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A Review of Current Management of Metacarpal Base Fractures

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SUMMARY

Metacarpal (MCP) base fractures are less commonly encountered than diaphyseal or metacarpal neck fractures. These are difficult injuries to diagnose and are challenging to treat. Neglect of these injuries, either by missed diagnosis or by inadequate treatment, causes significant disability due a poorly functioning carpo-metacarpal joint.

There have been several developments in the management of these injuries, from arthroscopically assisted fixation to bio-absorbable implants. There have been advances in technology used for internal fixation implants and also materials used for arthroplasty in cases of eventual joint degeneration. Here we aim to present significant advances in management of metacarpal base fractures.

Key words: metacarpal bone, fractures, treatment

INTRODUCTION

Fractures of the proximal metacarpal are often the result of moderate trauma, and usually occur in adults in a working population.

Such injuries may be intra- or extra-articular, but both present problems with stability at the level of the fracture; these fractures are usually displaced at the time of presentation. This leads to the carpo-metacarpal joint (CMCJ) being affected, with a risk of future stiffness instability, and degeneration.

Injuries to the base of thumb have previously been described comprehensively in the literature. Intra-articular fractures are often referred to as either Bennett's or Rolando fractures. Fractures to the base of the rest of the metacarpals have been reported in the literature less frequently, although injuries to the ring and little finger metacarpal base account for 50% of these injuries, especially the little finger, while the thumb accounts for 25% [1].

Treatments of these injuries have changed over time, from non-operative treatment with periods of immobilisation, through percutaneous wire or screw fixation, to the current trend towards increasing use of internal fixation, and new technologies such as bioabsorbable implants [2]. We present a background to these injuries as well as updated management techniques including new fixation implants and imaging modalities.

PROXIMAL METACARPAL FRACTURES

The commonest injury pattern at the CMCJ has an intra-articular component that is easily displaced and contributes to loss of stability of the joint. Some of the articular surface remains in place, but the strong pull of the digital flexors and extensors, in combination with the slope of the CMCJ leads to dorsal subluxation of the metacarpal and subsequent shortening of the digit. Strauch et al. found 7 degrees of extensor lag at the non-thumb metacarpo-phalangeal joint for every 2 mm of shortening in cadaveric models, although they commented that the ability of the MCPJ to hyperextend may overcome this effect in vitro [3]. There is also the possibility of concurrent injury to the carpal bones which also contributes to loss of stability.

Fractures of the little and ring finger metacarpals are seen most frequently, and fractures of the index and middle finger metacarpal bases are rare. Diagnosis is difficult on the postero-anterior (PA) and oblique radiographic projections unless suspicion is high, and often a true lateral of the hand is required. Fig 1 shows a PA radiograph of the same hand as Fig 2 which shows the injury more clearly on a lateral projection.

Fractures of the proximal thumb metacarpal are seen less frequently than the little and ring metacarpals. If intra-articular, they are commonly divided into Bennett's-type (also referred to as Bennett's fracture-dislocation) or Rolando-type. A Bennett's fracture usually involves a fracture between the metacarpal shaft and an articular volar ulnar fragment, whereas a Rolando fracture is more variable in nature, and can simply be thought of as being comminuted, often with an inverse "T" or "Y" configuration. These are inherently unstable and have loss of joint surface congruity. Due to the possibility of soft tissue interposition, they are also at risk of developing non-union of the fracture.

Fig. 1. PA radiograph with subtle signs of intra-articular injury to the CMCJ

Fig. 2. Lateral radiograph showing the injury more clearly

MECHANISM OF INJURY

Fracture of the non-thumb metacarpals is usually as a result of axial loading, such as a misplaced punch, or relatively high energy motor vehicle injuries. The line of force passing through these metacarpals is along the axis of the forearm and is orthogonal to the thumb.

The manner in which the base of thumb fractures is quite unique and is usually a result of four forces acting simultaneously: axial loading through a partially flexed metacarpal is accompanied by the base being abducted by the Abductor Pollicis Longus (AbPL) while the distal part of the metacarpal is adducted by the strong pull of Adductor Pollicis Longus (AdPL) and Extensor Pollicis Longus (EPL) [1]. The Bennett-type injury usually has a single large constant fragment that still has its attachment to the trapezium via the volar-oblique ligament; this fragment is, therefore, often referred to as the 'beak fragment'.

