

<http://hdl.handle.net/1765/125097>



Introduction and outline

Background & fracture classification

Epidemiology

Fractures in the hand are very common. Between 17 and 19% of all fractures seen on Accident and Emergency Departments (A&E) are located in the hand [1-4]. Metacarpal fractures account for 30–40 % of these hand fractures [5]. Most frequently fractures in the hand are located in the first and second ray (**Figure 1**) [1, 3, 4]. For metacarpal bone specifically, the most commonly affected is the fifth metacarpal. About 20-22% of all metacarpal fractures is a subcapital fifth metacarpal fracture is, also known as “boxer’s fracture” [6, 7].

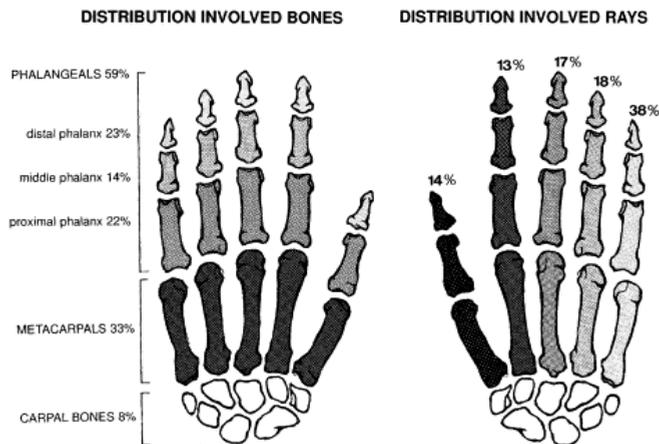


Figure 1. Distribution of metacarpal fractures (from: Prevalence and distribution of hand fractures. E.B.H. van Onselen, R.B. Karim, J.J. Hage, M.J.P.F. Ritt; J. Hand Surg (Eur), Oct 2003, Vol 28, pages 491-495) [1]

Patient characteristics

The majority of patients with metacarpal fractures are between 15 and 40 years old (**Figure 2**) [2]. A predominance exists for male patients, the male:female ratio varies from 1.8:1 to 3:1 [1, 4]. This male predominance exists up to the 6th decade of age and is explained by men doing heavy manual labour up to the age of retirement, sports and fighting [8, 9]. In the female population osteoporosis combined with an increased fall incidence later in life and a longer life expectancy results in an increase in metacarpal fractures in the 6th decade in comparison to males (**Figure 2**) [1].

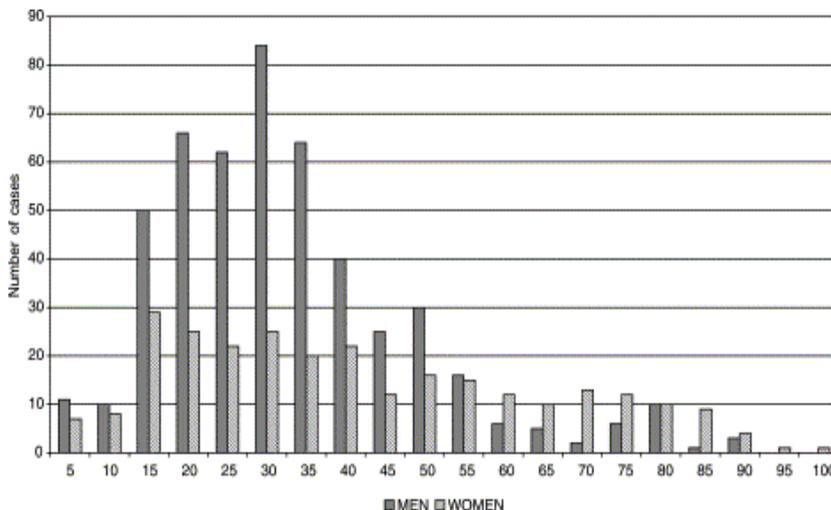


Figure 2. Incidence of metacarpal fractures (from: Prevalence and distribution of hand fractures. E.B.H. van Onselen, R.B. Karim, J.J. Hage, M.J.P.F. Ritt; J. Hand Surg (Eur), Oct 2003, Vol 28, pages 491-495) [1]

