FRACTURES AND DISLOCATIONS

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PREFACE

This book has been written in the hope of providing valuable assistance to students, post-graduates, residents and also a means of reference to members of the medical profession.

I have endeavoured to make it a practical work by the inclusion of copious diagrams and I am indebted to Mr. Dilip Chatterjee for his assistance in their preparation. I have not given a detailed description of operative techniques as this would have resulted in too voluminous a book.

The subject matter is the outcome of 20 years' personal experience of surgical practice in India, United Kingdom and other European countries.

I wish to place on record my appreciation and thanks for their help to :

My wife, Mrs. Patricia H. Bose for her inspiration and assistance in assembling and correcting materials.

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September 1979.

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CHAPTER ONE

GENERAL PRINCIPLES OF FRACTURES AND JOINT INJURIES

FRACTURES

Definition: A *Fracture* indicates disruption of the continuity of bone. This can involve a simple disruption of the periosteum and indentation to complete separation of the fracture segments.

CAUSES OF FRACTURE

Age and Sex: Fractures can occur at any age but are more common during the active period of life. Amongst the elderly people the bones may be weakened by porosis and are liable to break by trivial injuries. The neck of femur, for example, bears the burden of fracture very often in old women due to post-menopausal porotic condition.

Violence: Fractures are produced by violence which exceeds the strength of the bone. This violence can be of (*a*) direct or (*b*) indirect type.

(*a*) *Direct Violence*: This may be due to a direct hit or to part of the body being trapped between two opposing forces producing a crushing injury. The former type usually produces a transverse fracture whereas the latter results in a comminuted lesion.

(*b*) *Indirect Violence*: This type of injury occurs by the transmission of stress to a place of bony architecture distant from the site of impact, *e.g.*, fracture of clavicle after falling on outstretched hand. The force is transmitted upwards along the upper limb to the clavicle.

Torsional Injury: This is produced by a twisting sprain. When the foot is fixed on the ground, a sudden twisting movement of the leg can produce a fracture of the tibia.

Stress: Continuous stress may produce fatigue of the bone which can give way without being exposed to direct violence. This usually happens in the lower limb which has to bear the burden of the body weight. The lesion can affect either the tibia, metatarsal bones or neck of femur.

Muscular Contraction: Sudden muscular contraction can produce fracture at the site of its attachment to the bone. Examples are fractures of the greater tuberosity of humerus, patella and fractures in convulsive diseases.

(*a*) *Fracture of the greater tuberosity of the humerus*: Abduction force on the shoulder can produce fracture of the greater tuberosity of the humerus. This is due to the sudden contraction of the supra and infraspinatus muscles.

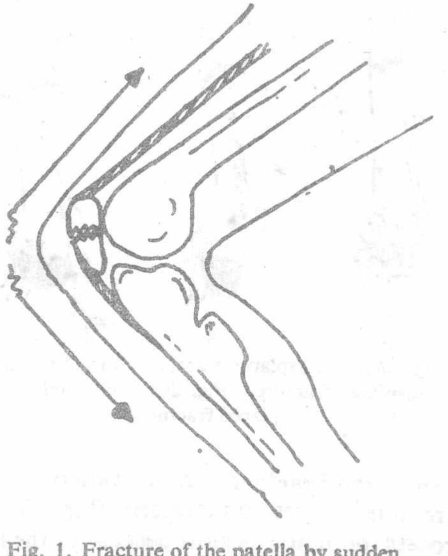


Fig. 1. Fracture of the patella by sudden contraction of the quadriceps.

