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SYMPOSIUM: THUMB CARPOMETACARPAL ARTHRITIS

Trapeziometacarpal Joint Stability

The Evolving Importance of the Dorsal Ligaments

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Abstract

Background Trapeziometacarpal (TMC) arthritis of the thumb is a common source of hand pain and disability. TMC ligamentous instability may play a role in TMC degeneration. However, the relative importance of the TMC ligaments in the etiology of degeneration and the use of surgery to treat instability in early-stage arthritis are unclear.

Questions/purposes In this review, we addressed several questions: (1) What are the primary ligamentous stabilizers of the thumb TMC joint? (2) What is the evidence for ligament reconstruction or ligament imbrication in the treatment of thumb TMC joint osteoarthritis? And (3) what is the evidence for thumb metacarpal osteotomy in the treatment of thumb TMC joint osteoarthritis?

Methods We performed a systematic review of the literature using PubMed (MEDLINE®) and Scopus® (EMBASE®) for peer-reviewed articles published until November 2012. Fifty-two studies fit the inclusion criteria. Twenty-four studies were anatomic, biomechanical, or histopathologic studies on TMC joint ligamentous anatomy, 16 studies were clinical studies concerning ligament reconstruction, and 12 studies were clinical studies on thumb metacarpal osteotomy.

Results Over the past two decades, increasing evidence suggests the dorsoradial ligament is the most important stabilizer of the TMC joint. Other ligaments consistently identified are the superficial anterior oblique, deep anterior oblique, intermetacarpal, ulnar collateral, and posterior oblique ligaments. Ligament reconstruction and metacarpal osteotomy relieve pain and improve grip strength based on Level IV studies.

Conclusions The dorsal ligaments are the primary stabilizers of the TMC joint. Ligament reconstruction and metacarpal osteotomy ameliorate ligamentous laxity and relieve pain based on Level IV studies.

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Introduction

Osteoarthritis (OA) of the thumb trapeziometacarpal (TMC) joint can be a debilitating disorder, resulting in hand pain and reduced strength and motion during activities of daily living [2, 15]. The disease is also exceedingly common. The prevalence of TMC OA is reportedly 7% for men and 15% for women 30 years or older [20]. As many as ⅓ of all postmenopausal women have radiographic evidence of arthritic changes, with ⅓ of these women experiencing basal joint pain [1].

The underlying etiology of TMC OA is poorly understood. Many investigators have theorized that ligamentous laxity of the TMC joint leads to an incongruous relationship between the joint surfaces [10, 15, 42]. This incongruity is thought to lead to smaller contact areas and thus greater contact stresses in certain areas of the joint, leading to degradation and OA [2, 14, 15].

However, controversy exists regarding both the number and relative importance of the TMC ligaments. The anterior oblique ligament (AOL) [26, 27, 42, 43], the intermetacarpal ligament (IML) [40], and the dorsoradial ligament (DRL) [4, 31, 37, 50, 54] have all been proposed as primary stabilizers of the TMC joint. Moreover, the use of ligament reconstruction or metacarpal osteotomy in the setting of ligamentous laxity and early-stage OA is also controversial.

In this review, we addressed the following questions: (1) What are the primary ligamentous stabilizers of the TMC joint? (2) What is the evidence for ligament reconstruction or ligament imbrication in the treatment of OA of the TMC joint? And (3) what is the evidence for thumb metacarpal osteotomy in the treatment of OA of the TMC joint?

Search Strategy and Criteria

We searched MEDLINE® (through PubMed) and EMBASE® (through Scopus®) up to November 2012. Articles were identified using the following query: "trapeziometacarpal joint" OR (("thumb" OR "first") AND ("carpometacarpal joint" OR "basal joint")). The search was performed under the guidance of our departmental librarian. We also performed a hand search of the following journals for articles published between January 2012 and November 2012: *Clinical Orthopaedics and Related Research*®, *Journal of Bone and Joint Surgery*, and *Journal of Hand Surgery*. We identified a total of 2112 articles. The results were then entered into EndNote® (Thomas Reuters, Carlsbad, CA, USA) for removal of duplicate entries, resulting in a total of 1334 articles for title and abstract review (Fig. 1).

