SCIENTIFIC ARTICLE

Dorsoradial Instability of the Thumb Metacarpophalangeal Joint: A Biomechanical Investigation

Byung-Sung Kim, MD, PhD,*† Alex Doermann, BS,† Michelle McGarry, MS,† Masaki Akeda, MD,† Hansel Ihn, BA,† Thay Q. Lee, PhD†

Purpose To define the role of the dorsal capsule and associated dorsal fibrocartilage (DFC) and their interactions with the radial collateral ligament (RCL) as a thumb metacarpophalangeal (MCP) joint stabilizer.

Methods Eight cadaveric thumbs were mounted onto a custom jig with 20 N of muscle load applied. The thumb position in space was digitized to measure ulnar-radial, pronation-supination, and volar-dorsal laxity at 0°, 30°, and 60° MCP joint flexion. Serial sectioning was performed and measurements were repeated for the intact state, proper RCL insufficiency, proper and accessory (complete) RCL insufficiency, complete RCL with 50% DFC (radial) insufficiency, and complete RCL with complete DFC insufficiency.

Results Ulnar-radial deviation, pronation-supination, and volar-dorsal translation significantly changed at 30° and 60° MCP joint flexion when comparing complete RCL insufficiency with complete RCL with 50% DFC insufficiency. At 30° flexion, significant increases were found in ulnar deviation, pronation, and volar translation, and there was a decrease in supination. At 60° flexion, ulnar deviation, pronation, and volar translation increased and radial deviation decreased significantly. At 30° flexion, the resting position significantly pronated and translated volarly. At 60° flexion, the resting position significantly shifted ulnarly, pronated, and translated volarly.

Conclusions The DFC acts as a secondary stabilizer of the thumb MCP joint, working in tandem with the RCL. It acts by stabilizing the MCP joint dorsoradially when external forces are applied across the joint. This cadaveric study shows that RCL insufficiency with a concomitant DFC injury is less likely to be stable than RCL injuries alone, and that this effect is more pronounced with MCP joint flexion.

Clinical relevance Increasing incompetence of the secondary stabilizers of the RCL, such as the DFC, will likely result in increased clinical instability upon physical examination. The results of this study also suggest the need to consider repair of the DFC at the time of RCL repair. *(J Hand Surg Am. 2017;■(■):1.e1-e8. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Dorsal capsule, dorsal fibrocartilage, dorsoradial instability, pronation, radial collateral ligament.

Online Exclusive

*From the *Department of Orthopedic Surgery, College of Medicine, Soonchunhyang University, Bucheon, Republic of Korea; and the †Orthopaedic Biomechanics Laboratory, VA Long Beach Healthcare System, University of California, Irvine, CA.*

Received for publication December 6, 2016; accepted in revised form June 28, 2017.

This research was funded by a grant from Soonchunhyang University.

Corresponding author: Byung-Sung Kim, MD, PhD, Department of Orthopaedic Surgery, College of Medicine, Soonchunhyang University, 170, Jomaru-ro, Wonmi-Gu, Bucheon-si, Gyeonggi-do 420-767, Korea; e-mail: kbsos@schmc.ac.kr.

0363-5023/17/■■-0001$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2017.06.102

Radial collateral ligament (RCL) injuries comprise approximately 10% to 42% of collateral ligament injuries of the thumb metacarpophalangeal (MCP) joint.[1–7] The MCP joint relies heavily on the ulnar collateral ligament (UCL) and RCL for lateral stability. It has been established that the RCL has an important role in thumb pinch function; complete disruption results in both static and dynamic instability.[2,5,6,8] Several sequelae have been described if an acute RCL injury is left untreated, including articular degeneration, pain, instability, and a pronated rotational deformity.[1,2,5]

