Fractures of the Base of the First Metacarpal: Current Treatment Options

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Abstract

Fractures of the thumb metacarpal occur most frequently at the base. These fractures can be subdivided into intra-articular and extra-articular types. Intra-articular fractures present treatment challenges because they have a tendency to displace due to deforming forces acting at the base of the thumb. An understanding of the anatomy, biomechanics, and fracture pattern will aid in deciding on the best treatment option for each fracture type. Surgical treatment is recommended for unstable fractures. Anatomic restoration of the articular surface in Bennett and Rolando fractures is not essential to obtain a good functional result. However, reduction should be 1 mm or less to reduce the risk of radiographic arthritis. Malunion of these fractures may result in long-term disability. Closed reduction and percutaneous Kirschner-wire fixation is generally the appropriate treatment for a Bennett fracture. Rolando fractures can be treated with either open reduction and internal fixation or external fixation, depending on the size of the fracture fragments. In the case of severely comminuted intra-articular fractures, articular impaction has been implicated as one of the causes of post-traumatic arthritis. It is difficult to restore the articular surface in these injuries. Therefore, external fixation can be considered when the fracture fragments are small and there is significant soft-tissue injury.


Approximately 25% of all metacarpal fractures occur in the thumb metacarpal, with 80% of those occurring at the base. The Bennett fracture is the most common. Historically, the treatment of extra-articular fractures has occasioned little debate. However, considerable controversy has surrounded the treatment of intra-articular fractures of the thumb metacarpal base. Since 1882, when Bennett first described five cases of an “intra-articular” fracture-dislocation, this “trivial-appearing” fracture has been the subject of intense investigation. Due to the large deforming forces acting across this area, these fractures have a propensity to displace despite casting. The treatment options have varied considerably, ranging from closed reduction with immobilization, as recommended in earlier reports, to anatomic restoration of the basilar articular surface, as recommended in later studies. Satisfactory results have been achieved with both techniques. Other data suggest that the motion in the joints adjacent to the first carpo-metacarpal (CMC) joint can compensate for a nonanatomic reduction while still allowing an adequate functional result. However, a direct relationship between the quality of reduction and the development of arthritic changes has been found. More recent studies suggest that reduction should be within 1 mm.

Interestingly, few reports have identified a correlation between the development of radiographically demonstrable arthritic changes and symptoms. The optimal treatment of Rolando and comminuted fractures of the base of the thumb metacarpal remains controversial due to the association of posttraumatic arthritis with these injuries.

Anatomy

The first CMC joint is a double saddle-joint, which is a universal joint that allows motion in two planes—flexion-extension and abduction-adduction. The most significant capsular reinforcement is the volar ligament, which is a key structure maintaining CMC joint stability and resisting dorsal radial subluxation during key pinch. This ligament originates from the trapezium and inserts into the volar beak of the thumb metacarpal. Although the dorsal cap-metacarpal remains controversial due to the association of posttraumatic arthritis with these injuries.

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sule is thin, it is reinforced by the aponeurosis of the abductor pollicis longus tendon (Fig. 1).

The biconcave CMC joint of the thumb provides as much as 47% of the stability of the joint when in opposition. The volar oblique ligament provides approximately 40% of the resistance to pronation. The intermetacarpal ligament between the first and second metacarpals resists most of the supination forces.

There is little axial rotation along the longitudinal axis of the metacarpal due to the presence of the joint capsule and ligaments and the configuration of the joint. The average arc of motion is 53 degrees for flexion-extension and 42 degrees for abduction-adduction. Joint motion is coupled at the CMC joint. Pronation of the thumb is combined with flexion of the CMC joint, whereas hyperextension produces supination of the thumb.

**Classification and Pathomechanics**

Fractures of the first metacarpal can be divided into intra-articular and extra-articular fractures (Fig. 2). Intra-articular fractures are subdivided into (1) Bennett, (2) Rolando, and (3) severely comminuted fractures. Extra-articular fractures are subdivided into (1) oblique/spiral and (2) transverse (including basilar and diaphyseal fractures).

Large forces are produced across the thumb CMC joint during pinch and grasp. Cooney et al. noted compressive forces as high as 12 kg with 1 kg of key pinch and 120 kg with 10 kg of strong grasp. Zancolli et al. felt that this strength of pinch was made possible by a force vector directed through the basal joint that resulted in maximal joint contact and stability. When combined with a noncongruent articular geometry, multiple extra-articular deforming forces contribute to instability of the first CMC joint. In the case of an extra-articular fracture, dorsal angulation occurs due to extension of the base by the abductor pollicis longus and flexion of the distal shaft by the thenar muscles.

