower third of the femur and midshaft of the tibia treated by McKee's method (see text).

Example.—The fracture of the femoral shaft was aligned first, by using the counter-traction of the ring of the splint against the root of the limb and applying temporary manual traction to the tibial nail. A pad and slings were placed behind the popliteal fossa and distal fragment of the femur. The tibial nail was then locked to the side bars of the Thomas splint using the McKee clamps. It was then possible to forget the femoral fracture and transfer all attention to the reduction of the tibial fracture. The final arrange-



B



C

FIG. 192

Example of compound comminuted fractures of the lower third of the femur and midshaft of the tibia treated by McKee's method (see text).

ment of the splint is seen in Fig. 192, C, where a sliding traction force of 7 lb. was applied to the foot of the splint merely to make the arrangement more comfortable for the patient by reducing the pressure of the splint ring against the groin. A better arrangement would be to arrange a complete floating counterpoise for the whole splint.

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THE BONE GRAFTING OF DELAYED UNION IN THE TIBIA

Though this monograph is devoted to the conservative treatment of fractures it is important to discuss the technique of bone grafting because the knowledge that there exists a certain safe and simple method of bone grafting has an important bearing on the planning of the initial treatment of recent fractures of the tibia. If a cortical bone graft, cut from the normal tibia and applied as an 'onlay' to the un-united fracture by the Albee technique, were to be the only technique, no surgeon would contemplate such a major procedure unless a full period of conservative treatment in walking plaster, or caliper splint, had shown that spontaneous union was impossible. The same applies with equal force to the use of 'sliding' tibial grafts which do not necessitate interference with the opposite tibia. If the original fracture has been compound and infected, prolonged delay—of at least six months—is essential when using massive tibial bone grafts, and the possibility of a flare-up of infection is still possible even several years after infected compound fractures. A recrudescence of infection when using a massive tibial onlay is a catastrophe of the first magnitude, because a cortical graft becomes an infected sequestrum with a very doubtful chance of being retained in the leg (Fig. 193); and to have violated the good tibia (with a 10 per cent. risk of spontaneous fracture in the donor leg) is a poor exchange for a sequestrating graft and the persistence of non-union.

FIG. 193
Cortical bone-graft by Albee technique extracted one year after infected operation. Note erosion of the dead graft by granulation tissue. This graft acted as a sequestrum and healing of the wound did not take place until it was extracted.

Excluding the catastrophic result of infection in a graft of cortical bone, a little consideration shows that this type of graft cannot be justified biologically or mechanically. Biologically, cortical bone is not 'osteogenic' because the sole source of osteogenesis is the living bone on which it is applied. It is a waste of valuable autogenous bone to have 75 per cent. of the graft situated remotely from the level of the pseudarthrosis instead of concentrating the grafted bone on all sides of the pseudarthrosis. Mechanically, a cortical bone graft can never be as strong as a steel plate forming one-quarter of the bulk. The most efficient combination of mechanical fixation with a bone graft, theoretically, would therefore be to use a plate for fixation, and chips of cancellous bone to surround the level of the pseudarthrosis to make an *artificial ensheathing callus.*

Naughton Dunn (1939) showed that in non-union of the tibia, when there was no loss of bone, and therefore no large gap between the ends of the bones, it was unnecessary to use a bone graft. By using a mallet and chisel he elevated the periosteum from the pseudarthrosis so that chips of cortex remained adherent to the periosteum. He called this technique his 'subcortical procedure,' and great care was taken not to strip the periosteum from the surface of the tibia before elevating these chips. The fracture line was occasionally curetted and the medullary canal opened up, but no graft was applied and the limb was merely immobilised in a plaster cast for three months. Jackson Burrows (1940), reporting on the technique taught by R. C. Elmslie, declared that it was unnecessary, and even harmful, to resect the bone ends or otherwise 'refresh' the fracture (which was popular at that time), and in this technique an inlaid cortical bone graft cut from the opposite tibia was applied across the line of the pseudarthrosis without otherwise disturbing it. It is, however, to D. B. Phemister (1947) that we owe the first clear statement of what I believe can now be accepted as axiomatic in bone grafting for non-union:

1. That a fibrous union should not be broken down nor should the bone ends be 'refreshed' or resected. To do so merely removes whatever mechanical stability is already present.
2. That the radiotranslucent tissues between the bone ends of a pseudarthrosis will ossify spontaneously when induced to do so by a bone graft laid on the surfaces.
3. That rigid immobilisation of the graft by screws, etc., is unnecessary if the graft is laid subperiosteally on the surface of the pseudarthrosis.
4. That such a subperiosteal graft can be used in the presence of recent sepsis if inserted through normal tissues away from the site of the original wound or sinus.

