Other principles of treatment are the same as for lacerations and incised wounds.

**Tongue lacerations**
- Most stop bleeding spontaneously and do not need sutures.
- Repair under general anaesthesia if there is profuse bleeding or the full thickness of tongue is involved.
- Use absorbable sutures.

**Stab wounds**
- Stabbing may cause serious penetrating injuries to deep structures, which may lead to rapid death from haemorrhage or air embolus.
- The external dimensions of a stab wound may be deceptively small compared with the damage to underlying structures.
- Superficial stab wounds are treated in the same way as lacerations and incised wounds.
- Patients with penetrating wounds need resuscitation and emergency exploration under general anaesthesia.
- Never remove the penetrating object until the patient has been resuscitated and is in a secure surgical environment with cross-matched blood available.

**Needlestick injuries**
- If there is skin puncture, encourage bleeding and wash the wound thoroughly with plenty of soap and water. Dry the wound and apply a dry dressing if appropriate.
- If there is only skin contact, wash the wound with plenty of soap and water but do not scrub it. Scrubbing may damage the skin.
- If there is splashing into the mouth, rinse with plenty of water.
- If there is splashing into the eye, rinse with plenty of water. Obtain the help of a colleague to do this.

- If the identity of the donor (the person whose blood is on the needle) is known, try to find out whether that person has hepatitis B and/or HIV infection.
- Consider immunisation for hepatitis B and triple therapy for HIV if these are available.

**Complications of wounds**

**Retained foreign body**
- This will cause swelling beneath the wound.
- Secondary infection is more likely if there is a retained foreign body. If the foreign body is superficial, it must be removed by a competent surgeon under local anaesthetic. A general anaesthetic will be required if the foreign body is deeply placed and/or in an area with important structures, such as the hand or face.

**Infection**
- Tetanus: this is most likely to occur if the wound has been contaminated with soil and/or manure and the child is not fully immunised (see above).
- Bacterial. Prophylactic antibiotics such as flu/cloxacillin or co-amoxycillin should be considered in cases where wounds have been contaminated, but this does not lessen the need for thorough cleaning of such wounds.
- Antibiotic doses: flu/cloxacillin 25–50 mg/kg four times a day or co-amoxycillin 125/31 mg three times a day for 1–6 years or 250/62 mg three times a day for 6–12 years. Co-amoxycillin is effective in bite injuries. A five day course is usually sufficient.

**Delayed healing**
- This may be due to poor apposition of the edges, malnutrition and/or infection.
- Excision of the edges of the wound and secondary suture may be helpful, except in malnutrition.

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**7.2 Fractures in children**

**BOX 7.2.1 Minimum standards**
- X-rays.
- Splints.
- Plaster of Paris bandages.
- Traction.
- External and internal fixation.
- Physiotherapy.

**Introduction**
As any parent knows, all children are susceptible to injury. However, children in resource-limited countries are probably more at risk than their developed-world counterparts, as they often live in less regulated and protective environments. Once injured, there may be a considerable delay in their presentation to a healthcare facility, a situation that can complicate and restrict treatment options.

Scarcely X-ray resources and a limited range of treatment modalities can then further complicate treatment of paediatric fractures.

However, on a more optimistic note it can be said that paediatric fractures are often more ‘forgiving’ when compared to those of the adult; they are often easier to reduce, less requiring of internal fixation, are quicker to unite and, due to the potential for remodelling with continued skeletal growth greater degrees of mal-union can be tolerated.

**Diagnosis**
Certain features of the history and examination may suggest the presence of a fracture:
Open fractures

Open fractures occur where the fracture site communicates with a laceration or break in the skin relating to it. There is potential for the introduction of contaminants and resultant infection. Often open fractures are the result of a greater degree of violence than is the case for closed fractures.

Open fractures are graded according to the Gustilo classification:

- grade 1: skin wound of < 1 cm with minimal soft-tissue injury
- grade 2: skin wound of > 1 cm, with moderate soft tissue injury
- grade 3: these wounds typically involve a far greater degree of violence and energy transfer. This is further subdivided into:
  - A: extensive wound > 10 cm with crushed tissue and contamination but for which soft-tissue coverage is usually possible.
  - B: extensive wound > 10 cm, again with crushed tissue and contamination, but where it is not thought that local soft-tissue coverage is possible, and therefore a regional or free flap may be necessary.
  - C: any open fracture with an associated major vascular injury requiring repair for limb salvage.