Fracture classification

The classification of metacarpal fractures is based on the anatomical location of the fracture. A first distinction is the metacarpal in which the fracture is located. A second distinction can be made based on the location of the fracture, i.e. the base, shaft, neck or head of the metacarpal (**Figure 3**). Metacarpal shaft fractures can be further classified into spiral, oblique or comminuted fractures [10]. First metacarpal base fractures can be reported as intra-articular (Bennett, Rolando, comminuted), extra-articular and epiphyseal fractures (**Figure 4**) [11].

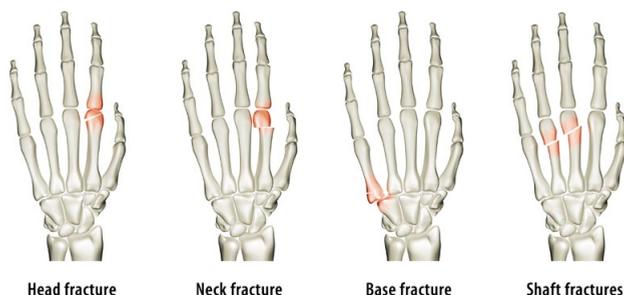


Figure 3. Classification of Metacarpal Fractures based on its anatomical location

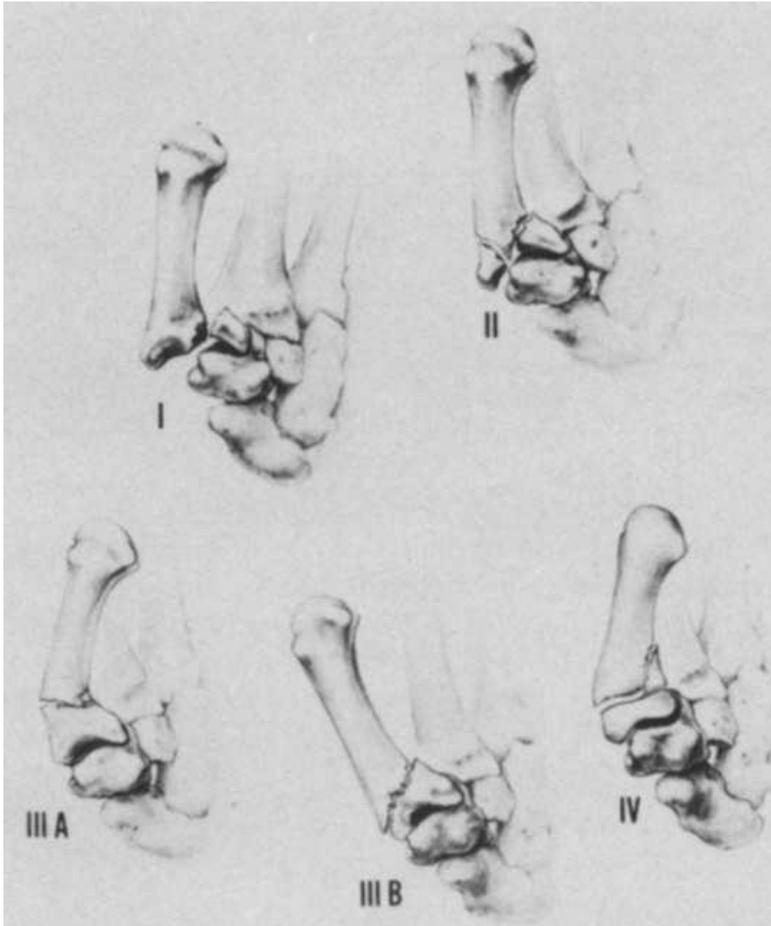


Figure 4. Classification of thumb fractures

Type I Bennett's fracture

Type II Rolando's fracture

Type IIIA Transverse extra-articular fracture

Type IIIB Oblique extra-articular fracture

Type IV Epiphyseal fracture

(Re-printed with kind permission from Elsevier Publisher® from "Fractures of the base of the first metacarpal bone: results of surgical treatment. J.L.M. van Niekerk, R. Ouwens; Injury, Vol 20, Issue 6, p 359-262 (Nov) 1989.)