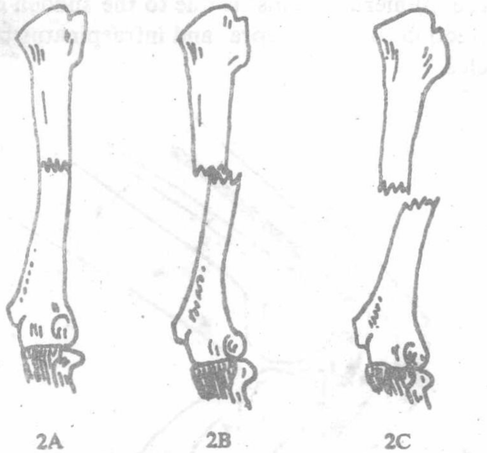
(*b*) *Fracture of the patella*: The patella may similarly sustain fracture by sudden contraction of the quadriceps (Fig. 1).

(c) *Fractures in convulsive diseases*: The diseases of convulsive nature like tetanus and epilepsy can produce fractures by sudden spasmodic contraction of the muscles.

TYPES OF FRACTURES

The types of fractures that are produced depend generally on the nature of the injury, *e.g.*, direct, crushing or a twisting force. The age of the patient has a characteristic influence. Children suffer mainly from greenstick fracture due to the soft texture of the bony architecture.

Displaced and Undisplaced Fractures: This terminology is applied on the amount of displacement of the fracture segments. Thus the fracture may be undisplaced, partly displaced or completely displaced (Figs. 2A, 2B, 2C).



2A 2B 2C

Fig. 2A. Undisplaced fracture. Fig. 2B. Partly displaced fracture. Fig. 2C. Completely displaced fracture.

Transverse Fracture: In this variety the fracture line passes transversely (Fig. 3). The process of union is slow because of the lesser fractured surface area in comparison to the other types. When the fracture surfaces are in apposition there is stability at the site of fracture. In cases where there are displacements of the segments, the fractures must be reduced and any deformity corrected.

Fig. 3. Transverse fracture.

In transverse fracture of the tibia, weight-bearing can be encouraged at an early date because of the stability at the site of lesion.

Oblique and Spiral Fractures: These types are produced by twisting injuries (Figs. 4A, 4B).

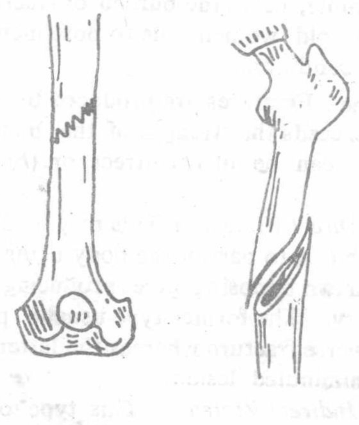


Fig. 4A. Oblique fracture. Fig. 4B. Spiral fracture.

The process of union can be quick because of the large fractured surface areas being opposed to each other.

The stability is not good and weight-bearing with these types of lesions in the lower limbs should be delayed. The oblique varieties of the fracture tend to form a gliding surface when early weight-bearing is allowed. This is therefore deferred till the radiological evidence of union is very sound. In these types success may be obtained by closed reduction ; but displacement may take place even after reduction because of the oblique nature of the fracture line. Open reduction and fixation with screw can be a simple device. This will provide perfect apposition and stability.

Impacted Fracture : The fractured segments are driven into one another and become impacted (Fig. 5). The fracture is stable ; but

Fig. 5. Impacted fracture.

this must be immobilised, otherwise displacement is likely to occur. Union is quick in this type of lesion.

Comminuted Fracture : This is the result of

Fig. 6. Comminuted fracture.

severe direct injury, usually that of a crushing variety. The bone is broken into several segments (Fig. 6). The fracture is unstable and is difficult to retain in the reduced position.

Butterfly Fracture : The bone breaks into three pieces and one small triangular segment lies in between the two main bone pieces. The segment looks like a butterfly (Fig. 7).

Fig. 7. Butterfly fracture.

Segmental Fracture : The bone is broken into several segments. In most cases there is a free intervening segment in between the two main pieces (Fig. 8).

Fig. 8. Segmental fracture.

