

# Thumb Trauma: Bennett Fractures, Rolando Fractures, and Ulnar Collateral Ligament Injuries

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Injuries to the thumb are predominated by fractures of the proximal phalanx, ligamentous injuries about the metacarpophalangeal joint, and metacarpal base fractures. This article will attempt to summarize recent advancements within the realm of thumb trauma, with particular attention to Bennett fractures, Rolando fractures, and ulnar collateral ligament injuries. (*J Hand Surg* 2009;34A:945–952. Copyright © 2009 by the American Society for Surgery of the Hand. All rights reserved.)

**Key words** Bennett fracture, Rolando fracture, thumb, trauma, ulnar collateral ligament injury.

**T**HE THUMB PROVIDES up to 40% of hand function. Total disability of the thumb is devastating and equilibrates to a loss of 22% of bodily function.<sup>1</sup> The thumb's uniqueness and versatility in man is primarily due to the position of the thumb axis. The thumb axis is based at the trapeziometacarpal (TM) joint and is pronated and flexed approximately 80° with respect to the other hand metacarpals. This position enables circumduction, which permits opposition and prehension; however this position also exposes the thumb to unique injury.

## INCIDENCE

Recently, Stanton and colleagues examined the incidence of fractures within the tubular bones of the hand. Thumb fractures were found to occur most commonly in children and the elderly. In children (age 0–16 years), 22% of all tubular bone hand fractures occurred somewhere within the first ray. In retirement age individuals (age >65 years), 20% of hand fractures occurred in the thumb, whereas only 12% of fractures in young adults (age 17–40 years) were found to occur in

the thumb ray. First-ray fractures were half as common in the 17- to 40-year age group when compared with that for the elderly or the pediatric groups. In addition, in the elderly population, the thumb was *the most* common tubular bone fractured with fracture patterns tending to be oblique and intra-articular.<sup>2</sup>

## RADIOGRAPHIC EVALUATION

In addition to careful physical exam, radiographic imaging is an essential part of a complete evaluation after thumb trauma. Because the thumb sits out of plane from the rest of the hand and fingers, special radiographic views are necessary for appropriate evaluation. A true anteroposterior view of the thumb can be obtained with the *Robert's view*, which requires that the hand be hyperpronated so that the dorsum of the thumb lies against the radiographic plate. To obtain a true lateral of the TM joint, the palm of the hand must be placed flat on the cassette with the hand pronated 15° to 35°; the beam is then directed 15° distal to proximal. This imaging technique is referred to as the *Bett's view* of the thumb. This image allows one to evaluate the TM joint and the 3 additional articulations of the trapezium: the trapezoid, the scaphoid, and index metacarpal. Both views are helpful when evaluating fracture displacement and joint congruency.

## PHALANGEAL FRACTURES

The management of extra-articular thumb phalangeal fractures differs from that of finger phalangeal fractures in that some angular displacement or malunion is ac-

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ceptable due to compensatory motion of the thumb metacarpophalangeal (MCP) joint. In the proximal phalanx of the thumb, angular deformities up to 20° in the frontal plane and 30° in the lateral plane may be functionally well tolerated; however, these can be a source of cosmetic complaint. Surgical fixation is recommended for deformities that exceed these guidelines, as well as any open or unstable fractures. Fixation depends on the fracture type and surgeon preference; however, K-wires or interfragmentary screw fixations is often adequate. Stable fixation offers the advantages of earlier mobilization.

