J Shoulder Elbow Surg (2020) 29, 1901–1911

Journal of
Shoulder and
Elbow
Surgery

www.elsevier.com/locate/ymse

# Sagittal orientation of coracoclavicular ligament reconstruction affects the stability of surgical repair

**Haluk Celik, MD[a,b,*], Aakash Chauhan, MD, MBA[a,b], Cesar Flores-Hernandez, BS[b], Erik Dorthe, MS[b], Darryl D'Lima, MD, PhD[b], Heinz Hoenecke, MD[a,b]**

[a]*Division of Sports Medicine, Department of Orthopaedic Surgery, Scripps Clinic, La Jolla, CA, USA*
[b]*Shiley Center for Orthopaedic Research & Education (SCORE) at Scripps Clinic, La Jolla, CA, USA*

**Background:** The variation in the anatomic relationship between the coracoid and the clavicle affects the biomechanical stability of coracoclavicular ligament reconstruction (CCLR).

**Methods:** Three-dimensional computed tomography reconstruction of 85 patients was analyzed. Anatomic landmarks were used to derive the coracoclavicular sagittal reconstruction angle (sRA). The lateral concave angle, which indicated the shape of the distal clavicle, and the offsets between the clavicle and coracoid were also measured. To investigate the biomechanical effects of the sRA on CCLR, 7 computed tomography scans with different sRAs were 3D printed. Two reconstructions, a single trans-coracoclavicular tunnel and a looped reconstruction technique, were performed sequentially. Models were cyclically loaded at 70 N in the anterior, posterior, and superior directions.

**Results:** The mean sRA was 68° ± 9.3° (range, 47°-85°). The superoinferior offset between the clavicle and the coracoid and the lateral concave angle positively correlated with the sRA ($r = 0.359$ and 0.837, respectively; $P \leq .001$), whereas the anteroposterior offset had a negative correlation ($r = -0.925$; $P < .001$). The sRA had a negative correlation with the anterior displacement of the clavicle (rho $= -0.96$; $P < .001$) and a positive correlation with the posterior displacement for both surgical techniques (rho $=$ 1.0; $P < .001$).

**Conclusion:** The anatomic orientation of the native coracoclavicular ligaments is highly variable in the sagittal plane. Low sagittal angles can reduce anterior stability, whereas high sagittal angles can reduce posterior stability of CCLR.

**Level of evidence:** Basic Science Study; Computer Modeling; Biomechanics

**Keywords:** Coracoclavicular ligament; biomechanics; acromioclavicular joint; reconstruction; horizontal stability; shoulder

Acromioclavicular (AC) joint dislocations are common among young athletes and make up 12% of shoulder girdle dislocations.[28] Although most separations can be treated nonoperatively, dislocations with complete rupture of the coracoclavicular (CC) ligaments may require

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The local Institutional Review Board (Scripps IRB-13-6297) approved this study.

*Reprint requests: Haluk Celik, MD, Scripps Clinic, 10666 North Torrey Pines Road, MS119, La Jolla, CA 92037, USA.

E-mail address: drhalukcelik@gmail.com (H. Celik).

https://doi.org/10.1016/j.jse.2019.11.034

surgical treatment to re-establish anatomy, alleviate pain, and improve strength. In spite of the attempts to recreate the native anatomy of the CC ligament with reconstruction procedures, loss of reduction is still a major issue.[7,10]

The CC ligament reconstruction techniques have largely focused on the clavicular attachments rather than coracoid insertions.[21,37] In arthroscopic and open CC reconstruction techniques, the stability of the construct is dependent on a fixation point on the inferior base of the coracoid using a metal button, or by looping a graft or synthetic material around the base of the coracoid.[22,33,36,37] Because of the risk of coracoid fracture, instead of a more anatomic reconstruction, the inferior base of the coracoid and a more distal location on the clavicle are commonly used as fixation points during surgery. This mismatch of fixation points results in a nonanatomic orientation of the reconstruction with respect to the anatomy of the native ligaments.[8] For a greater understanding of the biomechanical implications of nonanatomic reconstruction, the wide variations of clavicle and coracoid anatomy have to be carefully considered.[5,8,11]

In a recent cadaveric study that evaluated the anatomic orientation of the conoid and trapezoid ligaments, the relative oblique orientation of the ligaments was seen as an important factor for superior and horizontal instability.[39] The trapezoid and conoid ligaments are retroverted (average 6° and 11°, respectively) relative to the superior surface of the distal clavicle.[39] The medial or lateral tunnel placement on the clavicle relative to the AC joint has also been identified as a possible reason for failure in clinical and biomechanical studies.[10,35] However, the orientation of the reconstruction in the sagittal plane has not been clearly evaluated and is likely to have an important effect on stability after reconstruction.

In the present study, the multiaxial anatomic relationships of the CC ligaments and the surrounding structures were evaluated using three-dimensional (3D) computed tomography (CT) scans. A sagittal reconstruction angle (sRA) was developed to define an anatomic relationship between the inferior base of the coracoid and the convergence point of the clavicle. To support clinical relevance, the biomechanical significance of the differences in sRA was investigated by mechanically testing 3D printed models of the shoulder girdle that were surgically reconstructed using 2 different surgical techniques. In addition, spatial relationships between the sRA and surrounding anatomic structures of the shoulder girdle were documented. Our hypothesis was that the anatomic relationship between the coracoid and the clavicle will vary in the sagittal plane and this variation may affect the biomechanical stability of CC ligament reconstruction.

