FRACTURES
DISLOCATIONS AND SPRAINS

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By

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Preface to the Second Edition

I know that Philip Wiles wished to bring out a second edition of "Fractures, Dislocations and Sprains" and that he had planned to reduce its size to its new dimensions. To me therefore it was not only an honour to have been asked to help with this task, but also a great pleasure to have thereby ensured that the teaching of my former chief lives on.

In this revision I have made no alteration without compelling reason. The essential clarity of presentation remains, although obviously many alterations in layout were essential in order to reduce the page size. It is a tribute to Wiles's sound practice of fracture treatment that his teaching has stood the passage of time and remains as sound as ever. Here and there, of course, text matter had to be re-written and illustrations sometimes changed. Usually, though, the changes have been small and often merely of emphasis. The greatest difficulty has been to retain as much as possible of the original format and general character of the book yet reduce its dimensions by half.

I am sure that nothing that I have done will in any way detract from the original intention that this book should, in succinct form, provide a generously illustrated account of the diagnosis and treatment of fractures and dislocations, and that it will remain as popular as ever with undergraduates and members of the several ancillary professions who play such an important part in the treatment of the injured. No doubt general practitioners will continue to find it of value as a handy book of reference.

RODNEY SWEETNAM

London W.1.

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UPPER LIMB—*continued*

TRUNK

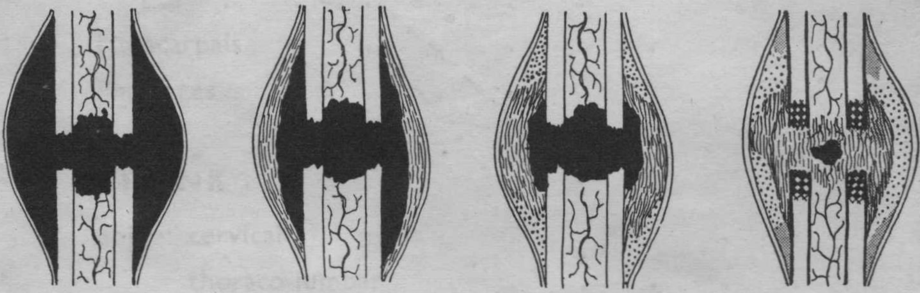
LOWER LIMB

HEALING OF FRACTURES

Tubular Bone. Bone is repaired in essentially the same way as soft tissues except that the granulation tissue formed around bone is converted into bone. The fracture haematoma is quickly invaded by granulation tissue and almost immediately the newly formed fibrous tissue, starting at the periphery, begins to differentiate into fibro-cartilage. This is followed by the deposition of woven bone which in turn is replaced by cancellous bone.

The new blood supply is derived from vessels that form on the periosteal surface, hence the process of repair begins at the periphery and spreads centrally. The nutrient arteries are necessarily damaged at the time of injury and reconstitution of the medullary blood supply takes place more slowly. It may be greatly delayed at sites such as the lower third of the tibia where no collateral nutrient arteries perforate the cortex distal to the fracture and therefore new medullary vessels can develop only on its proximal side.

Cancellous Bone. There is no surrounding haematoma or ensheathing callus. The clotted blood between the fragmented trabeculae is organized and calcified by direct spread from the adjacent bone. The process is quicker and more certain because cancellous bone has a generous blood supply and repair can proceed on both sides of the entire damaged area.

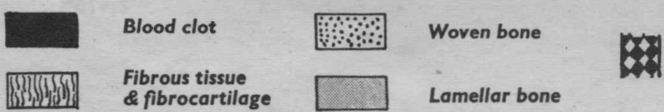


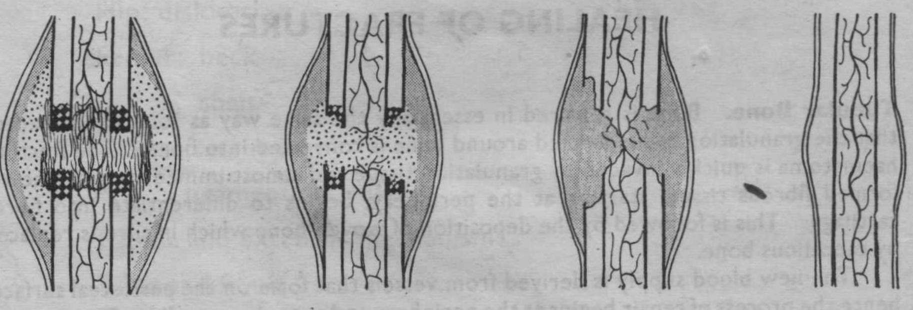
The blood clots and is quickly invaded by granulation tissue from the periosteal surface.

