Fractures in the child’s hand

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Summary
Most children’s hand fractures can be successfully treated by either simple protective splinting or closed reduction and a short period of immobilisation. However, failure to correct rotational deformities can produce long-term problems. Certain injuries that may require early operative treatment are frequently missed. These include fractures of the neck and condyles of the proximal phalanx and dislocation of the nail combined with an epiphyseal fracture of the distal phalanx.

Introduction
Injuries of the hand and wrist are among the most common injuries in the skeletally immature population.\textsuperscript{1,2} Hand fractures and dislocations are uncommon in the very young, but the prevalence of these injuries increases sharply after the eighth year and peaks around age 13.\textsuperscript{2–4} This coincides with the involvement of many boys in competitive contact sports and as children are introduced to such sports at a younger age, these injuries will inevitably increase.

Special considerations in the child

Diagnosis
Difficulties may be encountered in both clinical and radiographic assessment due to an uncooperative patient who is frightened and in pain, accompanied by an anxious parent or guardian. Other factors to take into account are inability to perform specific tests of hand function, unwillingness to have the other hand examined and a lack of bony detail on plain radiographs. Patience and minimal handling will help establish trust with the examiner. Pain management is very important. Obtaining useful radiographs may be impossible without sedation. The treating doctor will often need to accompany the child to the X-ray department to ensure correct positioning. Radiographs of the other hand may help in identifying subtle abnormalities. Posteroanterior and lateral films are often insufficient to establish the nature of the injury. Oblique films are often more reliable in identifying intra-articular fractures of the phalanges.

Ossification of the child’s hand

Radiographs of the child’s hand and wrist are notoriously difficult to interpret due to the extent of nonossified cartilage in the immature hand. Carpal injuries are particularly easy to overlook. Knowing the order of
ossification of the carpal bones may assist in identifying injuries.

The centre of ossification of the capitae is the first to appear radiologically at 3–4 months after birth, closely followed by the hamate, the triquetrum at 2–3 years, the lunate at 4 years, the scaphoid (where ossification begins distally) at 4–5 years, the trapezium at 5 years, the trapezoid at 6 years and the pisiform at 9 years. It will be noted that ossification centres appear in the carpus in an anticlockwise fashion (when looking at the dorsum of the right wrist).

The epiphyses of the phalanges and the thumb metacarpal are situated at their bases, whereas those of the other metacarpals lie distally. Occasionally there are anomalies such as an extra basal epiphysis of the index finger in a flexed position.

The periosteum around the long bones in the hand is a tough membrane. Its mechanical properties can be used to aid reduction of fractures and maintain them in reduction. However there is a tendency for displaced fractures to perforate the periosteum, which may then prevent reduction. There should be a relatively low threshold for operative exploration of an irreducible fracture, as not only periosteum but also other structures, such as tendons, may be interposed.

The growing skeleton

Fractures in children heal more quickly than in adults but the short healing time makes early diagnosis and prompt fracture reduction essential, particularly for injuries in the vicinity of the growth plate, where 5 days is the limit for safe reduction. Repeated, forceful and late attempts at reduction must be avoided to prevent iatrogenic injury where the growth plate is involved. Compression injuries of the growth plate in the upper arm are often the result of manipulation, while in the lower limb they usually result from the initial trauma.

Future growth and fracture remodelling provide a safety margin in many, but not all, fractures. Uncorrected angular deformity has the best potential for remodelling and this occurs by asymmetrical growth, with the growth plate changing its orientation to align with the mechanical axis rather than with the adjacent metaphysis. Remodelling is most rapid after metaphyseal injuries because they are close to the growth plate. Deformity in the plane of joint motion can be compensated for to some extent by the multiaxial movements of the metacarpophalangeal joints. However, the uniplanar movements of flexion and extension at the interphalangeal joints mean that radial and ulnar angulations of the proximal and intermediate phalanges are poorly compensated.

Malrotation does not correct by remodelling. Even when considerable epiphyseal development remains, there may be only limited adaptive changes in the shape of the joint surfaces. Viewed end-on with the fingers extended, the nails of the fingers form an arc. Malrotation of even 10° can be identified by loss of the arc. The effects of rotational malunion are more marked in fractures at the bases of the fingers. The resultant overlapping of fingers in flexion should be prevented by identifying and correcting rotation at the fracture site at an early stage.