Treatment

The majority of fractures in the hand can be treated non-operatively. The method of treatment of metacarpal fractures depends on the stability of the fracture. Surgical goals of treatment are restoration of length, alignment and correction of rotation. Isolated, stable fractures can be treated with non-operative immobilization for several weeks [5, 6, 12, 13]. The injured hand is immobilized in so-called “position of protection”, in which the meta-carpo-phalangeal joint flexed as near 90 degrees as possible and the interphalangeal joints almost straight [14].

Unfortunately, not all fracture types are suitable for non-operative treatment. For malrotation, angulation, longitudinal shortening, multiple metacarpal fractures and fractures with associated tissue injury or bone loss surgical treatment is indicated [15-18]. Each of these factors, negatively influences long-term functional outcome when treated non-operatively. Shortening or angulation of the metacarpal can biomechanically influence function and strength of the hand, i.e. Pinch and Grip strength [19]. Rotational deformity of the metacarpal causes scissoring of the fingers which results in loss of functional use of the scissoring fingers and can lead to functional loss of part of the hand.

Unstable intra-articular fractures will also benefit from operative fixation in which the fracture is stabilized and the position in which the fracture heals is controlled. Secondly, by intra-articular fracture reduction the development of post-traumatic arthrosis might be prevented. However, it is still debated if the intra-articular step-off and gap after fixation in such cases should be smaller than 2 mm or that an anatomical reduction without step-off and gap would be more beneficial in preventing post-traumatic arthrosis in metacarpal fractures (**Figure 5**) [20-22].

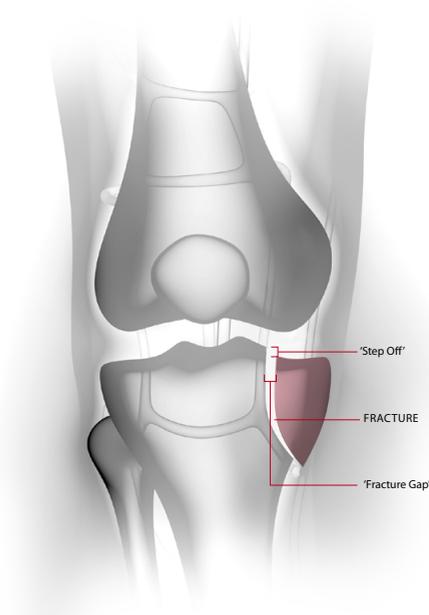


Figure 5. Intra-articular Tibia Plateau Fracture illustrating Step-off and Gap (i.e. step-off is displacement of fracture fragment in relation to the articular surface; gap is distance between two fracture fragments at articular level)

Introduction - What is the problem?

Unfortunately, it is currently unknown what type of operative treatment is preferable in the surgical treatment of different types of metacarpal fractures.

Up until the 1940's surgical treatment of metacarpal fractures consisted of closed reduction percutaneous fixation (CRIF) [23]. In 1950, Wagner et al. reported on CRIF in the treatment of first metacarpal fractures for the first time [24]. In the same decade Iselin et al. and Wiggins et al. reported on different CRIF techniques in first metacarpal surgery [25, 26]. During the same years the first reports of successfully applied open reduction internal fixation (ORIF) techniques in specific intra-articular fractures of the hand are reported [27, 28]. The introduction of new mini screw and plate systems in the 1990's has further promoted ORIF for surgical treatment of the hand.

