Review paper

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Ultrasound versus MRI in the evaluation of the thumb metacarpophalangeal joint

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Abstract

An intricate and unique combination of ligamentous, fibrocartilaginous, and osseous structures stabilize the thumb metacarpophalangeal joint. Both ultrasound and high-resolution magnetic resonance imaging are extremely useful in evaluating these critical structures. This article reviews common injuries of the thumb metacarpophalangeal joint, while highlighting the merits, limitations, and pitfalls of the two imaging modalities. A clear appreciation of each method, paired with anatomic knowledge, will lend greater confidence and accuracy to diagnosing impactful injuries and guiding intervention.

Introduction

Humans depend on the unique and complex anatomy of the opposable thumb, which affords a wide range of motion and allows fine manual dexterity. Conditions limiting the use of the thumb lead to profound functional impairments and reduced quality of life[1,2]. While the thumb carpometacarpal joint is commonly affected by joint degeneration due to its inherent instability, the thumb metacarpophalangeal (MCP) joint is most predisposed to injury[2]. In this article, we review the structures stabilizing the thumb MCP joint, and potential pathology impacting the joint, and also discuss the preferred advanced imaging modalities for their assessment, with attention to ultrasound (US) and magnetic resonance imaging (MRI).

Thumb MCP joint

The thumb MCP joint is a diarthrodial hinge joint with limited intrinsic osseous stability relying upon static and dynamic soft tissue stabilizers[3]. The static stabilizers include the radial (RCL) and ulnar (UCL) collateral ligaments, volar plate, and dorsal joint capsule (or dorsal plate) (Fig. 1). The dynamic stabilizers consist of intrinsic (flexor pollicis longus [FPL], extensor pollicis longus [EPL], and extensor pollicis brevis [EPB]) and extrinsic (adductor pollicis [AdP] and flexor pollicis brevis [FPB]) muscles and tendons of the thumb, as well as the aponeurotic expansions of the abductor pollicis brevis (APB), FPB, and AdP (Fig. 2)[4]. While the range of thumb MCP joint flexion is typically less relative to the other fingers, the joint anatomy offers greater resistance to radial and ulnar forces to enable pinching and grasping[5]. Due to the unique function of the thumb, injuries to these stabilizing structures require careful clinical consideration and imaging evaluation.

MRI and ultrasound

While physical examination and radiographs provide the critical baseline assessment of thumb MCP joint pathology, MRI and US allow direct visualization of the soft tissues, including the stabilizing anatomy[3,6]. MRI is the primary imaging modality used to evaluate the soft-tissue structures of the thumb, and is most beneficial when performed on a 3-Tesla magnet with a dedicated hand coil. Since the thumb is not in the same plane as the palm, MRI technologists must ensure careful attention to positioning and select an axial imaging plane through the MCP joint where the metacarpal head appears most rectangular (or resembles a 'slice of toast')[7].

Ultrasound offers real-time dynamic imaging with even greater spatial resolution, which is well-suited for the fine superficial structures of the digits[1]. The small footprint of the "hockey stick" probe allows optimal anatomic positioning when assessing structures like the UCL. For each topic in this review, we will discuss relevant diagnostic merits and shortcomings of these two primary imaging modalities.

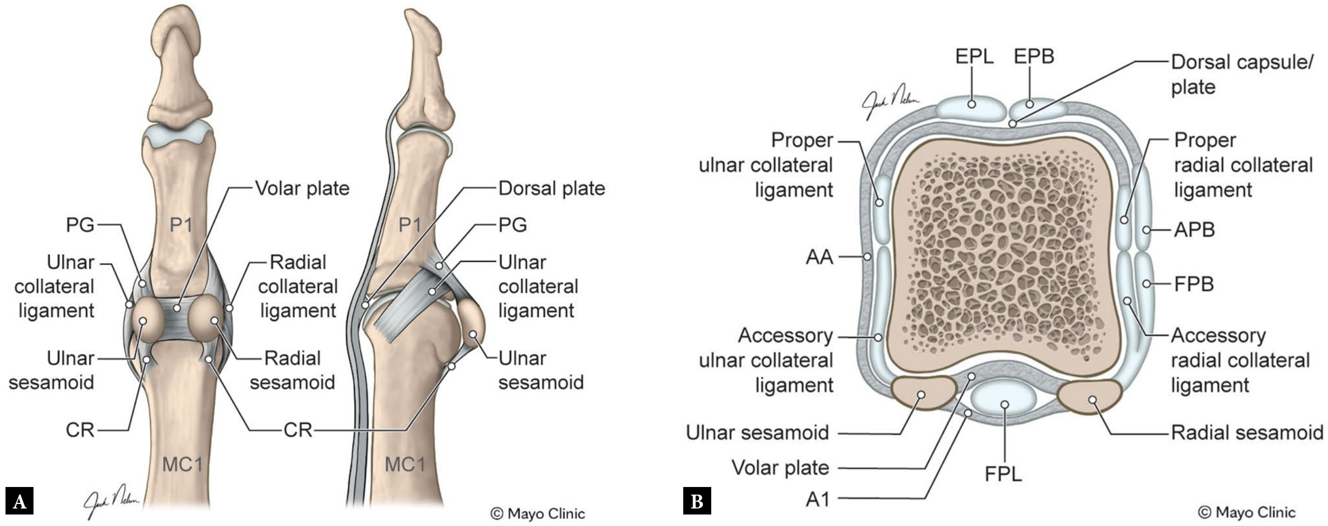

Fig. 1. *Anatomy of the thumb MCP joint. Illustrations depicting:* **A.** *Coronal and sagittal views of the relevant supporting structures at the thumb MCP joint including volar plate complex, consisting of the phalangoglenoid (PG) and checkrein (CR) ligaments.* **B.** *Transverse illustration at the level of the MCP joint shows important static stabilizers, along with key dynamic stabilizers: the extensor pollicis longus (EPL) and brevis (EPB), flexor pollicis longus (FPL), flexor pollicis brevis (FPB), and abductor pollicis brevis (APB). The adductor aponeurosis (AA) overlies the UCL. Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved*

Thumb MCP joint pathology

Volar plate

Located at the volar aspect of the thumb MCP joint, this wedge-shaped, intra-articular fibrocartilaginous structure augments the MCP joint capsule by opposing dorsally directed forces. With proximal and distal attachments on the metacarpal head and proximal phalangeal base, respectively, the volar plate is interposed between the two sesamoids. Like the great toe, there are additional supporting volar ligaments, including the paired checkrein and phalangoglenoid ligaments that secure the sesamoids to the metacarpal head and proximal phalangeal base, respectively[8].