Treatment is dictated by the extent of soft-tissue injury as reflected in the above grading system. The initial priority is a thorough debridement and copious irrigation of the fracture site in order to reduce the burden of contamination and lower the risk of infective sequelae. Once this has been done, some form of stabilisation is necessary: Internal fixation of open fractures carries a considerable risk of infection. Safer options are plaster application (with or without windowing to expose the wound) or external fixation.

It is often useful for a photograph of an open fracture to be taken by the initial assessor (perhaps on a mobile phone) so that the wound can remain covered until the patient is in the operating theatre. It helps to prevent frequent opening of the dressings and infection.

Compartment syndrome

The associated soft-tissue injury and subsequent swelling leads to an elevation of interstitial pressure within a closed fascial compartment, which results in microvascular compromise. If left untreated, tissue necrosis will occur. The commonest site is in the lower leg, but compartment syndromes can also occur in the thigh, foot and upper limb. The signs and symptoms of compartment syndrome include the following:

- a hard woody swollen extremity
- severe pain on passive movement
- tingling or burning sensations (paresthesia) in the skin
- pain out of proportion to the severity of the fracture and not relieved by splinting or analgesia
- numbness or paralysis (loss of movement) and absent distal pulses are late signs.

Although it is possible to monitor intra-compartment pressures, such technology will rarely be available. The alternative is to have a high index of suspicion for fractures involving significant soft-tissue injury, and regularly review the clinical condition of the limb.

Treatment of compartment syndrome is by prompt surgical fasciotomies to decompress the affected compartments. In the lower leg there are four muscular compartments separated by strong fascia:

1. the lateral compartment containing the peroneal muscles
2. the anterior compartment containing the dorsiflexor muscles of the ankle and toes
3. the superficial posterior compartment containing the gastrocnemius and soleus muscles
4. the deep posterior compartment containing the deep plantar flexors of the ankle and toes.

The lateral and anterior compartments can be decompressed through the same antero-lateral longitudinal incision. A single postero-medial incision can be used for the deep and superficial posterior compartments. In each case the fascial envelope containing the muscle group must be incised along its length in order to permit swelling and prevent the build-up of pressure within the compartment.

X-rays

X-rays are the most useful and specific diagnostic modality. Where possible, two orthogonal X-rays (at 90 degrees to each other) should be obtained, ideally including the joints above and below the suspected fracture site. Terms relating to fracture appearance on X-ray include the following:

- transverse: at 90 degrees to the long axis of the bone
- oblique: other than the above
- simple: involving a single fracture line
- comminuted: involving bony fragmentation
- greenstick: visible fracture at only one cortex on the X-ray view. Greenstick fractures are only seen in paediatric fractures, due to the flexible nature of paediatric bone; this implies intact periosteum along the opposite side to the fracture and is a good prognostic sign.

Salter–Harris classification

This relates to the X-ray pattern of fractures occurring around the epiphysis, or growth plate, of a bone. Such fractures occur in about 15–20% of major long bone fractures and 34% of hand fractures in childhood.

There are five grades, with increasingly poor prognosis for fracture outcome with increasing grade because of an increasing degree of damage to the growth plate. This will lead to limb shortening as the child grows.

1. Fracture across the epiphyseal line, not extending into the epiphysis or metaphysis. This occurs when the growth plate is very thick, and thus tends to be seen in young children. Healing is rapid and complications are rare.
2. Fracture across the epiphyseal line extending into the metaphysis, but not into the epiphysis. This usually occurs in children over the age of 10 years. Healing is usually rapid and there is rarely growth disturbance.
3. Fracture extending completely across the epiphyseal line
and into the epiphysis. This type of fracture can occur at any age and is associated with a poor prognosis.

4 Fracture extending from the metaphysis through the growth plate and into the epiphysis. This type of fracture occurs when the growth plate is partially fused, and it has a poorer prognosis.

5 Crush injury to the growth plate. This is caused by severe axial loading during a fall from a height. Inevitably there is partial destruction of the epiphyseal plate, and thus a considerable risk of growth disturbance.

