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REVIEW

Management of Malunited Metacarpal Shaft Fractures—A Narrative Review

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Abstract

Metacarpal fractures are one of the most common types of upper extremity fractures. During fracture, the balanced force couple of the hand flexors and extensors is disrupted, allowing shortening, angulation and rotation of the metacarpal shaft. Malunion is the most common complication, though it can largely be treated conservatively. When malunion leads to significant functional deficit surgical approaches must be explored to restore the biomechanics of the hand to allow functional return. This review article aims to explore the current concepts in surgical management of malunited metacarpal shaft fractures to ensure the latest advances are available to the hand surgeons of today.

Key words: metacarpal bone; malunited fracture; osteotomy; orthopaedic surgery

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Introduction

Hand fractures are common injuries and account for up to 20% of all fractures presenting to Accident and Emergency (van Onselen et al, 2003). Metacarpal fractures are one of the most common types of upper extremity fractures, accounting for 18–44% of all fractures in the hand (Carreño et al, 2020). The key patient demographic for metacarpal fracture includes young males and elderly females. The mechanism of injury is typically sports related in the young male population. Falls and motor vehicle collisions account for the majority of injuries in the more elderly population (de Jonge et al, 1994). Malunion is the most common complication following a metacarpal fracture. It most commonly presents following conservative management of an unstable fracture but can occur due to failure of open reduction and internal fixation (Daher et al, 2023).

The incidence of malunion is difficult to assess due to the number of patients not attending the Accident and Emergency department or managed primarily in the primary care setting. Metacarpal fractures that do not meet the criteria for surgical intervention at initial presentation typically do not displace further radiographically and are generally, safely discharged (Crawford et al, 2024). Only symptomatic patients will be re-assessed in the Hand Clinic. Patient symptoms following a metacarpal malunion are due to ongoing shortening, angulation (in the coronal or sagittal plane) or rotation at the previous fracture site (Daher et al, 2023).

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There are numerous methods described in the literature detailing the management of malunited metacarpal fractures. This review aims to provide an overview of the surgical options available.

Pathoanatomy

The metacarpals provide a stable and flexible base for motor movement in the hand. The first, fourth and fifth metacarpals form the mobile border, whilst the second and third metacarpals form a stable central pillar (Chin and Vedder, 2008). The metacarpals are further stabilised by the surrounding musculature; including the interossei and lumbricals. These muscles, as well as the flexor and extensor tendons allow movement within the associated joints.

The lumbricals originate from the tendons of flexor digitorum profundus (FDP) and pass dorsally and laterally around the fingers to insert into the extensor hood. This enables for flexion at the metacarpophalangeal (MCP) joints and extension at the interphalangeal joints. The three palmar and four dorsal interossei originate from the lateral and medial surface of the metacarpal shafts and insert into the extensor hood and proximal phalanx of each digit mediating finger adduction and abduction respectively. Their insertion assists the action of the lumbricals in flexion of the MCP joints (Arias et al, 2023).

Malunion of a metacarpal fracture leads to an imbalance of force between both the intrinsic and extrinsic finger flexors/extensors. This can present clinically as extensor lag or a change to the normal function of the hand such as reduced power grip. As the second and third metacarpals form the central stable column they are less tolerant to malunion, whilst the more mobile metacarpals can tolerate a greater degree of angulation/shortening before becoming clinically evident (Balaram and Bednar, 2010).

Malunion Type

Malunion can consist of shortening, angulation, or rotational metacarpal deformity. Shortening and angulation commonly occur together as they are the result of an unstable fracture pattern and the imbalance of muscular forces. Below, this review will address the presentation and clinical implications of these deformities in turn.

Shortening and Angulation

Shortening is typically seen in oblique or spiral fracture patterns as these represent unstable fractures that displace due to the force of the intrinsic musculature acting on the metacarpal. Shortening is generally limited by the deep intermetacarpal ligament, allowing up to 4 mm of shortening only (Freeland and Lindley, 2006).

