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Mechanoreceptor profile of the lateral collateral ligament complex in the human elbow

Erica Kholinne [a, e], Hyun-Joo Lee [b], Yu-Mi Lee [c], Suk-Joong Lee [d], Maria F. Deslivia [a], Ga-Yeong Kim [e], SungJoon Lim [e], In-Ho Jeon [e, *]

[a] Department of Orthopedic Surgery, St. Carolus Hospital, Jakarta, Indonesia
[b] Department of Orthopaedic Surgery, School of Medicine, Kyungpook National University, Kyungpook National University Hospital, Daegu, Republic of Korea
[c] Department of Preventive Medicine, School of Medicine, Kyungpook National University, Republic of Korea
[d] Department of Orthopedic Surgery, Keimyung University, Dongsan Medical Center, Daegu, Republic of Korea
[e] Department of Orthopedic Surgery, Asan Medical Center, University of Ulsan, Seoul, Republic of Korea

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ABSTRACT

Background: Active restraint for the elbow joint is provided by the soft tissue component, which consists of a musculoligamentous complex. A lesion of the lateral collateral ligament complex (LCLC) is thought to be the primary cause of posterolateral rotatory instability in the elbow. Its role as a protective reflexogenic structure is supported by the existence of ultrastructural mechanoreceptors. The aim of this study was to describe the existence and distribution of LCLC mechanoreceptors in the human elbow joint and to determine their role in providing joint stability.

Methods: Eight LCLCs were harvested from fresh frozen cadaver elbows. Specimens were carefully separated from the lateral epicondyle and ulna. The ligament complex was divided into 7 regions of interest and stained with modified gold chloride. Microscopic evaluation was performed for Golgi, Ruffini, and Pacinian corpuscles. The number, distribution, and density of each structure were recorded.

Results: Golgi, Ruffini, and Pacinian corpuscles were observed in LCLCs, with variable distribution in each region of interest. Ruffini corpuscles showed the highest total mechanoreceptor density. Mechanoreceptor density was higher at bony attachment sites.

Conclusion: The existence and role of each mechanoreceptor defined the purpose of each region of interest. Mechanoreceptors are beneficial for its proprioceptive feature towards a successful elbow ligament reconstruction.

Introduction

A lesion of the lateral collateral ligament complex (LCLC) is thought to be the primary cause of posterolateral rotatory instability of the elbow.[1] The functional properties of such protective mechanisms are supported by the existence of mechanoreceptors embedded in their structure.[2–5] Active restraint for the elbow joint is provided by the soft tissue component, which consists of the musculoligamentous complex.[1] Many authors[6–10] have provided information on the mechanoreceptors of the shoulder, knee, and ankle, which are less stable and thus protected by many ligaments and a thick capsule. However, the role of the ligament-muscular protective reflex of the elbow has not recently been considered due to its stable bony structure. Studies have been performed on mechanoreceptors in the elbow ligaments in felines and humans.[11,12] One study that evaluated the mechanoreceptors in the human elbow joint[11] failed to describe their spatial arrangement.

The purpose of this study was to determine the distribution of mechanoreceptors in the human elbow LCLC, i.e., the location of each mechanoreceptor and morphological evidence for LCLC reconstruction. Our hypotheses were as follow: 1) Bony attachment sites have higher mechanoreceptor density, and 2) the mechanoreceptor density at bony attachment sites is higher at the ulna compared to the radius.

* Corresponding author. Department of Orthopaedic Surgery, University of Ulsan, Asan Medical Center, 86 Asanbyeongwon-gil, Songpa-gu, Seoul, 138-736, Republic of Korea.
E-mail address: jeonchoi@gmail.com (I.-H. Jeon).

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Materials and methods

Cadaver dissection and specimen preparation

Institutional Board Review exemption were obtained for this study. Eight elbow joints from four fresh frozen cadavers were included in this study. Two were male with a mean age of 69 years (range, 56–79). LCLCs were harvested within 12 h after cadavers were thawed at room temperature. The ligament complex were carefully isolated from the surrounding muscle and capsule attachment. The dissection was carefully performed taking care not to damage the ligaments and preserving all portions. The attachment to the bone was peeled off. After dissection, the specimens were immersed in neutral pH, 4% paraformaldehyde solution. After at least 24 h of fixation, LCLCs were divided into 7 regions of interest with similar areas in each region (Fig. 1).