Avulsion Fracture : Sudden contraction of muscles can avulse a segment of bone. This can happen in fracture of the greater tuberosity of humerus and fracture of the calcaneum. These are the results of sudden contraction of supraspinatus muscle and tendo-achillis (Fig. 9).

Fig. 9. Avulsion fracture.

Compression Fracture : This is produced by a compression force. The commonest site is the body of the vertebra. The bones of the lumbar vertebra are more usually affected than the bones of other parts of the body (Fig. 10).

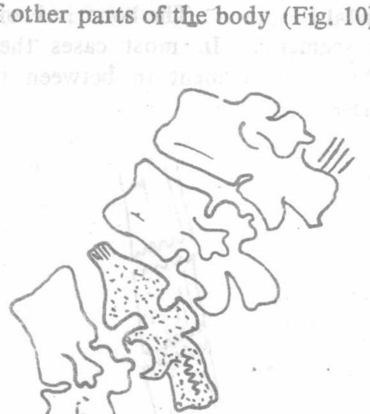


Fig. 10. Compression fracture.

Fractures in Children

Green Stick Fracture : Amongst the children the bones are not rigid. This causes the bone to break like a green stick with one surface intact. The periosteal continuity is maintained on one side while disruption takes place on the other (Fig. 11). The green stick fracture is

Fig. 11. Green stick fracture.

not always stable. There may be unstability in cases of spiral and comminuted fractures of the green stick variety (Fig. 12A, Fig. 12B, Fig. 12C).

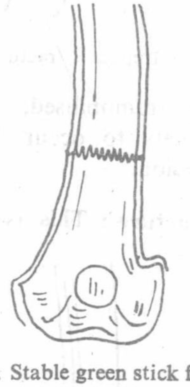


Fig. 12A. Stable green stick fracture.

Fig. 12B. Unstable spiral green stick fracture.

Epiphyseal Injury in Children : The epiphyseal plate may be injured in children along with the interruption of its blood supply. The

Fig. 12C. Unstable comminuted green stick fracture.

fracture separation of the epiphysis may take place along the transverse axis of the bone or it may split in a vertical direction (Fig. 13A,

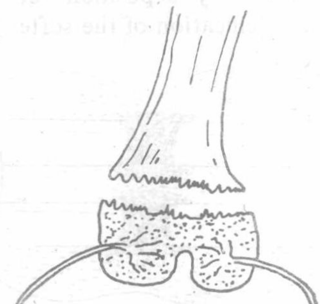


Fig. 13A. Transverse fracture of the epiphysis.

Fig. 13B). Defective development in the form of arrested growth or angular deformity of the bone may develop after this type of injury. This is the result of interference with the epiphyseal blood supply and irregular new bone formation. Treatment of these fractures should be followed on the same principles as the fractures at other sites. Early proper reduction and its management checked by repeated x-ray can assure proper blood supply of the epiphysis and its further growth.

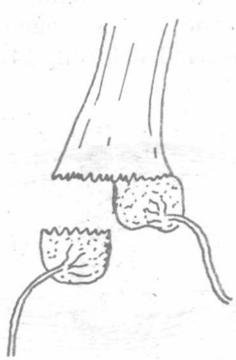


Fig. 13B. Vertical split of the epiphysis.

Compound Fracture : In this condition fracture segments communicate with the exterior through breach of the skin. This may be produced due to causes from inside or from outside.

Inside causes : The fractured bone may angulate and the sharp bony projections may penetrate through the muscles and skin.

Causes from-outside : The fracture area can be exposed by the loss of skin and soft tissues.

Risk of infection : This is high in compound fractures. Development of osteomyelitis is common even after proper care of wound and use of antibiotics.

UNION OF THE FRACTURE

To aid union of a fracture many changes take place both locally and generally. While these changes in the form of histological and biochemical reactions are well understood, many of the contributory factors which help in the union of a bone are not known at all. Our knowledge is yet quite inadequate to explain why cases managed by the same surgeon on the same principles, in comparable age group of patients having similar lesions, show variations in the process of union of bone.