The hypertrophic zone of the growth plate is most likely to fail under load. The resting and proliferative zones are stronger due to their high collagen content. Simple Salter–Harris type 1 and 2 injuries are not associated with significant long-term problems and the child can be discharged on return to full function. Salter–Harris type 3 and 4 injuries require to be followed for at least 1 year. Late growth disturbances due to premature fusion are usually seen after non-accidental injuries, thermal injuries and high-energy injuries. Fractures caused by such mechanisms should be followed up for long enough to exclude premature fusion.

Parents should always be warned of the possibility of a poor outcome after intra-articular fractures, even when they have been reduced anatomically.

Soft tissue anatomy and its relevance

The strength of the child’s soft tissues to withstand tensile forces often exceeds that of the adjacent growth plate and epiphysis. This predisposes to growth plate injuries whereas ligamentous ruptures and tendon avulsions are seldom seen. The soft tissues around the growth plate provide relatively poor protection. At the metacarpophalangeal joint the growth plates of both the metacarpal and proximal phalanx are particularly exposed due to the fact that the attachments of the collateral ligaments are on the epiphyses. Not surprisingly, fractures of the proximal phalanx are the most common injuries in the child’s hand. At the interphalangeal joints the collateral ligaments originate in the collateral recess of the juxta-epiphyseal region of the proximal segment and insert into the metaphysis as well as the epiphysis of the respective middle and distal phalanges. The collateral ligaments therefore protect the single growth plate at each interphalangeal joint.

The palmar plate and the weak extensors provide poor protection of the growth plate. The anatomy of the palmar plates of the metacarpophalangeal and interphalangeal joints is similar. They originate from the palmar aspect of the metaphysis of the proximal segment and insert into the epiphysis of the distal segment. Extensor tendons insert into the epiphyses of the middle and distal phalanges, making these growth plates vulnerable to avulsion injuries, especially at the distal phalanx.

Both superficial and deep flexor tendons insert into the shafts of their respective phalanges. Transverse midshaft fractures of the middle phalanges can be difficult to reduce or to control after reduction, due to the pull of intact flexor tendons. These fractures are often more stable with the fingers in a flexed position.

The periosteum around the long bones in the hand is a tough membrane. Its mechanical properties can be used to aid reduction of fractures and maintain them in reduction. However there is a tendency for displaced fractures to perforate the periosteum, which may then prevent reduction. There should be a relatively low threshold for operative exploration of an irreducible fracture, as not only periosteum but also other structures, such as tendons, may be interposed.
be inserted a right angles to the plate and be centrally placed to avoid the peripheral perichondrial ring. Such pins should be removed around three weeks after fixation. Screw fixation is an alternative to wiring but is technically much more demanding. Plate fixation should be avoided in children’s hands to prevent adhesions, prominence of the fixation device and the invariable need for a second procedure to remove the device.

**Fractures of the phalanx**

**Distal phalanx**

Crush injuries, such as trapping a finger in a closing door, cause fractures of the body of the phalanx with or without nail bed injury. Hyperflexion forces cause epiphyseal injuries.

A radiograph should be requested in all cases of nail bed injury to exclude a fracture, which is present in many cases. Management is by careful repair of the nail bed using 6–0 or 7–0 absorbable sutures. If the nail is relatively undamaged it should be sutured back into the nail fold as a splint; alternatively the foil from a suture pack can be used to keep the nail fold open, but it is less effective as a splint.

The characteristic epiphyseal plate injury of the terminal phalanx is sometimes called the Seymour fracture.\(^\text{10}\) It occurs in the 12–14-year-old age group and is effectively a type 2 Salter–Harris injury. The significance of the injury is that it is an open, displaced fracture with displacement of the nail from its fold (Fig. 1). Unless the nail is replaced in its correct position the fracture cannot be reduced and the risk of infection is high. The open fracture should be irrigated thoroughly before reducing the fracture and repositioning the nail. This can be done by removing the nail and replacing it in the fold, or by opening the fold laterally to allow reinsertion. The fracture is usually stable after reduction in this way and K-wire stabilisation is rarely necessary.

Salter–Harris type 3 and 4 growth-plate injuries can usually be reduced by extending the terminal phalanx and "massaging" the displaced fragment back into place. The joint is then held in slight extension using a splint on the flexor aspect of the finger. Dorsal splintage can cause pressure necrosis of the skin. Rarely a large fragment of the epiphysis may prove irreducible and open reduction and K-wire fixation may be indicated, but this is a procedure that can be difficult and associated with complications such as a poor healing and infection. It should be borne in mind that there is considerable scope for remodelling of even widely displaced epiphyseal injuries in this area in children.

**Fractures of the proximal and middle phalanges**

These fractures are divided into fractures of the shaft, neck and condyles and those involving the growth plate. As one would expect, those involving the growth plate are the most common.