Modified gold chloride staining

A modified gold chloride staining method was applied to the specimens.[13] Vials consisting of fresh lemon juice and 98% formic acid solution in a 3:1 ratio were prepared. The vials were transferred and shaken (Penetron Swirling Shaker Model Mark IV, SPI Supplies, Sunkay Laboratories, Tokyo, Japan) inside a fume hood (A-MB-1200TYPE; DH science, Daejeon, Korea) for 30 min. Gold chloride solution (gold chloride solution 200 mg/dL in deionized water, HT1004; Sigma-Aldrich, MO, USA) was poured into the solution vials and then processed with a shaker for 90 min. This process was repeated for subsequent batches with recycled gold chloride solution from previous batches by using a filtering process. The gold chloride solution was subsequently discarded and specimens were soaked in 2.5% formic acid solution and processed with a shaker for at least another 12 h. Specimens were repeatedly washed clean of gold chloride solution 3 times with running distilled water for 5 min. Each specimen was then transported to a conical tube prefilled with 30% sucrose solution and stored at 4 °C for 1–2 days. After a specimen sank to the conical tube bottom, it was then transferred to a new vial containing 30% sucrose and optimum cutting temperature compound (OCT). These vials were then processed with a shaker for 2 h. Once this process finished, the stained specimens were embedded in 30% sucrose and OCT compound in a 3:2 ratio and frozen according to a previous technique.[14] Frozen specimens were sectioned parallel to their longitudinal (horizontal) axis and perpendicular to their vertical axis with a cryosectioning machine (Leica CM3050-S Research Cryostat; Leica Biosystems, Nussloch, Germany) at 30-μm thickness and attached to a microscope glass slide.

Microscopic examination

Inverted light microscopy was used for mechanoreceptor observation. The Freeman and Wyke classification and Hagert et al. modification were used to evaluate types and numbers of Golgi, Ruffini, and Pacinian corpuscles.[15,16]

The slides were first examined under low-power magnification (100×) and subsequently at higher magnification (200×) in order to identify each receptor. Mechanoreceptor structure was evaluated on previous slides and lateral serial slides to determine whether the structures were consistently present. A confirmed structure was counted as one unit. Discontinuous objects with uncertain or doubtful morphology were not counted. We reconfirmed each structure using 400 × magnification in order to minimize any misreading or potential bias that might alter quantification. Mechanoreceptors were evaluated and recorded according to their bony attachment at the humeral, ulnar, or radial site, and at the ligament mid-substance.

Density calculation

To measure ligament volume, we customized software that automatically measured the dimension of each ligament fragment. The volume on one slide was multiplied by 30 μm to determine the total dimension. The volume of each compartment was calculated. The density was defined as the number of mechanoreceptors

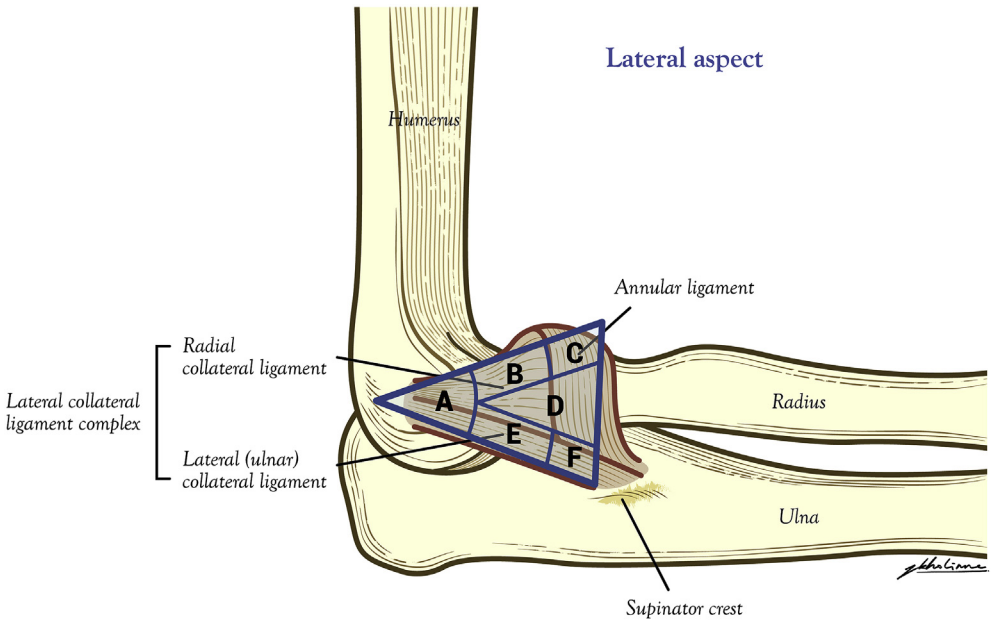

Fig. 1. Topographic diagram showing 7 regions of interest in the LCLC.
A: Humeral bony attachment; B: Radial collateral ligament mid-substance; C: Radial bony attachment and annular ligament; D: Inter-ligament mid-substance; E: Lateral ulnar collateral ligament mid-substance; F: Ulnar bony attachment.

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