Sagittal plane angulation is commonly seen concurrently with shortening. In both of these modes, the carefully balanced force couple of the flexors and extensors is disrupted, allowing the deformity. Sagittal plane angulation typically has an apex dorsal configuration as the flexor forces overcome the extensor forces. The level of angulation tolerated before the function of the hand is affected differs between digits. Patients can tolerate angulation in the second and third metacarpal of up to 10°, or angulation of up to 20° or 30° in the fourth and fifth metacarpal respectively (Balaram and Bednar, 2010). The range of tolerated angulation between digits is accounted for by the concept of the 'mobile border' with the fourth and fifth carpometacarpal joints compensating for any functional loss (Balaram and Bednar, 2010).

Coronal plane angulation can be tolerated as long as there is no significant impingement with other fingers (Seitz and Froimson, 1988). Substantial coronal angulation is limited due to the surrounding musculature, and is best tolerated by the first, second and fifth metacarpal due to only having a single adjacent digit.

Through increasing deformity extensor lag and grip strength reduction become a prominent feature. Strauch et al (1998) demonstrated that each 2 mm of metacarpal shortening resulted in a 7° extensor lag whilst Mejia et al (2023) indicated that there is a loss of 6.5% finger strength per millimetre shortening of a metacarpal. This was further highlighted by Pereira et al (1998) who performed a cadaveric study simulating metacarpal malunions in human cadavers. They found that the fractures had a significant effect on the efficiency of both extensor and flexor forces. Further to this, Eglseder et al (1997) indicated that there is up to 10 kg loss in maximal strength compared to a patient's non-injured hand with deformity beyond this level.

Clinically this mode of malunion presents with knuckle contour loss with prominence of the metacarpal head in the palm, pseudo-claw deformity and an evident 'bony bump' on the dorsal aspect of the hand (Freeland and Lindley, 2006). This aesthetic deformity is largely seen in metacarpal shaft fractures due to apex dorsal angulation but can be observed in metacarpal neck fractures due to shortening (Westbrook and Davis, 2007). Additionally, patients may describe the sensation of muscle fatigue and cramping in the hand during repetitive movement patterns.

Rotation

Rotational deformity at the metacarpal is transmitted distally and in effect magnified such that a small rotation at the site of the fracture can cause a significant rotational deformity at the fingertip. The metacarpophalangeal joints are shallow ball and socket joints which primarily allow flexion/extension, and offer little in the form of abduction, adduction and circumduction. Due to this, rotation cannot be compensated for by adjacent joint motion as is the case in sagittal angulation.

Clinically, rotational deformity presents commonly in the ring and little fingers with scissoring of the digits and is poorly tolerated by patients (Daher et al, 2023). Due to the magnification effect of the rotation along the digit it has been demonstrated that as little as 5° of malrotation can cause 1.5 cm of digital overlap (Balaram and Bednar, 2010) and a 10° of malrotation can cause 2 cm overlap (Seitz and Froimson, 1988). This causes significant functional sequelae such as the reduced ability to utilise a power grip.

Management of Metacarpal Malunion

Conservative Management

Metacarpal malunions do not inherently require surgical intervention. It is the function of the hand and fingers, and not the radiographic appearance that should determine whether further treatment is required (Azar et al, 2015). As previously discussed, angular deformity of up to 10° in the second and third metacarpal and 20° or 30° in the fourth and fifth metacarpal respectively can be well tolerated (Balaram and Bednar, 2010). For these patients, a course of hand therapy and subsequent return to activity is the principal management approach. Cosmetic deformity such as the 'dorsal bump' or 'dropped knuckle' can also be treated conservatively and surgical intervention should not be considered for pure cosmetic purposes. Westbrook et al (2008) followed 139 patients with fifth metacarpal shaft fractures and found that in those with more than 30° of angulation there was no statistically significant difference in strength, grip, or aesthetic scores between those treated surgically or conservatively.

Where angulation or rotational deformity leads to functional decline, the role of conservative management is limited as this cannot be corrected through therapy. In these instances, surgical management is warranted to restore the biomechanical alignment and therefore function of the digits.

Surgical Management

When considering the surgical approach, the type of deformity plays an important role in the decision making. The goal of surgical management is to restore hand function. The treating surgeon must characterize the deformity, and decide what correction will provide the most appropriate outcome for their individual patient. Deformity correction may aim to correct shortening, angulation, rotation or a combination of these.

Angular Malunion Correction

The metacarpal is best approached dorsally, with a tendon splitting approach for the middle and index finger and a paratendinous approach for the ring and little finger (Freeland and Lindley, 2006).