**Growth plate injuries**

The extra-articular Salter–Harris type 2 injury at the base of the proximal phalanx of the small finger is extremely common.\(^\text{2}\) It is an abduction-type injury that can occur in a variety of childhood activities. Because of the characteristic posture of the hand it is often called the "extra-octave" fracture. A similar deformity may be the result of a buckle fracture in the metaphyseal region. There may be considerable rotation at the site of injury (Fig. 2). Reduction is straightforward if the finger is flexed at the metacarpophalangeal joint, which tautens the collateral ligaments and stabilises the proximal fragment. Reduction over a pen placed between the fingers as a fulcrum is best avoided because of the possible risk of pressure damage to the digital nerves. The hand can be rested on a palmar slab with the metacarpophalangeal joints flexed for a few days and thereafter the little finger may be supported against the ring finger.

Intra-articular Salter–Harris type 3 and 4 injuries are more common in older children. Open reduction and stabilisation with a K-wire may be indicated if the fragment accounts for 25% of the joint surface or is displaced by more than 1.5 mm (Fig. 3).

It has been suggested that a haemarthrosis in the metacarpophalangeal joint may lead to avascular necrosis of the metacarpal head.\(^\text{11}\) This could occur after an intra-articular fracture at the base of the proximal phalanx or one involving the metacarpal head, a rare injury in childhood. There is no evidence that this is a common problem but there is no harm in aspirating the joint if this situation is suspected.

An abduction injury of the thumb in childhood may damage the ulnar collateral ligament but frequently there is

![Figure 1](a) Dislocation of the nail plate from the fold due to a fracture of the terminal phalanx, (b) Salter–Harris type 2 open fracture of the terminal phalanx.
an epiphyseal injury or a buckle injury of the adjacent metaphysis of the proximal phalanx. A type 3 fragment that is widely displaced may require open reduction and fixation using a transverse K-wire placed in the epiphysis. Buckle fractures heal and remodel very quickly.

Fractures of the shaft
These are relatively uncommon. Dorsal angulation of transverse midshaft fractures is easily overlooked on lateral films due to overlying shadows. A lateral film of the injured digit is necessary. Although remodelling of angulated fractures does occur, dorsal angulation of the proximal phalanx should be corrected as it results in imbalance between the flexors and extensors of the fingers, giving a clawed appearance.

Oblique fractures with unacceptable shortening are rare but are an indication for internal fixation using transverse wires.

Fractures of the neck and condyles
Such injuries account for only about 1% of phalangeal fractures in children. Their significance is often not appreciated by junior staff who first deal with the child. Fractures of the neck of the phalanx in young children are difficult to diagnose and difficult to treat. They typically occur in young children when a finger is trapped in a door. The bone is poorly ossified in the young child and the extent of the injury can only be inferred from radiographs (Fig. 4). There should be a readiness for early open exploration of such injuries as displaced fragments are impossible to reduce after a few days. Failure to reduce displaced fractures results in deformity and loss of movement. Callus formation can cause a mechanical block to flexion and it may be necessary to remove obstructing spikes later from the subcondylar fossa to improve the range of motion.

Nevertheless, in late presentations (more than a few days after injury) the deformity should be accepted and corrected later, rather than risk further damage by interfering with the fracture in the healing phase, which might result in avascular necrosis of the head of the phalanx. In very young children the remodelling of an untreated displaced fracture of the neck of the phalanx can be surprisingly good but this cannot be relied on in the older child.

Fractures involving the distal third of the proximal phalanx are approached by elevating the lateral bands through a curved dorsal skin incision, or by elevating a V-shaped slip of the extensor tendon based on the central slip, which allows excellent visualisation of the PIP joint. Fractures of the neck and those through the condyles are held by cross pinning. Unicondylar or avulsion fractures are held by wires or screws inserted parallel to the joint (Fig. 5).
K-wires should not be placed through the lateral bands, as these must be allowed to move freely after fixation has been achieved.

Neck and condylar fractures of the middle phalanx are managed in similar fashion but it is often possible to hold a displaced transverse fracture through the neck of the intermediate phalanx with a longitudinal K-wire. This is driven distally from the fracture site and used as a joystick to place the fragment in its correct position relative to the terminal phalanx, before driving the wire out through the terminal phalanx and back across the fracture and into the shaft of the intermediate phalanx.