Starting at the periphery, the fibrous tissue proliferates and differentiates into fibrocartilage.

Woven bone is laid down starting at the angles on about the fourth day.

Woven bone has bridged the fracture and its replacement by lamellar bone is already beginning.





Deposition of woven bone continues and lamellar bone has bridged the fracture.

Necrotic bone is being resorbed; new medullary blood vessels are forming.

Necrotic bone has been replaced and the shaft is being reshaped.

It may take more than a year for the bone to become normal.

Speed of Healing. The process cannot properly be divided into stages because all the various phases are in progress simultaneously in different areas. However, since the bone is strong enough for use long before remodelling is complete, it is convenient to recognize two clinical stages, union and consolidation. The following table gives an indication of the expected times at which these stages will be reached, but they are far from constant.

APPROXIMATE TIME-TABLE IN WEEKS (*Perkins*)

	Upper limb		Lower limb	
	Union	Consolidation	Union	Consolidation
Spiral or long oblique	3	6	6	12
Transverse	6	12	12	24

The times can be halved for young children.

Union is said to be present when the fracture has been bridged by woven bone. There is usually some radiological evidence of the new bone, the fracture no longer feels "springy" and it does not hurt when it is gently stressed, but the callus may still be tender. At this stage the splints can often be removed, but normal use, particularly weight-bearing, is not yet possible.

Consolidation. This, from a clinical point of view, may be said to have taken place when sufficient woven bone has been replaced by lamellar bone to give the necessary strength to permit normal use of the limb. There is no pain or tenderness and X-rays show that the fracture has been bridged by well-formed bone.

Slow & Delayed Union. Deposition of bone has been unusually slow, probably because of one of the reasons given below as hindering union. X-rays may show some resorption of bone but no sclerosis or cavitation, and there is no undue separation of the fragments. It is probable, but not certain, that union will eventually occur if good splinting is continued for long enough.

Non-Union. Established non-union (it is more accurately referred to as fibrous union) is present when the granulation tissue around the fracture has been converted into dense fibrous tissue and the ends of the bone are sclerosed. Osteogenesis has ceased and bony union will not take place spontaneously however long the limb is splinted. At a few sites strong fibrous union does not interfere with function in any way but as a rule there is pain and instability. Occasionally a cavity forms in the fibrous tissue and there is a wide range of movements that are not under proper muscular control (pseudarthrosis).

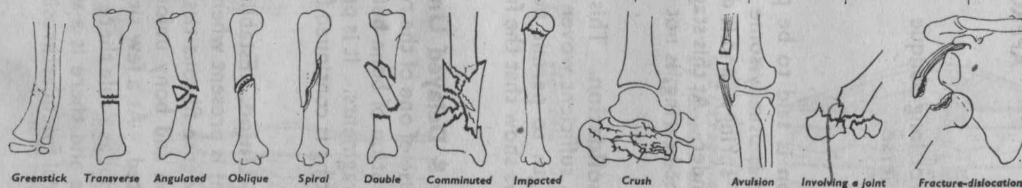
FACTORS	*FAVOURING UNION*	*HINDERING UNION*
Splinting	good	poor
Haematoma	undisturbed	dispersed by operation, etc.
Blood supply	good	poor
Apposition	wide, e.g. spiral fracture	interposed soft tissues
Bone ends	impacted	separated by traction
Age	youth	diseases of bone

CLASSIFICATION

FRACTURES MAY BE CAUSED BY

- **VIOLENCE** — DIRECT *or* INDIRECT
  - **CLOSED** (Simple fracture)
  - **OPEN** (Compound fracture)
    - **FROM WITHOUT** (An object penetrates the skin)
    - **FROM WITHIN** (A spike of bone perforates the skin)
- **FATIGUE** (Stress fracture)
- **DISEASE** (Pathological fracture)

PATTERN OF FRACTURE



NOMENCLATURE

MECHANISM

An overwhelming proportion of fractures is caused by violence. The relatively small number that is due to fatigue, and those occurring in diseased bone, are described on pages 18–21.

