Anatomical parameters of the coracoclavicular ligament: A study of 480 cases

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Abstract

Background: Although the optimal surgical technique for treatment of acromioclavicular (AC) joint dislocation still remains controversial, reconstruction of the coracoclavicular (CC) ligament has become the current tendency, particularly the transclavicular-transcoracoid drilling technique. The study investigated the anatomical characteristic of CC ligament by obtained anatomical parameters based on magnetic resonance imaging (MRI), for guiding surgeons to create transosseous tunnels precisely in reconstructing CC ligament. **Material/Methods :** Four hundred and eighty MRI scans of left shoulders from patients (ages from 11 years to 80 years, mean age of 51 years) were analyzed for the study. Some anatomical parameters were defined and measured in images of the coronal and sagittal plane, including four angles and seven distances. All measurement results were analyzed by SPSS 20.0. **Results :** In the coronal plane, the distance from the midpoint of AC joint to the insertion at the clavicle of male patients was greater than the average value of female patients. In the sagittal plane, in addition to the diameter of insertion at the coracoid process, other average distance values of male patients were greater than the average values of female patients, which were significantly different ($P < 0.05$). **Conclusion :** These anatomical parameters obtained from MRI could completely describe the anatomical characteristic of CC ligament, which are beneficial for the reconstruction of CC ligament to create transosseous tunnels accurately, contributing to reduce the incidence of postoperative complications and promote the operative treatment of AC joint dislocation.

Background

Acromioclavicular (AC) joint dislocation, a shared injury that accounts for approximately 9%-12% of shoulder girdle injuries (27), has received much attention in recent years. This injury is common in certain populations, such as teenagers and athletes, and its incidence is raising with the increase of traffic accidents and sports injuries (25). Depending on the rupture of ligaments and varying degrees of injury to the deltoid and trapezius muscles and fascia, Rockwood proposed a classification of AC joint dislocation to include type I to VI in 1984 (2). So that in accordance with different types, the treatment for AC joint dislocation have not been uniform and the results also vary. Most AC joint dislocations can be treated nonoperatively, symptomatic and high-grade dislocations like type III to VI may be managed by a myriad of surgical techniques (2, 9). Overall, more than 60 surgical techniques have been described so far (19), but the optimal one still remains controversial (4, 22). Due to a slice of biomechanical and anatomical studies confirmed that the coracoclavicular (CC) ligament and AC capsule had played an important role maintaining the stability of AC joint (2, 6, 17, 20, 26), reconstruction of CC ligament gains more popularity to treat AC joint dislocation operatively. Particularly, using grafts like tendon graft (4), or synthetic materials, such as anchors (23) and endobutton with suture (20, 25), to drill transosseous tunnels in the coracoid process and the clavicle for restoring the primitive anatomy of CC ligament has become the current tendency over the years (19). However, despite multiple clinical studies have indicated effective clinical and radiographic outcomes of the transclavicular-transcoracoid drilling technique (14, 20), there is no gold standard for precisely how to create transosseous tunnels (14, 19), which means a surgeon

might reconstruct CC ligament from experience or in a routine manner of his own, so as to it is quite a few differences between the reconstructed ligament and the native CC ligament. Once CC ligament was reconstructed improperly, it may lead to poor reduction of AC joint, cause fixed anterior subluxation or contribute to fractures (5, 11, 14, 19). Hence, it is no wonder that recent clinical studies have reported complication rates with CC reconstruction techniques as high as 23% to 80% (3).