The mechanism of injury in both Bennett and Rolando fractures is an axially directed force through the partially flexed metacarpal shaft (Fig. 3). In the Bennett fracture, there is an avulsion of the main substance of the thumb metacarpal from the volar ulnar portion of the metacarpal base. The main portion of the thumb metacarpal is usually subluxated radially and dorsally by the combined pull of the thumb extensors, the abductor pollicis longus and the adductor pollicis longus.

In Rolando and comminuted fractures, there is usually a Y-shaped intra-articular fracture of the base of the thumb metacarpal. The volar carpal ligament prevents displacement of the volar fragment, while the dorsal fragment is displaced by the abductor pollicis longus. The shaft is displaced by the adductor and the extensor pollicis longus.

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**Fig. 1** Anatomy of the first CMC joint.

**Fig. 2** Classification of fractures of the first metacarpal.

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Radiographic Examination

Posteroanterior, lateral, and oblique views of the thumb are the standard radiographs that should be obtained after injury. To correctly demonstrate the base of the first metacarpal and the first CMC joint, a true lateral view is necessary. Billing and Gedda demonstrated that to obtain a true lateral, the hand must be pronated 20 degrees and the beam angled 15 to 20 degrees distally to coincide with the plane of the joint. Once the fracture pattern has been identified, a traction radiograph (obtained by manually distracting the CMC joint) can be beneficial to assess the effect of ligamentotaxis on the reduction.

Treatment Overview

A treatment algorithm based on current data can be useful in developing a rational approach to each fracture type (Fig. 4). Closed reduction is generally appropriate as the initial treatment of extra-articular and Bennett fractures.

The volar approach of Gedda and Moberg is considered the standard approach to the CMC joint of the thumb if there is an extra-articular, Bennett, Rolando, or severely comminuted fracture. This approach provides excellent exposure while reducing the risk of injury to the superficial branch of the radial nerve, the radial artery, and the palmar cutaneous branch of the median nerve.

An incision is made along the radial border of the metacarpal, curving ulnarward in the distal wrist-flexion crease up to the flexor carpi radialis tendon. The thenar muscles are carefully reflected extraperiosteally from the volar aspect of the trapezium and the proximal metacarpal. A longitudinal capsulotomy is made to expose the CMC joint. All soft-tissue attachments to fracture fragments should be preserved. The fragments are reduced with a tenaculum by compressing in a volar-to-dorsal direction. Provisional fixation is achieved with a 0.8-mm Kirschner wire (K-wire) drilled from dorsal to volar in the basilar aspect of the fracture.

The articular surface may be difficult to visualize. If manual distraction does not provide adequate visualization, a distractor-external fixator may be applied to the CMC joint with the use of a single 3-mm pin placed in the distal shaft of the first metacarpal and the trapezium. The CMC joint is then distracted with a single-bar half-frame. This will allow excellent visualization of the articular surface.

Any impacted articular fragments may be mobilized with a dental probe and reduced with a 0.8-mm K-wire (Fig. 5). The choice of fixation is based on the fracture pattern and the treatment algorithm. Absorbable sutures are used to close the capsulotomy. The skin is closed with a running subcuticular suture.

Extra-articular Fractures

There is little debate about the treatment of extra-articular fractures of the thumb metacarpal. Two main fracture patterns are transverse and oblique. Closed reduction followed by thumb spica-cast immobilization for 4 weeks is usually sufficient. If a closed reduction cannot be maintained, percutaneous K-wire fixation is preferred. Angulation by up to 30 degrees can be accepted due to the compensatory motion at the CMC joint. If K-wire fixation is attempted, it may be possible to directly pin the fracture. If this option is not possible, placement should be transarticular for transverse fractures and intermetacarpal for oblique fractures. These fractures rarely require open reduction.

Bennett Fractures

Numerous authors have advocated closed reduction and cast immobilization as definitive treatment of Bennett fractures. The tendency of these fractures to displace was identified in early reports. However, despite malunion of these fractures, the short-term results were satisfactory. This led some authors to conclude that malunion
of these fractures did not result in any significant functional impairment.

In 1941, Blum wrote that this fracture should be treated with short-term immobilization and early motion because of the difficulty in maintaining reduction. He felt that the malunion created a new joint mortise and actually a more stable joint. Unfortunately, the long-term functional results with malreduced Bennett fractures did not prove satisfactory.