Study of the mechanism by which fractures are produced makes it easier to understand both the pattern and the displacement, and consequently the way in which the fragments can most easily be restored to position.

Direct Violence. The bone breaks at or near the place where it is struck. The pattern of the fracture depends on the severity and nature of the violence. A moderate force, for example an accidental kick on the shin, produces a transverse fracture without displacement; but a violent kick bends the bone at the site of the blow and causes an "angulated" fracture. A crushing injury such as a weight falling onto the toe, or a fall from a height onto the heel, causes comminution.

Indirect Violence. The stress is applied at points distant from the fracture. The site and pattern of the fracture depend on the physical condition of the bone and the precise distribution of forces at the moment of impact. Most fractures of the upper limb are caused by falls onto the outstretched hand; a young man may fracture his scaphoid or dislocate his wrist, but an old woman with porotic bones is more likely to sustain a Colles fracture. An added rotational force twists the arm and may produce a spiral fracture of the shaft of the humerus, but an abduction force fractures the surgical neck. The ankle breaks when the weight of the body twists the mortice of the ankle around the fixed talus; and the bodies of the vertebrae are crushed by forcible flexion of the spine.

PATTERN OF FRACTURE

The following descriptive terms are used:

Greenstick. A fracture of children, usually from indirect violence, in which the bone crumples on one side and may crack on the other

Transverse. Usually caused by direct violence.

Angulated. Usually direct violence; a triangular fragment or fragments are split from the concave side.

Oblique or spiral. Indirect violence, the bone being twisted in its long axis.

Double. Often from a combination of direct and indirect violence.

Comminuted. Broken into many fragments by direct or indirect violence.

Impacted. Indirect violence; the fragments are driven into each other and remain locked together.

Crush. Direct or indirect violence; always involves cancellous bone having only a thin cortical cover.

Avulsion. Stress applied to a ligament avulses a fragment of bone; or a contracting muscle, usually an extensor opposing a flexion force, avulses the fragment of bone into which it is inserted.

Involving a joint. The line of fracture crosses the articular cartilage of a joint.

Fracture-dislocation. The fracture either involves a joint that is dislocated, or it is so placed as to make the joint unstable.

DISPLACEMENT

The displacement of the fragments is determined by the nature and direction of the violence causing the fracture, and the subsequent effects of gravity and muscle pull. Displacement is described in the following terms:

Angulation. The angulation is said to be forwards when the concavity faces forwards.

Rotation. The distal fragment is rotated, usually in its long axis.

Lateral (medial, anterior or posterior). The distal fragment, usually of a transverse fracture, has shifted laterally but there is still some contact between the ends of the bones.

Overlap, or shortening. Complete lateral displacement enables the fragments to overlap; or the fracture is oblique and the distal fragment slides proximally.

Bayonet apposition. A spike of bone on one side of a jagged fracture is placed in the medullary cavity of the other; lateral displacement is present but the fracture is stable.

STABILITY

Some fractures are stable after reduction and need only simple splinting to prevent angulation or rotation, but others are inherently unstable and special precautions are necessary to prevent gross redisplacement. Stability depends partly on the direction of the line of fracture, partly on the forces applied by muscle pull, and partly on the integrity of the ligaments.

Line of fracture. Transverse fractures, those with "bayonet" apposition, greenstick fractures, and impacted fractures are usually stable. The first two, when treated with the limb horizontal, may angulate from the force of gravity (for example, a fracture of the shaft of the femur in a Thomas's splint), but there is little risk of redisplacement.

Spiral fractures and oblique fractures having a slope of more than 20° are usually unstable and shortening recurs unless steps are taken to prevent it. Gravity can sometimes be used for the purpose as when a fracture of the shaft of the humerus is treated by suspending the wrist from the neck.

Comminuted fractures are usually unstable unless impacted.

Muscle pull, when unbalanced, tends to redisplace certain fractures. Rotational fractures of the radius and ulna nearly always redisplace unless the pronators and supinators are balanced by correcting the rotational displacement of the radius; and oblique fractures of the shaft of the humerus just below the insertion of the deltoid are often insecure because of the unbalanced action of this muscle.