In order to determine the ideal transosseous tunnels in the clavicle and the coracoid process, many studies researched the anatomical characteristic of CC ligament. Most of them came to their values and conclusions by means of cadaveric specimens (18, 26, 27), which could visually represented the anatomic morphology of CC ligament. Such as Mazzocca et al. (18) and Zhu et al (13), who have described the origin of CC ligament by measuring the distance from the lateral edge of the clavicle to the center of the conoid and trapezoid ligaments. Otherwise, Zhu et al. also used two K-wires to measure the valgus angle and retroversion angle of the two ligaments and described the orientation of CC ligament. In addition, a limited studies have brought forth more accurate data about CC ligament with computed tomography (CT). Sella et al. (19) analyzed 74 CT scans and obtained a convergence point (cP) to determine the exact point on which the drilling of the bone, but actually what they emphasized was the anatomical relationship between the clavicle and the coracoid process, which only shows anatomical information about the attachments of CC ligament; Xue et al. (24) reported values about the trapezoid and conoid footprint at the clavicle and the coracoid process in terms of CT scan data, though their main goal was to verify the feasibility of drilling technique and recommended the non-collinear drilling technique provided the capability to prepare bony tunnels without any risk of cortical breach. With respect to magnetic resonance imaging (MRI), some studies have focused on the advantage of MRI for the diagnosis (1, 8, 12) and prognosis (20) of AC joint dislocation, rather than the detailed anatomy of CC ligament. Only several studies dynamically described the length of CC ligament when analyzing the CC ligament kinematics during shoulder Abduction. For example, Matthias et al. (11) proposed a semiautomatic method for the assessment of CC ligament length variations during different joint positions based on MRI data, provided a better understanding of the ligament length during joint motion and offered new possibilities for presurgical planning of reconstruction; Honal et al. (10) also discussed the distances between the CC insertion points with use of an open MRI scanner to examine the shoulders of 13 healthy volunteers in supine and sitting positions. They showed that there were significant dynamic changes of the distance along the conoid and the trapezoid ligament length, as well as the position should be taken to fixate the two ligaments. Therefore, to date, there is no complete systematic description of the anatomical characteristic of CC ligament with the help of imaging techniques, which could provide more samples, multifarious measurements and parameters compared with cadavers.

As a result of MRI has an excellent soft tissue resolution and could provide multiple plane imaging, the present study analyzed MRI scans to obtain the anatomical parameters of CC ligament for investigating its anatomical characteristic, in order that guiding surgeons to create transosseous tunnels accurately in reconstructing CC ligament.

Materials And Methods

Ethical statement

All procedures were allowed by the Medical Ethics Review Board of Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University with the following reference number: KY2018032.

Materials

A total of 480 MRI scans of left shoulders from patients, whose examine results were stored in the Picture Archiving and Communication Systems (PACS) at the Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University from 2014 to 2018, were analyzed for the study. There were 240 male and 240 female. All the scans were pre-screened, only the scans of patients that can clearly identify CC ligament with the sequence of T2-weighted (echo time [TE] 12-13 ms; repetition time [TR] 580-610 ms) and then CC ligament had no significant changes were included.

We have used PACS for viewing the images and taking measurements as well. The measurements were made by 3 researchers engaged in the work of radiology more than five years, henceforth referred to as observers. These observers would take measurements all alone and each measurement was repeated three times, next averaging the three values obtained. The measurements of lines recorded in millimetre.

Methods

To demonstrate the anatomical characteristic of CC ligament based on MRI scans, some parameters were defined and measured separately in the coronal and sagittal plane. We had access to collected scans at PACS and images in the two planes were performed initially. In each plane, what we observed carefully was the hypointensity region attached to the clavicle and the coracoid process, in which was the location of CC ligament (Figure 1). Afterwards, the following measurements were taken in this region.

Measurements in the coronal plane

The following points of this plane were marked: A: the insertion at the clavicle (the center of the attachment on the clavicle), B: the insertion at the coracoid process (the center of the attachment on the coracoid process), C: the midpoint of AC joint (Figure 2).

Anatomical structures in linear and angular orientation parameters of CC ligament were quantified, linear dimension including: the length of CC ligament was assessed with the distance from the insertion at the clavicle to the insertion at the coracoid process (AB). Another distance from the midpoint of AC joint to the insertion at the clavicle (AC) was measured for explaining the position of CC ligament at the clavicle. Furthermore, angular orientation including two angles: one was the angle between CC ligament and the clavicle ($\angle\alpha$), the other was the angle between CC ligament and the coracoid process ($\angle\beta$).

Measurements in the sagittal plane

The measurements in this plane were a little different from the coronal plane. The following points of this plane were marked: a: the insertion at the clavicle (the center of the attachment on the clavicle), b: the insertion at the coracoid process (the center of the attachment on the coracoid process), c: the tip of the coracoid process, x: the midpoint of the supraclavicular plane of the clavicle (represents the supraclavicular plane of the clavicle), y: the point closest to the tip of the coracoid process in the subcoracoid plane (represents the subcoracoid plane of the coracoid process) (Figure 3).