The technique of the Phemister bone graft can be improved by adding the 'subcortical' procedure of Naughton Dunn and by using slices of autogenous cancellous bone taken from the iliac crest in place of the cortical bone used by Phemister. Using this technique the procedure is so simple and efficacious that it can be used as early as three months after a fracture—*i.e.*, in 'delayed union' rather than in true 'non-union.' It can be used in recently infected fractures because even if it becomes infected itself the major part of the cancellous bone will survive and no sequestrum will be left behind because the infected part will either be dissolved away or extruded (Fig. 194).

The decision to graft can be made three months after a fracture of the tibia purely on the amount of movement which can be detected clinically. Little or no attention need be paid to the radiological appearance in making this decision. If there is only a trace of fibrous 'give' after three months of conservative treatment, so little in fact that quite careful attention is needed for it to be demonstrated, then spontaneous union in a further walking plaster or caliper splint can confidently be expected. If after three months of conservative treatment a fracture of the tibia shows a clearly detectable range of free motion, then an immediate Phemister graft is to be advised rather than perseverance with further plaster fixation.

The failure rate of the Phemister type of graft, if autogenous slices of iliac bone are used, is extremely small. One reason for this is that in accordance with the policy here advocated it is used 'prophylactically' and before the more difficult

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situation of true non-union has supervened. In a personal series of thirty cases there have been only three cases in which the graft was not completely solid when the plaster was removed three months after operation. One of these united later spontaneously, another was successfully treated by a second Phemister graft. The isolated failure was a case in which a large whole diameter segment of the tibia was completely ischæmic at the time of grafting (Fig. 159, p. 207).

I am indebted to D. B. Forbes [1] for analysing the results of my series of Phemister bone grafts as applied to the tibia. The infected cases are of particular interest. Thirty patients submitted to grafting included five who had a discharging sinus at the time of the operation and four in whom the wound developed infection

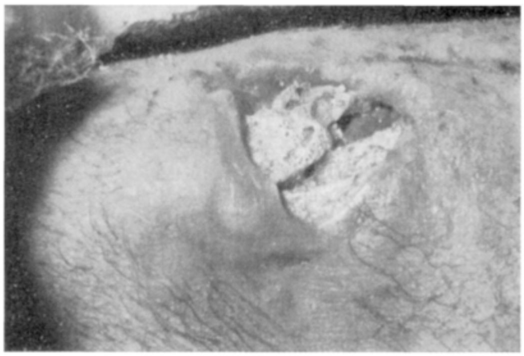

FIG. 194

Gross example of the infection of an autogenous iliac bone-graft when inserted into an infected compound fracture. Three dead fragments extruded spontaneously but the underlying fragments, four or five in number, were successfully incorporated and the fracture united. This procedure would be totally unjustifiable if an autogenous cortical bone-graft had been used.

though the compound tibial fracture appeared to have been sterile at the time of the operation. All nine of these infected cases united though one required a second graft by reason of the fact that 1 inch of bone had been lost from the tibial diaphysis at the original injury. In three patients the original sinus was healed by the time the plaster was removed after the graft. In six patients the fracture was united and the patients bearing weight before final healing of the wound occurred. In these severely compound cases the average interval between injury and union was fourteen months but in the cases where grafting was performed within twenty weeks of the injury the average time between injury and union was eight months.

These figures are the results over a period of twelve years during which I was gaining experience in this method and before the full value of the technique was realised. Very few of these cases were grafted under six months. By adopting the policy of grafting earlier, *i.e.*, about three months after the fracture, I feel certain

[1] In press.

that these figures could be greatly improved and that no serious hazard would be incurred as a result of early grafting.