## Materials and methods

### Three-dimensional CT modeling and quantitative analysis

After Scripps Institutional Review Board approval, CT imaging studies of 100 consecutive patients were reviewed and evaluated for glenohumeral arthritis from a pre-existing database of patients. After excluding 15 patients with a history of prior trauma (eg, fractures, dislocations) or surgery, 85 patients were included in this study. We reconstructed CT-based 3D models of the clavicle and scapula using MIMICS 20.0 (Materialise, Leuven, Belgium).

A standard clavicle-centered reference system was modified to identify and measure anatomic points consistently, as described by Bernat et al.[4] Three different clavicle-centered planes were created (Fig. 1). The axial plane of the clavicle was defined using the lateral third of the clavicle. The axial plane (superior surface of the clavicle) has primary surgical relevance because it was used to define the orientations of the bone tunnels during reconstruction. The long axis of the clavicle was defined as the line connecting the central points of the clavicle on the sternoclavicular and AC joints.[4] The clavicle coronal plane was then defined as the plane perpendicular to the clavicle at the projection of the long axis of the clavicle onto the axial clavicular plane (Fig. 1). The clavicular point (cP) was identified on the clavicle between the conoid tubercle and trapezoid attachment as described in the previous studies[8,29] (Fig. 2). The third plane (clavicle sagittal plane) was defined as the plane perpendicular to the first 2 planes at the cP (Fig. 1).

The coracoid inferior base point (corBaseP) was identified as the distal most aspect of the location of the CC tunnel in a reconstruction (Fig. 2). This point was located at the center of the inferior aspect of the coracoid base and marked the spot where a metal button or looped graft would be secured under the coracoid. The tip of the coracoid point and AC joint point were also identified. The lateral concave angle was measured to define the lateral curvature depth as previously described[23] (Fig. 2). The shape of the coracoid was classified as flat, curved, or banana shaped.[16] Superoinferior and anteroposterior offsets between cP and corBaseP were calculated with respect to the clavicular planes. The line between cP and corBaseP was defined as the sagittal reconstruction line. The angle between the sagittal reconstruction line and axial plane of the clavicle was defined the sRA (Fig. 3). The sRA was the primary measure used to support our hypothesis.

The 3D distances between the cP and AC joint point and between the corBaseP and tip of the coracoid point were also measured and recorded. All measurements were performed independently by 2 different authors to assess interobserver reliability.

### Biomechanical testing using 3D printed models

To understand the role of the CC sRA and its potential effect on the biomechanical stability of CC reconstructions, plastic models were 3D printed from CT scans. Seven CT scans were selected for 3D printing to represent the range of sRAs that were initially measured from our patient cohort: from 47° to 85°, at intervals of

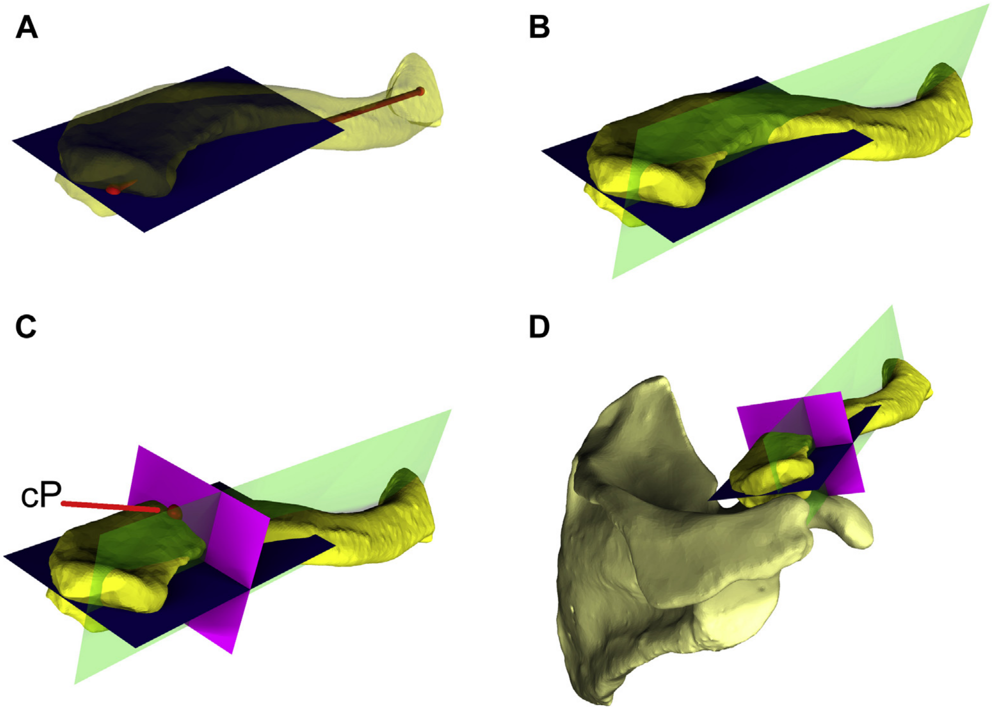

**Figure 1** Definition of the 3 clavicular geometric planes. (**A**) The axial plane was created on the distal clavicle using a best-fit technique (*blue plane*). (**B**) The coronal plane (*green plane*) was generated by projecting the long axis of the clavicle perpendicular to the clavicle axial plane in the coronal axis. (**C**) Clavicular sagittal plane (*magenta*) was the plane perpendicular to the both the clavicle axial and coronal planes. (**D**) The clavicle coordinate system with scapula for reference. *cP*, clavicular point.

approximately 6°. The 3D reconstructed CT scans were imported into computer-aided design software (Rhinoceros 3D; Robert McNeel & Associates, Seattle, WA, USA). To maintain the anatomic alignment of the scapula and clavicle, 3 supports were designed to hold the scapula and the clavicle together. This allowed us to maintain precise alignment during mounting on the testing machine. The resulting computer-aided design files were 3D printed in acrylonitrile butadiene styrene plastic by UPS (Atlanta, GA, USA) in a Stratasys printer (Eden Prairie, MN, USA) (Fig. 4).