Articles were included in the systematic review based on the following criteria: (1) published in English and (2) an anatomic, biomechanical, or histopathologic study on ligamentous stability of the thumb TMC joint or (3) a clinical study with a Level I, II, III, or IV study design or a biomechanical study on metacarpal extension osteotomy or (4) a clinical study with a Level I, II, III, or IV study design or biomechanical study on ligament reconstruction or ligament imbrication independent of arthroplasty. We excluded articles on ligament reconstruction in the setting of arthroplasty or fractures, trapezial osteotomy, review articles, and conference proceedings. Articles where full text was unavailable were excluded.

Two of us (JDL, RJS) independently reviewed the titles and abstracts of each article for inclusion and exclusion criteria. If an article was identified by one author and not another, it was included for full-text review. Forty-six

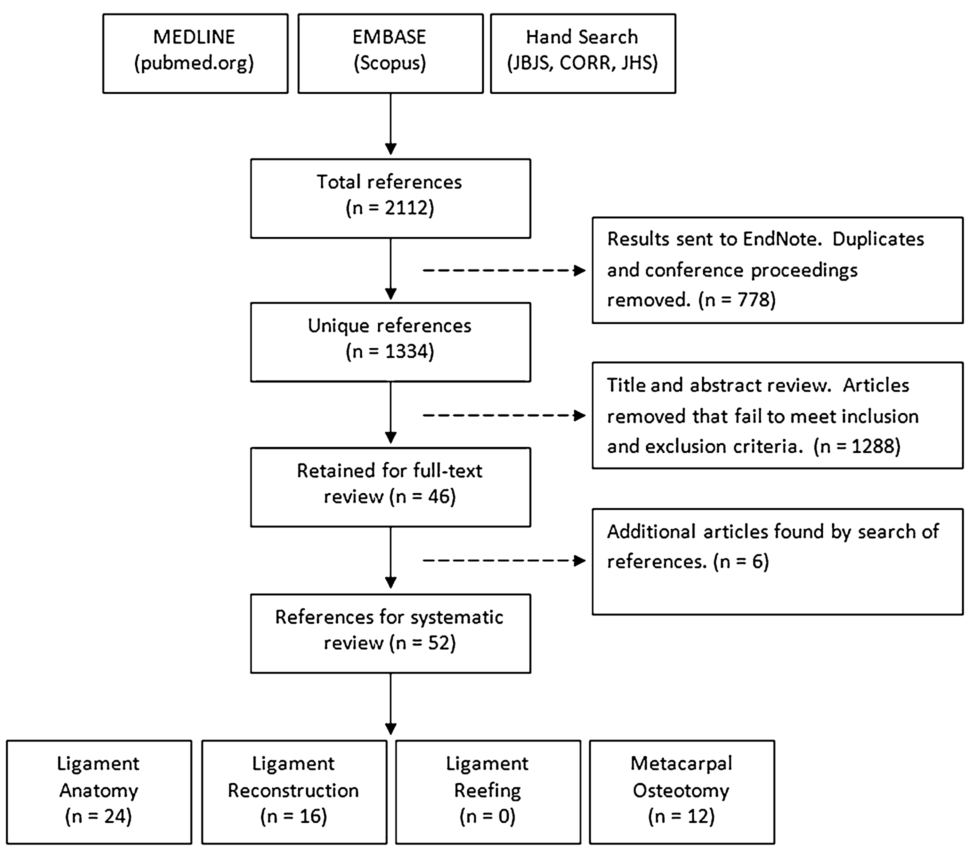

Fig. 1 A flowchart shows the search strategy and the number of included and excluded studies. JBJS = *Journal of Bone and Joint Surgery*; CORR = *Clinical Orthopaedics and Related Research*; JHS = *Journal of Hand Surgery*.

articles were identified for potential inclusion in the systematic review, and full-text articles were obtained and further reviewed by two of us (JDL, RJS). The bibliographies of included articles were searched for additional references and six additional references were identified.