The RCL is composed of 2 distinct collateral ligaments, the proper and accessory collateral ligaments. The proper ligament has been shown to be a static restraint with MCP joint flexion. The accessory ligament has been shown to be a static restraint with MCP joint extension.[2,3,9–11] A recent biomechanical study[4] showed that the greatest contribution of RCL stability is between 30° and 45° of MCP joint flexion. The RCL has an important role in dorsal stability because complete tears have been shown to result in loss of ligamentous and dorsal capsule support.[2,3] There is an association of concomitant dorsal capsule and RCL injuries, which can lead to an adducted and volarly translated metacarpal head.[3]

The dorsal capsule has not been shown to contribute substantially to radial stability when the collateral ligaments are intact.[9] Rather it provides moderate stability in distraction and supination-pronation rotations.[8] The dorsal capsule borders on, and attaches to, the perimeter of the dorsal fibrocartilage, a structure recently described. Hunter-Smith et al[12] suggested that the dorsal fibrocartilage has 2 possible functions: stabilization of the extensor pollicis longus tendon as it passes over MCP joint as well as the MCP joint itself through forming a dorsal fossa within the joint. For this study, the terms "dorsal fibrocartilage" and "dorsal capsule attachments" are used synonymously.

The purpose of this study was to define the stabilizing function, if any, of the dorsal capsule and associated dorsal fibrocartilage (DFC) on the MCP joint of the thumb. It was noted previously that dorsal capsular tears often occur concomitantly with RCL injuries[2]; thus, stability between an isolated RCL injury and an RCL injury with an associated DFC tear should be further explored. We hypothesized that the DFC acts as a secondary stabilizer and that a combined RCL and DFC injury would lead to increased MCP joint radial, pronation, and volar laxity compared with an isolated RCL injury.

MATERIALS AND METHODS

Pilot and Repeatability Testing

Before we investigated our hypothesis, we tested 5 pilot specimens to ensure a consistent method of data collection. Changes in ulnar-radial deviation, pronation-supination, and volar-dorsal translation were collected 4 times. Trial 1 consisted of recording 2 separate measurements at 0°, 30°, and 60° of MCP joint flexion. Trial 2 was then performed in the same manner. After we collected data for both trials, we tested the next condition. We could attain repeatable values between both measurements and trials (less than 0.9° change in angulation and less than 0.5 mm change in translation) across each variable tested at each tested flexion angle and condition.

Eight cadaveric thumbs (7 male and 1 female; mean age, 62 years; range, 53–73 years) were disarticulated at the scaphotrapeziod joint and examined to be macroscopically intact without features of previous surgery, and had an adequate range of motion from 0° to 60° MCP joint flexion.

Skin and subcutaneous tissue were removed. The tendinous insertions of abductor pollicis brevis (APB), adductor pollicis (AdP), extensor pollicis brevis, extensor pollicis longus (EPL), flexor pollicis brevis, and flexor pollicis longus (FPL) were preserved for muscle loading. Both the trapeziometacarpal joint and interphalangeal (IP) joint were fixed using 2 3.0-mm intramedullary half-pins, one across each joint. For additional rotational stability, a 6-hole, 2.5-mm locking compression plate (DePuy Synthes, West Chester, PA) was applied on the ulnar side of the IP joint. The plate was secured to both the thumb and distal intramedullary half-pin. The plate was fixed to the thumb by 2 2.5-mm locking screws; one screw was inserted bicortically through the proximal phalanx and the second was placed unicortically through the distal phalanx (Fig. 1). The distal-most hole of the plate was connected to the intramedullary half-pin through an external fixator clamp (DePuy Synthes).

The metacarpal base was potted with plaster of Paris within a 1-inch polyvinyl chloride (PVC) pipe. The metacarpal was further transfixed to the PVC pipe using 2 screws that were drilled through both ends of the PVC pipe and plaster of Paris, and bicortically through the metacarpal shaft. The PVC pipe with the fixed specimen was then mounted onto a custom testing system, which allowed for simultaneous control of MCP joint flexion while not restraining the position of the phalanx. The intramedullary rod connected to the distal phalanx was inserted through a trough on the base plate, which allowed simultaneous control of