Treatment of fractures

- **Reduce** the fracture (if displaced).
- **Hold** the fracture while bony healing occurs.
- **Rehabilitate**: restore function and range of motion.

The potential for remodelling with continued skeletal growth is more marked in younger children. It occurs to a greater degree in the plane of movement of the affected joint. As a result of remodelling, angular deformity can gradually resolve with growth, and thus accurate initial reduction is not mandatory. In contrast, it is important to accurately reduce intra-articular fractures in order to prevent secondary arthrosis.

Children will often be unable to tolerate reduction under local anaesthesia. General anaesthetic will usually be required (see Section 1.24).

Once reduced, the fracture needs to be held in position while bony union occurs.

During reduction of fractures, particularly in the lower limb, rotation of the limb should be checked clinically and compared with the opposite limb. X-rays, although useful for judging angulation, length and translation, are not very helpful for judging rotation.

Splintage

Splintage of a fracture involves immobilising the fracture, thereby preventing relative motion of the bone ends. In the acute phase, this will help to relieve the pain associated with the fracture. In the longer term, the fracture stability conferred by the splint will help to promote bony union.

The commonest form of splintage uses plaster of Paris bandages (see plastercraft below). If these are not available preformed, then it is possible to make them from crepe bandages and calcium sulphate. The bandages can be applied in the form of a complete (circumferential) cast or as a backslab, along only one side of the injured limb.

In any situation where swelling is anticipated, a complete cast should either be bivalved or split down to skin along its length.

In some circumstances, plaster of Paris may not be available. If this is the case, splints can often be fashioned from locally available materials. One example of this is the use of strips of bamboo and bandaging.

The splint should be applied with the limb in the position of function. Then if stiffness does occur the limb will still have some use. For the elbow, this position is 90 degrees of flexion. For the ankle, a position of neutral plantar/dorsiflexion (the sole of the foot at 90 degrees to the lower leg) is preferred.

Plastercraft

Before starting to apply a plaster, all of the necessary equipment should be ready to hand. The limb should be covered in stockinette, if available, and then cotton wool. Bony prominences (ankle malleoli, fibular head, wrist, olecranon) should be covered with extra padding to prevent pressure sores.

The plaster bandage should be immersed in water for about 5 seconds, by which time bubbles should have stopped rising from the plaster. Cold water is usually best, but hot water causes the plaster to set faster, so the temperature should be adjusted according to need.

For plaster slabs, the length required should have been premeasured and then the slab made up in readiness, most slabs requiring a thickness of between 5 and 10 layers of plaster bandage. Once dipped, the slab should be applied to the limb over the layer of cotton wool and then bandaged into place.

For circumferential casts, the bandage should be unwound half a turn before dipping, with the roll held in one hand and the free end in the other. After immersion, excess water should be allowed to fall from the plaster, but it should not be wrung or squeezed, as this will result in a plaster that is too dry to make a good cast. The plaster bandage can then be wound around the injured limb, with each turn overlapping the previous one by about two-thirds. Twists and turns in the plaster should be avoided, as these can constrict the limb. Once the plaster bandage has been applied, the limb should be held still until the plaster sets.

If proprietary plaster of Paris bandages are not available, it is possible to make them using gauze bandages and plaster. Medicinal-grade plaster (calcium sulphate PBC) is ideal, but failing this, building plaster can be used. The plaster should be sprinkled on to an unrolled bandage that is ideal, but failing this, building plaster can be used. The plaster should be sprinkled on to an unrolled bandage that

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applied, the intended date of removal, and even a sketch of the fracture configuration itself. This information can be invaluable for subsequent care, as notes and X-rays can easily be mislaid or lost.

Wedgeing of the plaster can be useful for improving reduction of the fracture.

**Traction**

An alternative to splintage is traction. By exerting a pull along the axis of the injured bone, traction helps to effect reduction and maintain alignment. Traction can either represent a definitive mode of treatment and be maintained until bony union, or be temporary, being maintained only until the fracture is stable enough to be treated in a plaster cast. Several types of traction exist:

- **Skin traction:** Traction is exerted on the limb by means of a bandage (usually adhesive) applied around the limb.
- **Balanced traction:** Traction of the more distal part of the limb is maintained by reaction against a more proximal structure. The classic example is the Thomas’ splint for femoral fractures, where the splint is braced against the ipsilateral ischial tuberosity.
- **Skeletal traction:** Traction is exerted by means of a pin inserted into bone distal to the fracture. An example is a traction pin inserted through the proximal tibia as treatment for a femoral fracture. In the paediatric context, care should be exercised to avoid growth plates when inserting the traction pins.