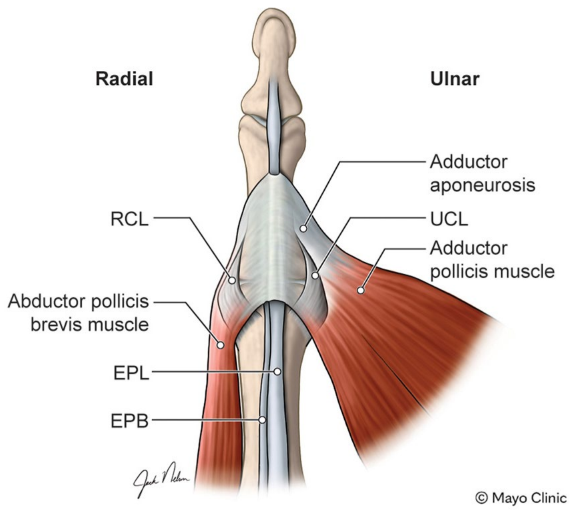

Fig. 2. *Musculotendinous anatomy of the thumb. Coronally oriented illustration depicting dynamic stabilizers including extensor pollicis longus (EPL), extensor pollicis brevis (EPB), as well as two associated static stabilizers, the radial (RCL) and ulnar collateral ligaments (UCL), with the latter lying deep to the adductor aponeurosis . Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved*

Injuries to the thumb volar plate occur rarely compared to the remaining digits, and commonly result from traumatic MCP joint hyperextension[9]. The progressive spectrum of injury ranges from isolated limited hyperextension sprain to complete dislocation with associated proximal phalangeal base fracture, capsular disruption, and collateral ligament injury[7,10]. The number of anatomic structures involved in a traumatic dislocation requires careful assessment of all the thumb soft tissue anatomy including attention to the volar plate, as it frequently requires an additional volar incision during surgical repair[9].

Best evaluated on sagittal MR images or longitudinal US, a thickened volar plate with an associated fluid-filled cleft at the proximal phalangeal insertion is diagnostic of a tear[11]. This discrete cleft demonstrates high signal intensity on fluid-sensitive MRI sequences and appears anechoic or hypoechoic on US images. Dynamic US imaging improves visualization of partial tears (Fig. 3). Both modalities, along with radiographs, readily identify associated avulsion fractures, while MRI also reveals bone marrow edema. Depending on size and degree of edema, the avulsed bone fragment may display variable signal intensi-

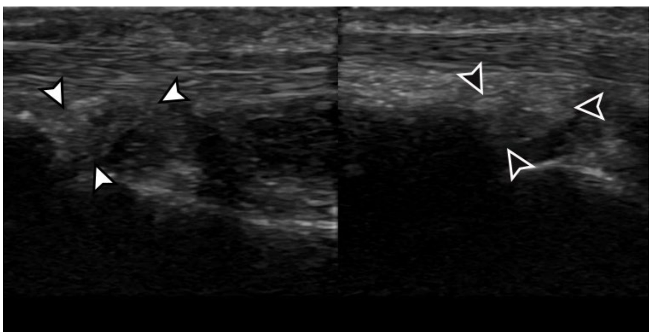

Fig. 3. *24-year-old female with right thumb volar plate injury. Longitudinal grayscale US image shows hypoechoic thickening and irregularity of the volar plate (white arrowheads) compared to the hyperechoic and smooth contralateral normal volar plate (black arrowheads). Dynamic US images during MCP joint flexion/extension demonstrate a focal hypoechoic cleft, consistent with tear (Video 1)*

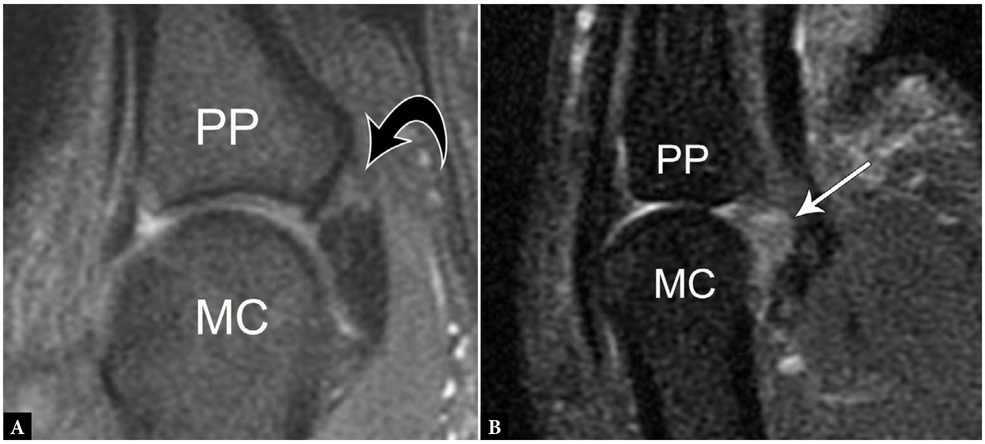

Fig. 4. A. *33-year-old female with normal volar plate. Sagittal T2 fat-suppressed MR image demonstrates the normal intermediate signal synovial recess (curved arrow) between the volar plate and proximal phalanx, not to be mistaken for tear.* **B.** *54-year-old male with partial volar plate injury. Sagittal T2 fat-suppressed MR image demonstrates edematous and thickened volar plate (arrow), consistent with a partial tear*