(*a*) **Formation of Haematoma :** The formation of haematoma takes place immediately at the site of lesion. Blood pours in from the bone marrow, ruptured periosteum, traumatised muscles and the adjoining soft tissues. The extravasated blood eventually is transformed into a semisolid clot surrounded by muscles, fascia, tendons and skin (Fig. 14).

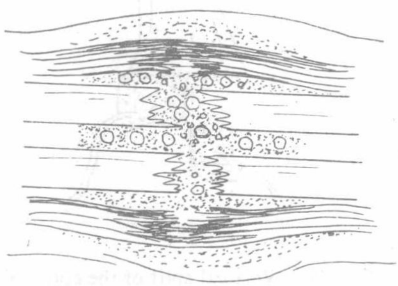


Fig. 14. Haematoma of the fracture site which forms a clot.

(*b*) **Formation of Callus** : The process starts in the form of a local inflammatory reaction. This usually develops after a period of about 48 hours from the time of the onset of fracture. Firstly, the dead and necrotic tissues are removed and the new ones proliferate. The osteogenic and chondroblast cells derived from the periosteum and the endosteum invade the area. The granulation tissues from the surrounding area enter at the site of lesion. This newly formed mass is called *temporary callus* or *woven bone*. Formation of this mass usually takes place between the fifth to tenth day (Fig. 15).

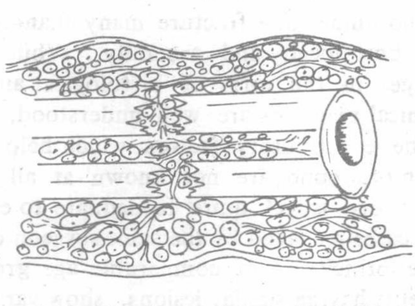


Fig. 15. Invasion by osteoblast, chondroblast and granulation tissue.

(*c*) **Further Development of Callus** : Deposition of further callus in the form of cartilaginous and fibrous mass takes place slowly. This is developed from the already formed mass composed of the cellular and granulation tissue. This newly formed mass occupies the space between the ends of the bone and surrounding the site of fracture (Fig. 16). The new bone when

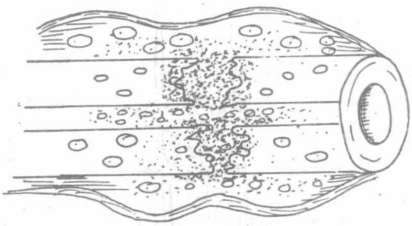


Fig. 16. New bone started forming in the endosteal space.

effectively formed is deposited in the endosteal space and in the subperiosteal area. They eventually fuse with each other to provide a firm support.

(*d*) **Deposition of New Bone** : New bones are laid down as the progress of union proceeds. The whole procedure involves absorption of the previously deposited fibrous and cartilaginous mass followed by deposition of new bones (Fig. 17). Calcification of the softer tissue takes

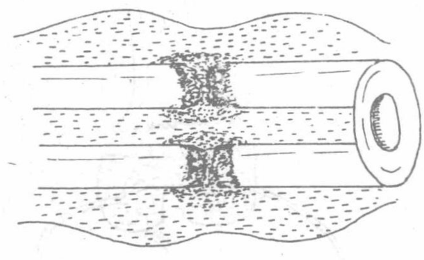


Fig. 17. Fibrous tissue and cartilage formation.

place simultaneously along with the deposition of new bone. Calcium and phosphate are collected probably due to some local biochemical reaction. The new bone when effectively formed is deposited between the ends of the bones and in the subperiosteal space and finally provide a firm support.

(*e*) **Remodelling of New Bone** : This is the final stage and may involve a period of several months. The whole callus now ossifies. The immature bone changes into a mature one. The bulky callus is absorbed and the whole mass takes the shape according to the contour of the bone. Finally the medullary canal is formed and the normal structure of the bone is restored (Fig.18).