Traction methods of treatment are most applicable to fractures of the lower limb, but there are occasional circumstances in which these methods are used in the upper limb. One example is temporary skin traction for a supracondylar fracture of the humerus.

**External fixation**

This involves stabilising the fracture by means of an external scaffold which is fixed to the bones proximal and distal to the fracture by means of threaded pins. It is relevant to unstable compound fractures, particularly those with extensive soft-tissue wounding. Several different types of fixator exist. The pins can be sited away from bone growth plates and the fracture reduced prior to the linking bar being tightened. Following application of the fixator, the pin tracks must be cleaned daily with saline in order to prevent the build-up of crust, infection of the track and secondary osteomyelitis. The fixator can remain in position until bony union occurs, or be replaced by a plaster cast once the fracture becomes stable enough to tolerate this and/or the soft-tissue wound heals.

A variant of external fixation is percutaneous K-wiring, usually used in conjunction with plaster casting. Particularly relevant to peri-articular fractures, this involves the insertion of smooth K-wires across the fracture line in order to prevent secondary displacement. The external ends of the wires should be bent to prevent migration. The wires can be removed once fracture stability permits, typically at 2–3 weeks. In the absence of K-wires, improvisation using long K-wires-type needles is possible.

**Internal fixation**

This involves the use of screws, plates and other types of metalwork to rigidly hold the reduction of a fracture. Although these techniques permit accurate stable reduction, there is an associated risk of infection of the fixation device. Thus, when considering this form of treatment, the following should be borne in mind:

- The fracture should warrant internal fixation, as opposed to splintage, traction or external fixation.
- There should be an adequate supply of the metalwork in a full range of sizes and the required instruments for their insertion. For a sustainable fracture treatment philosophy, a constant supply of fixation devices needs to be available.
- The surgeon should be trained in the application of the device and in the surgical approach necessary for it.
- The fixation devices and tools should be sterile and the level of asepsis in the operating theatre must be high.
- In some cases, intra-operative X-ray guidance (fluoroscopy) is necessary for accurate fixation.

Intramedullary methods of fixation, popular in well-resourced countries for the fixation of adult long bone fractures, are rarely appropriate in paediatric cases, as they violate the epiphyseal plates, potentially resulting in growth disturbance.

The decision to use this method of fixation will be based on a risk-benefit analysis with consideration given to the fracture configuration, the age of the child, the operative resources available and the training of the surgeon involved.

**Ongoing fracture care**

Once reduction and stabilisation of the fracture have occurred, ongoing care is required to monitor the progress of the fracture to union. The treating physician should document the treatment provided and estimate the duration of immobilisation needed. Where the provision of notes and X-rays is limited, one suggestion is to draw the fracture on the surface of the plaster cast along with the intended date of removal.

At initial follow-up, the quality of the plaster cast should be inspected and X-rays taken (where possible) to ensure that secondary displacement has not occurred. The overall duration of immobilisation required is dependent upon the age of the patient and the fracture configuration. Determination of bony union involves the removal of the plaster cast or external fixation device (after an appropriate time period during which union would have been predicted to occur) and the gentle stressing of the fracture site. The presence of persistent tenderness, swelling or abnormal movement all indicate that union has yet to occur. The extent of fracture callus on X-ray is also indicative of the state of union.

**Rehabilitation**

Children rarely need dedicated physical therapy following fracture healing. They should be encouraged to move their joints through a full range of motion, and exercises should be prescribed to restore muscle bulk.

**Specific fractures**

**Femoral shaft**

Closed femoral shaft fractures in children are usually best treated with traction, with the type dependent on the age of the child. Typically the duration required is 1 week per
year of age, but this can be shortened by transfer into a plaster hip spica once fracture stability permits.