Avulsion fractures caused by muscle pull are usually unstable and the fragments may be widely separated.

Ligaments. The stability of joints depends largely on the integrity of the ligaments so fracture-dislocations are unstable in most circumstances. Examples are fracture of the body of a vertebra accompanied by rupture of ligaments and fracture of the lateral malleolus of the ankle associated with rupture of the medial ligament.

TREATMENT

ASSOCIATED INJURIES

Fractures are always accompanied by some soft tissue injury; it may be negligible but on occasion it is so severe as to dominate the picture.

Shock. ***Primary Shock*** may occur immediately after any injury, even a minor one. The vaso-constricting nerves are inhibited, the peripheral vessels dilate and the blood pressure drops, the patient becomes pale, and he faints. Spontaneous recovery takes place in a few minutes.

Secondary Shock develops later although its development must be anticipated. It is usually due to haemorrhage (but occasionally to cerebral injury, respiratory embarrassment, etc.) It is common after fractures of the major long bones because the medullary blood vessels are torn and there is free bleeding into the soft tissues. The blood loss from a closed fracture of the femur is seldom less than two pints, and from a fractured tibia it may be as much as a pint.

Reduction of the total blood volume to an amount less than is necessary to supply all the tissues requiring it is quickly compensated by contraction of the peripheral blood vessels. The skin therefore becomes pale, cold and moist, and the heart beats faster. Recovery is prompt if the blood volume is immediately restored by transfusion.

Transfusion, particularly with older people and those who have taken some time to reach hospital, should be started immediately on arrival. A rough indication of the quantity of blood required when there are multiple injuries is two pints for each fractured femur plus one pint for each tibia, humerus, and forearm. Transfusion, of course, has priority to radiological examination.

Respiratory Obstruction is a frequent cause of early death following severe multiple injuries. Prevention and correction is a primary "first-aid" measure.

Visceral Injuries such as rupture of the bladder or spleen and perforation of the pleura have priority over the fracture in treatment, but shock is reduced, further damage is prevented, and it is easier to move the patient if a temporary splint is applied at once.

Joints. A dislocation should be reduced and the haemarthrosis aspirated before a fracture is set. An intra-articular injection of hyaluronidase reduces the subsequent infiltration of the joint capsule with blood and therefore the risk of joint stiffness.

Ischaemia may follow injury of a main artery, most commonly the brachial artery in children. The peripheral pulse must always be checked at the first examination, and during the next few hours watch for the *4 p's*—pulselessness, pallor, pain, paralysis. The appearance of any of these is an urgent indication to remove the splint, check the reduction, and then, if recovery is not immediate, to explore the artery—every minute counts (p. 44).

Nerve Injury is caused by the accident and not by the surgeon's attempts at reduction; nevertheless, failure to recognize its presence before reduction may involve him in expensive litigation. Always look for and record loss of sensation or active movement at the time of the first examination.

REDUCTION

Not all fractures require reduction. It is unnecessary when there is no displacement or the displacement is trivial; it is meddlesome when the displacement is of a nature that will leave no functional or cosmetic disability; and in some circumstances it is harmful.

Closed Reduction by manipulation is always the better method because it does not disperse the haematoma, it need not inflict further damage on the soft tissues, and it carries no risk of infection. Perfect anatomical reposition may not be obtained but this is seldom of importance provided there is reasonable apposition of the fragments and the alignment of the bone is restored.

The displacement is first studied so that the corrective forces, which need never be great, can be applied in the proper direction. Failure to take this precaution is probably the commonest cause of a poor result. The details vary with each fracture but reduction, on most occasions, is surprisingly easy once the mechanics have been appreciated.

The fragments cannot be moved relative to each other until they have been separated. Impacted fractures needing reduction must therefore be disimpacted. This is usually managed by increasing the deformity, e.g. with Colles's fracture the lower fragment is bent still further backwards.

Fractures of the shafts of long bones can sometimes be reduced after applying moderate traction in a longitudinal direction but this may be prevented by periosteum that has remained intact on the concave side. It is harmful to use sufficient force to rupture the periosteum. A better method is to increase the deformity by angulating

After Charnley

the fragments in the direction of the concavity, then bring the adjacent borders of the fragments into contact, and finally restore the alignment; the intact periosteum prevents over-correction.