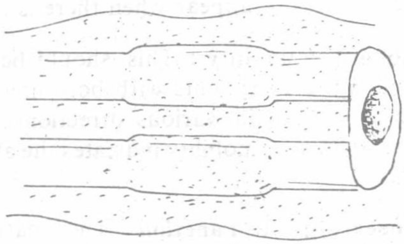


Fig. 18. Remodelling of the fracture site.

Nature of Callus Formation and Healing : The callus formation is recognised by x-ray during the process of healing. It is the effective distribution and not the excessive callus which is desirable. The amount of callus formation depends mainly on the type of bone and on the movements at the site of fracture. There are various types of union which may be observed at the end of healing process. This can be interpreted by radiological findings.

(*a*) No Callus Formation but Fibrous Union : There are cases where union takes place without any evidence of callus formation, but it takes place by the formation of fibrous tissues (Fig. 19). This is especially characteris-

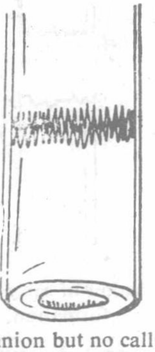


Fig. 19. Fibrous union but no callus formation.

tic where cancellous bones are abundant. Radiological evidence may be deceptive and one may proceed to the wrong diagnosis of non-union. It is the clinical evidence which provides the proof of satisfactory union characterised by strength and stability at the site of fracture.

(*b*) Minimal Callus but still Union : In this condition the callus formation takes place between the endosteal surfaces of the fracture ends whereas the subperiosteal callus formation is almost absent (Fig. 20). Clinically the union

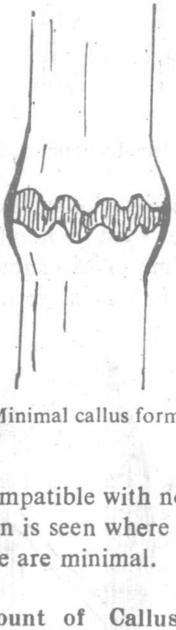


Fig. 20. Minimal callus formation.

is rigid and is compatible with normal activity. This type of union is seen where movements at the site of fracture are minimal.

(*c*) Normal Amount of Callus Formation: The desire of every surgeon is to see a fair amount of callus formation. This is formed between the ends of the fracture segments and in the adjoining subperiosteal area. This type of union produces an effective union both from inside and outside the bony ends (Fig. 21).

(*d*) Non-union with Excessive Callus Formation : In some cases excessive callus formation may be seen in the subperiosteal layer surrounding the fractured ends, while new bone is formed in the endosteal spaces. The ensheathing callus formation may provide some fixation but fails to provide an effective rigid support (Fig. 22). Refracture usually occurs when immobilisation is discontinued.

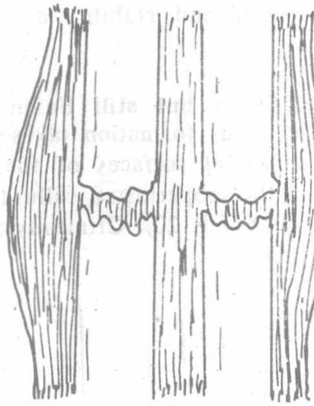


Fig. 21. Normal amount of callus formation.

The effective way to handle this situation is to provide further rigid immobilisation for a longer period of time. This enables the ensheathing callus to alter its character and it becomes more

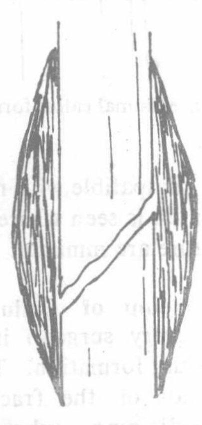


Fig. 22. No callus in the endosteal space but callus formation in the subperiosteal area.

rigid. Excessive subperiosteal callus is seen when the fractured ends are mobile.