Technique

Certain details of the technique need to be emphasised. The operation is essentially a *subcortical* procedure, the periosteum being raised with a hammer and chisel so as to produce ' shingles ' of cortical bone adherent to it. The idea is to construct an *artificial ensheathing callus*.

A straight longitudinal incision is made in the line of the subcutaneous border of the tibia and centred over the fracture line. The incision is deepened directly to bone throughout the length of the wound, *avoiding any undercutting of the subcutaneous tissues* which are usually indurated and adherent to the subjacent periosteum.

A sharp chisel is now used and, taking care not to strip the periosteum from the underlying bone, thin chips or shingles of cortical bone are elevated so that the periosteum is turned up as an osteoperiosteal flap. This procedure is adopted on the subcutaneous and the lateral surfaces of the tibia but no attempt is made to reach the posterior surface (Fig. 195, A). At the end of this stage it will be seen that two deep gutters have been produced, both lined with adherent bone chips. It will be immediately obvious that if these gutters were to be packed with slices of iliac bone they would be held open and it would be impossible to approximate the edges of the wound. This difficulty in closure is rendered the more so because the surrounding soft tissues are indurated and inelastic. To facilitate closure it is important to pass the chisel through the floor of the groove, using it as a lever against the fulcrum of the tibia to split open the deepest part of the groove (Fig. 195, B). This will mean tearing the periosteum and fibrous tissue in the region of the postero-medial and postero-lateral angles of the tibia. With tissue forceps attached to the edges of the wound, traction is applied to the osteoperiosteal walls of the gutter, and by palpating with the finger any tight fibrous structures can be discovered which are preventing them from being mobilised. Time spent in mobilising the osteoperiosteal structures sufficiently to allow easy closure after the iliac bone has been inserted will be well worth while.

Iliac bone slices, 2 to 3 mm. thick, are now cut from the iliac crest and laid on the surfaces of the tibia and the wound drawn together (Fig. 195, C). Closure is in one layer, using skin sutures alone. I think it is important to insist that the iliac bone should be in the form of flexible strips at least $2\frac{1}{2}$ inches long. Small chips of bone are not reliable by themselves because a pseudarthrosis line can form between them. It is impossible to close the osteoperiosteal flaps separately (nor is it desirable). The use of an interrupted vertical stitch is recommended for this closure in one layer (Fig. 195, D).

Plaster is then applied over the wool, care being taken to split the plaster longitudinally. In the subsequent twenty-four hours there is invariably a considerable expansion of this split, showing that its omission might have caused pain and perhaps dangerous circulatory embarrassment (Fig. 196).