To validate the use of printed plastic models as surrogates for cadaver bones, pilot testing of the reconstructions in 3 cadaver specimens was compared with the corresponding printed models. Three fresh-frozen cadaveric shoulders with an average age of 68 years (range, 65-72 years) were thawed overnight at room temperature and dissected free of skin and soft tissue leaving the scapula, clavicle, AC joint, CC ligaments, and coracoacromial ligaments intact. Three K-wires were used to fix the clavicle in anatomic orientation with respect to the scapula. The specimens were then CT-scanned, and a 3D reconstructed model of the clavicle and scapula was created using MIMICS. Plastic models of the cadavers were then printed as described above for the clinical scans. The CC ligament was transected and K wires were removed from the cadavers before the reconstruction and biomechanical testing (Fig. 5).

The 3D printed models and cadavers were mounted in a 6-axis hydraulic testing machine (AMTI VIVO; AMTI, Watertown, MA, USA). The inferior angle of the scapula to the edge of the glenoid was potted with methyl-methacrylate (Co-Oral-Ite Dental Mfg. Co., Diamond Springs, CA, USA) in a cylindrical cup. The clavicle was fixed to a custom metal block using a modification of the procedure described by Martetschlager et al,[19] such that fixation would be to 5 mm medial to the coracoid process (Fig. 4). Once the models were mounted in the AMTI VIVO, the connecting bars between the scapula and clavicle were removed with an oscillating saw and the CC ligament reconstructions were performed with 2 techniques described below. A caliper was used to measure the CC distance between each surgical step to prevent overtightening. The AC joint was kept free during the testing.

Two commonly used reconstruction techniques were used to test the effects of the sRA. The first technique involved a single bundle reconstruction that most closely reflected the sRA; the second technique was a looped reconstruction to replicate the clavicular attachments of the conoid and trapezoid. For the single bundle technique, a single trans-CC tunnel reconstruction was performed using 2 cortical buttons (Dog Bone; Arthrex, Inc., Naples, FL, USA). A CC aiming guide (Arthrex, Inc.) was placed with the superior and inferior points of the tunnel at the cP and corBaseP, respectively. A 2.4-mm tunnel was drilled through the clavicle and coracoid and a nitinol wire loop passed through the drill to pass the suture. The inferior cortical button was loaded onto the suture tape (FiberTape; Arthrex, Inc.). The limbs of the suture were passed into the nitinol loop and were shuttled superiorly through the drill hole. The inferior cortical button was then secured under the coracoid. Next, the shuttled limbs of the suture tape exiting from the superior surface of the clavicle were passed through the superior cortical button and tied down

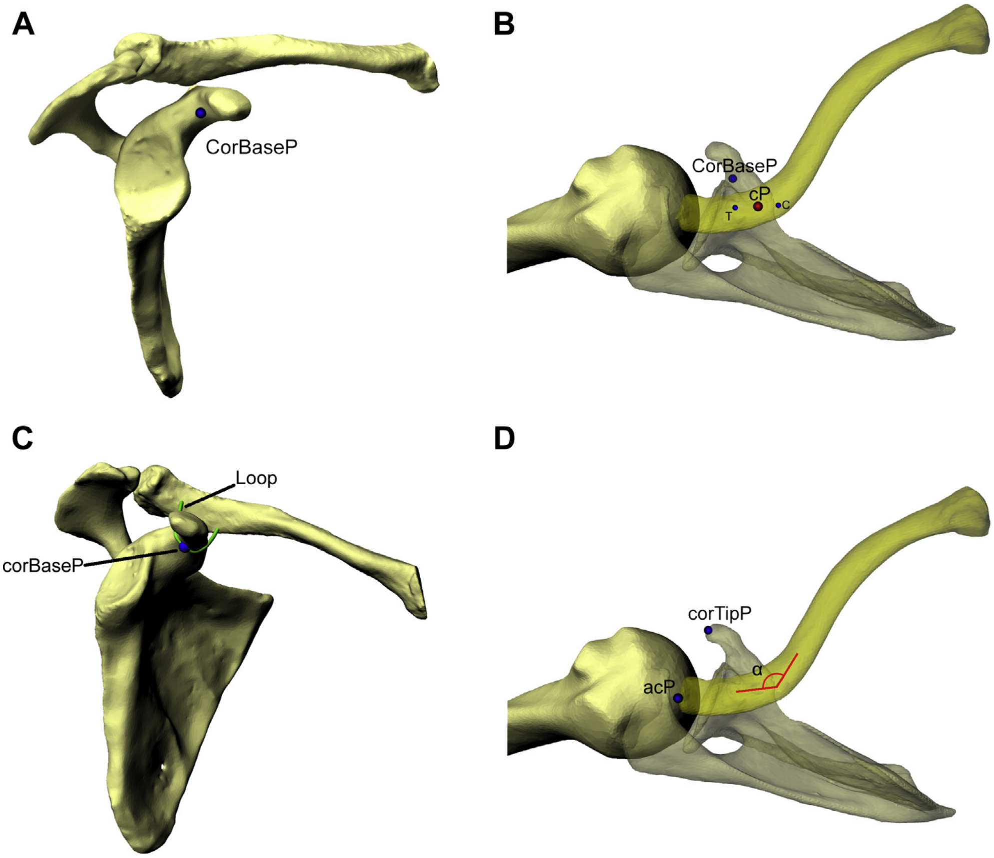

**Figure 2** Reference points on the clavicle and scapula. (**A**) The coracoid inferior base point (CorBaseP) was created on the center of the inferior base of the coracoid and identifies where the coracoclavicular tunnel exits. (**B**) The clavicular point (cP) was marked between the conoid (C) and trapezoid (T) and above the coracoid on the axial plane. (**C**) CorBaseP is on the corner of the coracoid and indicates the spot weld for loop reconstruction material under the coracoid. (**D**) The definition of the acromioclavicular joint point (acP), coracoid tip point (corTipP), and lateral concave angle (α) on the 3D model.