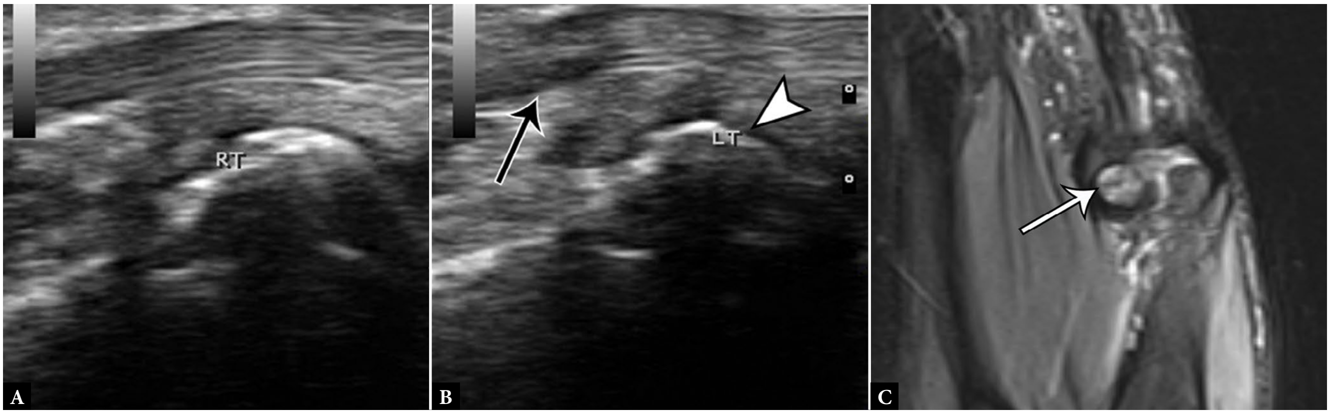

Fig. 5. *17-year-old female with radiographic and US-occult left thumb ulnar sesamoid fracture.* **A.** *Longitudinal grayscale US image demonstrates mild thickening and hypoechogenicity of the FPL tendon (arrow) compared to normal right thumb. No evidence of abnormality involving the left ulnar sesamoid (arrowhead).* **B.** *Coronal T2 fat-suppressed MR image shows transverse low signal fracture line (arrow) and accompanying bone marrow edema involving the ulnar sesamoid*

ty on MRI sequences, but typically appears hyperechoic on US images. It is important not to mistake the typical intermediate or striated MRI signal intensity of the volar plate, as well as the normal synovial recess between the plate and proximal phalanx, for an injury (Fig. 4)[12]. While US examination permits a focused assessment of a single ligament, MRI offers global MCP joint assessment following dislocation. Any US examination in the setting of traumatic dislocation should be thorough and comprehensive due to the wide injury spectrum.

Rarely, severe volar plate injuries result in proximal volar plate attachment rupture, allowing its interposition between the metacarpal head and proximal phalangeal base, thus preventing closed reduction[7]. Although clinically apparent, delayed presentation or chronic volar plate injuries confound evaluation. US permits dynamic assessment of a mechanical block or limited joint mobility to identify intermittently entrapped structures or impinging scar[13].

Sesamoid bones

Secured by the volar ligaments and embedded in the volar plate, the thumb sesamoids serve to decrease friction, maximize forces, and protect the adjacent tendons at the MCP joint[14]. The AdP tendon inserts on the ulnar sesamoid, and the FPB tendon inserts onto the radial sesamoid[1,2]. Additionally, the first annular (A1) pulley and accessory collateral ligaments attach to the sesamoid bones[2]. The FPL tendon passes between the sesamoid bones with slight deviation to the ulnar side.

While the thumb is the most common site for sesamoid bones in the hand, sesamoid fractures are quite rare, and typically arise from avulsive forces during a fall on an outstretched hand or other hyperextension injury[14,15]. Due to infrequency and overlapping anatomy, sesamoid fractures are often not detected on initial radiographs[16]. Notably, the ulnar sesamoid accounts for 60% of thumb sesamoid fractures[17].

The US features of a sesamoid fracture include irregular shape of the normally round or curved echogenic surface, with discontinuous, sharp margins[1]. Small adjacent echogenic ossific fragments reflect the underlying avulsive mechanism[18]. A bipartite sesamoid should not be confused for a nondisplaced fracture, and assessing for smooth, rounded contours at US is critical to avoid this pitfall[1]. While US enables assessment of soft-tissue injury, additional imaging, such as CT, MRI, or oblique radiographs, is often required for complete characterization of the fracture. MRI offers the advantage to evaluate for associated bone marrow edema, particularly in the setting of an acute, nondisplaced fracture. Ongoing stress, or sesamoiditis, in a bipartite sesamoid may be difficult to differentiate from a nondisplaced fracture at MRI, and clinical history may be necessary to reach the correct diagnosis (Fig. 5). Most sesamoid fractures undergo conservative management, but it is important to evaluate for associated volar plate injury, which may require surgical repair to restore effective flexion of the MCP joint[15].

Ulnar collateral ligament

The UCL, composed of proper and accessory bands, serves to stabilize the ulnar aspect of the MCP joint. The proper band extends from the dorsal thumb metacarpal head to the volar aspect of the proximal phalangeal base, while the accessory band lies volar to the ligament proper at the metacarpal head and attaches to the volar plate and ulnar sesamoid. Identifying these distinct components in the absence of abnormality is difficult. The closely apposed, overlying AdP aponeurosis provides the key distinguishing anatomic feature of the thumb MCP joint UCL from other collateral ligaments in the remainder of the hand[2].

UCL tears are the most common injury to the thumb MCP joint, occurring ten times more frequently than RCL tears[3,4]. While originally described as chronic microtraumatic injuries in Scottish gamekeepers, UCL tears occur most commonly during acute falls with MCP joint hyperabduction and varying degrees of hyperextension[6]. The frequency of the injuries due to falls while skiing with poles has led to the designation of an acute UCL injury as skier's thumb[6]. Also common in other sports, such as football and basketball, a similar mechanism occurs when a ball or racquet strikes the ulnar aspect of the thumb[19]. Today, gamekeeper's thumb describes both acute and chronic UCL injuries[10].