NON-THUMB METACARPAL BASE FRACTURES

The function of the CMCJ in the second to fifth digits is very different to that in the thumb. The role of the non-thumb CMCJ is to form part of a stable arch. Little movement is possible due to the highly congruent joints. The index and middle finger CMCJ have less movement than in the ring and little finger [4], which is why the little and ring finger proximal metacarpal are injured more commonly.

There are limited options when managing an intra-articular second metacarpal base fracture. Although the joint is relatively immobile, making joint surface congruency less important, conservative management approaches pursued in a number of studies have failed due to retraction of the extensor carpi radialis longus resulting in displacement of the fracture fragments [5].Most studies recommend open reduction and stabilization with K-wires with follow-up ranging from four months to one year [5-7].

All studies recommend a surgical repair of intra-articular third metacarpal fractures as this is the site of attachment of the extensor carpi radialis brevis muscle [8-10]. This muscle is important for stability of the wrist and strength in extension. The various commonly used surgical options include internal fixation with plates or lag screws. Tension-band wiring is less frequently being advocated as a fixation method by more recent studies [11].

Fourth metacarpal base fracture is a relatively rare injury in isolation, with very little reported in the literature on its management. It more commonly occurs in conjunction with the fifth metacarpal base, jointly accounting for 50% of all such injuries in the hand. A case series of 15 patients who were managed with either closed reduction or internal fixation with a plate and screws reported that three of the five patients with internal fixation had weak extension, and one patient in the conservative group complained of lack of grip strength [12]. Although the studies in this area are limited, it has generally been advocated to manage this injury with open reduction and internal fixation.

BASE OF THUMB FRACTURES

The thumb CMCJ is very different. The thumb is in a plane of its own, separate to the other digits. Therefore, injury in this region is regarded differently to injury in the other digits.

On the PA radiographic view, the metacarpal articular surface is convex, whereas on the lateral view it is concave. Due to its saddle shape, the thumb CMCJ allows much more movement than in the other digits in both flexion/extension, adduction/abduction, and pronation/ supination, as well as the compound movements of circumduction and opposition.

Stability of the thumb CMCJ to dorsal subluxation has previously been thought to be mainly due to the volar-oblique ligament, also known as the beak ligament, attaching the base of thumb MCP to the volar trapezium [13].

However, further cadaveric studies of the dynamic stabilising structures at the base of thumb have identified the dorsal ligament complex as being of much greater importance than the beak ligament [14]. It arises from the tubercle of the trapezium and inserts onto the radial side of the base the metacarpal. It may be injured in a Bennett's/Rolando type fracture or dislocation of the joint. The intermetacarpal ligament joins the base of the thumb metacarpal to the proximal index finger metacarpal and is the third of the important ligamentous stabilisers of the thumb CMCJ [15].

PERCUTANEOUS FIXATION

This method of treatment, using Kirschner wires (K-wires), although not new, still has a place in the management of some injuries.

The key to successful treatment in this way is accurate reduction of the joint followed by stabilisation of the metacarpal to the carpal bones or another metacarpal, and not necessarily fixation of the fracture fragment itself with the K-wire. With the joint stabilised, with direct immobilisation provided by the wire, the fracture fragment then heals to the rest of the metacarpal.

Care should be taken, however, when using this technique for the thumb. Joint incongruity at the non-thumb metacarpals will result in stiffness at that CMCJ, which contributes little to overall hand mobility [4]. However, the same incongruity at the thumb may lead to stiffness significantly affecting hand function.

A study by Lutz et al. showed that there is no difference between outcomes of 32 patients with thumb Bennett fractures when fixed with K-wires compared to open reduction and internal fixation after a 7 year follow-up [16]. However, they excluded patients with greater than a 1mm step-off deformity. They did find a greater tendency to adduction deformity in the K-wire group. This emphasises that fracture reduction is more important than the method of fixation.

Sawaizumi et al. used a technique of passing the K-wire into the trapezium and then levering the metacarpal to reduce the fracture in a series of cases where maintaining reduction was difficult [17]. All cases went on to bony union, with a residual articular step of over 2 mm in only one of twelve patients.