DIAGNOSIS OF UNION OF FRACTURE

Satisfactory union of the bone must be assessed by (1) clinical and (2) radiological findings. Sometimes the diagnosis may be difficult and the surgeon's clinical experience can only help to solve the problem.

Clinical Examination

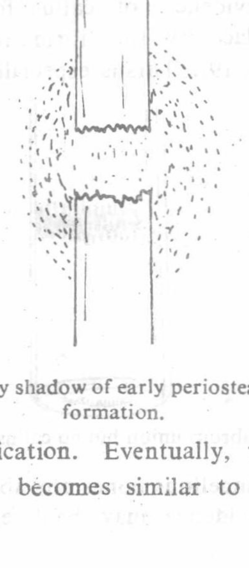
(*a*) **Pain and Tenderness** : The patient should be asked about any pain at the fractured site. Any local tenderness should be examined by finger pressure over the affected area. Pain and tenderness disappear when there is union.

(*b*) **Abnormal Mobility** : This should be tested by holding the segments with both hands and trying to angulate in various directions. Presence of abnormal mobility indicates the absence of union.

(*c*) **Observing the Function** : The patient is advised to perform the function involving the affected limb. In cases of fractures of the lower limb, the patient is advised to bear weight without any splintage. In case of non-union the patient experiences pain over the site of lesion. The condition is then confirmed by x-ray.

Radiological Evidence of Union

Periosteal Callus : This is the earliest evidence of union. First a hazy shadow is produced in the x-ray. The shadow becomes denser with pro-



23A. Hazy shadow of early periosteal callus formation.

gressive calcification. Eventually, the density of the callus becomes similar to that of the cortex of the bone. Finally, a continuous zone of calcification extends from one side of the fracture to the other (Figs. 23A, 23B, 23C). The

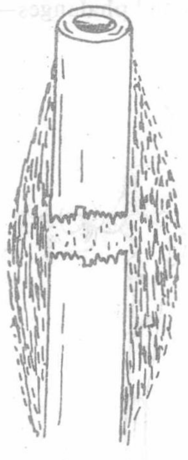


Fig. 23B. Progressive increase in density of callus formation.

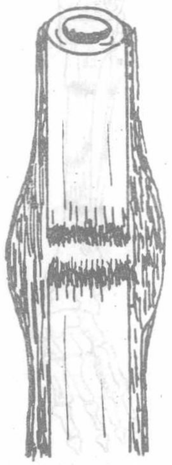


Fig. 23C. Continuous zone of calcification.

formation of callus depends on various conditions. More callus is formed when there is some distraction of the fracture segments rather than perfect apposition. The amount and nature of callus considerably differ at different sites. Intracapsular portion of the neck of femur, being devoid of periosteum, produces no periosteal callus. Union at this site depends completely on the formation of endosteal callus.

The bones surrounded by more muscles tend to produce more callus. Fracture of the femur therefore heals by excessive formation of callus whereas minimal amount is formed round the phalanges and skull which are surrounded by a minimum amount of muscles.

Endosteal Callus: The endosteal callus is found between the fractured segments. Immediately

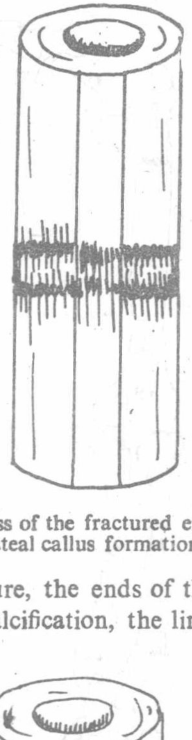


Fig. 24. Haziness of the fractured ends, opaque endosteal callus formation.

after the fracture, the ends of the bony fragments show decalcification, the line of fracture

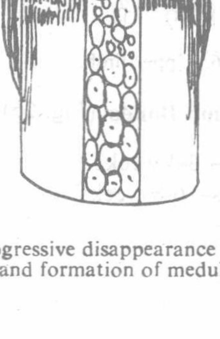


Fig. 25. Progressive disappearance of the fractured line and formation of medullary canal.

becomes more clear and comparatively smoother. With the formation of endosteal callus, the fracture line becomes more hazy (Fig 24). The space between the segments is found to be occupied by an opaque shadow. Finally, the fracture line disappears and the medullary cavity is reformed (Fig 25).