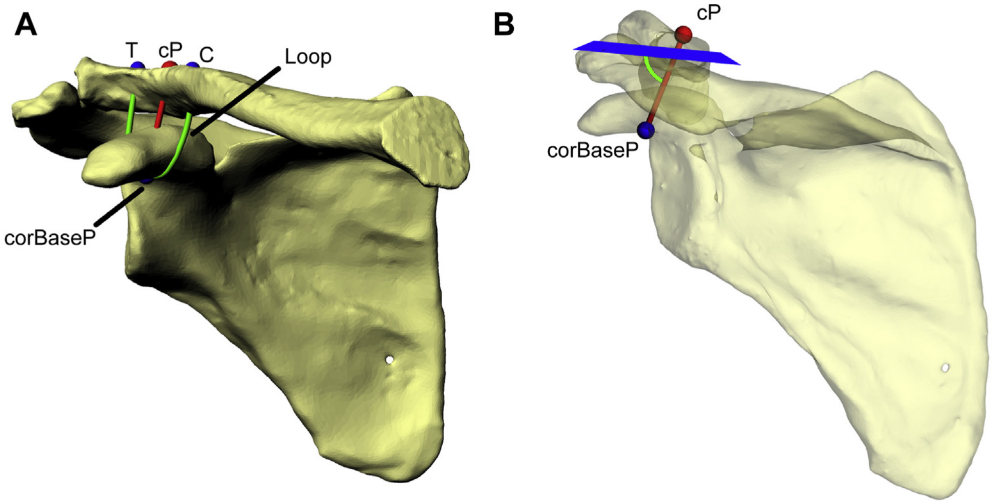

**Figure 3** Definition of the sagittal reconstruction line and the sagittal reconstruction angle. (**A**) The virtual loop technique and the sagittal reconstruction line. The sagittal reconstruction line indicates the vector of reconstruction on the sagittal plane. (**B**) Generation of the sagittal reconstruction angle using the sagittal reconstruction line and axial plane. *C*, conoid; *CorBaseP*, coracoid inferior base point; *cP*, clavicular point; *T*, trapezoid.

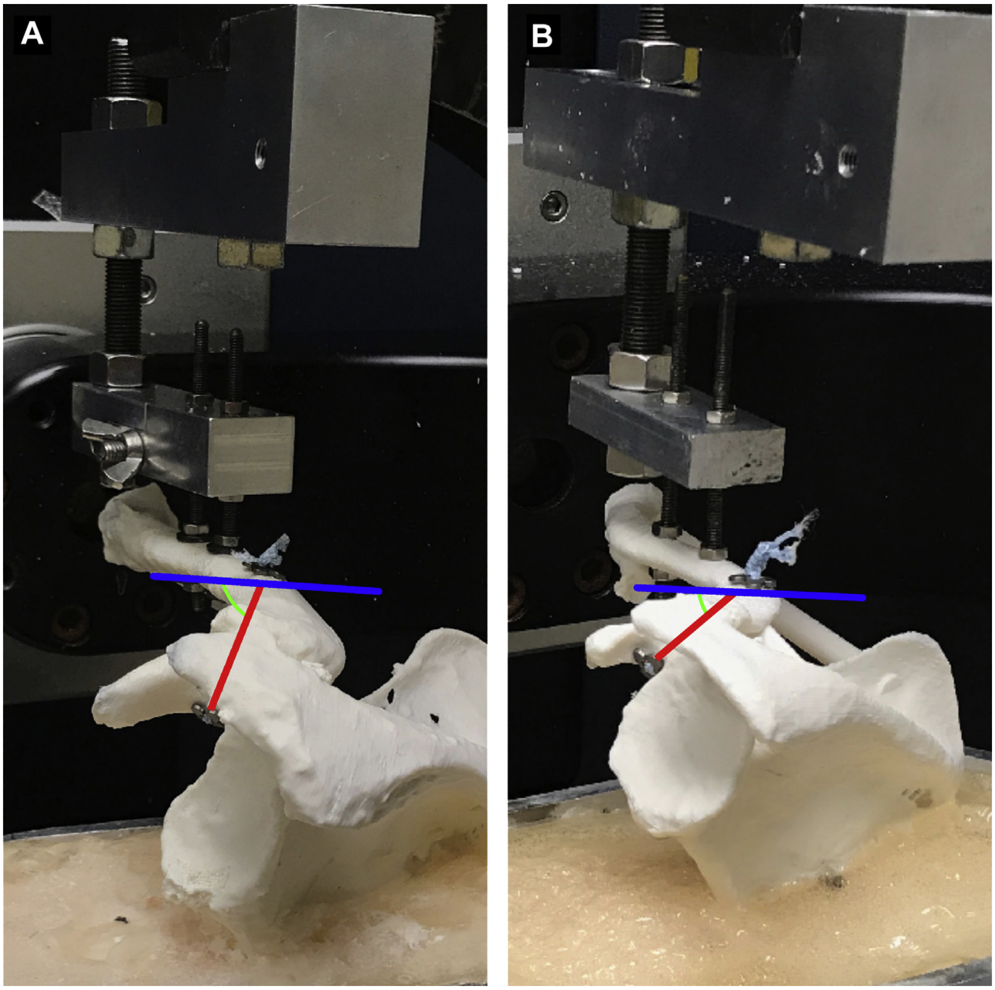

**Figure 4** The 3D printed models loaded for biomechanical testing. (**A**) The 3D printed shoulder with the sRA of 80°. (**B**) The 3D printed shoulder with the sRA of 47°. *sRA*, sagittal reconstruction angle.