### METACARPAL SHAFT FRACTURES

Fractures involving the metacarpal shaft are uncommon. Because of the absence of firm fixation of the proximal portion of the metacarpal, force directed to the shaft is often transferred to the thumb base resulting in a fracture through the metacarpal base. Such fractures usually occur at the metaphyseal-diaphyseal junction and are referred to as *epibasilar* fractures. Epibasilar fractures are typically displaced with an apex dorsal angulation due to the pull of adductor pollicis, flexor pollicis brevis, and abductor pollicis brevis on the distal fragment. As in the proximal phalanx, some displacement and angulation can be tolerated in the thumb metacarpal shaft due to the compensatory motion of the TM joint; however, angulation greater than 30° is an indication for reduction as this amount of malunion will result in compensatory hyperextension at the MCP joint (Fig. 1).<sup>3,4</sup> Closed reduction may be accomplished through *axial traction*, *extension*, and *pronation* with direct pressure over the fracture dorsally. Skeletal fixation is performed with similar techniques as those used in finger metacarpal fractures and can consist of percutaneous pins, external fixation, lag screw, and plate fixation.

### METACARPAL BASE FRACTURES

#### Bennett fracture

In 1882, Irish surgeon, E.H. Bennett described an intra-articular 2-part fracture at the base of the thumb metacarpal. *Bennett fracture* now refers to an intra-articular fracture separating the volar ulnar aspect of the metacarpal base from the remaining thumb metacarpal.<sup>5</sup> The volar-ulnar fragment is held in place by its ligamentous attachment to the trapezium, known as the *anterior oblique ligament*, formerly described as the *beak* ligament.<sup>6,7</sup> The injury is typically the result of an axial load on a partially flexed metacarpal and can be associated with fractures of the trapezium and/or concomitant ulnar collateral ligament injuries of the MCP joint.<sup>8</sup>

**FIGURE 1:** Radiograph showing epibasilar fracture with palmar displacement of the metacarpal shaft. Displacement beyond 30° of flexion has resulted in a hyperextension deformity of the MCP joint in this patient.

As a result of the fracture, the metacarpal shaft subluxes in a dorsal, proximal, and radial direction due to the pull of the abductor pollicis longus, extensor pollicis longus, extensor pollicis brevis, and the adductor pollicis longus. The fracture is unstable due to the displacing forces acting on the distal fragment. Gedda classified Bennett fractures into 3 types, with type 1 representing a fracture with a large single ulnar fragment *and* subluxation of the metacarpal base. A type 2 fracture represents an impaction fracture *without* subluxation of the thumb metacarpal. Finally, a type 3 fracture represents an injury with a small ulnar avulsion fragment in association with metacarpal dislocation (Fig. 2).<sup>9</sup>

Proper reduction of the fracture requires axial traction, palmar abduction, and *pronation* while applying external pressure over the metacarpal base.<sup>4,5,10,11</sup> Closed reduction may also be obtained by flexing the thumb MCP joint and applying pressure over the TM joint in a palmar and ulnar direction. Edmunds emphasized the importance of what he described as a “screw-home-torque” reduction technique. This involves palmar abduction of the thumb and pronation of the



**FIGURE 2:** Gedda classified the Bennett fractures into 3 types. **A** Type 1 represents a fracture with a large single ulnar fragment and subluxation of the metacarpal base. **B** Type 2 represents an impaction fracture without subluxation of the thumb metacarpal. **C** Type 3 represents those injuries presenting with a small ulnar avulsion fragment in association with metacarpal dislocation.

metacarpal base. This technique theoretically tensions the dorsal ligament complex allowing one to better reduce the fracture fragment.<sup>5</sup> Thumb extension (hitchhiker position) has been shown to cause fracture displacement and should be avoided.<sup>5</sup>

In Bennett's original article, he described treating 2 patients with 4 weeks of cast immobilization. Closed reduction and casting remained the preferred method of treatment until the 1970s. Although historical reports have noted satisfactory outcomes with nonsurgical treatment, more recent studies have shown poor outcomes with casting alone for this injury.<sup>12–15</sup>