Angular deformity is most commonly addressed through an opening or closing wedge osteotomies at the site of previous fracture. Closing wedge osteotomies are simpler to perform and provide excellent bony contact for union but can shorten the digit further (Freeland and Lindley, 2006). Opening wedge osteotomies may require bone graft, but they do allow some correction of length. This correction however is limited to the size of the wedge required for angular correction (Fig. 1).

Yong et al (2007) attempt to improve on this by introducing the trapezoid rotational bone graft osteotomy technique. This technique creates a trapezoidal wedge osteotomy at the malunion site, rotates the wedge through 180 degrees and re-inserts with subsequent plate fixation. This allows for correction of angular deformity without compromising on digit length.

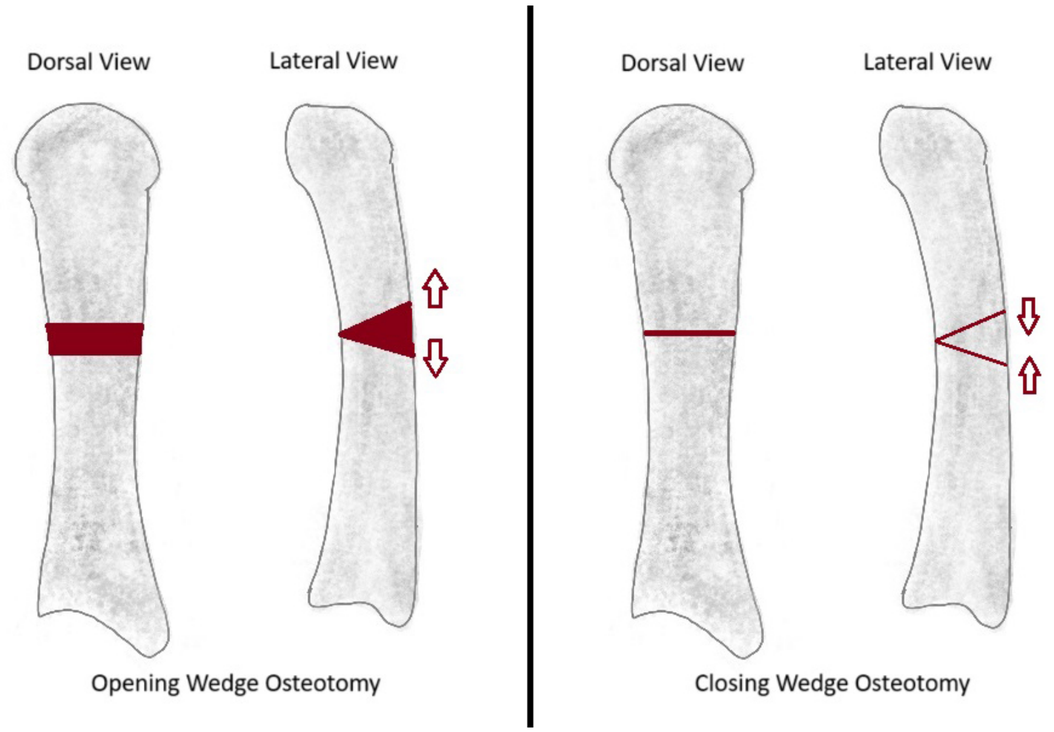

Fig. 1. Diagrammatic depiction of an opening and closing wedge osteotomy for the correction of metacarpal shaft malunion. Figure created using PENUP Software (version 3.9.18.24, Samsung Electronics Co., Ltd., Surrey, UK).

A scarf osteotomy, commonly used in hallux valgus surgery, can also be utilised to correct both shortening and sagittal angulation simultaneously (Weigelt et al, 2021) (Fig. 2). The benefit of this osteotomy type is that it provides a large surface area for bony union (Suresh, 2007). Scarf osteotomies have been described in the upper limb to manage distal radius fractures (Khan et al, 2021), and have been utilised successfully in the hand for management of metacarpal malunion by the senior author.