On completion of the search, 52 articles were included in the systematic review. Twenty-four articles were anatomic, biomechanical, or histopathologic studies on ligamentous anatomy [4, 5, 7, 11, 12, 15, 21–23, 26–28, 31, 34, 37–40, 42, 43, 45, 50, 52, 54], 12 articles were clinical studies on metacarpal osteotomy [3, 18, 19, 25, 30, 36, 41, 44, 48, 53, 57, 58], and 16 articles were on ligament reconstruction [6, 8, 9, 13, 16, 17, 24, 29, 32, 33, 35, 39, 47, 49, 51, 55]. No articles were on ligament imbrication.

Results

What Are the Primary Ligamentous Stabilizers of the TMC Joint?

In 1944, Haines [22] described five ligaments of the TMC joint: the radial ligament, AOL, posterior oblique ligament (POL), anterior IML, and posterior IML; essentially supporting Weitbrecht's [56] original descriptions in 1742. There have been further elucidations of ligamentous anatomy since then, with varying importance placed on the contributions of individual ligaments to TMC stability (Table 1). The role of the AOL, originally believed by Eaton and Littler [15] and Pellegrini [42, 43] to be the primary stabilizer of the TMC joint, has been questioned by biomechanical and anatomic studies performed over the past 20 years, indicating the DRL is the primary restraint to dorsal translation. Specifically, Strauch et al. [50], Najima et al. [37], Van Brenk et al. [54], Bettinger et al. [4, 5], Colman et al. [11], Tan et al. [52], Hagert et al. [21], and Ladd et al. [31], to varying degrees, found the DRL (or other nearby dorsal ligaments) to be the primary ligament resisting dorsal joint translation, as well as the most robust and well-innervated ligament. (See Appendix 1 for more detail on the individual studies. Supplemental materials are available with the online version of CORR.)

What Is the Evidence for Ligament Reconstruction or Ligament Imbrication in the Treatment of Thumb TMC Joint OA?

This systematic review produced 16 articles detailing ligamentous reconstruction of the TMC joint [6, 8–10, 13, 16, 17, 24, 29, 32, 33, 35, 47, 49, 51, 55]. These articles reflect a wide array of surgical procedures utilizing different grafts and reconstructing different ligaments around the TMC joint. The palmaris longus [8, 49], extensor carpi radialis longus [6, 16], abductor pollicis longus [9, 10, 29], extensor pollicis brevis [29], fascia lata [35], and flexor carpi radialis (FCR) [13] have been used by authors in a variety of reconstructions involving the volar ligament [10, 13, 24, 51], dorsal ligament [13, 29, 35, 49], or IMLs [6, 8, 9, 16].

The Eaton-Littler procedure is by far the most studied procedure, with five of 16 articles identified reporting on its outcomes, virtually all of which demonstrate that the procedure relieves pain and improves grip strength (Table 2). All studies reported are Level IV studies. On close inspection, the Eaton-Littler procedure, using a strip of the FCR through an extraarticular drill hole in the thumb metacarpal base and secured to the FCR tendon, actually reconstructs both the AOL and the DRL. We did not find any clinical studies on techniques of ligament reefing or imbrication to stabilize the TMC joint; however, Koff et al. [30], in a cadaveric biomechanical study, found the dorsal limb of the Eaton-Littler ligament reconstruction reduced laxity in the dorsovolar direction only, the volar limb of the reconstruction reduced laxity in both the dorsovolar and radioulnar directions, and the total ligament reconstruction reduced laxity in the dorsovolar, radioulnar, and pronation-supination directions. (See Appendix 2 for further detail on the individual studies. Supplemental materials are available with the online version of CORR.)

What Is the Evidence for Thumb Metacarpal Osteotomy in the Treatment of Thumb TMC Joint OA?