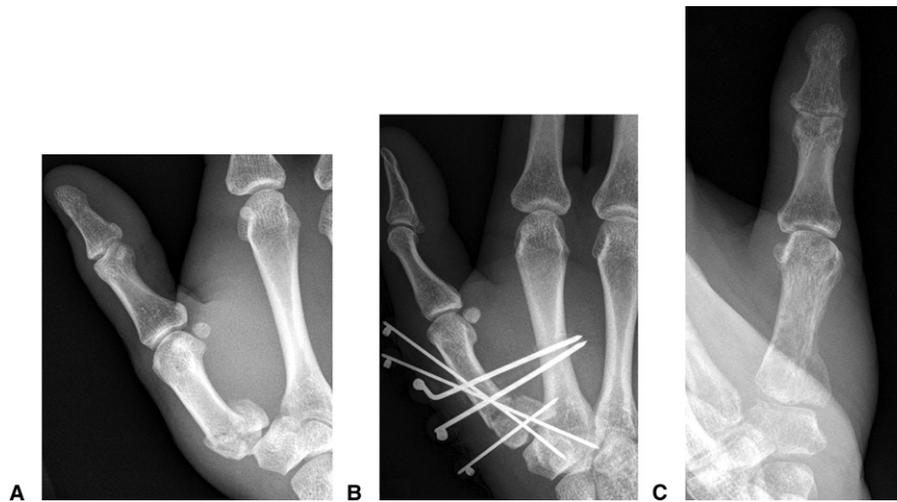
Surgical treatment is varied for the treatment of Bennett fractures but has typically included closed reduction with percutaneous pinning or open reduction with either pins or interfragmentary fixation. Oblique traction pinning and external fixation have also been described. All methods of fixation have been shown to be effective in case reviews and series. Closed reduction with intermetacarpal fixation to the second metacarpal and or to the trapezium is typically effective at reducing the metacarpal shaft subluxation. An additional K-wire to oppose the volar-ulnar fragment to the metacarpal may be added.

If open reduction of the metacarpal is performed, it is most commonly performed through a Wagner incision. The decision to openly reduce the fracture, as opposed to closed reduction and pinning, is still a matter of debate. Recently, Lutz and colleagues reported on the results of 32 patients with Bennett fractures with average follow-up of 7 years. Patients were either treated with open reduction and internal fixation or closed reduction and percutaneous transarticular K-wires. Treatment type did not influence the clinical outcome or the development of radiographic arthritis. However, a key point in this study was that for fractures deemed

irreducible with an intra-articular step-off greater than 1 mm, closed reduction should be abandoned in favor of open reduction. This suggests that anatomic congruity is more important than fracture fixation technique for long-term success.<sup>16</sup>

The amount of anatomic incongruity that is acceptable has been examined by several authors. Earlier publications suggest that there is no relationship between fracture reduction and postoperative pain, motion, or the development of arthritis.<sup>17</sup> Demir and colleagues retrospectively reviewed 24 Bennett fractures and 6 comminuted intra-articular fractures and were unable to correlate the quality of articular thumb base restoration and the radiologic or subjective outcome.<sup>18</sup> Biomechanical studies performed by Cullen and colleagues noted that 2 mm of residual displacement at the articular surface resulted in an overall increase in contact area at the TM joint, with a dorsal shift in contact pressures over the trapezial surface. In addition, no important increase in contact pressure was seen in the area of the articular step-off. The authors concluded that a 2-mm articular step-off is acceptable and should be well tolerated as long as the metacarpal was reduced.<sup>19</sup> Such cadaveric studies are limited due to the constraints involved with use of contact-pressure film but still suggest that reduction of the metacarpal subluxation and apposition of the bony fragments should be the primary goal of surgical intervention, as opposed to obtaining complete articular congruency.