UCL tears occur at the distal insertion on the proximal phalangeal base in approximately 90% of cases[4]. In the setting of partial and non-displaced full-thickness tears, the torn ligament remains beneath the adductor aponeurosis and overlies the MCP joint, permitting spontaneous healing[6]. A Stener lesion occurs when the torn ligament detaches from the proximal phalangeal base, retracts proximally, and becomes entrapped proximal and superficial to the adductor aponeurosis during the hyperabduction injury (Fig. 6)[10,20]. With the interposition of the adductor aponeurosis, the UCL cannot effectively heal or scar down, thus resulting in chronic joint laxity and degeneration[4]. Non-displaced full-thickness injuries frequently undergo conservative management, but Stener lesions and other full-thickness tears with more than 3 mm displacement undergo repair to restore joint stability (Fig. 7)[8]. Due to pain, swelling, and risk of converting a non-surgical injury to a displaced tear during stress

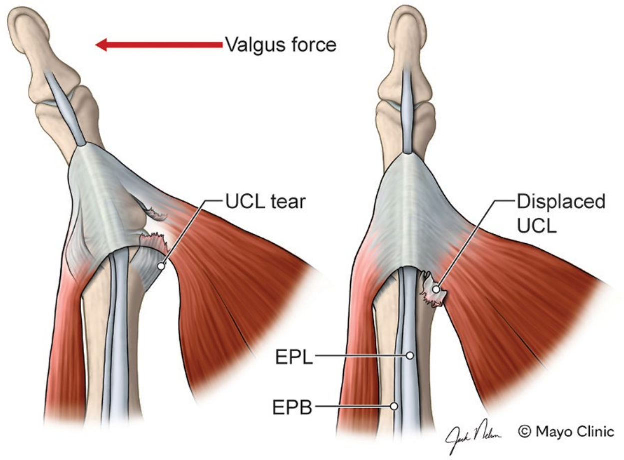

Fig. 6. *Full-thickness ulnar collateral ligament (UCL) tears. The illustration on the left depicts the mechanism of injury resulting in a nondisplaced full-thickness metacarpophalangeal joint UCL tear where the torn ligament remains beneath the adductor aponeurosis. On the right is a Stener lesion, where a torn and displaced UCL lies superficial and proximal to the adductor aponeurosis following injury. Extensor pollicis longus (EPL) and brevis (EPB) . Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved*

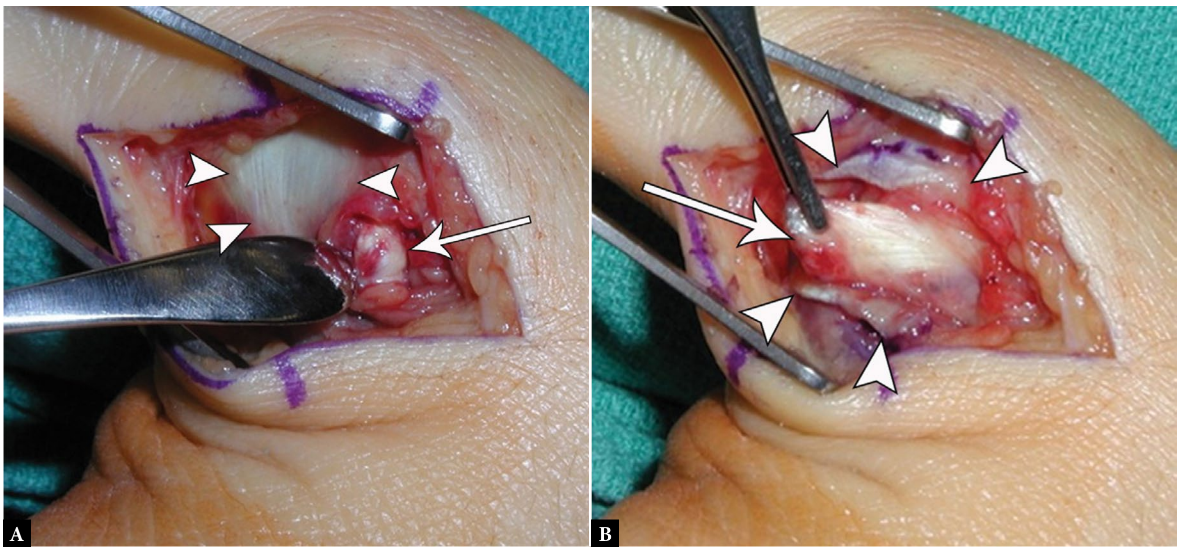

Fig. 7. *31-year-old male with Stener lesion undergoing repair.* **A.** *The balled-up, displaced UCL (arrow) is entrapped proximal to the adductor aponeurosis (arrowheads).* **B.** *An incision divides the adductor aponeurosis (arrowheads), and the torn UCL (arrow) is unfurled prior to reattachment with anchor to the thumb metacarpal base*

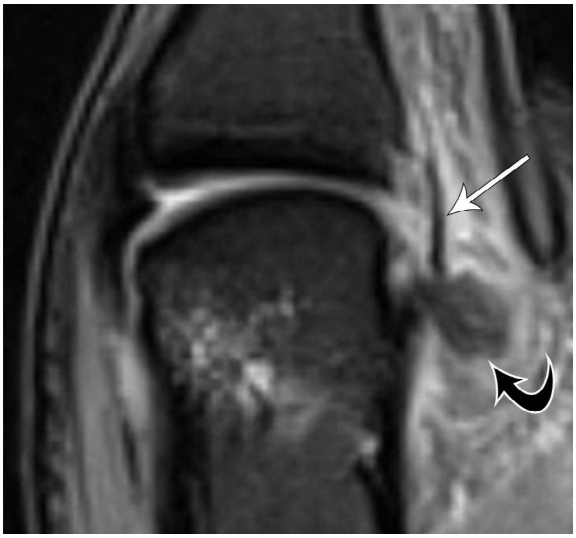

Fig. 8. *17-year-old female with Stener lesion. Coronal oblique T2 fat-suppressed MR image depicts the characteristic yo-yo (proximally displaced and mass-like UCL – curved arrow) on a string (adductor aponeurosis – arrow) appearance of Stener lesion*

radiographs, MRI and US offer valuable clinical information in the setting of UCL injury[6].