Open Reduction. The operative treatment of fractures not only requires special experience and special equipment, but it must be undertaken in conditions that reduce the risk of sepsis to a minimum—a badly reduced fracture gives a better functional result than an infected fracture.

Open reduction is indicated when:

- internal fixation of the fragments is desirable,
- perfect apposition is important, e.g. a fracture involving a joint,
- closed reduction has failed because soft tissues are interposed between the fragments, as when a flap of periosteum is infolded above the medial malleolus, or a spike of femur has perforated the quadriceps; or because of a special difficulty such as the correction of rotational deformity in some fractures of both bones of the forearm.

SPLINTING

The word splinting is used rather than the more popular "immobilization" because immobilization cannot in fact be achieved with an external splint and the use of the term gives the wrong impression of what is being done.

Not all fractures require splinting, indeed it may do more harm than good when the fracture is of a type that is naturally stable because it interferes with recovery of the soft tissues. The more important of these are impacted fractures of cancellous bone, e.g. some fractures of the surgical neck of the humerus and of the calcaneum, and minor crush fractures of the vertebrae.

There are a number of fractures that would unite satisfactorily and in good position without splinting but which need support to prevent pain when the limb is used. Amongst these are some fractures of the fibula, the metatarsals and metacarpals, and the phalanges of the toes, and cracks and chips of the tarsal and carpal bones. Recovery tends to be quicker if plaster-of-Paris is avoided and it will often be found that elastic strapping gives sufficient support; a plaster cast can be applied later if strapping proves to be inadequate.

Splinting is necessary for most fractures of the major long bones, for unstable fractures of the spine and pelvis, and for some fractures of the hands and feet. Its object is to maintain the position of the fragments and prevent movement between them but it should be so arranged as to permit the greatest possible use of the muscles included in the splint and of the limb as a whole. A plaster-of-Paris cast is the best splint for most fractures, but some are better treated by traction or by internal fixation.

Plaster-of-Paris. A plaster cast, whether padded or unpadded, cannot truly immobilize a fracture because of the softness of the surrounding muscles and fat, and because the size of the limb it encloses varies with the continually changing amount of oedema. However, it serves its purpose well enough if it is applied with skill; a badly padded, badly moulded cast cannot hold a fracture in position.

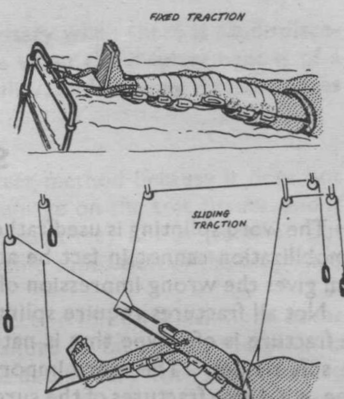
The skin should be protected by a sleeve of stockinette. A thin layer of "plaster wool" adds to the comfort of the patient, and it does not reduce the efficiency of a properly applied cast, but it must be rolled on evenly.

A plaster cast, as Charnley has eloquently pointed out, is not just a mould exerting even pressure over the whole surface of the contained limb. If it were, fractures with a tendency to redisplace would do so when the limb shrank. Fixation is provided by pressure at three points, one over the convexity of the original deformity and the other two at the ends of the bone on the opposite side. The periosteum on the concave side is often intact and prevents redisplacement in that direction.

Plaster technique cannot be taught by precept. It is only by practice that a surgeon can acquire the "feel" of a fracture, and learn to recognize the presence of an intact periosteal bridge, and the directions in which pressure should be applied whilst the plaster is setting.

Traction alone is seldom used for reducing fractures but it is valuable for holding the position after manual reduction, particularly with fractures of the shaft of the femur.

The following general terms are used in connection with traction:



Fixed traction. The cords leading from the adhesive plaster or Steinmann pin are tied to the end of the splint.

Weight or balanced traction. The cords pass over a pulley fastened beyond the foot of the bed and are tied to a weight. The splint is suspended from a beam by springs or counterbalanced by weights.

Skin traction. The force is exerted indirectly by means of adhesive plaster stuck to the skin.

Skeletal traction. The force is exerted directly through the skeleton by means of a Steinmann pin.