The metacarpal extension osteotomy procedure was first reported by Wilson [57] in 1973 as a treatment for TMC OA to improve pain and thumb position. Since then, the indications have expanded to patients with minimal arthritic changes and TMC instability, although all studies are Level IV case series (Table 3). These studies consistently demonstrate that metacarpal osteotomy results in pain relief at short- to medium-term followup (2–12 years). The biomechanical rationale for the clinical success of the procedure has been attributed to shifting of joint contact areas to nonarthritic cartilage [44] and improving dynamic joint stability in the position of lateral pinch by altering the tension arc of the dorsal TMC ligaments [30]. Typically, a 30° extension osteotomy is created at the metacarpal base, although experimentally Koff et al. [30] found a 15° osteotomy was equally effective in reducing joint laxity. (See Appendix 3 for a detailed description of osteotomy studies. Supplemental materials are available with the online version of CORR.)

Table 1. Summary of anatomic studies

Year	Study	Number of specimens	Ligaments studied	Conclusions on relative importance of ligaments
1944	Haines [22]	NA	AOL, POL, anterior IML, posterior IML, radial ligament	AOL, POL, posterior IML, and radial ligament are "strong," anterior IML is "weak"
1955	Napier [39]	48	AOL, POL, lateral ligament	No discussion regarding the relative importance
1973	Pieron [45]	8	AOL, DRL, POL, IML, UCL	AOL is "broad and strong," DRL is a "strong ligamentous structure"
1973	Eaton and Littler [15]	NA	Dorsal ligament, volar ligament	Volar ligament is "the key structure," dorsal ligament "contributes little"
1976	Harvey and Bye [23]	12	POL, dorsal IML, radial ligament	POL is "most substantial," lateral ligament is "poorly developed," dorsal IML is a "significant" stabilizer
1976	Bojsen-Moller [7]	20	AOL, POL, DRL, intermediate ligament, IML	IML able to limit the thumb motion when other ligaments were removed
1981	Pagalidis et al. [40]	17	AOL, DRL, POL, IML, volar ligament	IML is "main factor" limiting dorsal displacement of the first metacarpal
1991	Pellegrini [42]	47	Beak ligament	Loss of beak ligament has "central role" in causing TMC OA
1993	Pellegrini et al. [43]	23	Beak ligament	Beak ligament is a "vital static structure" influencing TMC contact patterns
1993	Imaeda et al. [26]	30	AOL, DRL, POL, IML, UCL	AOL is primary stabilizer, UCL and IML are "important," DRL has no role in stability
1994	Imaeda et al. [27]	12	AOL, IML, UCL	AOL and UCL are more important than first IML
1994	Strauch et al. [50]	38	AOL, DRL, POL, IML	DRL is the "main restraint to dorsal dislocation"
1997	Imaeda et al. [28]	12	AOL, DRL, POL, IML, UCL	Results are "suggestive of the role played by the AOL and IML in TMC OA"
1997	Najima et al. [37]	32	AOL, DRL, POL, IML, UCL	DRL is the "most elastic" and "strongest," the "primary restraint to dorsoradial subluxation"
1998	Van Brenk et al. [54]	6	AOL, DRL, palmar oblique ligament, IML	Largest displacement seen after sectioning of DRL
1999	Doerschuk et al. [12]	18	Beak ligament	Beak ligament degeneration correlates with articular cartilage degeneration
1999	Bettinger et al. [4]	37	Superficial AOL, deep AOL, DRL, POL, dorsal IML, IML, UCL	DRL is the "most substantial ligament surrounding the joint"
1999	Bettinger et al. [5]	20	AOL, DRL	DRL is the "strongest, toughest, and stiffest ligament stabling the TMC joint"
2006	Lubahn et al. [34]	8	Volar oblique	Relaxin binds to the volar oblique ligament, no conclusions regarding other ligaments
2006	Nanno et al. [38]	10	AOL, deep AOL, DRL, POL, dorsal IML, volar IML, UCL	AOL is the widest ligament, no specific conclusions drawn by authors
2007	Colman et al. [11]	17	Deep AOL, DRL	DRL is "relatively more important" than the deep AOL in stabilizing the TMC joint
2011	Tan et al. [52]	6	Deep AOL, DRL, POL, IML, dorsal IML	Results may support DRL's "critical role… in maintaining joint stability"
2012	Hagert et al. [21]	10	AOL, DRL, dorsocentral ligament, POL, UCL	Density of innervation of dorsal ligaments "infers their importance as … stabilizers"
2012	Ladd et al. [31]	30	AOL, DRL, dorsocentral ligament, dorsal TMC, POL, UCL, IML	Dorsal ligaments ("dorsal deltoid ligament complex") are important stabilizers

