Systematic Review

# Qualitative and Quantitative Anatomic Descriptions of the Coracoclavicular and Acromioclavicular Ligaments: A Systematic Review

Liam A. Peebles, B.A., Zachary S. Aman, B.A., Matthew J. Kraeutler, M.D., and Mary K. Mulcahey, M.D.

**Purpose:** To summarize the quantitative and qualitative anatomy of the acromioclavicular (AC) and coracoclavicular (CC) ligaments of the AC joint. **Methods:** A systematic review of the literature evaluating the quantitative and qualitative anatomy of the CC and AC ligaments of the AC joint was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. **Results:** The conoid ligament (CL) arises from the posterior coracoid precipice and courses with a tapered inferior apex to insert on the conoid tubercle of the posteroinferior clavicle. The trapezoid ligament originates from the anterior–superior coracoid with medially extending fibers anterior to the conoid's C-shaped footprint and runs with the CL to insert along the trapezoid line on the inferior aspect of the anterior clavicle, anterolateral to the conoid tubercle. The AC capsule's superoposterior bundle and the CL are robust stabilizing ligaments characterized by prominent attachment sites to the posteroinferior clavicle. **Conclusions:** Clear and consistent quantitative and qualitative descriptions of the CC ligaments (CL and trapezoid ligament) have been well defined; however, quantitative data on the capsuloligamentous anatomy of AC ligaments (superoposterior and anteroinferior) ligaments) remain limited. **Clinical Relevance:** There are high complication and failure rates after AC joint stabilization. To improve patient outcomes, the anatomy of the CC and AC joints needs to be better understood.

There remains a lack of consensus in the literature regarding the gold standard for the diagnosis and management of Rockwood type III-V acromioclavicular (AC) joint separations.[1,2] More than 160 surgical techniques have been described in the past decade, and thus determining the optimal treatment algorithm has become increasingly elusive secondary to the immense heterogeneity across clinical outcomes studies.[1,3,4] Despite improvements in anatomic surgical techniques leading to improved patient outcomes over the last decade, there remains a high rate of complications and failures following AC joint stabilization, which may be related to techniques focused on only reconstructing the coracoclavicular (CC) ligaments.[3,5-8] While the CC ligaments have been well-described as providing vertical stability to the AC joint, the AC capsule has become increasingly recognized for its role in vertical, rotational, and horizontal stability.[3,9-11]

Recent studies have suggested that horizontal instability negatively impacts clinical outcomes following AC joint stabilization regardless of surgical technique.[12,13] Furthermore, horizontal instability has been proposed as a crucial component that may influence outcomes following type III AC separation, leading to the restratification of these injuries into type IIIA and IIIB. In this modified classification scheme, type IIIB injuries are those with horizontal instability or therapy-resistant scapular dyskinesia, whereas type IIIA injuries present with purely vertical instability.[14] As such, there is a

*From the Department of Orthopaedic Surgery (M.K.M.), Tulane University School of Medicine (L.A.P., M.K.M.), New Orleans, Louisiana; Sidney Kimmel Medical College, Philadelphia, Pennsylvania (Z.S.A.); and Department of Orthopaedic Surgery, St. Joseph's University Medical Center, Paterson, New Jersey (M.J.K.), U.S.A.*

*The authors report the following potential conflicts of interest or sources of funding: M.K.M. reports board or committee member, AAOS; editorial or governing board,* American Journal of Sports Medicine Electronic Media*; board or committee member, American Orthopaedic Association and American Orthopaedic Society for Sports Medicine; paid consultant, Arthrex; editorial or governing board,* Arthroscopy*; board or committee member, Arthroscopy Association of North America; editorial or governing board, Ortho Info; and board or committee member, Ruth Jackson Orthopaedic Society and The Forum. Full ICMJE author disclosure forms are available for this article online, as supplementary material.*

*Received January 30, 2022; accepted April 28, 2022.*

*Address correspondence to Mary K. Mulcahey, M.D., 1430 Tulane Ave., #8632, New Orleans, LA 70112. E-mail: mary.mulcahey.md@gmail.com*



*2666-061X/22112*

*https://doi.org/10.1016/j.asmr.2022.04.026*

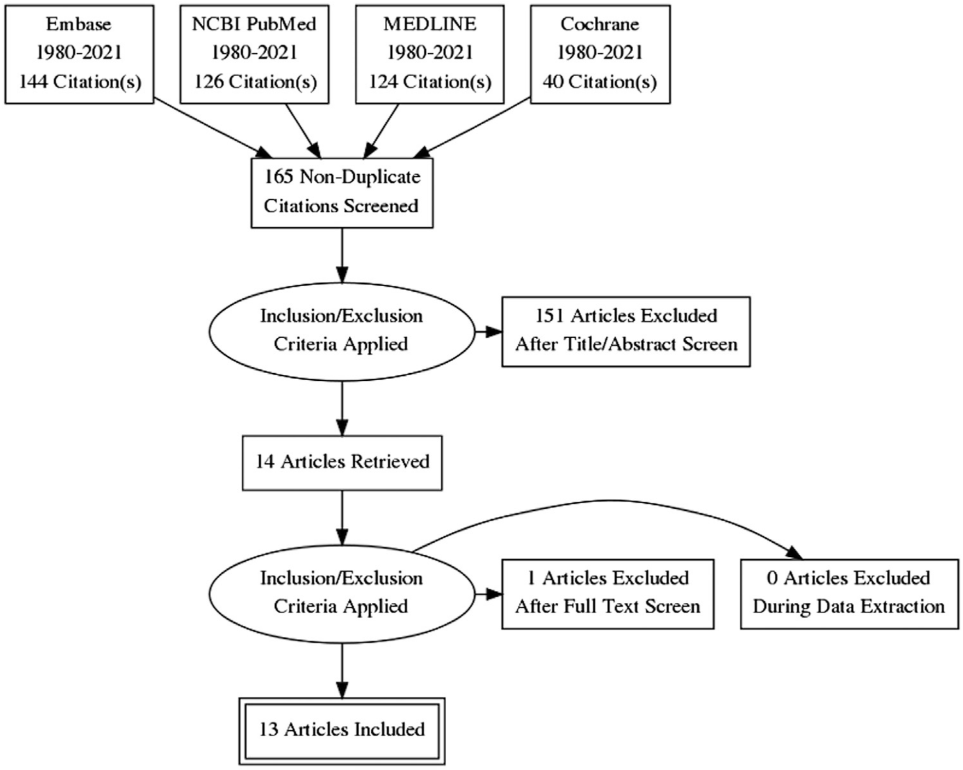


**Fig 1.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart diagram of the study exclusion process. (NCBI, National Center for Biotechnology Information.)

critical need to optimize diagnostic and surgical techniques to better identify and address the injured ligamentous anatomy that contributes to horizontal and rotational instability of the AC joint.[3]

Multiple studies evaluating heterogenous diagnostic and surgical methods have reported controversial and inconsistent clinical results in the available literature on management of type III AC joint injuries. Reassessing the descriptive native anatomy of the AC joint may provide actionable implications toward re-evaluating the optimal approach to diagnostic imaging, clinical decision-making, and surgical techniques aimed to reproduce native AC joint anatomy and biomechanics.[3,15] The purpose of this systematic review was to summarize the quantitative and qualitative anatomy of the CC and AC ligaments of the AC joint. It was hypothesized that the CC and AC ligaments as well as the AC capsule would have consistent anatomic descriptions throughout the literature and that both would be reported to contribute to overall horizontal stability of the AC joint.