AVERAGE TIME FOR UNION OF FRACTURES

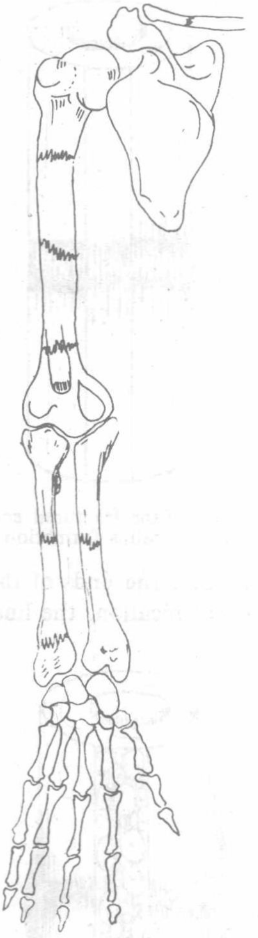


Fig. 26. Upper limb.

1. **Upper Limb Bones** (Fig. 26)

(*a*) Clavicle—3-4 weeks.
(*b*) Humerus—6-8 weeks.
(*c*) Radius—
Shaft—8-10 weeks.
Distal end—6-8 weeks.
(*d*) Ulna—8-10 weeks.
(*e*) Carpal bones—6-8 weeks.
(*f*) Metacarpals and phalanges—3 weeks.

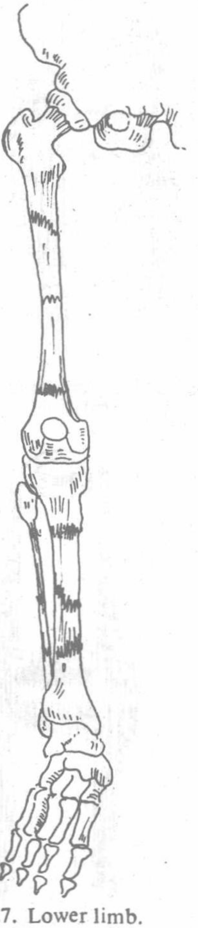


Fig. 27. Lower limb.

2. **Lower Limb Bones** (Fig. 27)

(*a*) Femur—10-12 weeks.
(*b*) Tibia—8-12 weeks.
(*c*) Fibula—8-10 weeks.
(*d*) Tarsal bones—6-8 weeks.
(*e*) Metatarsals—4-6 weeks.
(*f*) Calcaneum—8-12 weeks.

DEFECTS IN BONE UNION

Defective bony union can manifest in several forms and this may be due to various reasons. In most cases early recognition of these complications can be made during the process of healing. Most of the hazards are preventable. Sometimes the defect occurs at a later date, while the union has progressed satisfactorily, *e.g.*, growth disturbance in the form of shortening, lengthening and angulatory deformity.

The common defects in bone union are as follows :

1. Delayed union.
2. Non-union.
3. Mal-union.
4. Disturbance of growth—
   (*a*) Shortening of the bone.
   (*b*) Lengthening of the bone.

Delayed Union : This is a condition in which the power of developing new bone at the site of fracture has been impaired. The capacity for the growth of new bone still exists. If the condition is properly managed, the union will eventually establish but only after a longer period. Failure to recognise this condition and improper management will lead to non-union.

Non-union : This is an established condition where union can not take place without surgical interference. The bone ends are occupied by fibrous tissue. The osteogenic capacity to lay down new bone has already disappeared. Continuance of simple immobilisation will not alter the situation.

Causes of Delayed Union and Non-union : Most of the causes of non-union and delayed union are preventable. The factors which produce these conditions are almost common and are described together.

