Summary
Bone injuries are a daily challenge for the hand surgeon. The majority of the injuries are extra-articular, closed, simple, undisplaced or minimally displaced fractures and are best treated nonoperatively. Most closed fractures requiring manipulation and fixation are amenable to closed reduction and minimally invasive surgery. Open reduction and internal fixation, using mini plates or screws, of closed fractures is generally reserved for irreducible, displaced, intra-articular, comminuted, multiple displaced unstable or pathological fractures as well as displaced unstable fractures accompanied by ipsilateral extremity injuries or bilateral injuries. Open injuries of the hand are not only frequently associated with bone fractures but accompanied by additional soft tissue damage. The functional outcome of these injuries correlates with the severity of the injury but can be favourably influenced by the surgical treatment of all the involved structures, including stabilization and/or reconstruction of the bones. Most of these injuries have to be addressed individually. The hand surgeon treating these injuries has to be familiar with all techniques of bone reconstruction and stabilization to be able to individually choose the optimal combination of internal and external fixations.

Introduction
Most hand injuries are associated with injuries to the bones. Although, treatment guidelines for the most common fracture types are well described, the individual combinations of fractures as well as damage to the associated soft tissue structures makes each hand injury unique. Therefore, bone injuries remain a daily challenge for the hand surgeon. Fractures are classified into open or closed, simple (two fragments) or comminuted (multi-fragments), extra-articular or intra-articular and stable or unstable.

The skeletal tissue (bones, joints and ligaments) is only one of the five tissues of the hand; the others being tendons, nerves, vessels and integument. The close relationship between the soft tissues and the bones frequently leads to soft tissue oedema, tendon adhesions and joint stiffness in fractures of the hand. Therefore, early active motion in nonoperative as well as in operative treatment is most desirable to achieve a good functional outcome.

It is well known that the functional outcome of hand fractures highly correlates with the severity of the initial injury. On the other hand, primary repair or reconstruction of all the involved structures in acute hand injuries,
including fracture stabilization and primary bone recon-
struction may influence the outcome favourably.  

Assessment

The diagnosis of fractures in the hand is rarely difficult. The
history of the mechanism of the injury should be obtained to
estimate the nature and amount of external energy creating
the fracture (crush, axial load, torque) and to determine the
fracture configuration. Information about the occupation,
dominance and individual special requirements of the
patient may also affect the treatment decision. In closed
injuries the deformity, degree of swelling, the circulation
and loss of sensibility are noted. Thought must be given to
the possibility of a compartment syndrome. Correct rota-
tional alignment of the fingers has to be assessed with
fingers extended and flexed. This may require a wrist block
to permit painless motion. In open injuries, the wound is
carefully inspected for associated soft tissue injuries.
Examination of tendon and nerve function must be as
thorough as pain allows. Circulation of the fingers has to be
assessed, as the necessity for revascularization will affect
the fracture treatment. The degree of skin and soft tissue
injury, and possible skin defects following debridement,
have to be estimated to develop an immediate treatment
plan to include wound cover.

Standard radiographs of the entire hand in two planes are
necessary. Further radiographs, taken in several planes, may
be necessary to provide specific details about the severity of
the bone injury (simple, comminuted, bone loss). In cases of
intra-articular fractures of finger joints only correct radi-
ographs in two planes, focusing on the specific joint will
demonstrate the entire extent of the bone injury. In closed
intra-articular fractures of the finger, or especially the
carpometacarpal joints, additional CT examination may be
required to assess the true amount of comminution and/or
fracture and joint dislocation.

Principles of fracture management

Following the initial assessment the major decision to be
made by the surgeon is whether to treat the bone injury
nonoperatively or operatively, and many factors will
influence this decision. Most open fractures will have to be
treated operatively, within the context of the overall wound
management. Therefore, this question primarily arises for
closed fractures and the principles of fracture management
will further be discussed separately for closed and open
fractures.