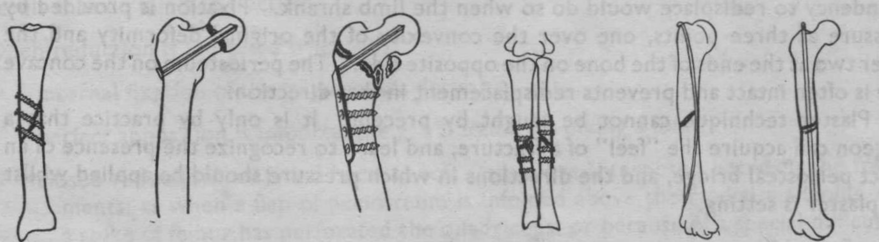
The simplest and most reliable method is fixed, skin traction applied to a limb supported on Thomas's splint. The mechanical forces concerned are then operating to the best advantage, and there is less risk of pulling the fragments apart or of damaging the knee.

Internal Fixation ensures close apposition of the fragments and prevents all but a trivial amount of movement. It does not, however, speed union, and in some circumstances it retards it. Nor does it give complete security against the deforming forces—screws break and nails bend with distressing regularity unless additional support is given. Therefore, with certain exceptions such as a trifin nail in the neck of the femur and an intramedullary rod in the shaft of the femur, a plaster cast is usually also applied.

Internal fixation is indicated when:

the fragments cannot be held in position by other means,
reduction can be effected only by open operation,
and sometimes to avoid a prolonged period in bed.

There are a number of different methods of internal fixation each serving a different purpose. The basic design of the appliances in common use is illustrated below but there is a great variety of each. There is a tendency towards more rigid internal fixation using stronger plates often applied with the help of a device to produce compression across the fracture. Intramedullary rods must be thick enough to fit tightly inside the medullary cavity.



Screws only ***Trifin nail*** ***Trifin nail and plate*** ***Plates and screws*** ***Intramedullary nail*** ***rod***

OPEN FRACTURES

An open (or compound) fracture is one in which there is direct communication between the fracture and the surface of the skin.

Open from within—the skin has been punctured by a spike of bone. The wound is potentially infected, and it should be treated as if it were, but a more limited operation than that described below is usually sufficient. Healing by first intention is the rule.

Open from without—the skin has been broken by the blow causing the fracture, or torn by the distortion of the limb, and much dirt may have been introduced. However grave the injury may at first appear, most limbs can be saved if the main arteries are intact, and even they can occasionally be repaired with a graft.

Haemorrhage. This is a major danger when there is extensive soft tissue damage as occurs with gunshot wounds. It can nearly always be controlled by elevating the limb and applying a pad and firm bandage directly over the wound—tourniquets have caused the loss of more limbs than they have saved.

Shock. Both primary neurogenic shock and secondary shock due to haemorrhage may be severe. They are reduced by temporary splinting applied where the victim lies, and by morphia. A transfusion should be started as soon as possible, and without waiting for the blood pressure to fall.

PRIMARY TREATMENT

All open fractures, even when there is no obvious contamination, must be treated as if they were infected. Bacteria have certainly been introduced and their chance of survival depends on the amount of soft tissue damage; they thrive on devitalized tissue which must be removed without delay.

Antibiotics cannot penetrate dead tissues so they cannot replace surgery; but although they cannot be relied on to prevent infection, they do reinforce the natural defences of the body and increase the number of wounds that heal by first intention. The combination of benzyl-penicillin and Ampicillin is often advised until the sensitivity of any surviving organisms is known.

Anaerobic organisms grow well in dead tissue and are a potential danger in spite of antibiotics. Anti-tetanus serum and anti-gas gangrene serum are of doubtful prophylactic value. A "booster" dose of tetanus toxoid for those already actively immunized is essential and for those not so immunized a course should be started forthwith.

Toilet of the Wound. Delay of more than six hours before removing dead and dying tissues is permissible only in exceptional circumstances. The operation, which is often known as "debridement", needs care and experience.

A tourniquet should not be applied. The wound is protected whilst the surrounding skin is cleaned and draped. The smallest possible margin of bruised or ragged skin is then excised. The wound is extended, usually in the long axis of the limb, and the deep fascia is incised for as far as it covers damaged muscle. Blood clot, foreign bodies and dirt are removed from intermuscular spaces and around bone, and all crushed and dead muscle, as judged by the colour and the absence of contraction when