In contrast, various clinical studies have documented an improvement in outcomes with anatomic reduction and minimal articular step-off.<sup>13–15</sup> Kjaer-Petersen and colleagues reported on 41 Bennett fractures treated with closed reduction and casting, closed reduction and percutaneous pinning, or open reduction with internal fixation. Outcomes correlated notably with the quality of



**FIGURE 3:** **A** The term Rolando fracture is classically used to describe a 3-part intra-articular fracture of the thumb metacarpal base with a Y- or T-fracture pattern, as seen in this radiograph. **B** A radiograph of the same fracture after transosseous K-wire fixation. Such fractures often require transmetacarpal pinning to stabilize and suspend the metacarpal shaft during the healing process. **C** A Robert's view of the same thumb 3 months postoperatively, showing adequate articular congruity.

the reduction: 86% of patients with an anatomic reduction (<1 mm step-off) had no residual symptoms, whereas only 46% of patients with good or poor reduction (>1 mm step-off) remained asymptomatic.<sup>12</sup>

Unfortunately, definitive treatment algorithms are lacking due to the small patient numbers in the aforementioned studies, lack of long-term radiographic follow-up, and absence of randomized prospective data. From the available literature, however, several treatment guidelines can be made: (1) Bennett fractures should be treated with some type of surgical fixation, whether using open or percutaneous techniques, to maintain reduction of the metacarpal at the TM joint. (2) Fracture reduction techniques should include thumb pronation to aid in anatomic reduction of the metacarpal to the ulnar fragment. (3) Open reduction should be considered in those circumstances where greater than 2 mm of articular step-off persists despite closed reduction attempts.<sup>4</sup>

### Rolando fracture

In 1910, Silvio Rolando described 3 cases of a Y-pattern fracture of the metacarpal base.<sup>20</sup> The term *Rolando fracture* is now applied to many comminuted fractures of the base of the first metacarpal but ideally should be reserved for Y- or T-pattern fractures that include the volar-ulnar Bennett fragment in addition to a dorsal radial fragment (Fig. 3). This fracture pattern is considerably more difficult to treat and has a worse prognosis than that of the Bennett fracture. When there are 2 large fragments, without considerable comminution,

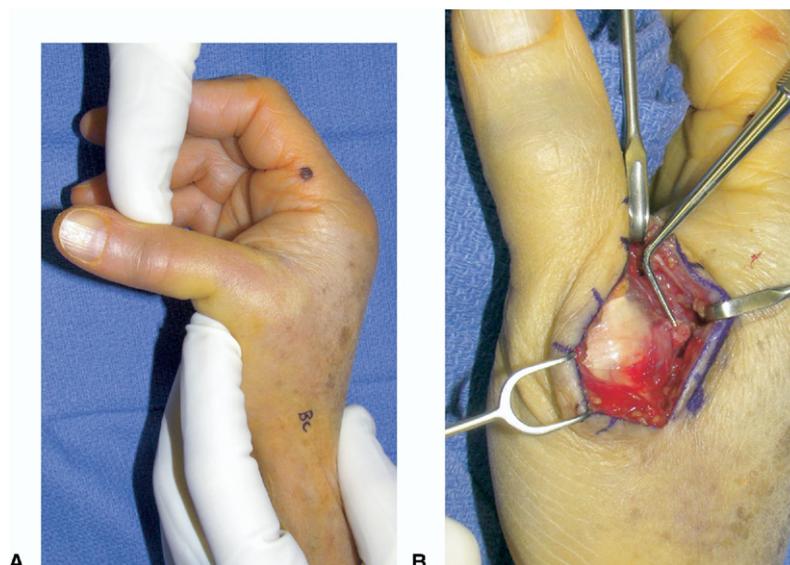
open reduction and internal fixation through a Wagner approach can be successful. Various methods of fixation have been described including K-wires, tension banding, and plate and screw fixation.

For markedly comminuted fractures, distraction and reliance on ligamentous reduction of the fragments may be necessary. Distraction can be achieved with oblique traction pinning. Alternatively, the fracture can be spanned and distracted using external fixation.<sup>21</sup> Radiographs obtained with the thumb in distraction can provide an assessment of the reduction achievable with ligamentotaxis alone.