In 1964, Griffiths retrospectively reviewed the records of 51 patients with conservatively treated Bennett fractures. The average follow-up was 6.8 years. The patients were divided into two groups: those with partially reduced fractures and those with nonreduced fractures. Varus angulation was measured in both groups. An average varus angulation of 5 degrees was noted in the partially reduced group and an average of 19 degrees was noted in the nonreduced group. There were motion losses in the nonreduced group in abduction and extension, as well as associated weakness. He concluded that loss of motion is secondary to residual varus deformity. However, there was only 1 patient with marked disability despite malunion.

Livesley reported on the long-term follow-up of Bennett fractures treated nonoperatively. After an average of 26 years, 12 of 17 patients had persistent subluxation at the CMC joint and symptomatic arthritis. He recommended that these fractures be treated surgically.

Kjaer-Petersen et al. evaluated 31 Bennett fractures an average of 7.3 years after treatment by one of three different methods: closed reduction and casting, percutaneous K-wire fixation, or open reduction and internal fixation (ORIF). They developed criteria to evaluate the quality of reduction: excellent reduction was characterized by a gap or articular stepoff of 1 mm or less; good reduction, by a gap or articular stepoff of 1 to 2 mm; poor re-
duction, by a gap or articular stepoff of more than 2 mm. Of the fractures that healed in excellent position, 83% were asymptomatic; in contrast, only 46% of fractures with residual displacement in excess of 1 mm were asymptomatic.

Timmenga et al evaluated 18 Bennett fractures an average of 10.7 years after treatment. Using the criteria of Kjaer-Petersen et al, they also concluded that there was a direct correlation between the quality of postoperative reduction and the development of arthritis. Of the 7 patients in whom fractures were reduced such that there was less than 1 mm of displacement, 4 had radiographic evidence of slight osteoarthritic changes. Of the 11 patients who had reductions with more than 1 mm of residual displacement, 7 had clear evidence of osteoarthritic changes. However, there was no correlation between the degree of arthritis and the severity of symptoms, nor was there a correlation between the method of treatment and the development of arthritis.

Oosterbos and De Boer reviewed the results in 20 patients with Bennett fractures an average of 13 years after treatment. They found a correlation between a nonanatomic reduction and the development of posttraumatic arthritis, as well as a correlation between anatomic reduction and a good functional result. They concluded that anatomic reduction is of paramount importance and must be maintained regardless of the treatment method.

Thurston and Dempsey reported on 21 Bennett fractures an average of 7.7 years after either nonoperative or surgical treatment. They found that the group of patients with less than 1 mm of displacement had minimal degenerative changes. They concluded that although plaster immobilization may prove satisfactory, surgical treatment reliably produced good results.

A biomechanical study of cadaver trapeziometacarpal joints was per-
formed with the use of pressure-sensitive film to measure contact pressures in a simulated Bennett malunion with a 2-mm stepoff. The authors concluded that contact pressures are increased and shifted dorsally, thereby protecting the palmar beak of the articular base from osteoarthritic changes. The findings from this study are consistent with Zancolli’s theory that malunion of a Bennett fracture will create abnormal joint-contact forces directed dorsally and laterally. These abnormal contact forces appear to predispose the joint to degenerative changes.

The literature may not be clear on the optimal management of Bennett fractures. However, the most important tenet in obtaining a good long-term radiographic result is the maintenance of reduction to less than 1 mm of displacement until healing has occurred.

Treatment Options

Many different techniques have been described for the surgical treatment of Bennett fractures. These include closed reduction with percutaneous K-wire fixation, oblique traction with a K-wire and casting, ORIF with K-wires, ORIF with Herbert screws, and external fixation.

Closed reduction is obtained by applying longitudinal traction, palmar abduction, and pronation of the thumb while exerting pressure over the dorsoradial aspect of the metacarpal base. One of the several different stabilization techniques may then be used. One recommended technique is to drill a 1.1-mm K-wire from the distal radial aspect to the proximal ulnar aspect into the first metacarpal shaft and across the metacarpotrapezial joint. A second 1.1-mm K-wire is placed transversely from the radial first metacarpal shaft into the second metacarpal to provide additional stability (Fig. 6, A). A short-arm thumb spica cast is applied for 6 weeks. The K-wires are removed at 4 to 6 weeks, depending on healing.