- Age 0–2 years and weight under 12 kg: Gallows traction, thighs in 45-degree flexion and hips 30-degree abduction. Limb length inequality is seldom a problem as fracture does not shorten excessively. Shortening of up to 1.5 cm and angulation of up to 30 degrees is acceptable. Early spica casting is often possible. This fracture is associated with non-accidental injury in 50–80% of cases at this age.

- Age 2–10 years: Skin traction, either in the 90/90 position (hip and knee flexed to 90 degrees) or Perkins type (straight traction). Alternatively, especially in the older members of this group, skeletal traction through a distal femoral traction pin; again either in the 90/90 position or straight. Up to 2 cm of bayonet shortening can be tolerated with no adverse effects. Early spica casting can be used if the position is acceptable. With skin traction the weight used should not exceed 5 kg, but with skeletal traction up to 10% of body weight can be applied.

- Age 10–15 years: Skeletal traction, either in 90/90 position or straight. There is a much greater risk of shortening in this group, and less potential for subsequent growth acceleration and length equalisation.

- Above the age of 15 years, children can be treated as adults.

**Tibial shaft**

Closed tibial shaft fractures in children are usually uncomplicated, and can be treated satisfactorily with closed reduction and long leg cast application.

- The cast should be applied with the knee in 5–10 degrees of flexion.

- In comparison to the femur there is less potential for overgrowth and thus it is important to maintain the fracture out to length, that is, to ensure that the length of the fractured limb is the same length as the uninjured side. Acceptable degrees of shortening are 5–10 mm in the 0–5 years age group, but aim for none in any older age group.

- Acceptable axial alignment is less than 10 degrees of recurvatum (where the apex of the fracture site points posteriorly) and less than 5 degrees of varus or valgus angulation.

- As union progresses it may be possible to convert the long leg cast to a patellar tendon bearing cast after 3 weeks.

- Undisplaced fractures in children aged 1–5 years can often be treated in below-knee casts or even below-knee plaster cylinders.

**Distal humeral**

Supracondylar fractures of the humerus have the highest rate of complications and some of the poorest results of treatment of all paediatric fractures. They are also difficult to diagnose without an X-ray. The peak incidence is at the age of 6 or 7 years.

- The vast majority (98%) are extension type, featuring a posteriorly displaced distal part. Only 2% are flexion type, resulting from a fall on to the point of the elbow.

- A careful assessment of distal vascularity should be made. In fractures with posterolateral displacement, the medial humeral spike can tether the brachial artery.

- If distal pulses are absent, closed reduction should be attempted. If this fails to restore pulses, immediate open reduction and surgical exploration of the brachial artery should be performed.

- In other displaced fractures with palpable distal pulses, closed reduction should be attempted, possibly combined with percutaneous pin fixation for unstable fractures.

- Acceptable reductions will have no more than 4 degrees of varus as determined by Baumann’s angle on the antero-posterior radiograph. Additionally, the axis of the capitellum should be at 45 degrees to the humeral shaft.

- If an acceptable position is not obtained, this may be an indication for open reduction and percutaneous K-wire fixation.

- Alternatively, the limb can be placed on traction in extension. As the swelling subsides, it will become easier to effect a closed reduction (with or without K-wiring).

- Once reduced, an above-elbow plaster backslab should be applied with the elbow flexed. Flexion above 90 degrees will assist in maintaining the reduction of extension-type fractures, but care should be taken to ensure that distal pulses are maintained.

- Ideally, X-rays should be taken on a weekly basis to ensure that reduction is maintained. The plaster cast can be completed once swelling has resolved, and percutaneous wires can be removed after 3 weeks.

- The typical duration of immobilisation necessary for union is 4–5 weeks in the 0–5 years age group and 6–7 weeks in the 5–10 years age group.

**Forearm fractures**

- Both types of bone paediatric forearm fractures typically result from the indirect violence of a fall on an outstretched hand. They may be greenstick or complete. If the periosteal sleeve is disrupted the fractures may be unstable.

- X-rays should include the wrist and elbow, as the integrity of the proximal and distal radio-ulnar joints needs to be determined.

- Be aware of the possibility of a Monteggia fracture, which consists of dislocation of the radial head along with fracture of the ulna.

- In contrast to adult forearm fractures, the majority of these injuries can be treated by closed reduction and plaster immobilisation.