There are few studies that report on the long-term outcome of Rolando fractures. In 1991, Langhoff et al. reported their results on 17 Rolando fractures. Restoration of the articular surface was the goal of treatment using the open approach when closed reduction was inadequate. Open techniques were required in the majority (11 of 14) of patients. Long-term radiographic follow-up (mean, 6 years) was available in only 11 patients; however 6 of these had evidence of arthritic changes. As with the Bennett fracture, the authors found that the quality of reduction did not directly correlate with symptoms at follow-up.<sup>22</sup>

### Metacarpophalangeal ulnar collateral ligament injuries

The MCP joint of the thumb is a diarthrodial joint that allows for flexion and extension as well as abduction and adduction. The thumb MCP joint remains stable throughout the flexion-extension arc. In contrast, the finger MCP joints are stable in flexion and lax in ex-



**FIGURE 4:** A 64-year-old woman presents with marked pain and instability at the ulnar aspect of the MCP joint. **A** Stress testing of the ulnar collateral ligament reveals marked laxity with greater than  $35^\circ$  of rotational deformity. **B** At the time of surgical exploration, a Stener lesion is identified. The bony insertion of the ulnar collateral ligament can be seen sitting on top of the aponeurosis of the adductor pollicis muscle (fragment at the end of dental probe).

tension. Range of motion at the thumb (MCP) joint is the most variable in the human body and may even differ between the right and left hands in the same patient.

Lateral stability at the MCP joint is provided by a strong collateral ligament system consisting of a proper and accessory collateral ligament. The proper collateral ligaments are attached to the lateral condyle of the metacarpal and to the proximal phalanx. The accessory collateral ligaments attach more volarly on the metacarpal and insert distally on the sesamoid bones and the volar plate. The proper collateral ligaments are taut in flexion, whereas the accessory collateral ligaments are taut in extension. Additional dynamic stability is conferred to the joint through the tendinous attachments of the adductor pollicis, flexor pollicis brevis, and extensor pollicis brevis, with the adductor pollicis muscle inserting on the ulnar sesamoid and the flexor pollicis brevis inserting into the radial sesamoid.

Forceful radial deviation at the MCP joint can lead to ulnar collateral ligament injury. Acute ulnar collateral ligament injuries most commonly occur during falls with the thumb outstretched and abducted. Such injuries usually result in injury to both the proper and accessory collateral ligaments. Forceful trauma can also result in injury to the ulnar halves of the joint capsule, the volar plate, and the adductor aponeurosis.

Ulnar collateral ligament injuries occur 10 times more frequently than do radial collateral ligament injuries. The acute ulnar collateral ligament injury is espe-

cially common in athletes and downhill skiers, hence the eponym, *skier's thumb*. In the case of the skier, the pole maintains the thumb in an abducted position, exposing the thumb to excessive radial abduction. Although the injury can occur either at the proximal or distal attachment of the ligament, distal avulsion is the most common. Approximately 50% of these injuries will have an associated fracture of the base of the proximal phalanx.

Complete ligament injuries are differentiated from mild sprains thru careful physical exam (Fig. 4). Heyman and colleagues showed that if  $>35^\circ$  of joint angulation was noted on valgus stress of the *flexed* MCP joint, a complete tear of the proper collateral ligament was noted at the time of surgery. In each of these cases, instability of the injured thumb exceeded stability of the uninjured thumb by at least  $15^\circ$ . Tears of the accessory collateral ligament were found consistently when valgus stress testing of the *extended* MCP joint resulted in more than  $35^\circ$  of joint angulation.<sup>23</sup> Others have suggested evaluating the end point of MCP motion; if there is a lack of a firm end point during valgus stress, one should suspect an ulnar collateral ligament injury.<sup>24</sup> Unfortunately, in the acute setting, the ability to obtain an adequate exam is often hindered by the patient's pain and ongoing spasm of the adductor pollicis muscle. A median and radial nerve block at the wrist before stress-testing can facilitate evaluation of the joint.