In addition to the distance from the insertion at the clavicle to the insertion at the coracoid process assessed the length of CC ligament (ab), we measured the distance from the tip of the coracoid process to the insertion at the coracoid process (bc) simultaneously for explaining the position of CC ligament at the coracoid process. The third distance was from the supraclavicular plane of the clavicle to the subcoracoid plane of the coracoid process (xy). What's more, the other quantified anatomical parameters including: the diameters of insertions at the clavicle (mn) and the coracoid process ($m \times n$) for evaluating the footprint of CC ligament. Two angles between CC ligament and the clavicle ($\angle \gamma$) and the coracoid process ($\angle \delta$) were obtained similarly.

Statistical Analysis

Statistical analysis was performed using SPSS 20.0 software (IBM Corp, Armonk, NY, USA). All data were presented as the mean $\pm$ standard deviation (SD). Independent samples t-test was applied to identify differences between measurements in male patients and female patients. All hypothesis tests were implemented by adopting a 5% significance level and P values equal to or smaller than 0.05 were considered statistically significant.

Results

Coronal plane

The mean length of CC ligament (AB) was 8.8 ± 3.4 mm. AC was 29.4 ± 4.2 mm, but the value of male patients (29.7 ± 4.4 mm) is greater than the value of females patients (26.7 ± 3.7 mm) ($P < 0.05$). $\angle \alpha$ was $75.5^\circ \pm 10.56^\circ$, $\angle \beta$ was $63.77^\circ \pm 13.62^\circ$ (Table 1).

Sagittal plane

The mean length of CC ligament (ab) was 19.0 ± 4.5 mm. xy was 38.8 ± 7.1 mm. $m \times n$ and mn was 7.1 ± 3.3 mm and 8.3 ± 2.3 mm, respectively. The distance bc was 12.0 ± 4.3 mm. $\angle \gamma$ was $31.44^\circ \pm 10.14^\circ$, $\angle \delta$ was $55.25^\circ \pm 11.45^\circ$. Additionally, the average values of ab, mn, xy and bc in male patients is greater than the average values of females patients, which were considered statistically significant ($P < 0.05$) (Table 2).

Discussion

Aiming to investigate the anatomical characteristic of CC ligament based on MRI and raise a reference for surgeons to create transosseous tunnels precisely in reconstructing CC ligament, we designed to review 480 cases of patients and analyze their MRI scans of left shoulders. By taking different measurements, we obtained some anatomical parameters related to the length of ligament, the location and footprint of the insertions at the clavicle and the coracoid process as well as the orientation of ligament in the coronal and sagittal plane, respectively. With these abundant parameters, the present study permits a better understanding of the anatomy of CC ligament and conduces to find the applicable points where transosseous tunnels should be drilled in the clavicle and the coracoid process. More importantly, MRI offers more possibilities for anatomical research of CC ligament. This is an improvement on previous studies in which similar measurements have been made using cadaveric specimens. In contrast, imaging techniques are able to acquire numerous samples in a short time and avoid potential errors caused by manual measuring due to the automatic operation. This study reveals that MRI not only has advantages in clinical diagnosis and prognosis of AC joint dislocations, also contributing to restore the primitive anatomy of CC ligament with high accuracy to reduce the incidence of postoperative complications and promote the operative treatment of AC joint dislocation.