(Fig. 4). The second technique was a looped reconstruction resembling an anatomic CC ligament reconstruction using suture tape (Arthrex, Inc.). Two 2.4-mm clavicular tunnels were drilled in the anatomic locations of the conoid and trapezoid ligaments. The suture tape was passed under the coracoid, and the 2 limbs were shuttled through the trapezoid and conoid tunnels and tied down together. One orthopedic surgeon performed all surgical procedures.

After surgical reconstructions were completed, the stability of the reconstruction was tested for 10 cycles under 70 N tensile force applied to the fixture holding the scapula, in the anterior, posterior, and inferior directions.[2] During the anterior and posterior tensile testing, the inferior direction was loaded with a constant 20 N in tension, allowing the scapula to rise and fall based on tension in the reconstruction. During the superoinferior tensile testing, the bones were fixed in the mediolateral and anteroposterior directions; the resultant mediolateral and anteroposterior forces generated were measured and used to calculate the magnitude of the net transverse resultant force to compute constraint in the transverse plane. Net displacements between the clavicle and scapula were recorded continuously at 200 Hz along each axis by the VIVO Control software (AMTI). Data were analyzed using a desktop computer and Excel software (Microsoft Corp., Redmond, WA, USA). For analysis of data, peak values were averaged across the cycles.

## Statistical analysis

Statistical analysis was performed using SPSS version 12 (IBM, Armonk, NY, USA). Means and frequencies were calculated to summarize the study data. Data were tested for normal distribution using the Kolmogorov-Smirnov and Shapiro-Wilk test. The relationships between different parameters were measured by Pearson's correlation coefficient, if the variable fit a normal distribution curve; otherwise, Spearman's correlation coefficient was used. A Student *t*-test or 1-way analysis of variance was used to detect significant differences between variables. Intraclass correlation coefficients were used to evaluate the interobserver reliability. The threshold for significance was set at $P < .05$.

## Results

The study evaluated 85 patients (44 female) with an average age of 68.3 ± 3.8 years (range, 56-72 years).

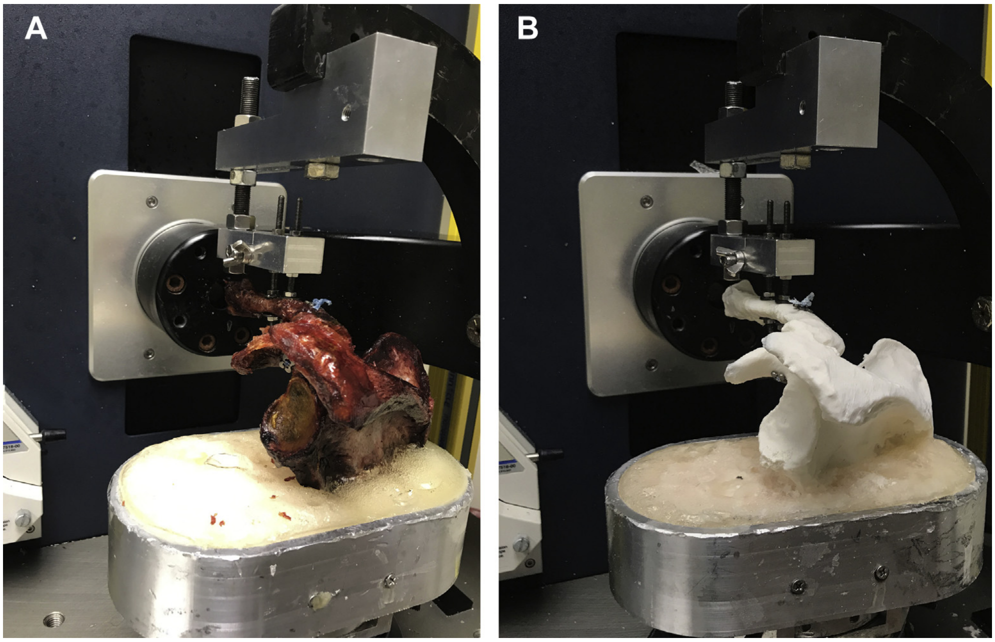

**Figure 5** Cadaveric shoulder (**A**) and the corresponding 3D printed model (**B**) loaded for biomechanical testing.

The mean sRA was 68° ± 9.3° (range, 47°-85°). Detailed results and the interobserver reliability of measurements are listed in Table I.

Although the superoinferior offset and the lateral concave angle had a statistically significant positive correlation with the sRA, anteroposterior offset was negatively correlated (Table II and Fig. 6). There was no significant correlation between the sRA and coracoid shape (flat-type = 40, curved-type = 30, banana-type = 8) or sex ($P$ = .387).

The average absolute difference between the measurements during the pilot testing of cadaver specimens and matched plastic models was 0.6 mm. During biomechanical testing of the 2 surgical reconstruction techniques, the sRA had a negative correlation ($P < .001$) with anterior displacement (eg, higher sRA resulted in lower anterior displacement) and a positive correlation ($P < .001$) with posterior displacement (eg, higher sRA resulted in higher posterior displacement, Table III and Fig. 7). During the inferior tensile test, a significant negative correlation was found between the sRA and the magnitude of the transverse resultant force (Table III). No significant differences in displacements were found between the single and loop techniques in the superior, anterior, and posterior directions (Table IV).