Closed fractures of the hand

Stiffness due to soft tissue oedema, tendon adhesions
and joint capsule or ligament contracture are the most
common complication of hand fractures. To minimize the
risk of stiffness every fracture in the hand should either
be stable enough to allow early active motion and
rehabilitation or it should be stabilized. The risk of
fibroplasia and scar generation resulting in stiffness of the
fingers following operative treatment of closed fractures of
the hand is well known. On the other hand, prolonged
immobilization of fractures will also lead to stiffness. As
well as the stability of the fracture, the decision for
conservative or operative treatment is influenced by the
type of fracture. Intra-articular fractures, displaced frac-
tures, comminuted fractures and multiple closed fractures
of the hand (Figure 1) are usually not amenable to
nonoperative treatment. Crush injuries with massive soft
tissue swelling and compartment syndrome of the hand may
require operative decompression of the compartments with
additional stabilization, even of nondisplaced simple frac-
tures of the hand.

Therefore, nonoperative treatment is indicated in the
majority of undisplaced or minimally displaced closed
fractures that are stable enough to allow early active
motion and rehabilitation. Reduction of a fracture is
indicated if the degree or the direction (rotation) of
malalignment would lead to an unsatisfactory outcome.
Many fractures are stable in their displaced position but will
become unstable following reduction and require some kind
of fixation. External stabilization by means of plaster splints
can be applied but this frequently leads either to stiffness, if
applied long enough to allow for fracture healing, or to loss
of position. The primary reason for operative treatment of a
fracture in the hand is to improve the functional outcome.
To achieve this outcome, anatomic reduction of the fracture
has to be the aim, with a fixation stable enough to allow
early active motion and rehabilitation. Furthermore, surgi-
cal soft tissue dissection and surgical trauma have to be
minimal.

In every patient the possible gain of operative treatment
has to be weighed against the increased scarring and the
potentially negative effect on tendon gliding and joint
motion. Thus, in closed fractures of the hand, three

Figure 1  Radiograph of a 38-year-old female who was injured
in a motorcycle accident sustaining displaced, closed fractures
of the metacarpals of all fingers, of the proximal phalanx of the
ring finger and a dislocation of the carpometacarpal (CMC) joint
of the thumb of the right hand. A combination of several
different kinds of fixation was performed. Closed reduction and
percutaneous stabilization of the CMC joint of the thumb and
the proximal phalanx of the ring finger was achieved. Open
reduction was performed on the metacarpal fractures with
mini-plate fixation of the metacarpals of the second, third and
fourth fingers and intramedullary Kirschner wire stabilization of
the subcapital fracture of the fifth metacarpal.
therapeutic options are available: nonoperative treatment, minimally invasive surgery or open reduction and internal fixation.

Nonoperative treatment
The majority of fractures in the hand are extra-articular, closed, simple, undisplaced or minimally displaced and stable. These fractures are most effectively and safely treated by minimal protective splinting or adjacent finger buddy taping and early motion. An initial short period of immobilization in a plaster, accompanied by elevation of the hand, may be advisable to reduce pain and soft tissue swelling before active rehabilitation is commenced. Whenever plaster immobilization is required, only the involved fingers should be included and the position should be in intrinsic-plus (Edinburgh position) to avoid joint contractures. Quite often minimal displacement of fractures of the hand can be accepted and will not lead to a functional deficit. Although a perfect anatomical position of the fracture would be preferred, the hand has a remarkable capacity for functional adaptation to small and sometimes even significant degrees of deformity. Shortening of the metacarpal or phalangeal bones is usually limited and functionally well tolerated. Dorso-palmar angulation of metacarpal fractures and fractures of the base of the proximal phalanx may be compensated to some extent by the motion of the adjacent joints. Rotational deformity of metacarpal or phalangeal fractures is poorly tolerated and even a few degrees of malrotation may lead to finger overlap during digital flexion. Finally, in instances of minor or moderate deformities, the surgeon will have to discuss with the patient the option of operative treatment with the possible benefits of anatomical fracture restoration and fixation against the possible risks of a surgical procedure.