The AC joint is a diarthrodial joint formed by the distal clavicle and the medial facet of the acromion (2), and its stability is mostly maintained by CC and AC ligaments and capsule (15). The AC ligament and capsule are essential in providing its anterior-posterior stability. The CC ligament is the laterally located trapezoid ligament and the more medial conoid ligament, which prevents superior-inferior displacement of the clavicle (2, 17, 27). The mechanism of AC joint dislocation usually involves a direct blow to the lateral aspect of the adducted shoulder, leading to downward displacement of the scapula opposed by impaction of the clavicle onto the first rib (7). The force initially damages AC ligament, then further injuries CC ligament as the force perpetuates. Thus AC joint dislocation range from a simple sprain of AC ligament to a complete dislocation of the joint. Variable severity of injuries results in the great diversity of treatment. However, no matter how many treatment exist, the controversy of almost all the literature about the therapies of AC joint dislocation eventually focus on the options of operative or nonoperative techniques. At present, most scholars generally accept that Rockwood type I and II choose conservative treatment while Rockwood type IV to VI use operative management. The ideal treatment of type-III injuries is debated (9, 21), each individual treatment should be carried out according to the specific conditions of patient, namely the type of injury, age, amount of exercise and aesthetic requirements.

In spite of there is ongoing debate as to which technique should be the gold standard of the surgical management of high-grade AC joint dislocations, operative techniques continue to advance with technology and an improved characterization of the anatomy (15). Early surgical procedures using K-wires, Steinman pins and cerclage wires to fixate AC joint. Because of there are a lot of shortcomings and the use of hardware across AC joint may worsen the intra-articular injury and might hasten the onset of joint arthrosis (2), these techniques have been largely eliminated. Later, AC joint reconstruction has gradually become the mainstream as clinicians gained a deeper understanding of the anatomical structure of AC joint. Hardware such as hook plate and screw was the main surgical material for reconstructing the anatomy of AC joint at first, but researches reported that it had been associated with

numerous complications (2) and required a secondary operation for implant removal (25). Then clinicians began to shift their attention to ligament reconstruction. In 1972, the Weaver-Dunn procedure was first described, which utilized the native AC ligament in AC joint reconstruction (15). Following this kind of technique was improved on, the utilization of autograft or allograft for the anatomic reconstruction of CC ligament in AC joint dislocation has rapidly gained popularity in the past few decades (9). The reconstructions using either tendon grafts or suture-button configurations in anatomically placed drill holes have been demonstrated to biomechanically replicate the intact CC ligament complex and improved clinical effects as well. Nevertheless, CC ligament reconstruction has its own limitations. On the one hand, the choice of materials for stabilization of CC ligament mainly relies on the clinical conditions. Historically, tendon graft is best for chronic AC joint injury while synthetic materials (buttons or tapes) suit for acute injury. Choi et al. (4) confirmed that using autogenous tendon graft caused loss of reduction rate of 47% and a complication rate of 20%, which adversely affected clinical outcomes. On the other hand, the technical difficulty is to create transosseous tunnels at the remaining stumps of the ruptured ligaments to reconstruct the normal anatomy of CC ligaments accurately. Actually, where and how to drill a transosseous tunnel either in the coracoid process or in the clavicle varies according to the authors.

With regard to cadaveric researches, Xue et al. (26) measured the mean lengths of the conoid ligament and the trapezoid ligament were 11.2 ± 2.5 and 12.8 ± 2.7 mm, which is similar to the values that Izadpanah et al. (11) measured with 0.25-T open-bore MRI scanner: the mean CC distance along the center course of the conoid ligament and the trapezoid ligament were 11.2 ± 2.9 mm and 13.5 ± 2.7 mm. Though using MRI equally, since the limitation of the image, our study can not clearly divide CC ligament into the conoid and trapezoid ligaments, the length of CC ligament in the coronal plane is different from theirs. More we did that we got a overlapped length was 19.0 ± 4.5 mm, as the two ligaments in the sagittal plane nearly overlap. Furthermore, for better to maintain the horizontal stability of AC joint, the relative orientation of the transosseous tunnels should be considered (16), which means the angle of drilling tunnels need to be consistent with the alignment of CC ligament. According to Zhu et al (27), they measured 20 fresh-frozen Chinese cadavers and found that the valgus angle and retroversion angle of the trapezoid ligament were $39.3^\circ \pm 0.9^\circ$ and $6.0^\circ \pm 0.6^\circ$, the valgus angle and retroversion angle of the conoid ligament was $6.6^\circ \pm 0.7^\circ$ and $11.0^\circ \pm 0.9^\circ$, respectively. Their references are two 2.0 mm K-wires, One at the anterior border of the clavicle just anterior to the center of the trapezoid ligament, the other was perpendicular with the anterior border and was parallel with the superior surface of the clavicle. While our reference are orientation of the clavicle and the coracoid process, emphasizing the anatomical positional relationship of the two vital structures with CC ligament.