The collateral ligaments are best assessed on coronally oriented MR and US images[2]. In the setting of an acute UCL tear, the ligament demonstrates thickening and increased T2-signal on MRI. Full-thickness injuries are accompanied by an avulsion fracture and/or a complete fluid-filled cleft at the proximal phalangeal base insertion site. The characteristic MRI appearance of a Stener lesion is that of a "yo-yo on a string", where the adductor aponeurosis forms the string attaching to the proximally displaced and mass-like UCL (Fig. 8)[10]. A meta-analysis assessing the diagnostic accuracy of MRI in diagnosing Stener lesions demonstrated pooled sensitivity and specificity of 93% and 98%, respectively[21].

To best image the UCL with US, the probe is placed in the long axis in the coronal plane relative to the metacarpal head. Identifying the osseous concavity at the ulnar aspect of the thumb metacarpal head between the lateral tubercle and articular surface, and a similar, but shallower groove at the ulnar aspect of the proximal phalangeal base allows optimal visualization of the UCL, including its origin and insertion (Fig. 9)[20]. A partially torn UCL appears thickened and hypoechoic on US, resulting in loss of fibrillar echotexture (Fig. 10 A)[11]. Dynamic evaluation with minimal MCP joint valgus stress allows better visualization of the ligamentous cleft to differentiate between partial and nondisplaced full-thickness tears (Fig. 10 B)[1]. A Stener lesion is diagnosed by the absence of normal UCL fibers and the presence of a heterogeneous mass-like abnormality proximal to the thumb MCP joint (Fig. 11)[20]. To improve confidence in diagnosing Stener lesions, minimal passive flexion of the thumb interphalangeal joint results in visible sliding of the adductor aponeurosis at the thumb MCP joint and depicts its position relative to torn UCL fibers[22]. Through application of this standardized technique, including dynamic assessment, US is 100% accurate in differentiating partial and full-thickness tears and identifying Stener lesions[1,20]. Owing to the low cost and similarly high diagnostic accuracy relative to MRI, US is recognized as an appropriate first-line modality for UCL tears[21,23].

Radial collateral ligament

The RCL, also consisting of proper and accessory bands, is the primary stabilizer at the radial aspect of the MCP joint, permitting pinch and button depression motions[24]. Differing from UCL anatomy, the APB completely overlies the RCL, thus preventing a Stener-like injury[1]. The wide aponeurotic attachment of the APB merges with AdP aponeurosis at the midline dorsal aspect of the

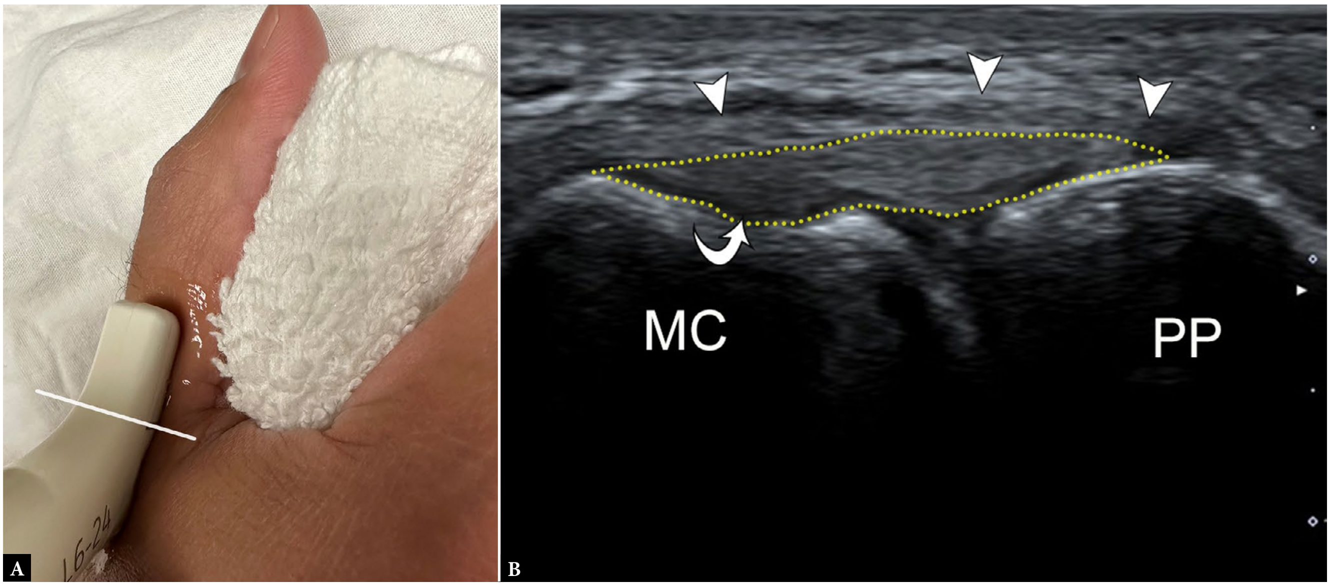

Fig. 9. A. *Photograph demonstrating positioning of the hand and US probe for scanning the UCL longitudinally in a coronal plane to the MCP joint. White line indicates position for transverse imaging.* **B.** *Using the coronal plane demonstrated above, a longitudinal grayscale US image of a 54-year-old female shows a normal UCL (dotted line) extending from the metacarpal head (MC) to the proximal phalangeal base (PP), with the thin overlying adductor aponeurosis (arrowheads). Note the anisotropy of the proximal UCL fibers (curved arrow). See Video 2 for normal clinical examination of the UCL*