## Methods

### Article Identification and Selection

A systematic review of the literature evaluating the quantitative and qualitative anatomy of the CC and AC ligaments of the AC joint was performed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Fig 1). The search query was performed in August 2021 using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed (1980-2021), MEDLINE (1980-2021), and Embase (1980-2021). The search terms used were as follows: (“Acromioclavicular” OR “AC Joint” OR “Acromioclavicular Joint” OR “Coracoclavicular” OR “CC Joint” OR “Coracoclavicular Joint”) AND (“Anatomy” OR “Anatomical” OR “Anatomic”). Inclusion criteria were English-language cadaveric studies published between 1980 and 2021 reporting the gross quantitative or qualitative anatomic descriptions of the CC or AC ligaments of the AC joint. The exclusion criteria were clinical outcomes studies, diagnostic imaging studies, surgical technique studies, biomechanical studies, histologic descriptions, case reports, and review articles. Included articles were obtained following assessment of identified abstracts and final review of full-text articles. Two investigators (L.A.P. and Z.S.A.) independently reviewed abstracts from all identified articles. If necessary, full-text articles were obtained for review to allow for further application of inclusion and exclusion criteria. In addition, the reference lists from included studies were reviewed and reconciled to ensure that all eligible articles were included.

**Table 1.** Study Demographics

| Study | LOE | No. Cadavers | No. Shoulders | No. Male Shoulders | No. Female Shoulders | Mean Age, y | Age Range, y | Measurement Device |
|---|---|---|---|---|---|---|---|---|
| Boehm et al., 2009[16] | N/A | 36 | 36 | 18 | 18 | 84 | 73-97 | Vernier micrometer and loupe magnification |
| Chahla et al., 2018[17] | N/A | 10 | 10 | – | – | 52 | 33-64 | 3D coordinate measuring device |
| Harris et al., 2001[18] | N/A | 24 | 24 | – | – | 70 | 59-90 | Vernier calipers (0.1 mm) |
| Nakazawa et al., 2016[35] | N/A | 13 | 26 | 6 | 10 | 83.7 | – | Digital goniometer |
| Nolte et al., 2021[26] | N/A | 12 | 12 | – | – | 55 | 41-64 | Digital protractor, 3D coordinate measuring device |
| Rios et al., 2007[19] | N/A | 60 | 120 | 96 | 24 | 48.3 | – | Vernier calipers (0.1 mm) |
| Salter et al., 1987[27] | N/A | 27 | 53 | 26 | 28 | – | – | Vernier micrometer |
| Salzmann et al., 2008[20] | N/A | 14 | 23 | 6 | 17 | – | – | Digital calipers |
| Stine and Vangsness, 2009[21] | N/A | 28 | 28 | – | – | – | – | Digital calipers, goniometer, loupe magnification |
| Takase et al., 2010[22] | N/A | 20 | 40 | 16 | 24 | 71.3 | 62-88 | Vernier calipers (0.1 mm) |
| Terra et al., 2013[23] | N/A | 15 | 30 | 18 | 12 | 54 | 24-66 | Vernier calipers (0.1 mm) |
| Xue et al., 2013[24] | N/A | 87 | 172 | 86 | 88 | 66 | – | Digital calipers |
| Zhu et al., 2016[25] | N/A | 20 | 40 | – | – | 56.4 | 43-75 | Digital protractor, Vernier calipers (0.1 mm) |
| No. specimens | | 366 | 614 | 272 | 221 | 510 | 192 | |
| No. studies | | 13 | 13 | 8 | 8 | 10 | 8 | |
| Weighted mean age, y | | | | | | 62.6 | 24-97 | |

N/A, not applicable.

### Data Collection and Quality Appraisal

Quantitative and qualitative descriptions of the CC ligaments (conoid ligament [CL] and trapezoid ligament [TL]) and AC capsular ligaments were recorded. Parameters included quantitative and qualitative descriptions of the attachment sites to the coracoid process, clavicle, and acromion; distances related to surgically relevant anatomic landmarks; and qualitative descriptions of ligament structure and trajectory. For reported quantitative data, the mean and range of measurements were documented.

## Results

### Study Demographics

The literature search identified 163 articles, and 13 studies met final inclusion criteria following full-text review (Table 1).[26,16-25,35] A total of 366 cadavers and 614 shoulders were analyzed in the included studies. There were 10 studies[16-25] that reported anatomic descriptions of the CC ligaments and 3 studies[26,16,21] that reported on the AC capsular ligaments. Two studies[16,21] reported anatomic descriptions for both the native CC and AC capsular ligaments. The sex of the analyzed cadavers was reported in 8 studies with a total of 344 shoulders, including 199 male and 145 female specimens. Mean ages of the cadavers were noted in 10 studies, for which a weighted mean was calculated using 510 total shoulders across the reporting studies. The mean age was 62.6 years, with ages ranging from 24 to 97 years.

### CC Ligaments

#### Conoid Ligament

Of the 13 studies included in the review, 7 provided qualitative descriptions of the CC ligament complex and its relationship to the surrounding osseous structures (Table 2).[17,18,20,22,24,25,27] The CL's footprint originates from the posterior-most margin of the coracoid's dorsal aspect in a C-shaped form, being limited anteriorly by the insertion of its trapezoid counterpart. From the posterior coracoid precipice, the CL courses upward in a posterolateral direction to its insertion on the conoid tubercle of the posteroinferior clavicle. The CL's footprint on the clavicle is approximately twice as wide (medial to lateral) and thick (anterior to posterior) as its coracoid attachment, yielding an inverted cone shape with a tapered inferior apex. The CL's C-shaped clavicular footprint typically lies directly adjacent to the attachment of the TL and is limited by the conoid tubercle posteriorly, extending anteriorly in an oval shape (Fig 2).