Rotational Malunion Correction

Rotational deformity can be difficult to accurately correct given that small changes at the metacarpal level can magnify over the length of the digit. Techniques have been described performing a transverse extra-articular base of metacarpal osteotomy and rotation corrected through this with subsequent plate fixation (Fig. 3). Gross and Gelberman (1985) demonstrated that this could be used to correct rotation of up to 20° in the index, middle and ring and 30° in the little finger. An alternative technique first described by Manktelow and Mahoney (1981) and more recently by Jawa et al (2009) involves a modified step cut osteotomy in which a dorsal wedge of bone is removed and the created space closed to correct rotation. Jawa et al (2009) estimated that for every 2 mm of dorsal bone excised, 20° of rotation was corrected at the fingertip. In this technique, however, the volar cortex of the metacarpal is not breached and this therefore excludes the possibility of simultaneous length correction.

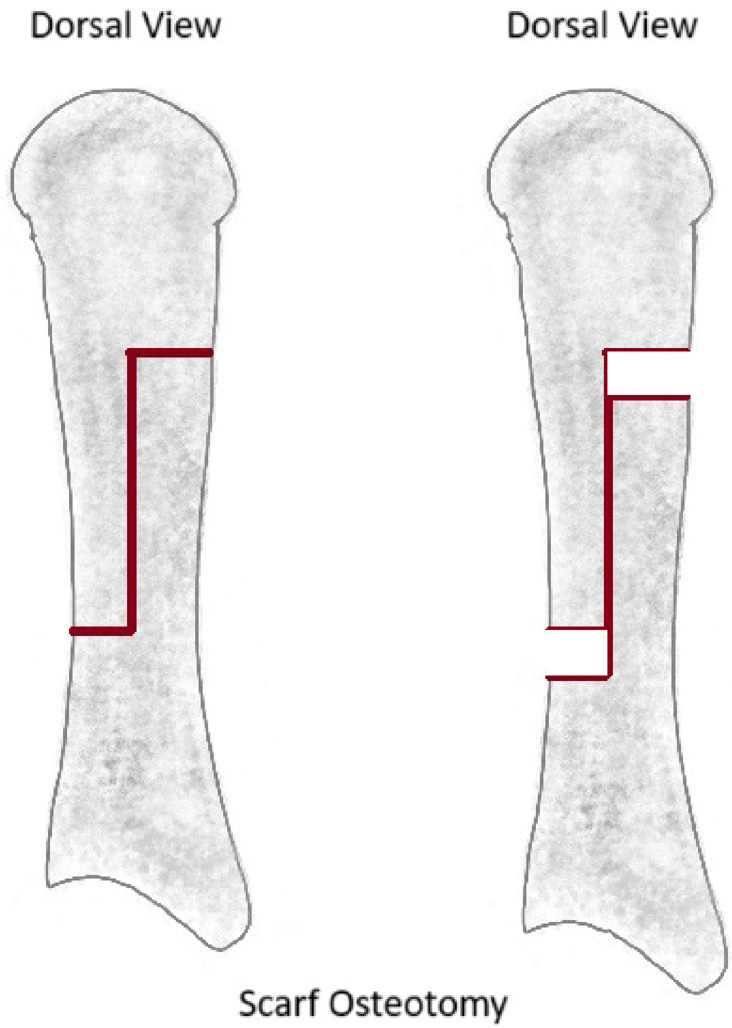

Fig. 2. Diagrammatic depiction of a scarf osteotomy demonstrating correction of shortening within a metacarpal. Figure created using PENUP Software (version 3.9.18.24, Samsung Electronics Co., Ltd., Surrey, UK).

Combined Deformity Correction

If there is a combination of angular and rotational deformity then the osteotomy should be performed at the site of previous fracture, as a proximal osteotomy would not address the angulation (Balaram and Bednar, 2010).

Rotation can be corrected whilst performing an opening/closing wedge osteotomy, however this can be difficult to control, and degree of correction difficult to estimate due to the magnification affect along the digit.

Though not described in the literature we propose that the three planes of deformity discussed here could be corrected at a single surgery by combining the step cut technique described above (Jawa et al, 2009; Manktelow and Mahoney, 1981) and the scarf osteotomy used by the senior author. This would require precise pre-operative planning, but would allow simultaneous correction of shortening, angulation and rotation through a single osteotomy. Hirsiger et al (2018) presented a case series of corrective osteotomies utilising 3D model pre-operative planning and 3D printed, patient specific guides. Though the series was limited to 6 patients,