1. **Types of Bone**

(*a*) Bones with good blood supply : Union happens with almost certainty in cases where the bones have abundant blood supply. This is seen in cases of scapula, head and neck of humerus, pelvis, vertebra and calcaneum.

(*b*) Bones with poor blood supply : Interruption of the existing blood supply may impair the healing process. Places of disrepute are the waist of scaphoid, distal one third of tibia, neck of talus, distal end of ulna and neck of femur. Anatomical distribution of arterial blood flow to these bones are such that they may be disrupted after fracture.

2. **Nature of Injury** : Certain types of injuries can impair the healing process. Comminuted fractures, wide separation of the fracture segments, compound fractures, intense injury to the adjoining soft tissues belong to this category.

3. **Interposition of Soft Tissue** : Between the fracture segments muscle tissues or even periosteum may be interposed and interfere with the healing. This can be corrected during the process of closed reduction, but in some cases internal fixation is ideal.

4. **Fracture of One Bone** : Chances of delayed union exist when a single bone is broken out of the paired one. This is seen in fractures of forearm and leg bones. It is due to imperfect apposition of the fractured segments produced by the intact companion bone.

5. **Imperfect Reduction** : Perfect reduction with anatomical alignment is the key to achieve success. This is applicable to all fractures whether treated by closed or by open reduction. In case of fracture of the neck of femur, simple insertion of pin without performing perfect reduction prior to surgery will not produce union.

6. **Inadequate Immobilisation** : Immobilisation enables the fractured segments to remain stable. Movements will disrupt the callus and granulation tissue formation. This is accomplished by plaster, traction and sometimes by internal fixation. The technique differs at di-

fferent sites and depends also on the nature of lesion. Fracture of tibia can only be immobilised by long leg plaster. Below knee plaster is inadequate. Fracture of the neck of femur will require internal fixation by pinning. Treatment by plaster immobilisation fails to achieve this purpose.

7. **Excessive Traction** : Excessive traction can produce too much separation of fragments. This is likely to develop when too much weight is applied in cases of skeletal or skin traction. Muscle contraction can also distract the fractured segments. In fractures of patella and olecranon process of ulna, the quadriceps and triceps muscle contractions tend to separate the fracture segments. This distracting force is ideally neutralised by operative fixation with wire and screw.

8. **Surgical Interference** : Sometimes surgical intervention can interfere with the healing process. This may be due to inadequate fixation, interference with the local blood supply following stripping of the periosteum and escape of fracture haematoma which helps in callus formation.

9. **Infection** : This usually develops in cases of compound fracture or following operative reduction. A discharging wound or osteomyelitis is the final outcome.

DIAGNOSIS OF DELAYED UNION AND NON-UNION

1. **Clinical Examination** : There may be visible deformity at the site of fracture. This may not be a characteristic feature. Abnormal mobility and localised tenderness are always present over the sites of fractures in cases of delayed union and non-union.

2. **X-ray Evidence** : Radiological appearance can be helpful in establishing the diagnosis.

Delayed Union : There is minimal or no callus formation. The fracture line is visible. Sclerosis, which is evident at the site of fracture in case of non-union, is absent in delayed union (Fig. 28).

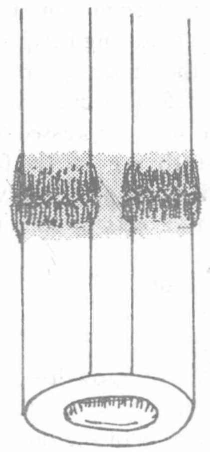


Fig. 28. Minimal callus with visible fracture line.

Non-union : Following features may be present in these cases.

1. **Separate Fragments** : In some cases x-ray evidence of non-union is clear by widely separated fragments without any visible communication between the ends (Fig. 29).

Fig. 29. Gross non-union.

2. **Smoothness and Sclerosis** : The ends of the fragments become rounded by the absorption