The distance between the center of the CL to the lateral clavicular margin was reported in 3 studies with a total of 188 cadaveric shoulders with a weighted mean of 34.9 mm (range 23.2-46.4 mm).[19,21,25] Using the same reference of the lateral clavicular margin, 3 other studies provided measurements of distances to the lateral border of the CL.[16,22,24] From the most

**Table 2.** Coracoclavicular Anatomic Descriptions by Study

| | Description of Clavicular Attachment | | | | Description of Coracoid Attachment | | | |
|---|---|---|---|---|---|---|---|---|
| | Conoid Ligament | | Trapezoid Ligament | | Conoid Ligament | | Trapezoid Ligament | |
| Study | Measurement Reference | Distance, mm | Measurement Reference | Distance, mm | Measurement Reference | Distance, mm | Measurement Reference | Distance, mm |
| Boehm et al., 2009[16] | In relation to lateral clavicle margin | | In relation to lateral clavicle margin | | NR | | | |
| | To lateral ligament border | 26.0 (20.0-37.0) | To lateral ligament border | 10.0 (4.0-16.0) | | | | |
| | To medial ligament border | 47.0 (39.0-62.0) | To medial ligament border | 26.0 (20.0-to 38.0) | | | | |
| Chahla et al., 2018[17] | Dimensions of ligament footprint | | Dimensions of ligament footprint | | Dimensions of ligament footprint | | Dimensions of ligament footprint | |
| | Total attachment area | 47.5 $mm^2$ (37.5-57.5) | Total attachment area | 60.6 $mm^2$ (43.8-77.5) | Total attachment area | 37.0 $mm^2$ (31.8- 42.2) | Total attachment area | 44.3 $mm^2$ (32.7- 55.9) |
| | | | | | Conoid center to landmarks | | Trapezoid center to landmarks | |
| | | | | | To base of coracoid | 10.1 (7.9-12.3) | To base of coracoid | 17.7 (16.1-19.4) |
| | | | | | To tip of coracoid | 33.9 (30.6-37.2) | To tip of coracoid | 27.0 (23.7-30.3) |
| Harris et al., 2001[18] | Dimensions of ligament footprint | | Dimensions of ligament footprint | | Dimensions of ligament footprint | | Dimensions of ligament footprint | |
| | Width/sagittal/M-L | 20.6 (15.5-25.0) | Width/sagittal/M-L | 21.7 (16.5-29.5) | Width/sagittal/M-L | 10.6 (7.0-12.5) | Width/sagittal/M-L | 14.0 (10.5-18.0) |
| | Medial conoid length | 19.4 (13.5-27.3) | Anterior trapezoid length | 19.3 (15.0-23.0) | | | | |
| | Conoid thickness | | Trapezoid thickness | | | | | |
| | Superior | 8.6 (5.7-10.5) | Superior | 16.0 (12.2-20.5) | | | | |
| | Middle | 5.9 (3.8-7.1) | Middle | 5.5 (3.1-8.9) | | | | |
| | Inferior | 4.4 (3.2-5.2) | Inferior | 4.8 (3.8-5.6) | | | | |
| Rios et al., 2007[19] | Conoid center to landmarks | | Conoid center to landmarks | | NR | | | |
| | To lateral clavicle margin | 35.0 ± 5.9 | To lateral clavicle margin | 25.9 ± 3.9 | | | | |
| | Dimensions of ligament footprint | | Dimensions of ligament footprint | | | | | |
| | Width/sagittal/M-L | 25.3 ± 4.9 | Width/sagittal/M-L | 11.8 ± 1.0 | | | | |
| Salzmann et al., 2008[20] | NR | | | | Dimensions of ligament footprint | | Dimensions of ligament footprint | |
| | | | | | Width/sagittal/M-L | 4.4 ± 1.4 | Width/sagittal/M-L | 5.7 ± 1.6 |
| | | | | | Length/coronal/A-P | 9.6 ± 2.5 | Length/coronal/A-P | 15.2 ± 2.5 |
| | | | | | Conoid center to landmarks | | Trapezoid center to landmarks | |
| | | | | | To medial coracoid border | 1.7 ± 0.7 | To medial border | 8.7 ± 3 |
| | | | | | To lateral coracoid border | 10.3 ± 2 | To lateral border | 4.4 ± 2.8 |
| | | | | | To base of coracoid | 6.3 ± 3 | To base | 12.1 ± 2.8 |
| | | | | | To tip of coracoid | 36.8 ± 3.7 | To tip | 31 ± 3.3 |
| | | | | | To the precipice | 16.4 ± 2.4 | To precipice | 10.9 ± 2.4 |

(continued)

**Table 2.** Continued

| | Description of Clavicular Attachment | | | | Description of Coracoid Attachment | | | |
|---|---|---|---|---|---|---|---|---|
| | Conoid Ligament | | Trapezoid Ligament | | Conoid Ligament | | Trapezoid Ligament | |
| Study | Measurement Reference | Distance, mm | Measurement Reference | Distance, mm | Measurement Reference | Distance, mm | Measurement Reference | Distance, mm |
| Stine and Vangsness, 2009[21] | Dimensions of ligament footprint | | Dimensions of ligament footprint | | NR | | | |
| | Width/sagittal/M-L | 15.6 (10.9-20) | Width/sagittal/M-L | 14.7 (8.0-20.6) | | | | |
| | Conoid center to landmarks | | Trapezoid center to landmarks | | | | | |
| | To lateral clavicle margin | 32.1 (23.2-46.4) | To lateral clavicle margin | 16.0 (9-21.1) | | | | |
| Takase et al., 2010[22] | In relation to lateral clavicle margin | | In relation to lateral clavicle margin | | In relation to tip of coracoid | | In relation to tip of coracoid | |
| | To lateral ligament border | 27.0 (15.0-36.0) | To lateral ligament border | 8.2 (5.0-13.0) | To anterior end of attachment | 42.1 (37.0-48.0) | To anterior end of attachment | 22.6 (18.0-30.0) |
| | To widest site of attachment | 38.0 (25.0-43.0) | To widest site of attachment | 17.4 (12.0-21.0) | | | | |
| | Dimensions of ligament footprint | | Dimensions of ligament footprint | | Dimensions of ligament footprint | | Dimensions of ligament footprint | |
| | Width/sagittal/M-L | 17.4 (10.0 to 30.0) | Width/sagittal/M-L | 18.5 (13.0 to 26.0) | Width/sagittal/M-L | 4.8 (3.0 to 6.0) | Width/sagittal/M-L | 12.6 (5.0 to 16.0) |
| | Length/coronal/A-P | 5.4 (3.0-11.0) | Length/coronal/A-P | 15.4 (12.0-20.0) | Length/coronal/A-P | 13.1 (10.0-18.0) | Length/coronal/A-P | 19.6 (16.0-26.0) |
| Terra et al., 2013[23] | NR | | | | Conoid center-landmarks | | Trapezoid center-landmarks | |
| | | | | | To tip of coracoid | 36.6 ± 3.5 | To tip of coracoid | 33.3 ± 3.8 |
| Xue et al., 2013[24] | In relation-lateral clavicle margin | | In relation-lateral clavicle margin | | Conoid center-landmarks | | Trapezoid center-landmarks | |
| | To lateral ligament border | 35.7 ± 3.4 | To lateral ligament border | 21.8 ± 2.7 | To tip of coracoid | 35.1 ± 3.2 | To tip of coracoid | 29.7 ± 2.9 |
| | Dimensions of ligament footprint | | Dimensions of ligament footprint | | Dimensions of ligament footprint | | Dimensions of ligament footprint | |
| | Width/sagittal/M-L | 13.1 ± 2.2 | Width/sagittal/M-L | 14.7 ± 2.0 | Width/sagittal/M-L | 5.0 ± 0.7 | Width/sagittal/M-L | 6.1 ± 1.5 |
| | Length/coronal/A-P | 6.0 ± 1.4 | Length/coronal/A-P | 8.2 ± 2.5 | Length/coronal/A-P | 10.7 ± 1.8 | Length/coronal/A-P | 13.2 ± 2.3 |
| Zhu et al., 2016[25] | Conoid center-landmarks | | Trapezoid center-landmarks | | NR | | | |
| | To lateral clavicle margin | 36.6 (35.0-38.5) | To lateral clavicle margin | 21.7 (19.8-24.0) | | | | |
| | To posterior clavicle margin | 5.5 (4.9-6.3) | To anterior clavicle margin | 6.4 (5.5-7.2) | | | | |