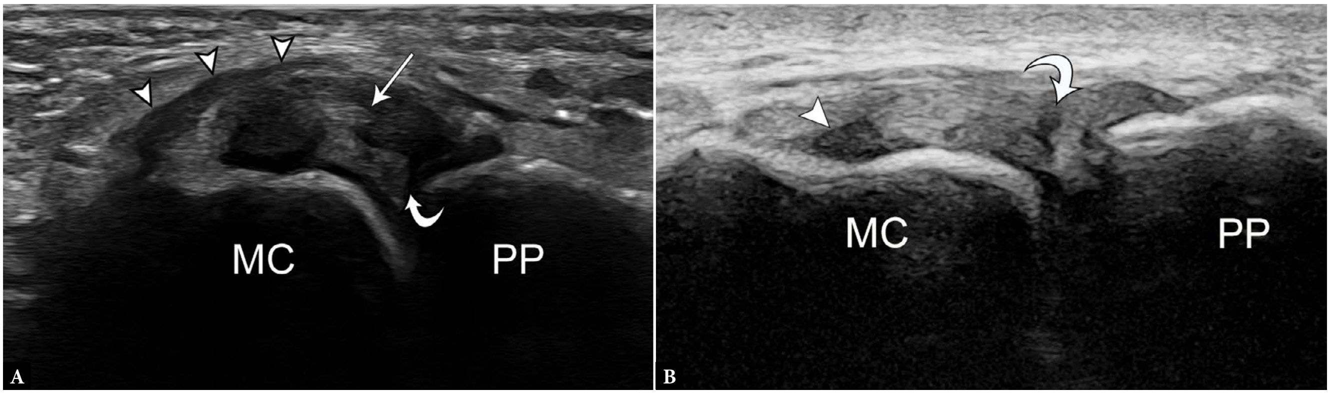

Fig. 10. *Nondisplaced and partial UCL tears.* **A.** *29-year-old female with nondisplaced full-thickness UCL tear. Longitudinal US image shows fluid-filled cleft at the thumb proximal phalangeal base (curved arrow) with irregular, disrupted UCL fibers (arrow) deep to the thickened adductor aponeurosis (arrowheads).* **B.** *37-year-old female with partial thickness UCL tear. Longitudinal US image shows thickening and hypoechogenicity with possible fluid-filled cleft involving the deep distal fibers (arrow). Note anisotropy proximally (arrowhead), not to be mistaken for tear. Dynamic imaging with slight valgus stress confirms presence of partial tear (Video 3)*

thumb[6]. Thus, injuries to the RCL potentially result in disruption of dorsal capsular support, leading to volar and ulnar subluxation of the proximal phalanx. This unstable malalignment progresses to degenerative osteoarthritis. Additionally, variable insertion of the thin EPB tendon at the dorsal MCP joint capsule results in rare concomitant tendon tears and potentially exacerbates joint instability[25].

Unlike the much more common UCL tear, the majority of RCL tears occur proximally, with the remainder occurring at the distal attachment (29%) and midsubstance (16%) (Fig. 12)[26]. Evaluating the injured ligament with US during minimal ulnar stress test allows improved delineation of partial versus complete midsubstance tears[1]. As with UCL tears, dynamic US comparison with the contralateral side allows detection of subtle volar and ulnar instability. In addition to unopposed ulnar deviation, important surgical indicators include avulsion fracture fragment displacement (>2 mm) and rotation (>30 to 45 degrees), as well as articular surface involvement of greater than 30%[1,4]. Ultrasound and radiographs offer better assessment of small fracture fragments compared to MRI, which may be obscured by associated edema.

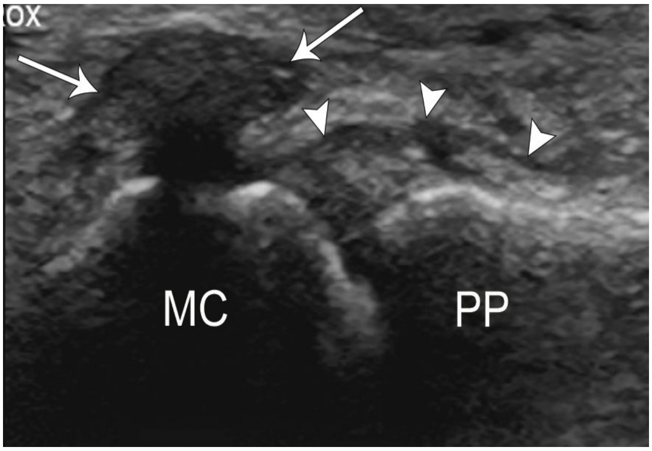

Fig. 11. *Stener Lesion – US. 31-year-old male with Stener lesion.* **A***. Longitudinal US shows hypoechoic mass-like abnormality overlying the metacarpal head (arrows) proximal and superficial to the adductor aponeurosis (arrowheads), with no visible underlying ligamentous fibers, consistent with a completely torn and displaced UCL*