Parallel to these developments CRIF was also still applied and in 1989 Van Niekerk et al. reported on 23 patients who had been successfully treated for first metacarpal fractures [11]. This has been the start of a revival in the scientific research into CRIF for the surgical treatment of metacarpal fractures [29-31].

CRIF - Minimal tissue dissection vs. post-operative immobilization?

Closed reduction and internal fixation (CRIF) is also referred to as closed reduction percutaneous fixation (CRPF). CRIF implies that the fixation of the fracture is performed with a percutaneous technique, for instance percutaneous Kirschner wire fixation, after indirect reduction of the fracture. Fluoroscopy is used to confirm fracture reduction and fixation during surgery.

The advantage of CRIF is that no surgical dissection is necessary leaving the fracture hematoma intact. The fracture hematoma has developed while the fracture occurred by blood loss from the fractured bone. The bone marrow contributes to the fracture hematoma, thereby pluripotent stem cells are part of the fracture hematoma. These stem cells are essential for the formation of new bone. Over time, fibrinous tissue and later bony depositions called "callus formation" are formed in the fracture hematoma. This bone healing process is known as "secondary bone healing". During this process small movements at the fracture site are allowed and even contribute to callus formation and strong bone healing.

Another advantage of CRIF is that it is a minimal invasive technique, which requires minimal tissue dissection. CRIF may possibly be associated with a smaller risk of iatrogenic injury in comparison with ORIF.

Possible disadvantages of CRIF might be that without direct vision of the fracture a less adequate reduction is achieved. While treating an intra-articular fracture this might result in a higher change of post-traumatic arthrosis at long-term follow-up. Furthermore, during closed surgical technique, radiographic instruments are used to assess fracture reduction. Some authors believe these to be less accurate in the assessment of fracture reduction in comparison with direct vision during open surgical reduction [32].

Another possible disadvantage of CRIF might be that the percutaneous fracture fixation is less stable in comparison to internal fixation after open reduction. For this reason, percutaneous fixated fractures are often additionally immobilized in a plaster cast. A period of immobilization of several weeks may negatively influence long-term functional outcome because of adhesion formation between anatomical layers in the hand thereby restricting movement.

The Kirschner-wires can be removed after consolidation of the fracture. In most cases this can be facilitated in the outpatient clinic, if necessary under local anaesthetics.

ORIF - Anatomical reduction vs. soft tissue dissection?

During open reduction and internal fixation, the tissues surrounding the fracture are dissected and the fracture fragments are explored. During open surgery fracture reduction can be directly visualized, which may contribute to an anatomical reduction of the fracture. Fracture fixation occurs with screws and/or plate fixation. Fluoroscopy is additionally used to assess fracture reduction and position of osteosynthesis material. Consequently, the fracture hematoma is released during dissection. Therefore, after open surgical treatment the fracture hematoma is lost for future contribution to the fracture healing process.

After ORIF the fracture healing process is based on a process called “primary bone healing”. Because of the loss of the fracture hematoma consolidation of the fracture occurs by osteoblasts crossing the fracture site, while creating bone bridges that cross the fracture. No movement is allowed at the fracture site during this process not to damage this bone bridge formation. Therefore, ORIF requires a rigid fixation of the fracture.

The rigid fixation necessary for direct bone healing has the advantage that no post-operative immobilization is required. The soft tissue dissection necessary for ORIF contributes to possibly more adhesion formation in comparison to CRIF. However, direct mobilization of the patient after ORIF theoretically reduces this risk of adhesion formation again by allowing movement between dissected layers.

ORIF allows anatomical reduction with no persistent intra-articular step-off and gap therefore theoretically preventing the development of post-traumatic arthrosis. During fixation of intra-articular fractures a persistent step-off and gap up to 2 mm is sometimes accepted, based on a study reporting on distal radial fractures in which a persistent step-off and gap larger than 2 mm was associated with post-traumatic arthrosis formation [33]. However, it is still debated what the allowed step-off and gap after fixation of intra-articular fractures of the hand might be without increasing the risk of post-traumatic arthrosis formation [20-22].