NOTE. Quantitative measurements are reported as means and standard deviations or ranges.
A-P, anteroposterior; M-L, medial-to-lateral; NR, not reported.

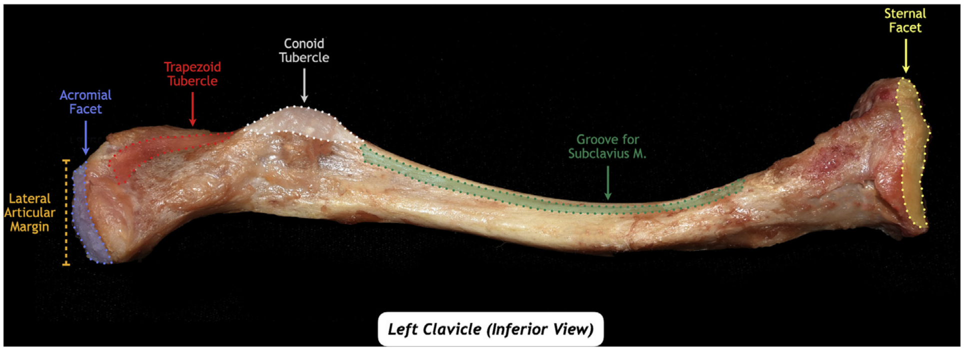


**Fig 2.** Inferior-to-superior view of a left clavicle demonstrating common bony landmarks and soft-tissue insertions of the AC-CC ligament complex. (AC, acromioclavicular; CC, coracoclavicular.)

lateral extent of the conoid footprint, there was an average distance of 32.9 mm (range 15.0-37.0 mm) to the lateral clavicle border in 248 total specimens. Multiple studies also reported on length[22,24] and width[18,19,21,22,24] of the ligament's footprint at the conoid tubercle of the clavicle. In 348 shoulders, the conoid footprint was found to have an average width of 18.0 mm (range 10.0-30.0 mm) and in 212 shoulders, the conoid footprint length was found to be a mean 5.9 mm (range 3.0-11.0 mm).

In an assessment of the CL's coracoid attachments, four[17,20,23,24] studies reported a mean distance of 35.4 mm (range 30.6-37.2 mm) from the footprint center to the tip of the coracoid in 235 shoulders. Two[17,20] of these 4 studies also provided measurements to the coracoid base, with reported mean distances of 6.3 mm and 10.1 mm, respectively. Four studies measured the length (in 235 shoulders)[20,22,24] and width (in 259 shoulders)[18,20,22,24] of the conoid's footprint along the posteromedial margin of the coracoid. On average, the ligament's attachment was 5.4 mm wide (range 3.0-12.5 mm) and 11.0 mm long (range 10.0-18.0).

### Trapezoid Ligament

Six studies[17,18,22,24,27,28] provided qualitative descriptions of the TL and its respective insertions on the coracoid and clavicle. The TL was commonly described as originating on the anterior-superior aspect of the coracoid with fibers extending to its medial surface, just anterior to the conoid's footprint. Interestingly, one study reported specimens occasionally having CC ligaments with fibrous fusion at their base on the coracoid.[17] The TL runs with the CL on a posteromedial to anterolateral trajectory and attaches to the trapezoid line on the inferior aspect of the anterior clavicle, anterolateral to the conoid tubercle (Fig 3). The TL is 2 to 3 times thicker at its clavicular attachment site than at its coracoid attachment site, though the width has been reported to narrow less noticeably than the CL's inverted conical structure.[18] The TL's clavicular footprint is typically oval or elliptical in shape, encircling the trapezoid ridge and an extensive area medial to it.

The distance between the center of the TL to the lateral clavicular margin was reported in 3 studies, with a total of 188 cadaveric shoulders and a weighted mean of 25.3 mm (range 9.0-24.0 mm). Using a similar reference of the lateral clavicular margin, three[16,22,24] other studies with a total of 248 specimens also provided measurements of distances to the lateral border of the TL with a mean distance of 17.9 mm (range 4.0-24.5 mm). Multiple studies also reported on length[22,24] and width[18,19,21,22,24] of the ligament's footprint at the conoid tubercle of the clavicle. In 348 shoulders, the TL footprint was found to have an average width of 14.6 mm (range 8.0-29.5 mm) and in 212 shoulders, the average length was found to be 9.6 mm (range 5.7-20.0 mm).

Regarding the TL's coracoid attachments, four[17,20,23,24] studies reported a mean distance of 30.2 mm (range

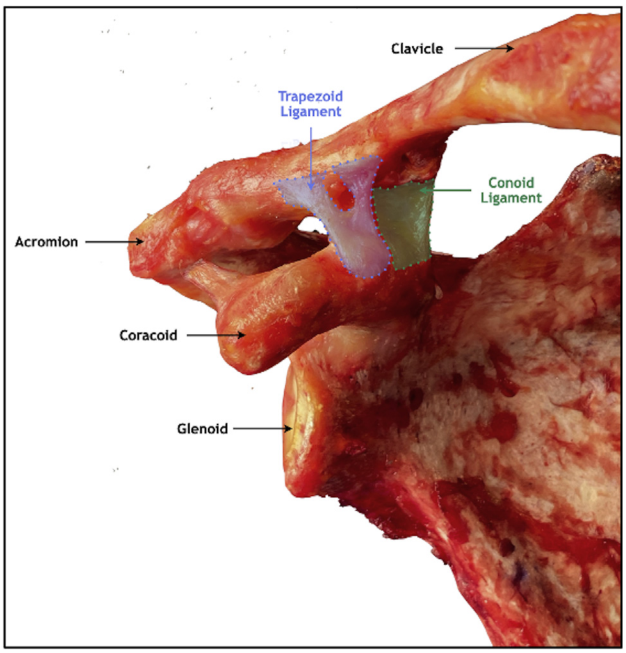


**Fig 3.** Anterior-to-posterior view of a right shoulder highlighting the CC ligament complex, composed of the trapezoid and conoid ligaments. (CC, coracoclavicular.)