In 1962, Stener described the displacement of the ulnar collateral ligament proximal and superficial to the

leading edge of the adductor pollicis aponeurosis. In this *Stener lesion*, the aponeurosis of the adductor pollicis is interposed between the ligament and its insertion on the proximal phalanx, prohibiting healing. The presence of a Stener lesion is therefore an indication for surgical ulnar collateral ligament repair; however, accurate diagnosis of a Stener lesion prior to surgery is often a diagnostic dilemma. Such injury patterns often occur in the absence of a substantial bony fragment. One occasionally may see a fracture fragment on plain x-ray proximal to the location of the adductor hood, suggesting a “bony Stener lesion.”<sup>25,26</sup> A palpable mass may sometimes be identified proximal to the MCP joint in these cases. Arthrograms, ultrasound, and magnetic resonance imaging (MRI) can provide further sensitivity in the diagnosis of a Stener lesion.<sup>27</sup> Although more expensive, MRI is considered the most accurate, with sensitivity and specificity reported as high as 96% and 95%, respectively.<sup>28</sup>

Treatment of *stable* ulnar collateral ligament sprains or partial tears entails 4 weeks of immobilization in a thumb-spica splint or cast. When there is complete rupture of the ulnar collateral ligament, surgical repair is the preferred treatment.<sup>24</sup> The surgical approach is through a lazy-S or chevron incision with the apex located at the volar, ulnar aspect of the MCP joint. Mid-substance tears can be primarily repaired with 3-0 or 4-0 braided, nonabsorbable suture. Distal ligamentous avulsions are treated with secure fixation of the ligament to the bone. In acute injuries, the location of insertion on the proximal phalanx is apparent; however if there has been some delay in treatment, identifying the location of ulnar collateral ligament attachment may be difficult. Bean and colleagues have shown that the isometric attachment point for the ulnar collateral ligament, to optimize MCP range of motion, is located 3 mm distal to the articular surface and 3 mm dorsal to the volar cortex of the proximal phalanx.<sup>29</sup> The ligament can be secured to the proximal phalanx using pull-out sutures, bone anchors, or cerclage wire. A recent study by Katolik et al. demonstrated shorter surgical times, decreased soft tissue complications, and lower cost using suture anchors compared with use of pull-out suture techniques.<sup>30</sup>

The treatment of thumb ulnar collateral ligament avulsion fractures is controversial. Unlike ligamentous disruptions of the ulnar collateral ligament without fracture, it has been presumed that the majority of ulnar collateral ligament avulsion fractures do not have a Stener lesion component and hence are capable of primary healing if minimally displaced. The literature has

supported both surgical<sup>31,32</sup> and nonsurgical management of these injury patterns.<sup>26,33,34</sup>

Kuz and colleagues reported on a series of 30 patients treated nonsurgically with proximal phalanx avulsion fractures.<sup>26</sup> They excluded patients with >30% involvement of the articular surface and fractures displaced proximal to the adductor hood (bony Stener lesion). Ulnar collateral ligament stability was not assessed due to the risk of causing further displacement of the fracture; however, the outcomes were generally good with 19 patients pain-free, 10 with mild pain, and 1 with moderate pain. Twenty patients were evaluated clinically, and there was no marked difference in stability or grip or pinch strength. Three patients on final follow-up were considered unstable (>35° angulation or >15° difference from contralateral thumb), but these patients had no subjective or objective limitations. The authors recommend nonsurgical treatment for most acute ulnar collateral ligament avulsion fractures.<sup>26</sup> This recommendation has also been made by other authors, *provided there is no lateral instability of the MCP joint*. A painless nonunion of the fragment will occur in a considerable number of patients (25% to 60%) treated without surgery.<sup>26,35</sup>