More importantly, how to precisely determine the position and size of the transosseous tunnels depend on the attachments of the native CC ligament on the clavicle and the coracoid process. In many cadaveric studies, researchers often measured the distance from the lateral edge of the clavicle to the center of the trapezoid and conoid tuberosities. Mazzocca et al. (18) reported the values were 25.9 ± 3.9 mm and 35 ± 5.9 mm, respectively. Xue et al. (26) measured the distances of Chinese population were 21.8 ± 2.7 mm and 35.7 ± 3.4 mm. Besides, it is necessary to calculate the ratios of the distance to the conoidal center

and to the trapezoidal center divided by clavicular length and coracoid length. As for the coracoid process, researchers focused more on the footprint of ligaments. Izadpanah et al. (11) showed on the coracoid process, footprint expansion of the conoid ligament and the trapezoid ligament in medial-to-lateral direction from MRI were 8 ± 2 mm and 9.6 ± 2.9 mm. In like manner, our study described the attachments of CC ligament with some defined parameters. In the coronal plane, on the basis of the structures that can be observed in the image, we measured the distance from AC joint to the insertion at the clavicle and the value was 29.4 ± 4.2 mm. In the sagittal plane, the distance from the tip of the coracoid process to the insertion at the coracoid process was 12.0 ± 4.3 mm. Moreover, we described the footprint of ligaments by measuring the diameters of insertions at the clavicle and the coracoid process. The values we obtained, 8.2 ± 2.3 mm and 7.1 ± 3.3 mm, resemble to footprint on the coracoid process of Izadpanah et al, but unlike Katsumi (13), whose results on the clavicle are the attachments of the conoid ligament and the trapezoid ligament extended from 15 to 30 mm and 13 to 26 mm in sagittal dimension. Last but not least, we creatively measured the distance from the supraclavicular plane to the subcoracoid plane to study the anatomic relationship between the clavicle and the coracoid process. This will provide a guidance for the length of sutures in surgeries with synthetic materials.

This study has several limitations. First, there are deficiencies in the collection of materials. These prospective MRI scans without taking into account whether the diseases of the shoulder joint or even AC joint itself affect the normal structure of CC ligament, which may lead to measurement errors. Second, experimental method of this study is a combination of physical anatomy and MRI images, its rationality and availability need to be confirmed by further biomechanical studies. Third, one of the main purposes of operative treatment for AC joint dislocation is to return the motor function of the shoulder joint. Hence, more studies should perform dynamic analysis of CC ligament in vivo and conduce to the long-term clinical outcome of operative treatment.

Conclusions

In conclusion, these anatomical parameters obtained from MRI could completely describe the anatomical characteristic of CC ligament, which are beneficial for the reconstruction of CC ligament to create transosseous tunnels accurately. Mastering the anatomical characteristic of CC ligament encourages operative treatment of AC joint dislocation. MRI develops the anatomy of CC ligament, provides a new idea for creating transosseous tunnels in CC ligament reconstruction and achieves the goal of reducing complications and improving postoperative efficacy ultimately.

Abbreviations

AC: acromioclavicular;

CC: coracoclavicular;

MRI: magnetic resonance imaging;

CT: computed tomography;

PACS: Picture Archiving and Communication Systems;

SD: standard deviation;

Declarations

Ethical approval

All procedures were allowed by the Medical Ethics Review Board of Affiliated Traditional Chinese Medicine Hospital of Southwest Medical University with the following reference number: KY2018032.

Consent for publication

All authors agree to publish.

Data availability

The related data used to support the findings of this study are restricted by the medical ethics committee of School of Basic Medical Sciences, Southwest Medical University. Data are available from Lei Zhang (email: zhanglei870722@126.com) for researchers who meet the criteria for access to confidential data.

Competing Interests

The authors declare that they have no competing interests.

Founding

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Disclosure

Lei Zhang is the first author. Youliang Wen, Wenli Jia and Shaoqun Zhang are the co-first authors. Xin Zhou is the co-second author. Shi-jie Fu is the corresponding author.