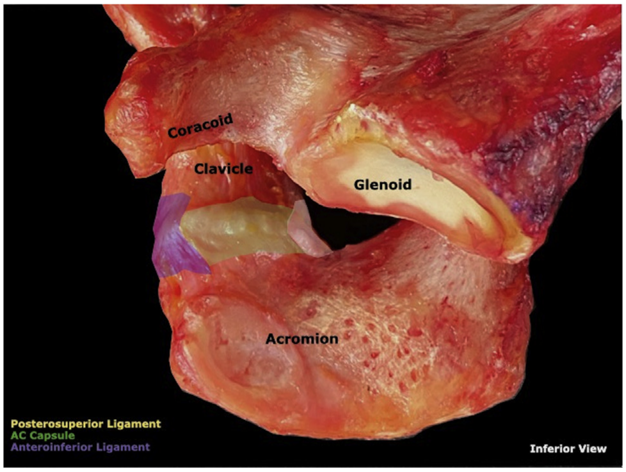


**Fig 4.** Inferior view of a right scapula, highlighting the posterosuperior (yellow) and anteroinferior (purple) ligaments and AC capsule (green) that serve as the primary soft-tissue stabilizers of the AC joint. (AC, acromioclavicular.)

(range, 30.6-37.2 mm) from the footprint center to the tip of the coracoid in 235 shoulders. Two of these four studies also provided measurements to the coracoid base, which reported mean distances of 12.1[25] mm and 17.7[22] mm, respectively. Four studies measured the length (in 235 shoulders)[22,24] and width (in 259 shoulders)[18,19,21,22,24] of the trapezoid's footprint along the anterior—superior margin of the coracoid. On average, the TL's attachment was 7.8 mm wide (range 5.0-16.0 mm) and 14.5 mm long (range 10.9-26.0 mm).

## AC Ligaments and Joint Capsule

In the analysis of qualitative descriptions and landmarks specific to the AC joint's ligamentous or capsular architecture, three[26,16,21] of the 13 studies met criteria for inclusion. Although emerging designations of distinct structures comprising the AC ligament complex makes cross-study analysis more difficult, the current literature suggests that the complex can be divided into 2 parts: a bundle situated in the superoposterior (SP) aspect of the joint and one primarily situated in the anteroinferior (AI) aspect of the joint (Figs 4-6). While the SP bundle has commonly been described as a more robust and easily identifiable structure, the AI bundle is much more variable in its presence and morphology.[26,16,21] The SP bundle of the AC complex runs in an oblique manner to traverse the AC joint surface, reinforcing the joint capsule from the anterior aspect of the acromion to the posterior aspect of the distal clavicle.[26,21] At its clavicular insertion, the SP bundle's attachment extends from the superior to the inferior surface of the distal clavicle and around the posterior edge.

The AI bundle is typically a thinner ligamentous structure and is thought to contribute to AC joint capsular integrity less than its SP counterpart.[26,17] The AI bundle was less commonly identified and has inconsistent origins and insertions along the acromion, clavicle, and joint capsule.[26] Originating from the anterior aspect of the acromion or AC joint capsule, the AI bundle was described as having insertions along the superior and inferior joint capsule as well as the anterior margin of the distal clavicle. Lastly, the superior portion of the AC capsule has been found to have a noticeably thicker and wider acromial attachment relative to that of the inferior AC capsule, which is comprised of a segment of thin tissue covering the inferior aspect of the joint lacking any appreciable ligamentous reinforcement.

There was an even greater scarcity of studies providing quantitative data on AC joint ligamentous and capsular anatomy (Table 3). Of the 3 studies meeting inclusion criteria for quantitative data extraction, two[26,17] provided more than one measurement related to capsule or ligament structure or bony attachments to the acromion and clavicle. Due to this lack of adequate power, meaningful statistical analysis could not be performed, and only individual means and ranges were reported. Both studies reported on the width of the capsuloligamentous clavicular attachment, with the mean width of the superior and inferior insertions ranging from 2.8[26] to 6.4[15] mm and 2.8[26] to 4.4[15] mm, respectively. In addition, Stine and Vangsness[21] found the mean widths of the AC joint capsule's anterior and posterior clavicular insertions to be 2.2 mm and 2.9 mm, respectively. Both studies also measured distances from the medial (from joint line) capsular insertion to the clavicular cartilage border,

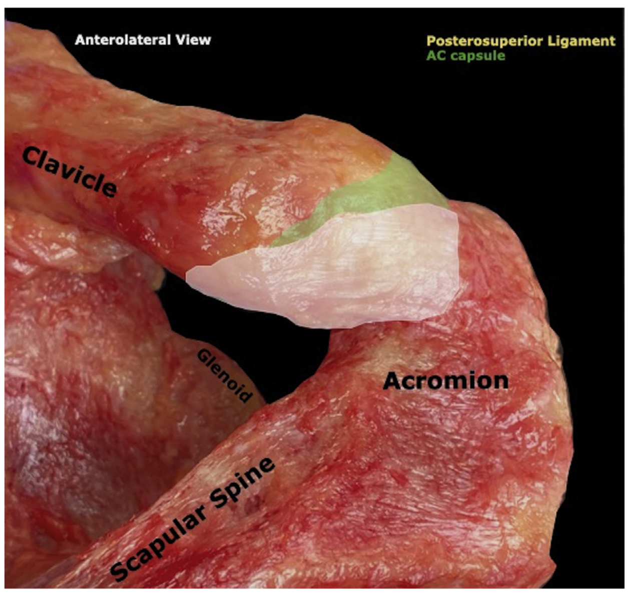


**Fig 5.** Anterolateral view of a right scapula, highlighting the posterosuperior (yellow) ligament and the AC capsule (green) of the AC joint. (AC, acromioclavicular.)