## Discussion

This study was conducted to document the anatomic relationship between the coracoid and the clavicle and to analyze the effect of anatomic variations on the biomechanical stability of CC ligament reconstruction. Our results found a wide variation in sRA among patients. The superoinferior and anterosuperior offsets between the clavicle and the coracoid, and the lateral curvature of the distal clavicle were major factors associated with the sRA. In biomechanical testing after CC reconstruction, the sRA had a negative correlation with the anterior displacement of the clavicle and a positive correlation with the posterior displacement. These findings have significant potential relevance to a surgical technique to enhance stability after reconstruction.

Numerous techniques have been described for CC ligament reconstruction with a reported loss of reduction ranging from 11% to 39%.[9,20,24,27,31] Attempts at reproducible solutions for CC ligament reconstructions using different techniques and implants have been confounded by the anatomic variability of the CC ligaments. The variable shape of the bony structures around the CC ligaments has been investigated in several studies in 2 dimensions.[1,17] However, the use of 3D morphometric analysis provides more accurate results.[4,11,14] In a CT-based study, Coale et al[8] showed that attempting to restore the footprints of the conoid and trapezoid ligaments using an anatomic transclavicular-transcoracoid drilling technique introduces significant risk of cortical breach and coracoid fracture. Knowing the orientation of the native ligaments is important because a true anatomic reconstruction using those angles is likely not possible using current techniques.[38]

Therefore, we measured the variability of the native anatomy and its effect on the orientation and stability of CC reconstructions in the sagittal plane. To define the sRA,

**Table I** Results of anatomic measurements

| Variable measured | Mean | SD | Range | ICC |
|---|---|---|---|---|
| Sagittal reconstruction angle (sRA) (degree) | 68 | 9.3 | 47-85 | 0.91 |
| Anteroposterior offset (mm) | 12.2 | 5.2 | 4.1-25.4 | 0.94 |
| Superoinferior offset (mm) | 30.6 | 4.9 | 20.7-40 | 0.91 |
| AC-CP (mm) | 31.6 | 4.7 | 21-40.9 | 0.98 |
| corTipP-corBaseP (mm) | 22.2 | 3.3 | 15.8-27.8 | 0.92 |
| Lateral concave angle (degree) | 140.4 | 9.3 | 124-157 | 0.97 |

*AC-CP*, from acromioclavicular joint to convergence point; *corTipP-corBaseP*, from coracoid tip to coracoid base point; *SD*, standard deviation; *ICC*, intraclass correlation coefficient.

**Table II** Correlation of sagittal reconstruction angle and anatomic measurements

| | S-I offset | A-P offset | AC-CP | CorTipP-CorBaseP | Lateral concave angle |
|---|---|---|---|---|---|
| Pearson's *r* | 0.359[*] | −0.925[*] | −0.099 | −0.143 | 0.837[†] |
| *P* | **.001** | **<.001** | .368 | .191 | **<.001** |

*S-I*, superoinferior; *A-P*, anteroposterior; *AC-CP*, acromioclavicular to convergence point; *CorTipP-CorBaseP*, coracoid tip to coracoid base.
Statistical significance marked in bold.

[*] Positive correlation.

[†] Negative correlation.

reference points on the distal clavicle, a point between the trapezoid and conoid attachments, and the inferior base of the coracoid were used in the present study. In the vast majority of described techniques, coracoid fixation was obtained by using the inferior base of the coracoid.[6,22,33,36,37] The recommended location for the exit of the coracoid tunnel is the central region of the lower cortical surface of the coracoid.[13] Using these as guidelines, we were able to identify the relationship of the surrounding native anatomy with the reconstruction angle in the sagittal plane.

A wide distribution of the sRA (between 47° and 85°) resulted in more vertical or horizontal reconstruction vectors on the sagittal plane. This angle was closely related to the anteroposterior and superoinferior offsets between the clavicular and coracoid fixation points. One possible reason for the variability of the sRA is variability of the distal clavicular shape. Daruwalla et al[11] reported 3 different shapes of distal clavicle in terms of superoinferior bowing. Even though there is no classification for the lateral curvature of the clavicle in the literature, Huang et al[17] concluded that the lateral curvature could be more variable than the medial curvature. In the present study, the lateral concave angle varied between 124° and 157° similar to a previous study.[23] A strong correlation was found between the sRA and lateral curvature of the clavicle, such that higher lateral curvature was associated with a smaller sRA. The shape of the distal clavicle can therefore serve as an indirect indicator for anteroposterior offset between the 2 points. Reconstruction landmarks are usually placed through the lateral curvature of the distal clavicle, and deeper lateral curvature results in clavicular tunnel points further away from the inferior coracoid base.

To investigate the biomechanical effects of variability in sRA, 3D printed anatomic clavicles and scapulae were printed using models selected from the CT analysis. The small differences (<0.6 mm absolute average error) in the results between cadavers and matched 3D printed models supported our use of plastic bones to assess the biomechanical stability of CC reconstruction. In our biomechanical testing, a statistically significant correlation was found between the magnitude of the transverse resultant force during inferior displacement and sRA. In addition, there was an even stronger correlation between sRA and the magnitude of horizontal displacement during testing in the anteroposterior direction. Collectively, these results indicate that the angle of the reconstruction is a major factor on the biomechanical stability of the reconstruction.