- Up to the age of 9 years, acceptable reduction can be defined as anything less than 15 degrees of displacement and 45 degrees of malrotation.

- Above 9 years, at least bayonet apposition is required with less than 30 degrees of malrotation, less than 10 degrees angulation if the fracture is proximal or less than 15 degrees if it is distal.

- Immediately following fracture union, there may be a cosmetic deformity if the above reduction criteria are utilised, but this deformity should remodel if there is over 2 years of skeletal growth remaining.

- Following reduction, an assessment of forearm supination and pronation should be undertaken to ensure there is no block.

- The arm should be immobilised in an above-elbow cast with the elbow flexed to 90 degrees. Opinion varies as to the position of the wrist in the cast. Some surgeons place the wrist in neutral supination/pronation for all fractures, others placing it in supination for proximal...
third fractures, neutral for middle third and pronation for distal third.

- Follow-up X-rays should be taken at 1- and 2-week intervals following manipulation to ensure that secondary displacement has not occurred. If displacement does occur, re-manipulation can be attempted.
- Some very unstable fractures may prove difficult to treat by closed methods. These may benefit from intramedullary pinning (Rush pins) or cross-K-wiring if facilities exist for this (intra-operative fluoroscopy is required). 

**Distal radial ('wrist') fractures**

- Children’s distal radial fractures are usually the result of a fall on the outstretched hand, and are rarely intra-articular.
- Common types include the following:
  - Galeazzi fracture (isolated fracture of the distal radius) implies associated disruption of the distal radio-ulnar joint.
  - Physeal fracture (pattern of injury described by the Salter-Harris classification)
  - Torus (buckling of the cortex on the compression side of the fracture without angulation).
  - Greenstick fracture (incomplete fracture).

In children these fractures can almost always be treated with closed reduction and plaster immobilisation.

- In children these fractures can almost always be treated with closed reduction and plaster immobilisation.
- The reduction manoeuvre is to hyperextend the wrist, followed by traction and ‘hinging’ of the distal fragment over the fracture site.
- Acceptable reduction can be defined as anything less than complete displacement and slight angulation. As in forearm fractures, cosmetic deformity should remodel if more than 2 years of skeletal growth remain.
- Check X-rays should be taken at 1 and 2 weeks post-reduction to exclude secondary displacement.
- The duration of immobilisation required depends upon the fracture configuration and the age of the child, but is typically 3–5 weeks.

**Conclusions**

- Most paediatric fractures can be treated by closed methods.
- Very often the periosteal sleeve will be intact, leading to enhanced fracture stability.
- Completely accurate reduction is not always necessary, as children’s bones have the potential to remodel with continued skeletal growth.

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### 7.3. Life-threatening trauma

#### 7.3.A Structured approach to trauma in pregnancy and childhood

**BOX 7.3.A.1 Minimum standards**

- Triage.
- Structured approach: primary assessment and resuscitation, and then secondary assessment and emergency treatment.
- Availability of emergency surgery or safe transport system.
- Oxygen.
- Blood transfusion service.
- Chest drain.
- Analgesia.
- High-dependency care.
- Tetanus immunoglobulin and toxoid.
- Mannitol or hypertonic saline.
- Tranexamic acid.

**Introduction**

Most regions of the world are experiencing an epidemic of trauma, but the most serious increase has been in the resource-limited countries.

Proliferation of roads and increased use of vehicles have led to an increase in injuries and deaths, and many peripheral medical facilities find themselves faced with multiple casualties from bus crashes or other disasters. Severe burns and drownings have always been more common in middle- and low-income countries. There are a number of important differences between high- and low-income countries:

- use of open fires and kerosene stoves for cooking and heating
- unsafe water storage practices and unsupervised play in water courses, lakes and ponds by young children
- poor or absent flood defences, making poor people much more vulnerable to natural disasters
- poorly maintained road networks and vehicles, contributing to a higher injury rate per distance travelled in low-income countries
- the absence of a paramedic-managed emergency ambulance service to give life-saving medical care at the scene
- the great distances over which the injured may have to be transported, and therefore the time taken for them to reach medical care, thus losing the opportunity to prevent secondary damage caused by hypoxia and hypovolaemia
- the absence of appropriate equipment, supplies, and the