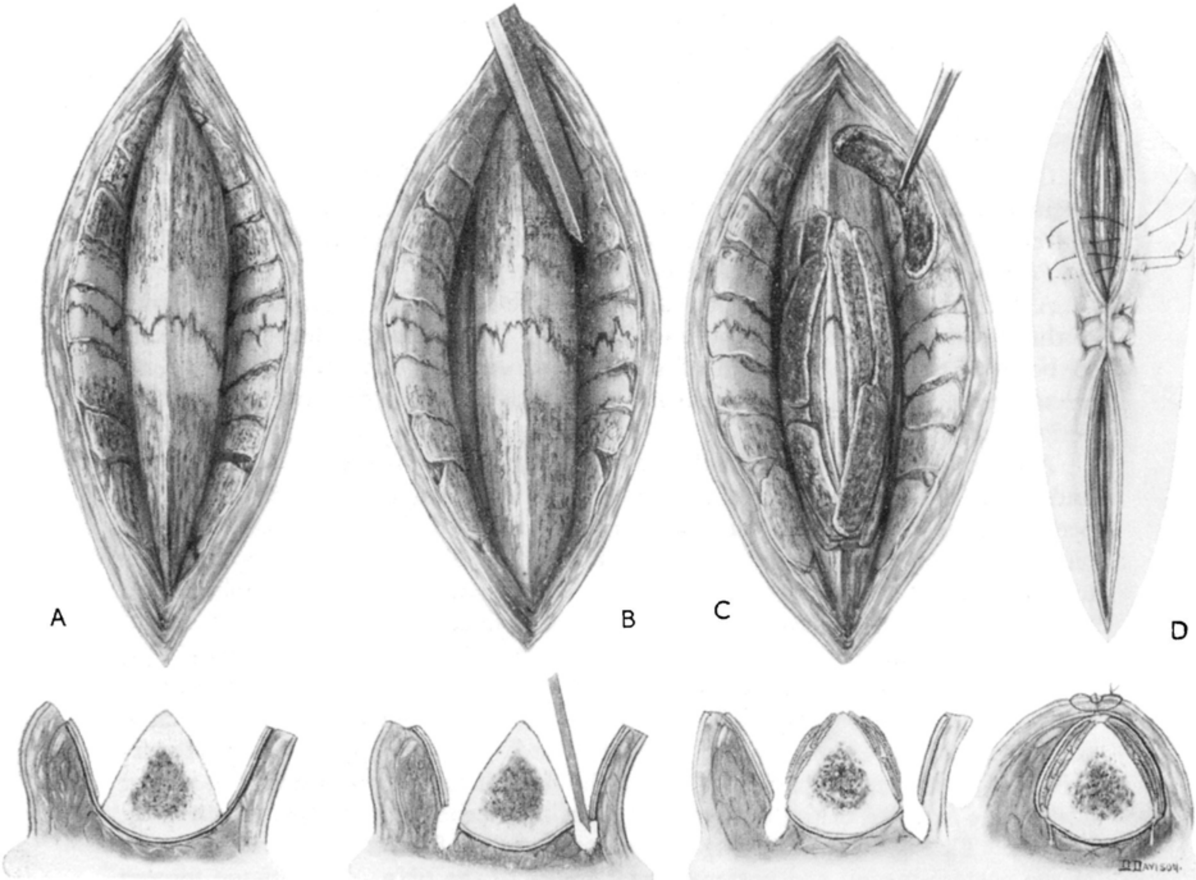

FIG. 195
Stages in the Phemister bone graft
A, Subcortical exposure in one layer.
B, Opening the posterior gutter to mobilise the osteoperiosteal flaps.
C, Applying the iliac bone slices.
D, Closure in one layer, skin alone.

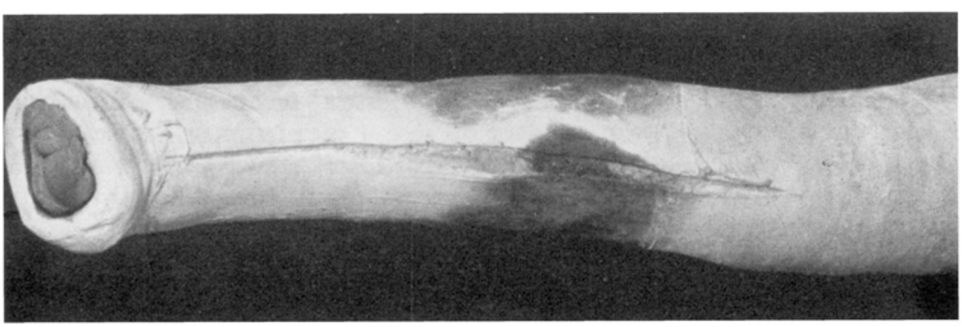

FIG. 196
Plaster split immediately after application. Note gaping of the split within first twelve hours.

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This plaster is left untouched for six weeks, during which time the patient can be ambulatory but non-weight-bearing on crutches. The plaster is then changed, the stitches removed, and a close-fitting walking plaster applied for a further six weeks. Usually the tibia will be found clinically solid six weeks after operation when the first plaster is changed, and three months after operation it will be possible to allow the start of full function without plaster and *before radiological consolidation of the shaft of the tibia is proved* (Fig. 197). By permitting weight-bearing when clinical union is present, irrespective of radiological appearances, no case in my series of thirty patients later developed movement or pseudarthrosis.

Special Note

I must emphasise that *strips* of cancellous bone are superior to chips or small fragments of cancellous bone in this method of grafting. When small chips of bone are used it is possible for these to fuse into two or three conglomerations with a fibrous union forming between the main masses. This possibility of failure does not occur when relatively long slices of iliac bone are laid on the surface of the bone.

FIG. 197

Fig. 197—Typical result of Phemister graft three months after operation. Clinically solid though radiologically tibial fracture still visible. Patient permitted full weight-bearing without plaster.

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