In Vivo Measurement Of Coracoclavicular Functional Distance During Shoulder Elevation Following Acromioclavicular Joint Reconstruction

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INTRODUCTION: Understanding the functional roles and mechanical properties of the coracoclavicular (CC) ligaments is critical for acromioclavicular joint (ACJ) reconstruction. The CC ligaments are the primary restraint against vertical displacement of the clavicle. It consists of the trapezoid ligament, responsible for shear forces and preventing posterior translation, and the conoid ligament, providing support against superior translation [1]. This study aimed to estimate the functional distance between CC ligament insertion sites in ACJ reconstructed patients during different shoulder elevation movements. We hypothesized that surgically reconstructed shoulders would demonstrate larger CC functional distance, as well as different temporal characteristics, when compared to the uninjured contralateral limb.

METHODS: Twelve participants (10 men and 2 women, mean age 38 ± 7 years, mean body mass 89 ± 18kg) who had sustained an acute unilateral ACJ disruption (Rockwood classification of III-IV), within 1 to 3 years post-treatment, were recruited (IRB code: HSC-MS-20-0585). Participants underwent 3-D computerized tomography, as well as dynamic stereo x-ray (DSX) imaging that captured abduction (Abd), scaption (Scap), and flexion (Flex) movement. Patient-specific bone models were generated for the clavicle, scapula, and humerus, with the bone models' contours aligned along each frame of the biplanar X-ray images [2]. The motion data for each subject-specific bone model was calculated using this method (Fig. 1). The location of the conoid and trapezoid insertion points was also registered onto the bone models, allowing the functional distance to be estimated at each time point throughout the recorded motions. From this, the peak functional distance and the time of peak distance were measured across each movement trial.

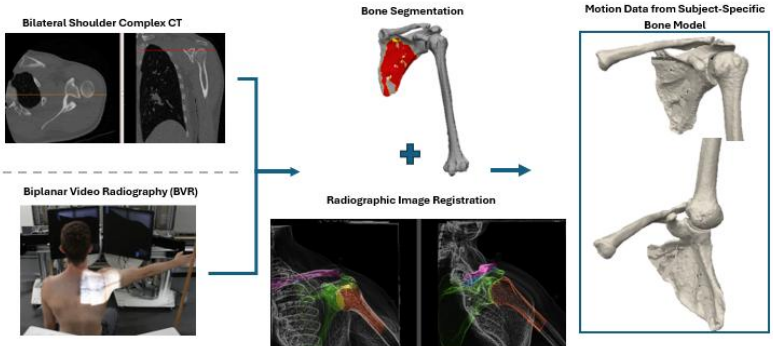

Fig 1: Patient specific 3D bone models combined with DSX to measure joint motion

RESULTS: During the upward and downward phase of movements, the conoid ligaments were found to have a larger peak distance between insertion points, in the ipsilateral limb compared to the contralateral limb across abduction, flexion and scaption ($p<0.001$) (Fig. 2). In addition to this, the conoid reached peak length at a later stage of the movement cycle during upward abduction ($p=0.021$), and at an earlier stage during downward abduction ($p<0.001$). During the upward and downward phase of movements, the trapezoid ligaments were found to have a larger peak distance between insertion points, in the ipsilateral limb compared to the contralateral limb across flexion ($p<0.001$) and scaption ($p=0.01$). Further, the trapezoid peak lengths were reached at a later stage during abduction ($p<0.001$) and scaption ($p<0.001$) during upward movements. While for downward movements, they reached peak length at an earlier stage during abduction ($p<0.001$) and flexion ($p<0.001$).

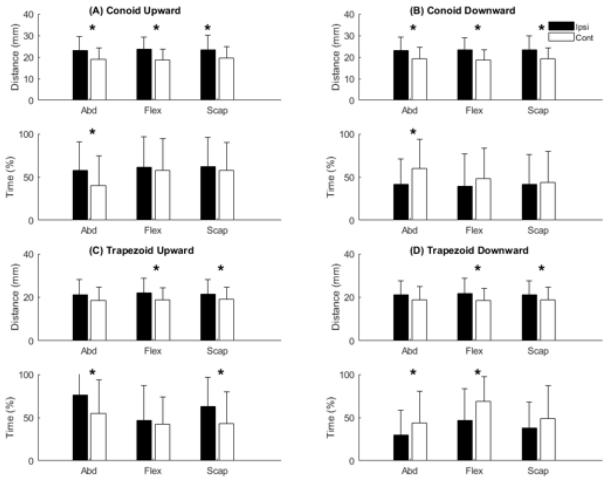

Fig 2: Peak distance (mm) and Time of peak distance (% of movement cycle) during Abd, Flex & Scap for (A&B) Conoid Upward/Downward, (C&D) Trapezoid Upward/Downward

DISCUSSION: This study investigated the functional distance and temporal characteristics of the coracoclavicular (CC) ligaments using patient-specific 3D bone models in combination with DSX imaging. The conoid and trapezoid ligaments exhibited 23% and 17% greater peak distances between their insertion points, respectively, in the ipsilateral limb compared to the contralateral limb during abduction, flexion, and scaption. Given the conoid ligament's critical role in limiting clavicular elevation during abduction, its increased functional distance may indicate superior-inferior instability of the clavicle. This finding is clinically relevant, as excessive clavicular elevation is often associated with shoulder pain and poor cosmetic outcomes.[3] Similarly, increased functional distance between the trapezoid insertion points may reflect anterior-posterior instability, which has been linked to lower clinical outcome scores when not properly addressed.[4] Supporting this, cadaveric studies have shown that conoid ligament removal increases clavicular upward rotation during abduction, while trapezoid removal reduces scapular external rotation during flexion.[1] Such changes in clavicular-scapular mechanics can increase the risk of secondary pathologies such as impingement, rotator cuff degeneration, and glenohumeral instability. These findings reinforce the significance of the CC ligaments in maintaining proper biomechanics during humeral elevation, as AC joint motion relies on coordinated function between the AC and CC ligaments. Additionally, the reconstructed limb demonstrated altered timing of peak ligament elongation. These deviations in elongation temporal patterns may contribute to persistent disruptions in scapulothoracic rhythm, potentially predisposing patients to scapular dyskinesis and scapulohumeral rhythm. Overall, our findings confirm that CC ligament kinematics can be significantly altered following surgical reconstruction, with differences evident across various planes of shoulder elevation.

SIGNIFICANCE/CLINICAL RELEVANCE: DSX-based analysis offers a novel method for assessing CC ligament function following reconstruction. Using this approach in future large-scale clinical trials could inform graft design, tunnel placement, and surgical technique to optimize dynamic joint restoration following ACJ injuries with significant disruption of CC ligaments.

REFERENCES: [1] Oki et al. (2012) *Am J Sports Med.* 40(11):2617-2626; [2] Zandiyeh et al. (2024) *Orthop J Sports Med.* 12(10); [3] Ludewig et al. (2009) *J Bone Jt Surg.* 91(2):378-389. [4] Cisneros et al. (2017) *Eur J Ortho Surg Traum.* 27(3):323-333.