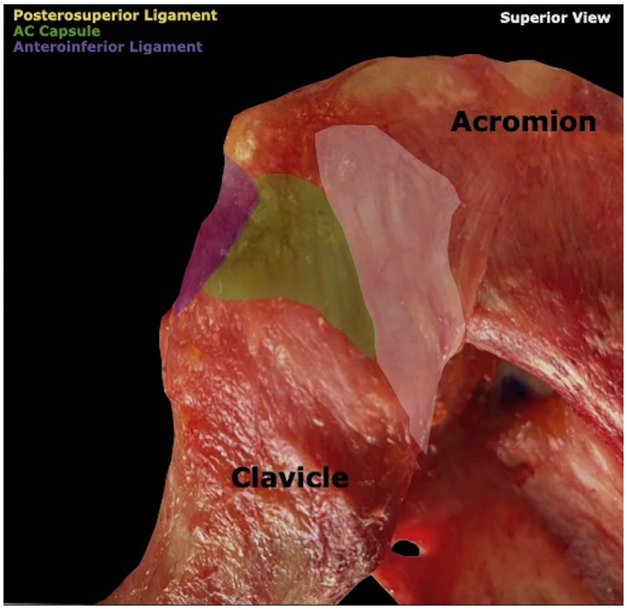


**Fig 6.** Superior view of a right scapula, highlighting the posterosuperior (yellow) and anteroinferior (purple) ligaments and AC capsule (green) that serve as the primary soft-tissue stabilizers of the AC joint. (AC, acromioclavicular.)

reporting means of 3.9[26] to 4.6[15] mm for the superior AC capsule and 2.9[26] to 4.0[15] mm from its inferior aspect. Stine and Vangsness[21] measured these same distances for the anterior and posterior borders of the capsule's medial clavicular insertion as well, calculating means of 3.8 mm and 3.5 mm, respectively. Furthermore, the authors also reported distances from the lateral (from joint line) capsular insertion on the distal clavicle to the clavicular cartilage border. For the anterior, posterior, superior, and inferior borders, these distances had means of 6.4 mm, 6.3 mm, 6.6 mm, and 5.5 mm, respectively.[21]

The anatomic studies by Nolte et al.[26] and Stine and Vangsness[21] also provided similar measurements for the AC capsule's acromial insertions. Both studies reported on the width of the capsuloligamentous acromial footprint, with the means of the superior and inferior insertions ranging from 2.5[26] to 4.6[15] mm and 1.6[26] to 4.0[15] mm, respectively. In addition, Stine and Vangsness[21] found the mean width of the AC joint capsule's anterior and posterior acromial insertions to be 2.4 mm and 2.1 mm, respectively. Both studies measured distances from the medial (from joint line)

**Table 3.** Acromioclavicular Anatomic Descriptions by Study

| | Description of Clavicular Attachment | | Description of Acromial Attachment | |
|---|---|---|---|---|
| Author | Measurement Reference | Distance, mm | Measurement Reference | Distance, mm |
| Boehm et al. (2009)[16] | Posterosuperior AC ligament in relation to lateral clavicle | 7.5 (4.0-12.0) | NR | |
| Nolte et al. (2021)[26] | Mean width of capsuloligamentous clavicular attachment | | Mean width of capsuloligamentous acromial attachment | |
| | Complete attachment | 5.4 (5.0-5.8) | Complete attachment | 4.3 (4.0-4.6) |
| | Superior attachment | 6.4 (5.8-6.9) | Superior attachment | 4.6 (4.2-4.9) |
| | Inferior attachment | 4.4 (3.9-4.8) | Inferior attachment | 4.0 (3.6-4.4) |
| | Medial (from joint line) capsular insertion to clavicular cartilage border | | Medial (from joint line) capsular insertion to medial acromion | |
| | Complete capsule | 4.3 (4.0-4.6) | Complete capsule | 3.1 (2.9-3.4) |
| | Superior capsule | 4.6 (4.2-4.9) | Superior capsule | 3.1 (2.9-3.4) |
| | Inferior capsule | 4.0 (3.6-4.4) | Inferior capsule | 2.5 (2.2-2.7) |
| Stine and Vangsness 2009[21] | Mean width of capsuloligamentous clavicular attachment | | Mean width of capsuloligamentous acromial attachment | |
| | Anterior insertion | 2.2 (1.0-5.2) | Anterior insertion | 2.4 (1.2-4.6) |
| | Posterior insertion | 2.9 (1.1-4.5) | Posterior insertion | 2.1 (1.1-4.4) |
| | Superior insertion | 2.8 (1.2-4.2) | Superior insertion | 2.5 (1.1-4.5) |
| | Inferior insertion | 2.8 (1.0-5.1) | Inferior insertion | 1.6 (1.0-3.1) |
| | Medial (from joint line) capsular insertion to clavicular cartilage border | | Medial (from joint line) capsular insertion to medial acromion | |
| | Anterior border | 3.8 (2.0-5.1) | Anterior border | 3.3 (2.2-6.1) |
| | Posterior border | 3.5 (1.6-6.2) | Posterior border | 2.3 (1.1-3.5) |
| | Superior border | 3.9 (2.1-6.3) | Superior border | 3.0 (0.6-5.5) |
| | Inferior border | 2.9 (1.8-5.2) | Inferior border | 2.4 (1.0-5.3) |
| | Lateral (from joint line) capsular insertion to clavicular cartilage border | | Lateral (from joint line) capsular insertion to medial acromion | |
| | Anterior border | 6.4 (4.0-8.3) | Anterior border | 5.6 (3.9-9.0) |
| | Posterior border | 6.3 (4.0-8.1) | Posterior border | 4.3 (4.1-6.2) |
| | Superior border | 6.6 (4.0-9.3) | Superior border | 5.3 (3.0-8.5) |
| | Inferior border | 5.4 (3.9-8.8) | Inferior border | 4.0 (3.3-6.5) |

NOTE. Quantitative measurements are reported as means and ranges.
NR, not reported.

capsular insertion to the border of the medial acromion, reporting means of 3.0[26] to 3.1[15] mm for the superior AC capsule and 2.4[26] to 2.5[15] mm for its inferior aspect. Stine and Vangsness[21] provided these distances for the anterior and posterior borders of the capsule's medial acromial insertion as well, calculating means of 3.3 mm and 2.3 mm, respectively. Lastly, the authors reported distances from the lateral (from joint line) capsular insertion to the medial acromion. For the anterior, posterior, superior, and inferior borders, these distances had means of 6.4 mm, 6.3 mm, 6.6 mm, and 5.5 mm, respectively.[21]

## Discussion

The most important finding of this systematic review was the paucity of quantitative data on the capsuloligamentous anatomy of the AC joint. Second, a much clearer consensus has been reached across a relatively larger body of literature regarding the same qualitative and quantitative data for CL and TL anatomy. Qualitatively, the AC joint receives soft-tissue support from the thicker SP and thinner AI bundles of the AC joint complex. In considering the CC ligament complex, the most common CL anatomic location was described to arise from the posterior coracoid precipice and course in the form of an inverted cone with a tapered inferior apex to insert on the conoid tubercle of the posteroinferior clavicle. The TL most commonly originates from the anterior—superior coracoid with fibers extending to its medial surface anterior to the conoid's C-shaped footprint and runs with the CL to insert along the trapezoid line on the inferior aspect of the anterior clavicle, anterolateral to the conoid tubercle.