Metacarpal fractures

Metacarpal fractures are seldom problematic due to effective splinting of the shaft and protection of the growth plate by surrounding soft tissues. The remodelling potential is considerable after fractures of the metacarpal neck and shaft and there is seldom a poor outcome unless malrotation has been overlooked, although this is rarely present. In most cases a protective cast only is required until the acute discomfort subsides.

Midshaft fractures with sufficient displacement to cause shortening are rare in childhood. Again the remodelling potential is significant, but very occasionally fixation using an intramedullary pre-bent K-wire might be considered, particularly if there are multiple fractures and soft-tissue damage.

Fractures of the metacarpal shaft of the thumb are common and again remodel quite quickly. They are often overtreated since there is concern that the function of the thumb will be affected if there is even slight angulation. In fact the multiplanar motion of the trapeziometacarpal joint readily compensates for any malunion and 30° of lateral angulation will rapidly disappear with remodelling. If reduction is required, it is readily achieved by pressure over the fracture and counter-pressure at the metacarpal head.

Basal metacarpal fractures of the thumb are either growth plate injuries or buckle fractures of the metaphysis. The latter heal and remodel very rapidly. Salter–Harris type 2 injuries are very common and occur by various mechanisms of injury (Fig. 6). Since the injury usually occurs after forceful abduction of the thumb, the metaphyseal fragment attached to the growth plate lies on the ulnar side. Reduction may be incomplete because of inability to stabilise the proximal fragment but remodelling is usually rapid. The metaphyseal fragment lies on the palmar side in the much rarer type 2 injury caused by forced adduction. In this pattern of fracture the periosteum may become interposed between the bone fragments, making closed reduction impossible. Type 3 and 4 injuries are rare and a decision must be made about open reduction and stabilisation with K-wires if displacement is marked. Closed manipulation will seldom reduce these fractures when they are displaced and closed insertion of K-wires is not recommended. The wires may be removed after three weeks and free mobilisation is allowed.

Carpal fractures

The carpal bones are resistant to injury in early childhood since they are largely cartilaginous and ligamentous injuries of the carpus are also rare. Not uncommonly in the older child a scapholunate injury may be suspected after a wrist radiograph has been taken following an injury. However the scapholunate gap appears to be wide in the normal child’s wrist because ossification is incomplete. A comparison film of the other wrist will clarify this situation.
Nonunions rather than a congenital variation. Which is now regarded as being a long-standing scaphoid osteoarthritis. Only minimal symptoms have been reported in adults, with the gradual onset of characteristic patterns of arthritis. It seems unlikely that they follow the same course as in those seen in adults. The typical fracture through the scaphoid waist due to a hyperextension injury is relatively uncommon until later childhood. In children 50% of fractures occur at the distal pole, most often on the dorsoradial aspect, as a result of ligamentous avulsions. Treatment of scaphoid fractures in children is no different from that in adults. A clinically suspect fracture without abnormal radiographic findings is treated in a thumb spica cast, usually extending above the elbow in younger children. Further treatment is based on clinical findings rather than special investigations as bone scans are not particularly reliable in children and an MR scan may require a general anesthetic. Most fractures are minimally displaced, stable and suitable for closed treatment. They will heal after 6–8 weeks treatment in a cast. Open reduction and fixation is usually only necessary when the scaphoid fracture is part of a more extensive carpal injury.

Nonunions are seldom seen in scaphoid fractures in childhood due to the rich blood supply of the bone, the predominantly distal situation of the fracture and the excellent healing potential after childhood fractures. Even in established nonunions of the waist there are cystic changes, casting is the first line of treatment and union will often occur. The natural history of scaphoid nonunions in childhood has not been documented in the longer term, but is seen as unlikely that they follow the same course as in adults, with the gradual onset of characteristic patterns of osteoarthritis. Only minimal symptoms have been reported at long-term follow-up of the so-called bipartite scaphoid, which is now regarded as being a long-standing scaphoid nonunion rather than a congenital variation.

Other carpal injuries

Carpal fracture-dislocations do occur in children, almost invariably after a high-energy injury such as a fall from a tree. As with adults in the same situation, there may be other, possibly life-threatening injuries that draw attention away from the wrist. Even if the wrist is examined radiologically, the injury may not be recognised due to inexperience in assessing radiographs of children’s wrists. Trainees should be taught the importance of Gilula’s lines when assessing wrist radiographs (Fig. 7).

A clue to the presence of a more major carpal injury is a displaced scaphoid fracture. The capitate is the bone that is most frequently injured in association with the scaphoid and the proximal pole may rotate through 180°. Distraction films of the wrist may be helpful in identifying these complex injuries, which almost invariably require open reduction and stabilisation with K-wires.

References