Author contributions statement:

Lei Zhang and Shijie-Fu: Conception and design, Wenli-Jia, Xin Zhou and Yoliang-Wen: Manuscript writing/editing and Protocol/project development, Shaoqun-Zhang: Data collection and literature search.

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References

1. Alyas F, Curtis M, Speed C, Saifuddin A and Connell D: MR imaging appearances of acromioclavicular joint dislocation. *Radiographics*, 2008; 28: 463-479
2. Babhulkar A and Pawaskar A: Acromioclavicular joint dislocations. *Current reviews in musculoskeletal medicine*, 2014; 7: 33-39.
3. Campbell ST, Heckmann ND, Shin SJ, et al: Biomechanical evaluation of coracoid tunnel size and location for coracoclavicular ligament reconstruction. *Arthroscopy*, 2015; 31: 825-830.
4. Choi NH, Lim SM, Lee SY and Lim TK: Loss of reduction and complications of coracoclavicular ligament reconstruction with autogenous tendon graft in acute acromioclavicular dislocations. *Journal of shoulder and elbow surgery*, 2017; 26: 692-698.
5. Coale RM, Hollister SJ, Dines JS, Allen AA and Bedi A: Anatomic considerations of transclavicular-transcoracoid drilling for coracoclavicular ligament reconstruction. *Journal of shoulder and elbow surgery*, 2013; 22: 137-144.
6. Dawson PA, Adamson GJ, Pink MM, et al: Relative contribution of acromioclavicular joint capsule and coracoclavicular ligaments to acromioclavicular stability. *Journal of shoulder and elbow surgery*, 2009; 18: 237-244.
7. Dias JJ and Gregg PJ: Acromioclavicular joint injuries in sport. Recommendations for treatment. *Sports Med*, 1991; 11:125-132.
8. Faruch Bilfeld M, Lapègue F, Chiavassa Gandois H, Bayol MA, Bonneville N and Sans N: Ultrasound of the coracoclavicular ligaments in the acute phase of an acromioclavicular disjunction: Comparison of radiographic, ultrasound and MRI findings. *European radiology*, 2017; 27: 483-490.
9. Gowd AK, Liu JN, Cabarcas BC, et al: Current Concepts in the Operative Management of Acromioclavicular Dislocations: A Systematic Review and Meta-analysis of Operative Techniques. *The American journal of sports medicine*, 2018; 1: 363546518795147.
10. Honal M, Lovell-Smith C, Vicari M, Weitzel E, Izadpanah K and Weigel M: Accurate semiautomatic assessment of ligament length variations from MRI data. *Medical physics*, 2013; 40: 092301.
11. Izadpanah K, Weitzel E, Honal M, et al: In vivo analysis of coracoclavicular ligament kinematics during shoulder abduction. *The American journal of sports medicine*, 2012; 40: 185-192.
12. Izadpanah K, Winterer J, Vicari M, et al: A stress MRI of the shoulder for evaluation of ligamentous stabilizers in acute and chronic acromioclavicular joint instabilities. *Journal of magnetic resonance imaging: JMRI*, 2013; 37: 1486-1492.
13. Katsumi Takase: The coracoclavicular ligaments: an anatomic study. *Surgical and radiologic anatomy: SRA*, 2010; 32: 683-688.