The lack of reliable gold standards for the diagnosis and treatment of patients with acute or chronic AC joint injuries has necessitated a staggering increase in investigational efforts to advance the current understanding of native AC joint anatomy. To date, more than 160 different surgical techniques have been described for AC joint reconstruction and it has been found that anatomic techniques generally yield more favorable outcomes.[1] However, the potential value in clinical outcomes of "anatomic" reconstructions is directly related to the clear understanding of the native anatomy of the AC and CC ligaments. Failure to completely appreciate the native attachments and course of these critical ligaments may ultimately be reflected in failure to restore native joint mechanics. This may be reflected by most techniques focusing primarily on reproducing native CC ligament anatomy and restoring vertical stability, but neglecting to address the AC capsule, which plays a crucial role in horizontal joint stability. In managing chronic AC joint injuries, it has been suggested[3] that some reconstructive techniques (e.g., modified Weaver—Dunn) may fail to recreate the native force transfer from the medial acromion to the lateral clavicle. Instead, the force is transferred from the lateral clavicle to the tip of the coracoid in a nonphysiologic manner. Furthermore, numerous clinical outcomes studies have identified a high incidence of persistent horizontal instability in anatomic reconstructions of the CC ligaments alone leading to poor long-term outcomes in terms of pain and disability when the horizontal component of AC joint instability remains uncorrected, highlighting the recommendations of addressing the ligaments of the AC capsule.[29,30]

A more detailed understanding of the anatomy of the CC and AC ligaments is essential to improve diagnostic techniques and clinical decision-making, as identifying pathology of the AC capsule may have predictive value for horizontal instability when evaluation may be difficult in acute cases. In a 2021 European Society for Sports Traumatology, Knee Surgery and Arthroscopy consensus statement on best practices for AC joint instability management, nearly all members (>93.0%) felt the Tossy et al.[31] and Bannister et al.[32] classification systems were insufficient for classifying AC dislocations, and, as such, the Rockwood classification remains the most valid classification to date. A lesser majority (>60.0%) considered the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine statement[14] to be sufficient as a comprehensive classification for type III injuries specifically, which is a modification of the Rockwood classification that further delineates between IIIA and IIIB injuries. Type IIIA and IIIB injuries are differentiated based on the presence of therapy resistant scapular dysfunction and/or horizontal AC joint instability. With a thorough understanding of the anatomical components involved in horizontal joint instability, a clearer clinical delineation between IIIA and IIIB classifications and subsequent prognosis of conservative versus surgical treatment prognosis may be possible.

The results of this systematic review reveal that the anatomic attachment sites and course of the native CL and AC ligaments may play a larger role in horizontal stability in addition to superior stability than previously appreciated.[26,33-35] Namely, the course of the SP ligament arising from the superior aspect of the acromion and running obliquely to attach posteriorly on the distal clavicle implicates a role in posterior translation of the clavicle as already evident by previous biomechanical studies. The robust nature of this ligament and the distance of its superior attachment site to the acromion from the medial joint line in comparison with the AI ligament also makes reconstruction more clinically feasible, as this distance may allow adequate bone stock for tunnel placement while avoiding damage to the AC joint cartilage.[35] The course and attachment site of the CL also suggests that it may contribute to horizontal stability of the AC joint, as it courses from the posterior-most margin of the coracoid dorsum in a posterolateral direction to the conoid tubercle of the posteroinferior clavicle. Innate to the oblique course of the CL highlighted by the measured angles by Zhu et al.,[25] it is suggested that the directionality should be accounted for, as purely vertical reconstruction may not adequately restore anterior-posterior translation. Overall, these findings support the recommendation of ensuring accurate clavicular, coracoid, and acromion tunnel placement and directionality, as previous clinical studies have reported that even slight medialization of CC ligament tunnel placement is predictive of reconstruction failure.[36] Furthermore, replication of the course of the ligaments of the AC capsule may help address persistent horizontal instability and lead to improved outcomes.

This systematic review of the qualitative and quantitative anatomy of the CC and AC ligaments sought to provide a clearer understanding of the native AC joint anatomy and build a foundation for the clinical diagnosis, decision-making, and future anatomic reconstruction techniques to improve outcomes in patients with AC joint separations. Future biomechanical studies assessing the translation of these anatomic relationships and their vital role in native and reconstructed AC joint biomechanics should be performed to further improve management and surgical techniques. Furthermore, diagnostic imaging studies should seek to identify ligamentous pathology and correlate with its predictive value of classification and persistent horizontal instability, especially in acute cases in which horizontal instability may not be fully appreciated on plain radiographs.

### Limitations

We acknowledge some limitations to this systematic review. It is possible that all relevant articles may not have been included, as is inherent to the nature of all systematic reviews. However, all references of the included studies were evaluated to ensure all available studies were included in the final review. There was also heterogeneity in quality of caliper measuring devices, description methods of the native anatomy, and variation in age and gender of the included cadaveric specimens. Lastly, there were limited quantitative studies evaluating the AC ligaments, including those that did not report on the unique anatomy of the SP and AI bundles of the AC capsule, which may affect the pooled quantitative analysis of these structures.

## Conclusions

Clear and consistent quantitative and qualitative descriptions of the CC ligaments (CL and TL) have been well defined, however, quantitative data on the capsuloligamentous anatomy of AC ligaments (SP and anteroinferior AI) remains limited.