Another disadvantage of ORIF is the required soft tissue dissection for exposure of the fracture, resulting in an increased risk of iatrogenic injury during surgery [34]. The osteosynthesis material is removed when necessary, mostly because of local discomfort experienced by the patient. The removal is done during a second operation, which also increases the risk of iatrogenic injury.

Outcome measures

To assess long term functional outcome in the hand Grip and Pinch strength are usually used [35]. With Grip strength the force of the entire hand is tested. The greater part of force in Grip strength is produced by the thumb and the second and third ray of the hand [35]. Pinch strength tests the specific force of one single ray by measuring the Pinch force between the thumb and the tested digit. Because Grip and Pinch tests are different outcome measures, correlation between the two scores can be poor. For instance, a fourth metacarpal fracture which is consolidated in a shortened position might not affect the Grip strength of this hand but may affect Pinch strength.

Because strength of the injured hand before trauma is unknown, the Pinch and Grip strength of the injured hand are compared with the patients uninjured hand. A complicating factor is the fact that hand strength is not similar for left and right. In general, the dominant right hand is 10% stronger than the left hand [35]. Interestingly, left hand dominance results in equal strength in both hands in half of the patients [35].

To detect clinically important functional deficit a minimally clinical important difference (MCID) is used comparing Grip and Pinch strength. This MCID is usually set at a difference of 20% in comparison with the contra-lateral side and adjusted for hand dominance as suggested by Crosby et al [35].

The Visual Analogue Scale (VAS) is used to evaluate pain experienced by the patient. This analogue scale ranges from 0cm (no pain) to 10cm (worst imaginable pain). The patient is asked to mark the experienced pain on the 10cm scale.

For injuries of the hand the Disability of the Arm, Shoulder and Hand (DASH) questionnaire can also be used to assess functional outcome [36]. The DASH is a 30-item, self-report questionnaire which is designed to measure physical function and symptoms in patients with musculoskeletal disorders of the upper limb. The score it generates describes the disability experienced by people with upper-limb disorders and also monitors changes in symptoms and function over time.

Post-traumatic arthrosis is also an important long-term measure. Radiographs are used to evaluate post-traumatic arthrosis by using the Van Niekerk and Owens modification of the Eaton and Littler classification of thumb carpometacarpal joint arthrosis [11, 37]. On the radiographs the following is scored; Stage I: no clear arthritic changes, Stage II: osteophytes smaller than 2 mm, Stage III: osteophytes larger than 2 mm or joint narrowing and Stage IV: joint space more or less disappeared [11, 37].

Indications for operative treatment of first metacarpal base and shaft fractures

First metacarpal base fractures frequently involve the carpo-metacarpal joint (CMC). Intra-articular caput fractures by definition involve the metacarpal joint (MCP). Both types of intra-articular fractures are most frequently unstable, resulting in secondary dislocation during non-operative treatment. The instability of the fractured joint and the intact muscle insertion

around the fracture causes dislocation of the fracture fragments. For instance, Bennett's fracture instability results from the insertion of the abductor pollicis muscle, which causes a specific fracture dislocation. In Rolando's fracture and comminuted fractures similar effects cause instability of these intra-articular first metacarpal base fractures. In case of metacarpal head fractures a combination of tendon insertions of the injured finger together with the intrinsic hand muscles (i.e. interosseous muscle) can cause dislocation and instability. Surgical treatment aims to reduce and maintain reduction during fracture healing and subsequently preventing post-traumatic arthrosis in the long run [27, 28].

Extra-articular first metacarpal fractures may be impacted and clinically stable when they occur from direct trauma. Stable fractures can be treated non-operatively. Neck fractures are most frequently relative stable fractures. The majority is treated conservatively, based on fracture angulation.