14. Koh KH, Shon MS, Choi NH and Lim TK: Anatomic Tunnel Placement Is Not Feasible by Transclavicular-Transcoracoid Drilling Technique for Coracoclavicular Reconstruction: A Cadaveric Study. *Arthroscopy*, 2018; 34: 2012-2017.
15. Lee S and Bedi A: Shoulder acromioclavicular joint reconstruction options and outcomes. *Current Reviews in Musculoskeletal Medicine*, 2016; 9: 368-377.
16. Li Q, Hsueh PL and Chen YF: Coracoclavicular ligament reconstruction: a systematic review and a biomechanical study of a triple endobutton technique. *Med Baltim*, 2014; 93: e193.
17. Masionis P, Šatkauskas I, Mikelevičius V, et al; Biomechanical evaluation of native acromioclavicular joint ligaments and two reconstruction techniques in the presence of the sternoclavicular joint: A cadaver study. *Journal of Orthopaedic Surgery*, 2017; 25: 1-5.
18. Rios CG, Arciero RA and Mazzocca AD: Anatomy of the clavicle and coracoid process for reconstruction of the coracoclavicular ligaments. *The American journal of sports medicine*, 2007; 35: 811-817.
19. Sella GDV, Miyazaki AN, Nico MAC, Filho GH, Silva LA and Checchia SL: Study on the anatomic relationship between the clavicle and the coracoid process using computed tomography scans of the shoulder. *Journal of shoulder and elbow surgery*, 2017; 26: 1740-1747.
20. Struhl S and Wolfson TS: Continuous Loop Double Endobutton Reconstruction for Acromioclavicular Joint Dislocation. *The American journal of sports medicine*, 2015; 43: 2437-2444.
21. Virk MS, Apostolakos J, Cote MP, Baker B, Beitzel K and Mazzocca AD: Operative and Nonoperative Treatment of Acromioclavicular Dislocation: A Critical Analysis Review. *Jbjs Reviews*, 2015; 3:
22. Voss A, Singh H, Dyrna F, et al: Biomechanical Analysis of Intra-articular Pressure After Coracoclavicular Reconstruction. *The American journal of sports medicine*, 2017; 45: 150-156.
23. Xiong C, Lu Y, Wang Q, Chen G, Hu H and Lu Z: Anatomical principles for minimally invasive reconstruction of the acromioclavicular joint with anchors. *International orthopaedics*, 2016; 40: 2317-2324.
24. Xue C, Song LJ, Li X, Zhang GY and Fang JH: Coracoclavicular ligaments anatomical reconstruction: a feasibility study. *Int J Med Robot*, 2015; 11: 181-187.
25. Xue C, Song LJ, Zhang H, Tang GL, Li X and Fang JH: Truly anatomic coracoclavicular ligament reconstruction with 2 Endobutton devices for acute Rockwood type V acromioclavicular joint dislocations. *Journal of shoulder and elbow surgery*, 2018; 27: e196-e202.
26. Xue C, Song LJ, Zhang M, Zheng TS, Fang JH and Li X; Coracoclavicular ligament attachment regions of the Chinese population: a quantitative anatomic study. *Anatomical science international*, 2013; 88: 189-194.
27. Zhu NF, Rui BY, Zhang YL and Chen YF: Anatomic study of coracoclavicular ligaments for reconstruction of acromioclavicular joint dislocations. *Journal of orthopaedic science: official journal of the Japanese Orthopaedic Association*, 2016; 21: 749-752.

Figures

Figure 1

The location of CC ligament in MRI image with the sequence of T2-weighted. (A) The arrow shows CC ligament in the coronal plane. (B) The arrow shows CC ligament in the sagittal plane.

Figure 2

The measurements in the coronal plane. In this figure, the points and lines were defined to measure distances and angles: (1) point A represents the insertion at the clavicle (the center of the attachment on the clavicle). B: the insertion at the coracoid process (the center of the attachment on the coracoid process). C: the midpoint of AC joint. (2) two angles between CC ligament and the clavicle ($\angle\alpha$) and the

coracoid process ($\angle\beta$). These lines represent the orientation of the clavicle, CC ligament and the coracoid process, respectively.

Figure 3

The measurements in the sagittal plane. In this figure, the points and lines were defined to measure distances and angles: (A) a: the insertion at the clavicle (the center of the attachment on the clavicle). b: the insertion at the coracoid process (the center of the attachment on the coracoid process). c: the tip of the coracoid process. (B) mn: the diameter of insertion at the clavicle. m'n': the diameter of insertion at the coracoid process. x: represents the supraclavicular plane of the clavicle (the midpoint of the supraclavicular plane). y: represents the subcoracoid plane of the coracoid process (the point closest to the tip of the coracoid process in the subcoracoid plane). (C) two angles between CC ligament and the clavicle ($\angle\gamma$) and the coracoid process ($\angle\delta$). These lines represent the orientation of the clavicle, CC ligament and the coracoid process, respectively.