## References


1. Beitzel K, Cote MP, Apostolakos J, et al. Current concepts in the treatment of acromioclavicular joint dislocations. *Arthroscopy* 2013;29:387-397.
2. Frank RM, Cotter EJ, Leroux TS, Romeo AA. Acromioclavicular joint injuries: Evidence-based treatment. *J Am Acad Orthop Surg* 2019;27:e775-e788.
3. Voss A, Imhoff AB. Editorial Commentary: Why we have to respect the anatomy in acromioclavicular joint surgery and why clinical shoulder scores might not give us the information we need! *Arthroscopy* 2019;35:1336-1338.
4. Moatshe G, Kruckeberg BM, Chahla J, et al. Acromioclavicular and coracoclavicular ligament reconstruction for acromioclavicular joint instability: A systematic review of clinical and radiographic outcomes. *Arthroscopy* 2018;34:1979-1995.e8.
5. Jones HP, Lemos MJ, Schepsis AA. Salvage of failed acromioclavicular joint reconstruction using autogenous semitendinosus tendon from the knee. Surgical technique and case report. *Am J Sports Med* 2001;29:234-237.
6. Fauci F, Merolla G, Paladini P, Campi F, Porcellini G. Surgical treatment of chronic acromioclavicular dislocation with biologic graft vs synthetic ligament: A prospective randomized comparative study. *J Orthop Traumatol* 2013;14:283-290.
7. Fraschini G, Ciampi P, Scotti C, Ballis R, Peretti GM. Surgical treatment of chronic acromioclavicular dislocation: Comparison between two surgical procedures for anatomic reconstruction. *Injury* 2010;41:1103-1106.
8. Tauber M, Gordon K, Koller H, Fox M, Resch H. Semitendinosus tendon graft versus a modified Weaver-Dunn procedure for acromioclavicular joint reconstruction in chronic cases: A prospective comparative study. *Am J Sports Med* 2009;37:181-190.
9. Dawson PA, Adamson GJ, Pink MM, et al. Relative contribution of acromioclavicular joint capsule and coracoclavicular ligaments-acromioclavicular stability. *J Shoulder Elbow Surg* 2009;18:237-244.
10. Dyrna F, Imhoff FB, Haller B, et al. Primary stability of an acromioclavicular joint repair is affected by the type of additional reconstruction of the acromioclavicular capsule. *Am J Sports Med* 2018;46:3471-3479.
11. Dyrna FGE, Imhoff FB, Voss A, et al. The integrity of the acromioclavicular capsule ensures physiological centering of the acromioclavicular joint under rotational loading. *Am J Sports Med* 2018;46:1432-1440.
12. Scheibel M, Droschel S, Gerhardt C, Kraus N. Arthroscopically assisted stabilization of acute high-grade acromioclavicular joint separations. *Am J Sports Med* 2011;39:1507-1516.
13. Aliberti GM, Kraeutler MJ, Trojan JD, Mulcahey MK. Horizontal instability of the acromioclavicular joint: A systematic review. *Am J Sports Med* 2020;48:504-510.
14. Beitzel K, Mazzocca AD, Bak K, et al. ISAKOS upper extremity committee consensus statement on the need for diversification of the Rockwood classification for acromioclavicular joint injuries. *Arthroscopy* 2014;30:271-278.
15. LaPrade RF, Engebretsen L. Editorial Commentary: Those who don't know history are condemned to repeat it -

what are the next steps to improve posterolateral knee outcomes? *Arthroscopy* 2020;36:1386-1389.
16. Boehm TD, Kirschner S, Fischer A, Gohlke F. The relation of the coracoclavicular ligament insertion to the acromioclavicular joint: A cadaver study of relevance to lateral clavicle resection. *Acta Orthop Scand* 2003;74:718-721.
17. Chahla J, Marchetti DC, Moatshe G, et al. Quantitative assessment of the coracoacromial and the coracoclavicular ligaments with 3-dimensional mapping of the coracoid process anatomy: A cadaveric study of surgically relevant structures. *Arthroscopy* 2018;34:1403-1411.
18. Harris RI, Vu DH, Sonnabend DH, Goldberg JA, Walsh WR. Anatomic variance of the coracoclavicular ligaments. *J Shoulder Elbow Surg* 2001;10:585-588.
19. Rios CG, Arciero RA, Mazzocca AD. Anatomy of the clavicle and coracoid process for reconstruction of the coracoclavicular ligaments. *Am J Sports Med* 2007;35:811-817.
20. Salzmann GM, Paul J, Sandmann GH, Imhoff AB, Schottle PB. The coracoidal insertion of the coracoclavicular ligaments: An anatomic study. *Am J Sports Med* 2008;36:2392-2397.
21. Stine IA, Vangsness CT Jr. Analysis of the capsule and ligament insertions about the acromioclavicular joint: A cadaveric study. *Arthroscopy* 2009;25:968-974.
22. Takase K. The coracoclavicular ligaments: An anatomic study. *Surg Radiol Anat* 2010;32:683-688.
23. Terra BB, Ejnisman B, de Figueiredo EA, et al. Anatomic study of the coracoid process: Safety margin and practical implications. *Arthroscopy* 2013;29:25-30.
24. Xue C, Song LJ, Zhang M, Zheng TS, Fang JH, Li X. Coracoclavicular ligament attachment regions of the Chinese population: A quantitative anatomic study. *Anat Sci Int* 2013;88:189-194.
25. Zhu NF, Rui BY, Zhang YL, Chen YF. Anatomic study of coracoclavicular ligaments for reconstruction of acromioclavicular joint dislocations. *J Orthop Sci* 2016;21:749-752.
26. Nolte PC, Ruzbarsky JJ, Midtgaard KS, et al. Quantitative and qualitative surgical anatomy of the acromioclavicular joint capsule and ligament: A cadaveric study. *Am J Sports Med* 2021;49:1183-1191.
27. Salter EG Jr, Nasca RJ, Shelley BS. Anatomical observations on the acromioclavicular joint and supporting ligaments. *Am J Sports Med* 1987;15:199-206.
28. Zhu D, Carrig CB, Conners RW, Swecker WS Jr. Canine bone shape analysis by use of a radiographic image-classification system. *Am J Vet Res* 1992;53:1090-1095.
29. Aliberti GM, Mulcahey MK, Brown SM, O'Brien MJ. Restoring horizontal stability of the acromioclavicular joint: Open acromioclavicular ligament reconstruction and repair with semitendinosus allograft. *Arthrosc Tech* 2020;9:e1619-e1626.
30. Mouhsine E, Garofalo R, Crevoisier X, Farron A. Grade I and II acromioclavicular dislocations: Results of conservative treatment. *J Shoulder Elbow Surg* 2003;12:599-602.
31. Tossy JD, Mead NC, Sigmond HM. Acromioclavicular separations: Useful and practical classification for treatment. *Clin Orthop Relat Res* 1963;28:111-119.
32. Bannister GC, Wallace WA, Stableforth PG, Hutson MA. A classification of acute acromioclavicular dislocation: A clinical, radiological and anatomical study. *Injury* 1992;23:194-196.
33. Morikawa D, Dyrna F, Cote MP, et al. Repair of the entire superior acromioclavicular ligament complex best restores posterior translation and rotational stability. *Knee Surg Sports Traumatol Arthrosc* 2019;27:3764-3770.
34. Morikawa D, Huleatt JB, Muench LN, et al. Posterior rotational and translational stability in acromioclavicular ligament complex reconstruction: A comparative biomechanical analysis in cadaveric specimens. *Am J Sports Med* 2020;48:2525-2533.
35. Nakazawa M, Nimura A, Mochizuki T, Koizumi M, Sato T, Akita K. The orientation and variation of the acromioclavicular ligament: An anatomic study. *Am J Sports Med* 2016;44:2690-2695.
36. Eisenstein ED, Lanzi JT, Waterman BR, Bader JM, Pallis MP. Medialized clavicular bone tunnel position predicts failure after anatomic coracoclavicular ligament reconstruction in young, active male patients. *Am J Sports Med* 2016;44:2682-2689.