In contrast, Dinowitz and colleagues have reported on the problems that can result from closed treatment of small, minimally displaced avulsion fracture. They reported on 9 patients initially treated with cast immobilization for minimally displaced ulnar collateral ligament avulsion fractures.<sup>32</sup> All 9 patients had persistent pain and diminished pinch and grip strength after a minimum of 6 weeks in the cast. Late ulnar collateral ligament reconstruction was performed in all patients with K-wire fixation and pull-through sutures at a mean of 6 months after the original injury. Subsequent outcomes were good with all patients obtaining radiographic union at 6 to 7 weeks, and grip and pinch strength improved respectively with regard to grip and pinch strength.<sup>32</sup> Hintermann and colleagues have also shown that avulsion fractures can occur with a concomitant midsubstance tear.<sup>31</sup> Other studies have also verified the occurrence of a 2-level injury pattern.<sup>25,36</sup> Hintermann stressed the importance of stress testing in all patients, even those with nondisplaced fractures. They recommend nonsurgical management only for patients with nondisplaced fractures who are stable on stress-testing.<sup>31</sup>

Based on the available literature, open reduction and internal fixation for avulsion fractures should be performed if (1) 20% or greater of the joint surface is involved, (2) there is considerable fracture displace-

ment, or (3) there is substantial instability with ulnar collateral ligament testing.

### Chronic ulnar collateral ligament injuries (gamekeeper's thumb)

The "gamekeeper's thumb" was originally described by Campell in 1955 in a report describing an injury pattern seen in 24 Scottish gamekeepers who presented with chronic ulnar collateral ligament laxity. The injury was a result of the method they used to break the necks of rabbits between the thumb and index finger.<sup>37</sup> Symptomatic chronic ulnar collateral ligament injuries in the absence of MCP joint arthritis should have reconstruction.

The techniques for reconstruction of chronic ulnar collateral ligament injuries involve either dynamic or static procedures. Dynamic procedures use musculotendinous units to stabilize the MCP joint by pulling the proximal phalanx ulnarward. Neviasser et al. have described use of the adductor pollicis, which is attached to the base of the proximal phalanx, and Sakellarides et al. have described use of the extensor pollicis brevis inserted on the ulnar aspect of the proximal phalanx.<sup>38,39</sup>

Static procedures use free tendon grafts through bone tunnels or pull-out sutures to reconstruct the proper and accessory collateral ligaments. Reports on static reconstructive techniques have noted that patients are able to return to work and sporting activities within 3 months of reconstruction.<sup>40,41</sup> Static procedures have gained in popularity as they allow for ligament reconstruction and preservation of existing thumb function, whereas dynamic procedures require the removal of existing muscle units and do not restore the anatomy of the ulnar collateral ligament. Unfortunately, prospective long-term outcome studies comparing dynamic and static reconstructions have not been performed.

Recent studies by Pai and others have shown that even in the delayed setting, the ulnar collateral ligament can often be mobilized from surrounding scar tissue and advanced distally back to its insertion on the proximal phalanx. These studies have shown that patients presenting as late as 2 years were still candidates for primary repair with bone anchors. In such chronic cases, release of the contracted volar plate was found to be helpful in correcting volar subluxation of the proximal phalanx prior to ligament reconstruction.<sup>42,43</sup>

Attempts at bone-ligament-bone reconstruction have also been employed to reconstruct chronic ulnar collateral ligament injury cases.<sup>44</sup> Though the case series is small, Wong and colleagues have reported a minimum of 5-year follow-up in 7 patients having bone-ligament-bone reconstruction of the ulnar collateral ligament.

Patients recovered normal pinch and had no evidence of osteoarthritis.<sup>45</sup> Further examination of this technique is warranted.

Injuries to the thumb are relatively common and include fractures, dislocations, and soft tissue injury patterns. Substantial disability may result if thumb trauma is inadequately diagnosed and/or treated. Fractures and soft tissue injuries are best managed with early diagnosis and prompt treatment. Principles of fracture management have been clearly defined with an emphasis on bony alignment and articular congruity. The optimum treatment of ulnar collateral ligament injuries depends upon the degree of ligament damage and remaining MCP joint stability.

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