Previous biomechanical studies evaluating techniques for CC ligament reconstruction have shown that vertical stability can be obtained with the vast majority of the techniques.[3,18,21,33] More recent studies have raised the issues associated with instability in the transverse plane.[2,26,36] Although AC ligaments and the surrounding muscles are important for horizontal stability, the CC ligaments also play important roles in providing stability in both planes. Debski et al[12] showed that in cases of complete rupture of the AC ligaments, the conoid ligament is the primary restraint against anterosuperior loading and the trapezoid ligament is the major restraint against posterior loading. In a magnetic resonance imaging study, in addition

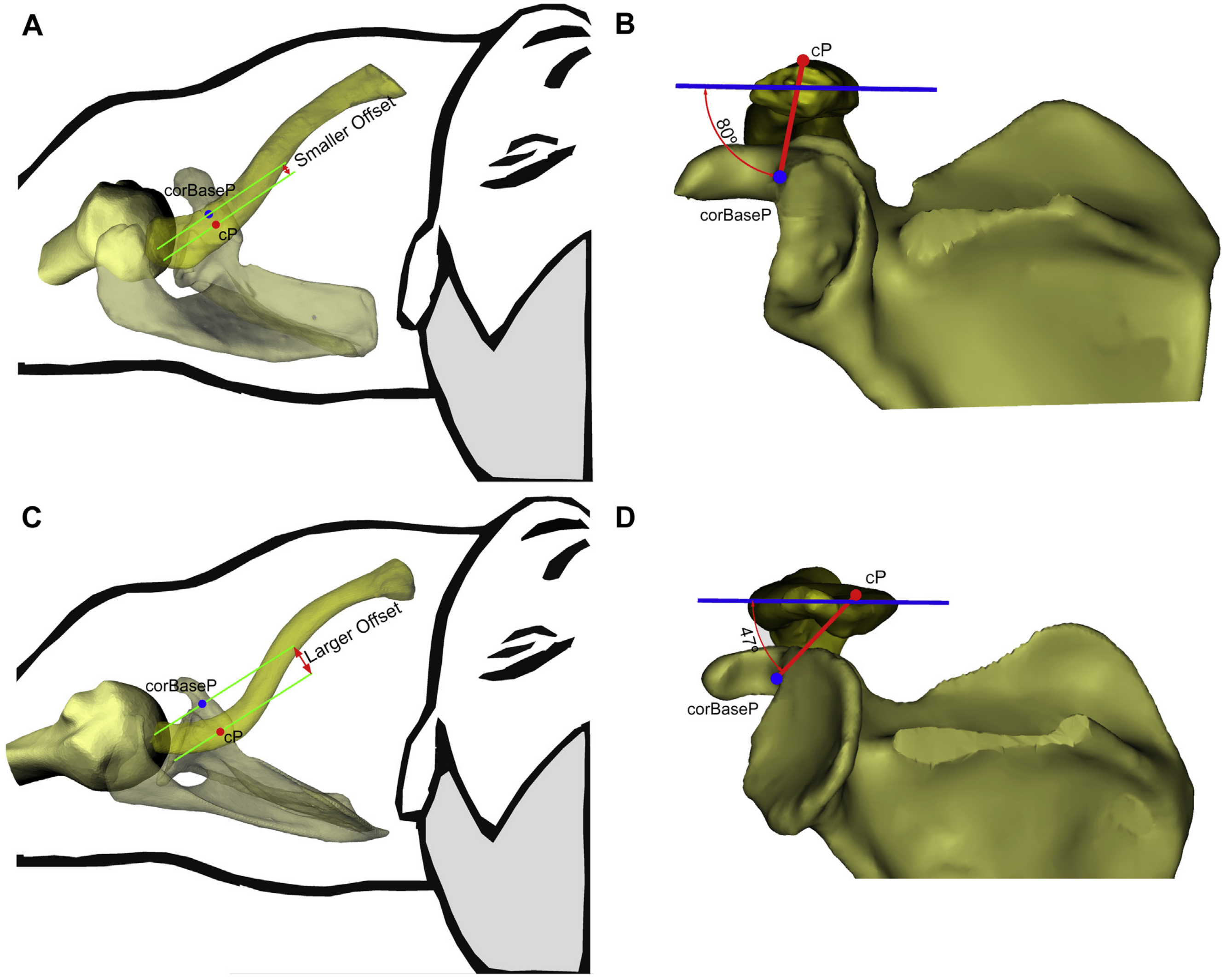

**Figure 6** Comparison of small and large sRA and corresponding differences in offset. (**A**, **B**) The patient with the sRA of 80° had a smaller anteroposterior offset. (**C**, **D**) The patient with 47° angle indicates a larger anteroposterior offset. (Acromion has been removed in **B** and **D** for better visualization.) *CorBaseP*, coracoid inferior base point; *cP*, clavicular point; *sRA*, sagittal reconstruction angle.

**Table III** Correlation between sagittal reconstruction angle and direction of translation

| sRA | Single tunnel | | | Loop | | |
|---|---|---|---|---|---|---|
| | TRF | Ant | Post | TRF | Ant | Post |
| Spearman's Rho | −0.57* | −0.96* | 1.00† | −0.38* | −1.00* | 0.96† |
| *P* | **.048** | **<.001** | **<.001** | **.045** | **<.001** | **<.001** |

*sRA*, sagittal reconstruction angle; *TRF*, transverse resultant force; *Ant*, translation in anterior direction; *Post*, translation in posterior direction. Statistical significance marked in bold.

* Negative correlation.