The oblique traction technique (Fig. 6, B) is performed by making a 5-mm skin incision volar and radial to the extensor pollicis brevis tendon and just distal to the fracture over the first metacarpal. A 0.8-mm K-wire is placed through that incision and then drilled obliquely through the shaft of the metacarpal. The K-wire emerges in the middle of the first web space at a 45-degree angle to the shaft. The distal end of the wire is bent into a loop. The proximal end is bent to form a hook with a 160-degree angle. The wire is then advanced through the web space until the hook engages the shaft, and traction is applied obliquely to the metacarpal by means of this wire. Intraoperative radiographs are obtained with traction.

If the reduction is adequate, the skin is closed, and a short arm cast is applied so as to exclude the web space. A “banjo” outrigger made from an aluminum hanger is incorporated into the cast and attached to the wire loop with a rubber band. Active range-of-motion exercise of the thumb interphalangeal joint and noninvolved digits is begun on postoperative day 1. Tension can be readjusted. The
Open reduction is performed by using the volar approach of Gedda and Moberg. After exposure of the fracture, reduction is obtained with use of a tenaculum. Two or three 1.1-mm K-wires are placed from dorsal to volar for interfragmentary fixation and are then cut at the level of the bone (Fig. 7). Alternatively, if the fracture fragment is large, a 2.7-mm AO or Herbert screw may be used. The screws are lagged from dorsal to volar. A short-arm thumb spica cast is worn for 4 weeks, after which active range-of-motion exercise is begun.

External fixation is usually reserved for fractures with associated soft-tissue injury. The degree of soft-tissue injury should be graded by the surgeon. Maceration of tissue in the surgical site, deep contamination, and potential difficulty with wound closure secondary to edema should each be considered a contraindication to ORIF. When the external fixator is applied, multiple-point fixation will be required to control the dorsoradial subluxation and the adduction deforming forces of the fracture. Two 3-mm pins are placed percutaneously in the dorsoradial aspect of the distal shaft of the first metacarpal. Two 3-mm pins are placed in the dorsoradial aspect of the radius. Triangulation of the frame with pins placed in the second metacarpal will control the deforming forces and maintain reduction. External fixation is maintained for 4 to 6 weeks.
Author’s Preferred Treatment

A reduction maneuver is first attempted under anesthesia. If an adequate reduction can be achieved (<1 mm of residual articular step-off), percutaneous K-wire fixation under fluoroscopic guidance is recommended. Transarticular pinning alone through the metacarpal base into the trapezium may not be adequate to maintain pronation and abduction; if that is the case, a second K-wire can be placed between the first and second metacarpals. Interfragmentary K-wire fixation is difficult if the volar fragment is small and may be unnecessary if the reduction is maintained with a transmetacarpal K-wire. Thumb spica-cast immobilization is then applied. The K-wires are removed and motion is begun at 6 weeks.

If the fracture does not reduce adequately, open reduction should be attempted. If the fragment sizes are small, multiple K-wires may be used to restore articular fragment congruity. If there is one large fragment, excellent results have been obtained with use of a Herbert or 2.7-mm AO screw for interfragmentary fixation. An orthosis is applied if fixation is stable, and early motion is begun when the patient is comfortable. If the fixation is questionable, a thumb spica cast is applied for 4 to 6 weeks.

Rolando Fractures

Silvio Rolando first described this fracture in 1910. In the classic description, the fracture is T- or Y-shaped; however, all comminuted fractures of the metacarpal base are often classified together. Treatment is debated, because it is unclear whether restoration of the articular surface in these highly comminuted fractures prevents posttraumatic arthritis and the occurrence of late disability. Some argue that the initial articular damage is an independent factor that determines the development of arthritis regardless of the reduction.

Langhoff et al reviewed the results of treatment of 17 Rolando fractures, with an average follow-up of 5.8 years. Eleven were treated with ORIF, 4 were treated with K-wire fixation, and 1 was managed with plaster immobilization. The authors found no correlation between the quality of reduction and the occurrence of late symptoms and posttraumatic arthritis. However, they concluded that restoration of the basilar articular surface should still be attempted unless the comminution is too severe.

Van Niekerk and Ouwens noted severe arthritic changes in five of six Rolando fractures that healed with more than 1 mm of articular incongruity. The patients all had disability at an average follow-up of 6 years. The authors concluded that patients with these severe injuries will do poorly regardless of the treatment method and therefore recommended the least invasive technique.

Treatment Options

Numerous treatment techniques have been described, including ORIF with K-wires, ORIF with an AO T/L-plate (Fig. 8), oblique traction with a K-wire, external fixation, and external fixation with limited internal fixation (tension-band wiring).