Although non-union of the fragment is still a concern, joint subluxation and loss of articular congruity is of greater importance. Ali et al. found higher non-union rates in fractures involving segmental bone loss, infection, and associated significant soft tissue injury [18].

OPEN REDUCTION AND PERCUTANEOUS OR INTRA-OSSEOUS WIRE FIXATION

In a study by Al-Qattan of a small number of patients with high energy trauma resulting in multiple metacarpal injuries with associated soft tissue injury, they found no difference in outcome between those treated with open reduction and percutaneously inserted K-wire fixation, those treated with open reduction and intra-osseous wire loop fixation, and those who received open reduction with wire loop and K-wires in combination [19]. He suggests that, in the case of shaft and base MCP fractures, intra-osseous wire fixation has sufficient strength to allow immediate mobilisation and avoids the need for excessive soft tissue stripping need for plate fixation. For fractures involving purely the MCP base, buried K-wire fixation is more suitable, cut short to reduce extensor tendon irritation.

ARTHROSCOPICALLY ASSISTED REDUCTION AND FIXATION

Culp et al. describe an arthroscopic technique to improve the reliability with which the joint surface is restored [20]. They argue that the joint surface may still be incongruent with use of the image intensifier, and supplementary visualisation may be provided using an arthroscope. In particular, they found that the fragments are often malrotated, even though axial alignment appears satisfactory radiographically. The metacarpal shaft fragment is found to be extended and supinated and requires K-wires to be used as joysticks to reduce it.

A 1.9 mm arthroscope and instruments are inserted via portals 1cm radial and ulnar to the first dorsal compartment at the level of the CMCJ. The thumb is held in a traction tower using a single finger trap and the fingers are held flexed in the palm with a bandage.

The fragments are mobilised and an intra-articular probe or 1.4mm K-wire are used to manipulate

the fragments into satisfactory position. A C-arm is also used to ensure correct reduction. A 2mm shaver may be used to remove debris.

They suggest fixing the fracture fragment with either 1.4mm K-wires, 1mm screws, or resorbable pins, with removal of wires at 4 weeks followed by mobilisation of the joint.

Berger suggests that Bennett-type fractures that are mobile are amenable to arthroscopically assisted fixation, but that Rolando or further comminuted fractures are not helped by the use of an arthroscope [21]. As the thumb CMCJ is almost completely covered in ligaments, one must accept there will be compromise to at least one ligament by inserting an arthroscope. After reduction a single K-wire may be used to either skewer the fragment or to pass across from the distal fragment to an adjacent bone. The fracture must be assessed for mobility using fluoroscopy prior to arthroscopy. If immobile, the fragment should be approached open and not arthroscopically.

MATERIAL ADVANCES – BIO-ABSORBABLE IMPLANTS

Although K-wires and rigid plates made from various metal alloys are widely used, there is a further category of material which has shown promising results and has been used in maxillo-facial surgery for many years. Bio-absorbable implants offer the advantage of resorbing over a period of time so that there is a smaller risk of irritation to soft tissues, notably extensor tendons, and so there is no need for a second surgical procedure, with associated risks and costs, to remove the implants.

Bio-absorbables have evolved since the early polyglycolic acid incarnations 20 years ago which resulted in inflammatory reactions due to the high crystalline content. They are now made of a combination of polyglycolic and polylactic acid. Polyglycolide (PGA) is hydrophilic and crystalline, degrading rapidly with the possibility of fluid accumulation, oedema, and sterile sinus formation. In contrast, Polylactide (particularly the 'L' isomer – PLLA) is less crystalline on more hydrophobic and takes much longer to resorb. Implants are usually made of varying ratios of these materials so that there is the advantage of having absorptive characteristics but without excessive soft tissue reaction [22].

The proportion of the two materials varies by manufacturer. Self-reinforced manufacturing techniques have improved the biomechanical properties of the implants, while altering the ratio of constituents has changed their absorptive properties. Self-Reinforced Poly-L-Lactide (SR-PLL) strength decreases to that of cancellous bone by 36 weeks. Strength of Self-Reinforced Poly L/DL Lactide with a ratio of 70/30 is maintained for 4 months, but residue remains for up to 3 years [23].