Minimally invasive surgery
Minimally invasive surgery, with closed reduction and internal or external fixation of the fractures, is relatively atraumatic in comparison to open operative procedures and applies for many fractures in the hand. Internal stabilization is achieved using percutaneous Kirschner wires, pins or mini-screws. Many transverse and short oblique phalangeal and metacarpal fractures may be stabilized with single or multiple intramedullary wires (Figure 1). Transverse proximal phalangeal or metacarpal fractures may best be stabilized using crossed percutaneous Kirschner wires, especially if the proximal fragment is too small for open reduction and plate fixation. Percutaneous transfraction wires may be inserted transversely through an intact adjacent metacarpal to stabilize displaced intra-articular fractures of the carpometacarpal joints following closed reduction with traction. Alternatively, these intra-articular fractures may be stabilized using a mini external fixator. Long oblique or spiral fractures of the phalangeal or metacarpal bones may be stabilized by the percutaneous insertion of mini-screws. This option has become more favoured as many manufacturers now provide small sized cannulated screws or cannulated reduction forceps allowing temporary fixation and radiographic control of the reduction before the final screw is inserted. This method is also applicable to simple intra-articular fractures of the metacarpal heads or the phalanges. However, in some of these fractures anatomic closed reduction may not be possible, or the temporary fixation with guide wires or reduction forceps cannot maintain the original reduction. In such cases, several attempts at reduction or temporary stabilization should be avoided and the method changed to an open procedure.

Stabilization of closed fractures of the hand by means of a static external fixator may be indicated in severe crush injuries with massive comminution of phalangeal or metacarpal fractures, not amenable to open reduction and internal fixation. It may also be used as a temporary device to retain the reduction if a primary open procedure is not possible (e.g. severe swelling, anticoagulation, polytrauma).

Dynamic external fixation, as described by Suzuki et al., may be used in intra-articular fractures of the base of the middle phalanx (pilon fracture) if either the degree of comminution or the small size of fracture fragments does not allow open reduction and internal fixation (ORIF) (Figure 2). The dynamic pins and rubber band traction frame may be combined with additional percutaneous Kirschner wire fixation of isolated fragments.

Open reduction and internal fixation
Open treatment of closed fractures in the hand is generally reserved for irreducible displaced fractures, comminuted fractures, multiple displaced unstable fractures, pathologic fractures and displaced unstable fractures accompanied by ipsilateral extremity injuries or bilateral injuries. Principle, any of the above methods of fixation may be used following the open reduction of the fracture. However, with ORIF, the aim should be an anatomic restoration with an internal fixation device that allows for primary bone healing and early mobilization. Generally, this is achieved by means of mini screw or mini plate fixation depending on the type and the position of the fracture (Figure 1). However, fixation should not be compromised and combinations of the different kinds of fixation may be necessary to achieve the goal of sufficient stability for early active rehabilitation. Although with ORIF adequate exposure is required, the number of incisions as well as the extent of operative dissection should be minimized in order to reduce the amount of scar tissue formation and the risk of post-operative adhesions and stiffness.

Open fractures of the hand
Open fractures of the hand have to be treated within the context of overall wound management. The fractures may be accompanied by simple lacerations with or without tendon, nerve or vessel disruption. These fractures have to be treated by the same principles described above. Even simple open injuries may be a challenge for the hand surgeon. However, with complex open hand injuries, injury patterns are often unique and have to be assessed and treated individually, according to the amount of soft tissue and bone damage, the possibilities available for reconstruction and the individual requirements of the patient. Initial assessment has to determine the condition of all tissues including possible skin defects, loss of circulation, tendon and nerve disruption, fracture patterns and bone defects. Following this initial assessment, and a second assessment in
the operating theatre, the surgeon needs to plan the reconstruction. The concept may include amputation of a finger or ray that is not amenable to reconstruction or, in the case of multiple finger amputations, not to replant one finger but to use the tissues of this finger to reconstruct other digits. The overall concept has to consider not only the bone injuries but all the involved structures, including possible skin defects. Nerves, vessels or tendons should be repaired or reconstructed primarily whenever possible, as secondary reconstruction will necessitate re-operations with difficult access, increased risk of skin defects, infection, delayed healing and rehabilitation leading to less favourable results. Skin defects may be covered temporarily to allow for a second look and further debridement, but definitive coverage by means of skin grafts or free or pedicled flaps should be performed within the first 48–72 h following the injury. As these considerations have to include all the involved tissues, severe hand injuries should be treated by a hand surgeon who is competent to deal with all the tissues and with experience in all the different operative techniques (including microsurgical techniques) that may be required.