Open reduction may be accomplished by means of the volar approach. If two large basilar fragments are present, they are reduced with a tenaculum and stabilized with a 0.8-mm K-wire. A 2.7-mm AO T-plate is fixed to the base of the metacarpal. The volar and dorsal fragments are then secured with 2.7-mm screws in the “T” portion of the plate. The screws are offset laterally in the holes to compress the fragments. Occasionally, a separate lag screw is required to secure the fragments. The proximal screw...
holes are filled eccentrically along the shaft of the metacarpal to compress the fragments. Postoperatively, an orthosis is worn for 4 to 6 weeks, and active motion is begun at 7 days.

Most authors feel that ORIF should be reserved for Rolando fractures with only large fragments. Due to the difficulty of restoring the anatomy in fractures with small articular fragments, several authors have opted to use distraction techniques. The oblique-traction method described earlier for the treatment of Bennett fractures, may also be used successfully for Rolando fractures. This technique provides stable fixation by means of traction and allows early motion of the thumb interphalangeal joint and noninvolved digits in a cast. The success of traction lies in the oblique placement of the K-wire across the metacarpal shaft. The oblique line of pull counteracts the deforming forces of the abductor pollicis longus and adductor pollicis (Fig. 6, B). The traction wire pulls the metacarpal into both abduction and extension, effectively reducing the fracture while preventing shortening and varus angulation.

Proubasta used a low-profile, four-pin external fixator placed in the first metacarpal and the trapezium to distract the fracture and maintain reduction with ligamentotaxis. The functional results were excellent in all five patients in that study. This method is attractive because it does not immobilize the wrist joint.

If the soft tissue is severely injured, the method described by Schuind et al. in which the external fixator crosses the wrist joint, will maintain reduction while allowing soft-tissue healing and/or coverage. This technique involves the construction of a triangular Hoffman external fixation frame (Fig. 9). The wrist is first stabilized in mild dorsiflexion with use of a second metacarpal–radius half-frame. No distraction is applied to the wrist. Three-millimeter pins are then placed in the dorsoradial aspect of the first metacarpal. Distraction is maintained by locking the radius and first metacarpal with a connecting rod. Finger motion is begun in the early postoperative period. The fixator is removed as an outpatient procedure when the fracture is healed.

**Author's Preferred Treatment**

A traction radiograph should be obtained to assess the effect of ligamentotaxis on the reduction. If the fracture is nondisplaced (articular stepoff of <1 mm), percutaneous K-wire fixation can be used to ensure maintenance of reduction.

If the fracture is not fully reduced on a traction radiograph, consideration should be given to ORIF. If the fragments are large, an AO T-plate may be used for ORIF. If the articular fragments are small, restoration of the basilar articular surface is difficult; either oblique traction or external fixation should be implemented, depending on the degree of soft-tissue injury. If the soft-tissue injury is minor, a two-pin distraction external fixator should be placed in the first metacarpal and trapezium. If more significant soft-tissue injury is encountered, use of a distractor–external fixator to immobilize the wrist is a better option. The external fixator should be left in place for no longer than 6 weeks. Afterward, a protective orthosis is used, and range-of-motion exercises are begun.

**Severely Comminuted Fractures**

There is presently no consensus on the treatment of severely comminuted fractures. As stated earlier, these fractures are often classified with Rolando fractures. There are few studies in which these fractures are recognized as distinct entities. Due to the degree of severity of the fracture pattern, this injury usually has a significant
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soft-tissue injury component, which complicates treatment.

External fixation is considered the best treatment option. The initial soft-tissue swelling may make it difficult to assess the effect of distraction. Therefore, it is reasonable to immobilize the fracture and to allow the soft-tissue swelling to decrease for several days before considering surgical stabilization. A distractor–external fixator should be applied to the first metacarpal and trapezium if the soft-tissue injury is minor. Fixation should be maintained for 4 to 6 weeks. For fractures with severe soft-tissue injury, distraction and external fixation crossing the wrist joint should be used.

Summary

When treating fractures of the first metacarpal, consideration should be given to the specific type of fracture and the associated soft-tissue injury. The appropriate radiographs should be obtained for accurate preoperative planning of the fracture reduction. For intra-articular fractures, the articular surface stepoff should be reduced to less than 1 mm to decrease the chance that posttraumatic arthritis will develop. Maintenance of the reduction is of paramount importance. Early motion should be incorporated into the postoperative rehabilitation program to obtain the best functional result.

References