NA = not available; AOL = anterior oblique ligament; POL = posterior oblique ligament; IML = intermetacarpal ligament; DRL = dorsoradial ligament; UCL = ulnar collateral ligament; TMC = trapeziometacarpal; OA = osteoarthritis.

Table 2. Summary of Eaton-Littler ligament reconstructions

Year	Study	Number of patients	Mean followup (years)	Outcome	Comments
1973	Eaton and Littler [15]	18	2.6	11/18 "excellent" (no pain, > 90% grip strength, no further articular degeneration)	All Eaton stages
1984	Eaton et al. [13]	38	7.1	32/38 "excellent" or "good" (occasional pain, > 70% grip strength, minimal laxity)	All Eaton stages
1987	Lane and Eaton [32]	42	5.2	Stage I: 25/25 "excellent" or "good" Stage II: 14/17 "excellent" or "good"	Eaton Stages I and II
2000	Freedman et al. [17]	24	15	7 no pain, 13 intermittent pain, 4 daily pain 87% stable, 13% unstable to stress testing	Eaton Stages I and II
2001	Lane and Henley [33]	37	5.2	25/37 "excellent," 11/37 "good," 1/37 "poor"	Eaton Stage I only
2002	Van Giffen et al. [55]	18	5.8	VAS: 3.1; DASH: 23.2 14/18 no laxity, 4/18 "mild" laxity	Eaton Stages I and II; 3 patients excluded

Table 3. Summary of metacarpal osteotomy studies

Year	Study	Number of patients	Mean followup (years)	Outcome	Comments
1973	Wilson [57]	8	0.5–9	All patients "entirely relieved of pain and entirely satisfied"	Original indication was to improve pain and thumb position
1983	Wilson and Bossley [58]	23	12	"[A]ll had lasting relief" of pain, 3 were not completely relieved of pain	Surgery performed for pain relief and improvement of function
1991	Molitor et al. [36]	17	NA	All patients either pain free or had pain improvement	Main indication was pain All patients had weakness and adduction deformity
1992	Futami et al. [19]	12	4	10/12 "satisfactory" (increased pinch strength, returned to work, increased ROM)	All patients presented with Burton (1973) Stage 2 or 3
1998	Futami et al. [18]	14	NA	NA (appears to be same data reported on previous patients)	
1996	Pellegrini et al. [44]	NA	Biomechanical	Biomechanical basis of osteotomy is unloading of the palmar compartment	
1998	Hobby et al. [25]	41	6.8	80% with either no pain or discomfort only with heavy use	All patients presented with Eaton Stages I–III, no scaphotrapezial joint arthritis
2000	Tomaino [53]	12	2.1	8/12 "very satisfied," 3 "satisfied," 1 "dissatisfied" Pain decreased from 5 to 1 Grip increased by 8.5 kg	All Eaton Stage I patients
2003	Shrivastava et al. [48]	NA	Biomechanical	Authors conclude benefits of metacarpal extension osteotomy may be due to reduced joint laxity	
2006	Koff et al. [30]	NA	Biomechanical	Simulated 15° osteotomy and Eaton-Littler reconstruction reduced laxity in all directions	
2007	Badia and Khanchandani [3]	43	NA	Authors report "satisfactory results in terms of pain relief, stability, and pinch strength"	No other outcome measures
2008	Parker et al. [41]	8	9	6/8 patients had excellent outcomes as defined by pain and functional limitations	Eaton Stages I–III

NA = not available.