† Positive correlation.

to the AC joint capsule, the trapezoid ligament was shown to restrict posterior translation and the conoid ligament to restrict anterior translation.[25] Therefore, the orientation of the CC ligament reconstruction can have a significant impact on instability in the transverse plane.[39] Patients with transverse plane instability have also been reported to have significantly inferior outcomes,[34] and recent techniques have attempted to solve this problem. Posterior or anterior subluxation and dynamic instability are major complications after CC ligament reconstruction.[15,32] Even in clinical

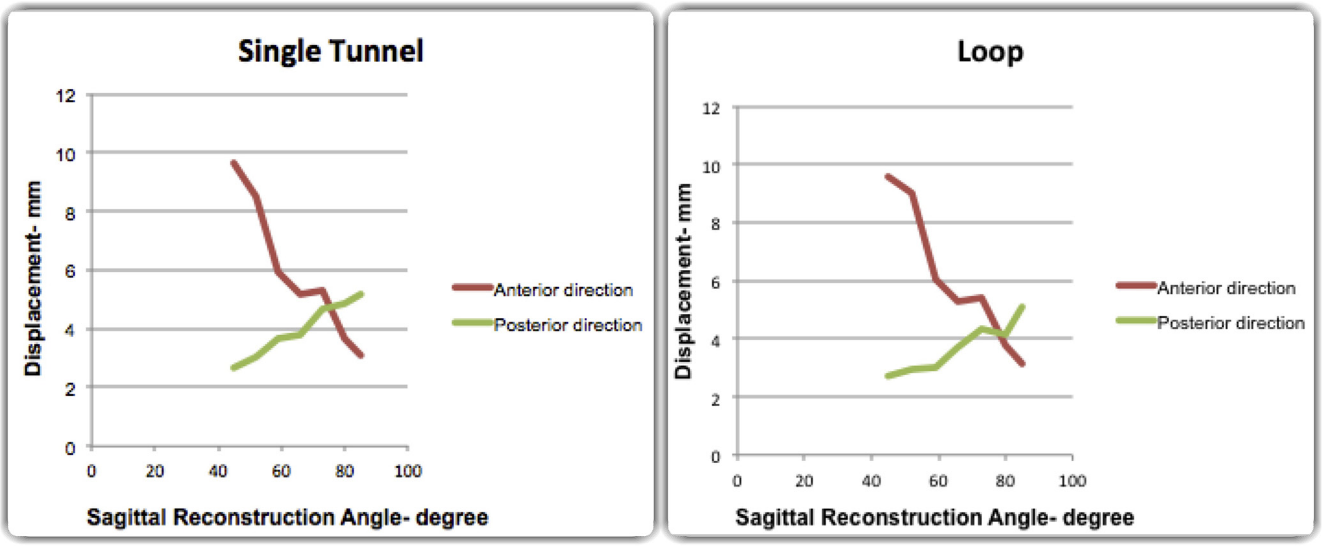

**Figure 7** Correlation between sagittal reconstruction angle and translation by reconstruction technique.

**Table IV** Biomechanical results of single tunnel vs. loop technique

| Comparison of surgical techniques | Single tunnel | Loop | *P* value |
|---|---|---|---|
| Superior displacement (mm ± SD) | 2.6 ± 0.4 | 2.5 ± 0.3 | .48 |
| Anterior displacement (mm ± SD) | 5.9 ± 2.4 | 6.1 ± 2.4 | .94 |
| Posterior displacement (mm ± SD) | 3.9 ± 0.9 | 3.7 ± 0.8 | .68 |

*SD*, standard deviation.

studies reporting favorable results with AC-CC joint reconstructions, no study has directly compared different techniques. Despite the biomechanical studies that support several AC-CC joint reconstruction techniques,[26,30] transverse plane instability has been seen as a point of weakness for some techniques.[2,36] The results of our study indicate that the sRA may have a significant effect on transverse plane instability.

The wide variation in sRAs suggests that CC ligament reconstruction techniques should not be standardized for all patients. Given the variability in the sRA and associated anatomic correlations identified in this study, a more thoughtful approach to CC ligament reconstruction should be employed based on the patients' anatomy. In our study, a smaller sRA led to greater anterior instability of the clavicle, whereas a larger sRA led to greater posterior instability. For specific cases with very low or very high sRA measurements, we suggest that an additional procedure such as AC joint stabilization or more robust fixation may be beneficial. It might also be possible to adjust tunnel placement to target a more optimal sRA.

This study has the following limitations. The measurement of the sRA was performed using 3D reconstructed CT scans using a commercial software program (MIMICS) that may preclude it from routine clinical use. MIMICS was used to gain a more complete analysis of the variable relationships that exist around the bony structures that encompass the CC ligament complex and the shoulder girdle. However, we believe that the sRA can be measured on CT scans by identifying anatomic landmarks on clinically available CT visualization software. The CT scans we used were obtained from patients with glenohumeral arthritis (and possible AC joint arthritis); therefore, these scans may not be completely representative of the patient population that typically has these injuries. However, our finding of the biomechanical relevance of varying sRAs is still valid. Plastic models from human CT scans were used to test specimens over a range of sRAs. Although the material properties of plastic are different from that of human bone, the differences in biomechanical stiffness of the reconstruction in plastic bones were small compared with that in matched human cadavers.

## Conclusion

The anatomic orientation of the native CC ligaments is highly variable in the sagittal plane. Variation in the shape of the distal clavicle leads to a variation of the sagittal trajectory of CC reconstruction as measured by the sRA. Low sagittal angles can reduce anterior stability, whereas high sagittal angles can reduce posterior stability of the CC complex. The shape of the distal clavicle and the CC distance are also predictors of this sagittal angle. Further studies are necessary to establish the clinical significance of these findings.

## Disclaimer

This study was funded by the Shaffer Family Foundation.

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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