When planning treatment, skeletal stabilization is the foundation for soft tissue management and has to be performed prior to the consecutive repair of tendons, nerves, vessels and skin coverage. Anatomic reconstruction and stabilization of the skeleton are prerequisites to restore function of the injured hand. They allow soft tissue repair, help to control pain, minimize the risk of “dead space” in the wound, inhibit infection and allow for early and intensive hand rehabilitation. The best results are to be expected if all the involved structures are primarily repaired. Radical debridement of all necrotic, nonvital or damaged tissue has to be performed. Limited shortening of the bones at the fracture side by transverse mini saw cuts, together with excision of damaged adjacent tissue, will not only reduce the possible contamination and comminution area but allow easier fixation and may allow primary repair of undamaged ends of tendons, nerves, skin and vessels.

Fracture stabilization may be achieved by means of any of the previously mentioned methods but the factor of time has to be considered. In mid-hand amputations through the metacarpal bones a quick and stable fixation may be achieved by shortening of the bones and intramedullary Kirschner wire fixation of all the metacarpals. Crossed Kirschner wires may be used to stabilize phalangeal fractures or in replantations at the phalangeal or metacarpal levels. More stability in these fractures may be achieved using 90–90 cerclage wires or a simple cerclage wire combined with an additional oblique Kirschner wire. The wound may allow mini plate fixation of comminuted, transverse or short oblique fractures of the metacarpals and phalanges. Long oblique or spiral fractures may be amenable to mini plate fixation of comminuted, transverse or short oblique fractures of the metacarpals and phalanges, Long oblique or spiral fractures may be amenable to mini screw fixation. Mini external fixators may be applied provisionally, or to definitively stabilize fractures if the wound condition is not amenable to primary radical debridement, which precludes internal stabilization.

Bone defects due to primary loss of bone substance, or following debridement, will require reconstruction. Definitive, one-stage primary reconstruction using a corticocancellous bone graft with internal stabilization may be considered in cases where adequate debridement of the wound can be achieved (Figure 3). This avoids secondary reconstruction and allows earlier rehabilitation with favourable functional results. If the condition of the wound does not allow primary bone reconstruction, provisional fixation has to be achieved using spacer wires, axial intramedullary wires, transfixation wires or mini external fixateurs followed by delayed primary reconstruction 48–72 h later.
Although anatomical reconstruction, as the basis for a good functional outcome, is the goal of acute as well as reconstructive hand surgery this cannot always be achieved. In intra-articular fractures with comminution or bone loss, reconstruction of joint function may not be possible. If the distal or the proximal interphalangeal joints are not reconstructable primary or delayed primary arthrodesis, with or without a corticocancellous bone graft, may have to be performed. In cases of a destroyed metacarpo-phalangeal joint arthrodesis will lead to very limited function, not only of the involved finger but of the complete hand. For these patients it may be an option to perform a resection interposition arthroplasty and provisionally stabilize the joint with a mini external fixator to allow early active mobilization and rehabilitation of the uninvolved joints and the soft tissues.

Conclusions

Bone injuries of the hand are very common and stiffness with loss of motion and function is the major problem. Early active motion and rehabilitation are essential to minimize the risk of stiffness. The majority of closed fractures will be suitable for nonoperative treatment, consisting of minimal protective splinting or adjacent finger buddy taping and early motion. For the remaining fractures the aim of operative treatment is to anatomically restore the position and stabilize the fracture fragments so as to minimize the problems of pain, stiffness and functional loss by means of early motion and rehabilitation. Operating on a fracture without achieving a sufficiently stable fixation, and thus not being able to take advantage of early motion, exposes the patient to the worst situation. The potential gain of operative treatment is lost and the additional operative trauma increases the risk of stiffness and functional loss. Therefore, the hand surgeon treating these injuries has to be familiar with all the various available techniques of bone reconstruction and stabilization to be able to individually choose the optimal combination of internal and external fixation.

References