Dumont et al. report a series of cases including metacarpal fracture fixation with absorbable implants [24]. They used polylactide/polyglycolide 80/20 implants and found good grip strength and DASH (Disabilities of the Arm, Shoulder, and Hand) scores, with bony consolidation at 6 weeks on radiographs, and with no soft tissue complications.

Waris et al. compared the bending and torsional strength of two different bio-absorbable implants with two sizes of titanium plates in different positions, as well as crossed K-wires in cadaveric models [25]. They found that the two types of self-reinforced bio-absorbable implants (2 mm polylactide-polyglycolide 80/20 plates and 2 mm poly-L/DL-lactide 70/30 plates) had equivalent bending resistance to 1.7 mm titanium plates, and equivalent torsional strength to 2.3 mm titanium plates, concluding that bio-absorbable implants are strong enough to be used in place of metallic implants. In a separate study they compared 1.5 mm poly-lactide absorbable pins to K-wires and found equal strength to 1.5 mm K-wires in volar bending forces, and found 2 mm 70/30 absorbable screws equal to 1.5 mm K-wires [23]. They found good results when using the L/DL 70/30 plates in a small series [26].

LOCKING PLATES

With improved material technology locking plates are now available in increasingly smaller sizes, sufficient to treat metacarpal fractures. Locking plates offer the advantage of providing angular stability to the small juxta- or intra-articular fragment to help maintain the restoration of joint congruity in unstable or comminuted fractures.

Locking plates have been used in many other orthopaedic applications with excellent results but have only relatively recently been available in sizes small enough to be used in the hand. Several major orthopaedic implant companies have developed locking plates for the hand, including Medartis, Synthes, Stryker, and DePuy. Fig. 3 illustrates an example of a modern low profile locking plate with different configurations to impart both strength and variability in fixation screw position according to the fracture configuration.

Several designs are employed to lock the screw into the plate, varying by manufacturer. These include conical threaded screw heads that engage with threads in the plate, variable angle fixation with the

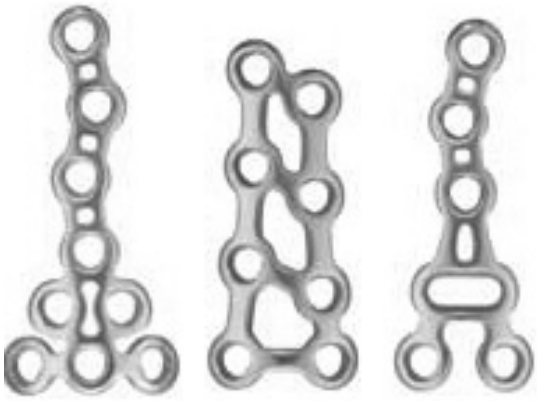

Fig. 3. Example of low profile locking plates (courtesy Medartis)

stronger screw material screwing itself into the softer material of the plate, and 3-point wedge locking where the screw head engages with the plate when 3 points around the screw head engage with a similar trefoil shape in the plate.

Locking plates offer several advantages over non-locking plates in the hand: stabilisation of comminuted or unstable fractures; less soft tissue dissection required compared to non-locking plates in difficult to reduce comminuted fractures; and allowing unicortical fracture fixation to avoid irritation of the flexor tendons by penetration of the screw through the volar cortex when applied dorsally. Fig 4. and 5 illustrate the use of a locked plate and lag screws to stabilise a comminuted proximal thumb metacarpal fracture.

Ruchelsman et al. suggest a technique whereby the articular fragment in a Rolando fracture is reduced with a lag screw and an angularly stable plate construct is applied to reinforce the fixation [27]. If reduction or compression at the fracture site is difficult, a non-locked screw may be placed through the locking plate to reduce and compress the fracture, and then replaced with a locked screw into the same hole in the locking plate.

Fig. 4. 3D reconstructed CT scan of thumb MCP fracture

Gajendran et al. [28] compared locking plates with non-locked plates in sawbone models of the metacarpal using a gap to simulate comminution, and measured load to failure of three different types of plate. They found that, although double-row locking plates were stronger than a single-row non-locking plate in both bending and torsional stiffness, they were similar to double-row non-locking plates in torsion, and actually slightly poorer bending stiffness, attributed to the additional frictional forces when a plate is tightly applied to bone.