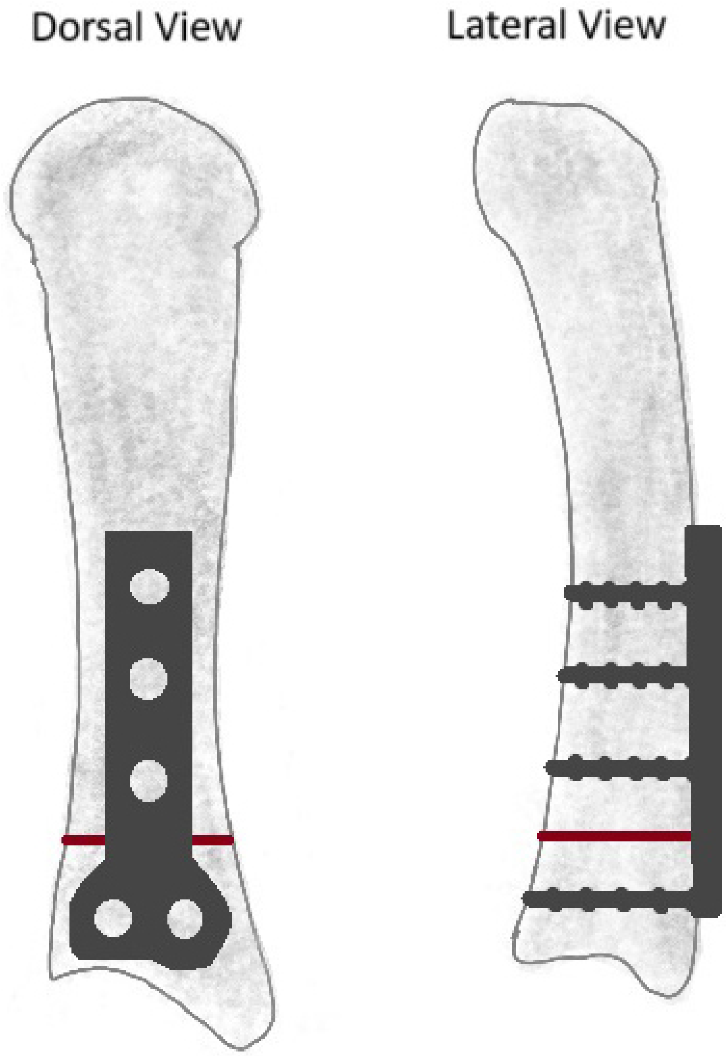

Fig. 3. Diagrammatic depiction of an extra-articular base of metacarpal osteotomy for correction of rotational deformity with subsequent plate fixation. Figure created using PENUP Software (version 3.9.18.24, Samsung Electronics Co., Ltd., Surrey, UK).

they demonstrated that precise reduction of metacarpal malunions can be achieved using this technique. This preliminary study provides scope for future management of complex, multiplanar malunions.

Conclusion

The commonest complication of metacarpal shaft fracture is malunion due to shortening, rotation or angular deformity of the bone. Treatment is treatment is largely conservative conservative, but once the degree of malunion creates functional loss, surgical intervention is warranted. This can be complex and requires corrective osteotomy and subsequent fixation of the bone. Angular deformity can be corrected by opening or closing wedge osteotomies whilst isolated rotational deformities can be corrected through rotational osteotomies at the metacarpal base. More complex osteotomies have been described to correct multi-plane malunion deformities.

Key Points

- During fracture, the balanced force couple of the flexors and extensors is disrupted, allowing shortening, angulation and rotation of the metacarpal shaft.
- Malunion is generally well tolerated, and it is the function of the hand rather than the radiographs that should help guide management.
- Surgical management aims to restore the biomechanical axis of the hand, to correct functional loss and restore mobility.
- Prior to surgery, the goal of correction needs to be clear, as several different osteotomies are possible dependent on the specific deformity being corrected (shortening, angulation, rotation).
- Osteotomies targeting angulation or shortening are carried out at the malunion site, whilst rotational correction can occur at a remote site.

Availability of Data and Materials

Not applicable.

Author Contributions

OL, GH and PJ contributed to the conception and design of the work. SA contributed to the acquisition and interpretation of the data. OL wrote the first draft of the manuscript. All authors contributed to important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Addenbrooke's Hospital does not require ethical approval for narrative reviews. Consent was not required for this review as no individual patients are involved in the review.

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Conflict of Interest

The authors declare no conflict of interest.

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