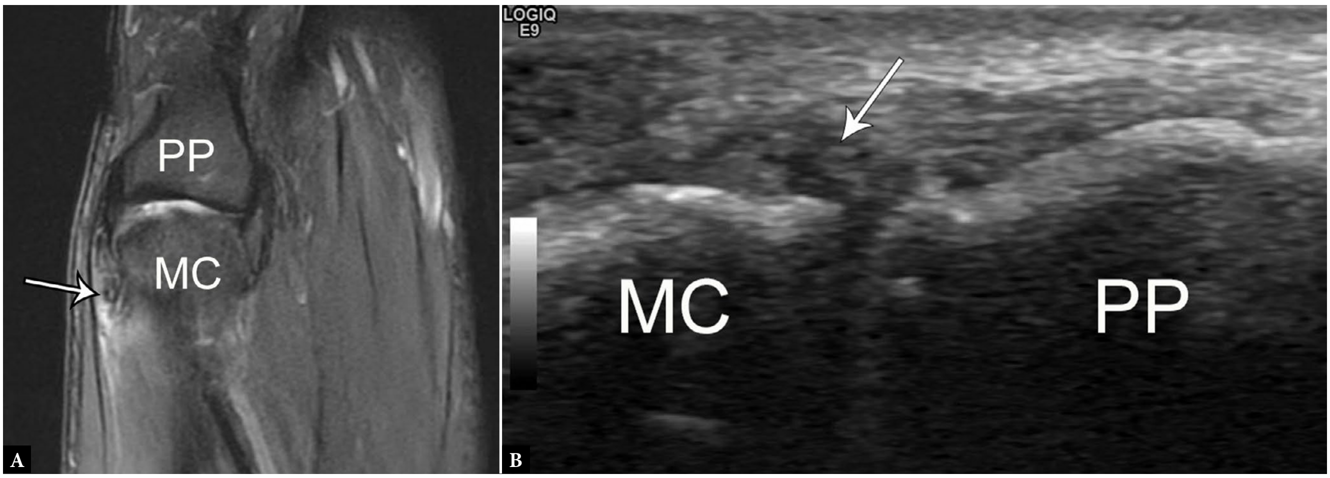

Fig. 12. *RCL Tear. 27-year-old male with left RCL tear.* **A.** *Initial coronal oblique T2 fat-suppressed MR image shows apparent high-grade partial thickness tear at the proximal phalangeal attachment of the RCL.* **B.** *Follow-up US to assess stability shows near full-thickness tear (arrow). Dynamic exam better demonstrates depth of tear with no asymmetric instability compared to right (not shown)*

Fig. 13. *Multiligamentous injury. 41-year-old male with multiligamentous injury. Coronal T2 fat-suppressed MR image shows non-displaced full-thickness tear involving the distal UCL (curved arrow) with near-full thickness tear involving the RCL midsubstance (arrow). Associated dorsal capsular injury not shown*

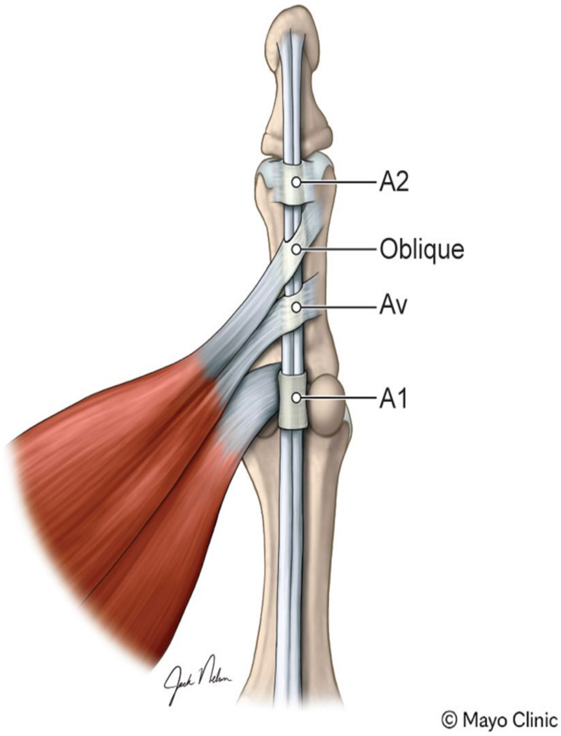

Fig. 14. *Pulley anatomy. Coronally oriented illustration showing the first (A1) and second (A2) annular pulleys at the level of MCP and interphalangeal joints, respectively. The oblique annular pulley (Ao) extends distally from the ulnar to radial aspects of the proximal phalanx with additional variable (Av) annular pulley located more proximally and following a similar trajectory. Both Ao and Av are contiguous with the adductor aponeurosis . Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved*

Combined collateral ligament tears

Combined collateral ligament injuries are rare, with most reported cases occurring in athletes participating in high-impact sports with a complex mechanism including MCP joint rotation, axial loading, and hyperextension combined with an applied adduction/abduction force (Fig. 13)[27]. These injuries are often associated with volar plate or dorsal capsular injuries[19]. Due to the complexity and extent of these injuries, surgical literature advocates for assessment with MRI, but a detailed and comprehensive US examination could serve the same role[27].

Pulley system

The flexor pulleys enable effective tendon mechanics by maintaining the tendons near the bone, while permitting smooth gliding with movement[7]. While the thumb has A1 and A2 pulleys at the MCP and interphalangeal joints similar to the other digits, it lacks the cruciform pulleys, but features an oblique pulley (Ao) located at the proximal phalanx and a variable pulley (Av) between the A1 and Ao pulleys (Fig. 14)[2,28].

Pulley tears involving the thumb occur rarely compared to the other digits[29]. When evaluating pulley injuries, the A1 pulley is visualized on MRI axial sequences and transverse US images as a semicircular structure surrounding the flexor tendon near the MCP joint. On US, an injured pulley appears thickened and hypoechoic or completely absent in the setting or rupture. Similarly, at MRI, pulley edema, discontinuous fibers, or complete absence denote an injury, but these direct signs are not always apparent (Fig. 15)[7,30]. Both modalities demonstrate a halo of edema surrounding the flexor tendon at the level of the injury. While both longitudinal US and sagittal MR images help identify abnormal volar displacement of the flexor tendons, or bowstringing, dynamic evaluation in the longitudinal axis with US allows for dynamic assessment of subtle or increased bowstringing during active forced finger flexion[30,31].