Discussion

TMC OA of the thumb is a common source of hand pain and disability, and TMC ligamentous instability may play a role in TMC degeneration. However, controversy exists regarding both the number and relative importance of the TMC ligaments. Similarly, the use of ligament reconstruction or metacarpal osteotomy in the setting of ligamentous laxity and early-stage OA is also controversial. In this review, we addressed the following questions: (1) What are the primary ligamentous stabilizers of the TMC joint? (2) What is the evidence for ligament reconstruction or ligament imbrication in the treatment of OA of the TMC joint? And (3) what is the evidence for thumb metacarpal osteotomy in the treatment of OA of the TMC joint?

There are several limitations to this study. First, only English literature articles were included in our systematic review. Translation of non-English literature would have been cost-prohibitive and may have introduced bias by the translator. In addition, our search was limited to indexed peer-reviewed articles. This type of search excludes original texts and book chapters, but this is the accepted methodology for a systematic review and we believe the results to be comprehensive. Second, biomechanical and anatomic studies are generally reported in an inconsistent manner, and therefore this review may reflect the bias of the authors in synthesizing the results. However, we believe the comprehensive and systematic nature of this review accurately conveys the evolution in and our current understanding of TMC ligamentous stability and the associated surgical procedures.

The six thumb TMC ligaments consistently identified in the literature are the DRL, superficial AOL, deep AOL, IML, ulnar collateral ligament, and POL. Other ligaments identified include a dorsocentral ligament [21, 31], dorsal TMC [31], intermediate (dorsal) [7], and distinct dorsal and volar IMLs. Controversy exists over the primary stabilizer of the TMC joint, but over the past two decades, the DRL has emerged as the most likely candidate to limit dorsal translation of the TMC joint. Various authors have shown the DRL not only is the primary biomechanical restraint to subluxation [11, 50, 54] but also is anatomically thick [4], mechanically robust [5], highly cellular [31], and well innervated [21, 31]. Nevertheless, the role that each TMC ligament plays in the development of TMC OA remains incompletely defined. It is likely all the TMC ligaments act in a coordinated fashion to maintain thumb TMC stability across a large ROM and joint forces. Our understanding of TMC ligamentous anatomy continues to evolve.

The Eaton-Litter ligament reconstruction is the most common and most studied procedure identified in this review and reconstructs the function of both the AOL and DRL. However, many authors [6, 9, 10, 16, 29, 35] have published other techniques that utilize different grafts to reconstruct different TMC ligaments. While ligament reconstruction stabilizes the TMC joint [30], there is currently no evidence that joint stabilization can prevent or retard the development of TMC OA. The Eaton-Littler reconstruction appears to have excellent and durable outcomes in most patients. Authors have consistently shown this procedure reduces pain and improves strength and function in patients with early-stage TMC OA. However, the highest level of clinical evidence for ligament reconstruction is Level IV case series. During our systematic review, we identified no papers discussing DRL reefing as an alternative and isolated treatment for instability or early-stage TMC OA. However, after submission of this manuscript, a surgical technique paper was published on DRL reefing [46]. This is a potential area where future research is needed. Tightening or advancing the DRL on either the metacarpal or trapezial side is an intriguing method of improving joint stability without complicated tendon weaves and grafts. Whether this procedure will relieve pain and improve function depends on the outcome of pending clinical studies.

Thumb metacarpal osteotomy appears to have excellent and durable outcomes. The mechanism by which it works is believed to be a combination of shifting the contact area and tightening of the dorsal ligaments when the thumb is placed into the lateral pinch position.

Over the past two decades, our understanding of TMC ligamentous anatomy has evolved, with most recent authors designating the dorsal ligaments as the primary stabilizers of the TMC joint. Ligament reconstruction and metacarpal osteotomy ameliorate TMC ligamentous laxity and relieve pain based on Level IV studies.

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