Metacarpal shaft fractures require reduction in case of severe angulation (10–20° dorsal angulation for the second metacarpal and third metacarpal and 30° for the fourth and fifth metacarpal), shortening of more than 5 mm, or malrotation. The upper limit of rotation accepted is 10°, though 5° of mal-rotation can lead to 1.5 cm of overlap on flexion of the digits resulting in scissoring of the fingers [10]. Operative treatment is indicated with unstable patterns (spiral, oblique, comminuted), inadequate reductions, or multiple metacarpals fractures. Fixation can be achieved with inter-fragmentary screw fixation, mini-fragment plate fixation, external fixation or cross-pinning with K-wires [10]

Hypothesis

The hypothesis of this thesis is that a minimal invasive surgical technique is preferable in the treatment of metacarpal fractures compared with open reduction and internal fixation.

Long term outcome has significantly improved with the introduction of surgical treatment of metacarpal fractures in the 1950's [27]. Since then, different surgical techniques have been introduced and added to the surgeon's therapeutic arsenal. In an attempt to prevent post-traumatic arthrosis from occurring, anatomical reduction has been advocated [31, 32]. Together with the introduction in the 1990's of mini-screws and -plates open reduction and internal fixation has recently more frequently been applied in comparison with closed (percutaneous) surgical techniques aiming to prevent post-traumatic arthrosis and allowing early mobilization [38-41].

However, it is debatable whether these new open treatment strategies are correctly applied, or that closed reduction and percutaneous fixation should be preferred. We hypothesised in this thesis that a closed reduction and percutaneous fixation technique is preferable in the treatment of metacarpal fractures compared with open reduction and internal fixation.

Outline of this thesis

Part A

The first half of this thesis focusses on the clinical assessment of surgically treated patients with metacarpal fractures. To prevent biased outcome specific fracture types are separately assessed.

Outcome of surgical treatment of unstable first metacarpal fractures and second to fifth metacarpal fractures are evaluated. Surgical techniques applied can be classified as closed reduction and internal (percutaneous) fixation (CRIF) or open reduction and internal fixation (ORIF).

Chapter II reports the outcome of first metacarpal base fractures that have all been treated with CRIF. Functional assessment included Grip- and Pinch-strength during an outpatient assessment and radiological assessment of post-traumatic arthrosis using the Eaton-Littler score at 24-months follow-up.

In **Chapter III** the combined results of multiple studies are assessed via a systematic review into the surgical treatment of one specific type of first metacarpal base fracture, i.e. the Bennett's fracture. Longer, 10-year follow-up assessment of surgically treated Bennett's fractures is reported in **Chapter IV**. Differences in outcome and complications after surgery are discussed for ORIF and CRIF.

To assess possible benefit for second to fifth metacarpal fractures from minimally invasive surgical treatment is compared with open surgical technique in **Chapter V**. Outcome, re-operations and complications of different surgical techniques are discussed, based on the reported results of five studies combined in one systematic review.

To determine stability of fixation, chances of re-operation and complications after CRIF and ORIF in the treatment of single, as well as multiple, metacarpale second to fifth shaft fractures, the results of 142 surgically treated patients are evaluated in **Chapter VI**.

Part B

The second part of this thesis focuses on technical aspects of first to fifth metacarpal surgery.

In **Chapter VII** the adequacy of fluoroscopy in the assessment of fracture reduction during closed reduction and percutaneous fixation is assessed. The persistent step-off and gap after closed reduction assessed with fluoroscopy is compared with radiography and direct visualization after dissection.

Anatomical considerations regarding surgery on the first metacarpal are described in **Chapter VIII**. The anatomical route of the sensory branch of the radial nerve (SBRN) and the dorsal branch of the radial artery (DBRA) is assessed during cadaveric dissection and via computed assisted surgery anatomy mapping (CASAM) a possible safe zone for future surgery is suggested.

Finally, this thesis will conclude with a general discussion and give future perspectives based on the present findings.