Trigger thumb is a more common thumb pulley pathology, affecting both adults and children, characterized by a locking or clicking sensation at the thumb metacarpophalangeal joint initiated by flexion and associated with a painful snapping during extension[28]. This condition involves the A1 pulley, along with the volar plate and contiguous sesamoid, which form a fibro-osseous tunnel. Long-axis dynamic tendon imaging with US allows direct identification of the abnormal motion (Fig. 16)[31]. The involved A1 pulley is frequently thickened on both MRI and US[16,32]. Associated hyperemia at Doppler imaging and hypoechogenicity of the tendon subjacent to the A1 pulley (dark tendon sign) help distinguish equivocal US cases[33]. Proposed etiologies for the condition include repetitive microtrauma and stenosing flexor tenosynovitis[11,34]. Atypical secondary causes include tumors, rheumatoid arthritis, ganglion cysts, and fibrous scar[16,32]. The superior spatial resolution of US aids in the identification of subtle tissue distortions and scarring. Unlike MRI, US may be used to both diagnose

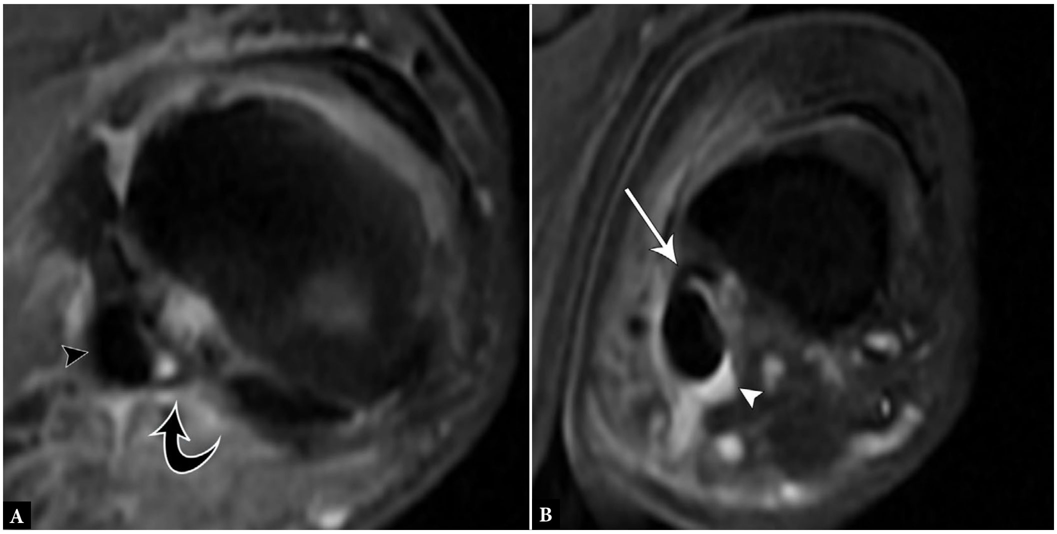

Fig. 15. *Pulley injury – MRI. 45-year-old female with A1 pulley complex tear. Axial images at the MCP joint (***A***) and proximal phalanx (***B***) show tear at the radial aspect of the A1 pulley (curved arrow) with volar displacement of the FPL (black arrowhead) with full-thickness tear of the Ao (white arrowhead) and undulation of the remaining obliquely oriented fibers (arrow)*

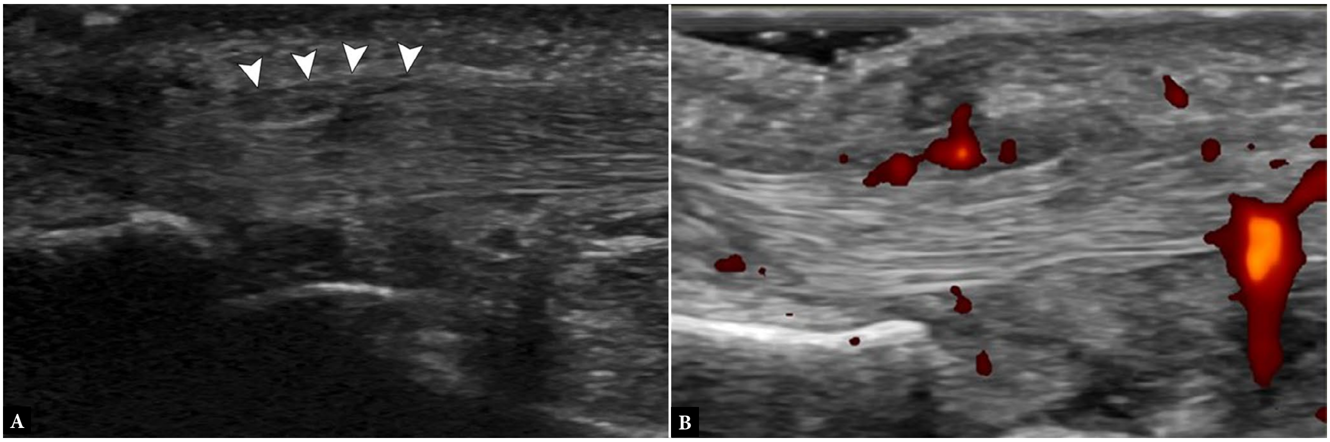

Fig. 16. *Trigger thumb. 67-year-old female with trigger thumb. Longitudinal grayscale (***A***) and power Doppler (***B***) US images show thickening (arrowheads) and hyperemia (arrow) of the A1 pulley at the MCP joint. Dynamic US images during interphalangeal joint flexion demonstrate severely restricted motion and tendon kinking distal to the thickened A1 pulley (Video 4)*

and treat trigger thumb guiding steroid injections or percutaneous pulley release[34].

Conclusion

The thumb MCP joint is a small, yet functionally critical articulation consisting of numerous intricate and inter-related stabilizing structures. Diagnosis and characterization of injuries at the thumb MCP joint rely on high-resolution imaging with excellent spatial resolution. The use of 3-T MRI and dedicated hand coils combined with appropriate image planes allows for comprehensive assessment of the MCP joint, including the osseous anatomy. The increasing availability of high-frequency, small-footprint US transducers permits rapid and dynamic evaluation of thumb MCP joint soft tissues, while providing an easy and accurate means to identify radiolucent foreign bodies. An awareness of the strengths and limitations of each modality combined with patterns of injury allows radiologists to confidently and accurately diagnose conditions involving this complex joint.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contributions

Writing of manuscript: DMM, SSN, BK.

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