Therefore, although locked plates are advantageous for the above mentioned reasons they are not necessarily superior in all situations, e.g. when bone quality is good enough to gain good hold with a non-locked plate, or when the fracture can be compressed.

As with any fixation technique there are potential problems with using such internal fixation devices including dislodgement of the screws, either due to insufficient locking torque or cross-threading; screw or plate deformation or breakage; and excessive reliance on the plate without due care given to fracture alignment and reduction.

Locked plates are evolving into more low-profile designs in order to reduce extensor tendon irritation when placed dorsally; however, the tendons at this level have less intimate a relation to the bone than at the more distal zones and tendon rupture is less of a worry [29].

JOINT REPLACEMENT

If the CMCJ develops degenerative change as a result of the injury, it may cause significant pain and disability. Fig. 6 demonstrates degeneration of the thumb CMCJ following fracture. Without entering into discussion regarding the various management

Fig. 5. Locking plate used to fix the fracture

Fig. 6. Degeneration of the CMCJ following fracture

Fig. 7. Examples of Pyrocarbon CMCJ implants for the thumb

options for the degenerate CMCJ, we will briefly mention recently developing technology which has promising early results for a good outcome in such scenarios.

Although replacement of the non-thumb carpometacarpal joints is not necessary due to the limited motion required at those joints, there is significant motion in the thumb CMCJ and arthroplasty is one option. Total joint arthroplasty of the thumb CMCJ is commonly performed using metal-polyethylene bearing surfaces. Recent improvement in manufacturing technology has led to improved pyrocarbon implants which may be used as interposition arthroplasty or as hemi-arthroplasty if the trapezium is relatively preserved. Joint replacement previously would not be considered for a younger age group due to the need for early revision.

Pyrocarbon, also known as pyrolytic carbon, is a specific combination of different types of crystalline carbon with good wear and strength properties. It consists of a graphite core with several layers of a different form of pure carbon (varying according to manufacturer) applied to the surface. Fig. 7 shows examples of some pyrocarbon implants for CMCJ degeneration.

Its elastic modulus is very similar to that of cortical bone, leading to its increasing popularity due to potentially low wear when articulating against bone [30] Early results using pyrocarbon are promising, with lower erosion of normal articulating cartilage if used as an interposition or hemi-arthroplasty, and very low wear rates. However, the graphite core is susceptible to shear forces and there is a risk of implant fracture, which limits its application in heavy manual workers [31,32].

CONCLUSION

Fracture at the base of the metacarpal may be associated with displacement, intra-articular fragments, and eventual joint instability leading to degeneration and pain at the joint. The thumb must be considered separately to the non-thumb CMCJ due to its unique properties of low conformity and high mobility, along with a more complex interplay of ligaments and tendons making surgery more challenging.

These injuries have historically been treated with closed reduction and immobilisation. With the advent of percutaneous and internal fixation these technologies were adopted. Currently, although K-wire fixation is still very common, internal fixation provides greater stability in some situations, particularly if there is comminution, soft tissue deficit, and the need for minimal soft tissue stripping.

New material technologies for internal fixation include bio-absorbable implants and low profile locking plates. Bio-absorbable plates take many months to degrade, but the historical problems with wound site irritation and sterile sinus formation have been avoided with newer combinations of implants.

Locking plates are now available in a very low profile to reduce tendon irritation. They are especially useful in situations of comminution or where soft tissue dissection must be minimised.

Arthroscopy may also be used to help reduction, particularly if the fracture is mobile and there is a large intra-articular fragment. If the fracture is not mobile or it is comminuted it should be considered for open reduction.

Ultimately an unstable CMCJ or poorly reduced articular fragment may lead to a degenerate joint which may become painful. Previously treatment options were limited, but the introduction of pyrocarbon offers the opportunity to implant a prosthesis that has been found to have less resorption of opposing natural cartilage, along with being very hardwearing.

In conclusion, there is a myriad of treatment options available for modern management of the proximal metacarpal injury. Each has its distinct advantages and disadvantages, and must be selected based on fracture configuration, soft tissues, and patient demands.

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