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Quantitative Assessment of the Distal Clavicle with Its Clinical Implications in Anatomical Reconstruction of the Coracoclavicular Ligament

Ligamentum Coracoclaviculare'nin Anatomik Rekonstruksiyonunda Klinik Etkisi Olan Distal Clavicula'nın Kantitatif Değerlendirilmesi

Hilal AKDEMİR AKTAŞ
0000-0002-7353-8069
Helin YÜCEDAĞ GÜNDOĞDU
0000-0001-7724-6031

Department of Anatomy, Hacettepe University Faculty of Medicine, Ankara, Türkiye

Corresponding Author
Sorumlu Yazar
Hilal AKDEMİR AKTAŞ
hakdemir06@hotmail.com

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ABSTRACT

Aim: Anatomical reconstruction of the coracoclavicular ligament has recently become popular in the treatment of acromioclavicular joint injuries. To perform this procedure correctly, the anatomy of the conoid tubercle and trapezoid line, which are the attachment sites of the coracoclavicular ligament, should be known accurately. Therefore, this study aimed to evaluate the distal clavicle along with morphometry of the conoid tubercle and trapezoid line.
Material and Methods: In the present study, 77 human dry clavicles (39 right, 38 left) were examined using a digital caliper and digital thickness gauge. The clavicle length, thickness and width of the distal clavicle, morphometric features of the conoid tubercle, and trapezoid line were examined. Measurements were performed by two researchers independently.
Results: The clavicle length was 138.37±10.69 mm. Supero-inferior thickness of the distal clavicle was 9.08±1.69 mm, and the antero-posterior width was 17.70±2.37 mm. Medio-lateral and supero-inferior dimensions of the conoid tubercle were 17.17±3.58 mm and 7.59±1.38 mm, respectively. The distance between the clavicle acromial end and the center of the conoid tubercle was 34.43±5.41 mm. Medio-lateral dimension of trapezoid line was 16.69±2.73 mm, and antero-posterior dimension was 9.61±1.80 mm. The distance between the clavicle acromial end and the center of the trapezoid line was measured as 18.15±2.80 mm.
Conclusion: Accordingly, the tunnels for trapezoid and conoid ligaments should be created 18 mm and 34 mm medial from the clavicle acromial end, respectively. The measurements obtained in this study can be used as a guide for coracoclavicular ligament reconstruction.
Keywords: Anatomical reconstruction; conoid tubercle; coracoclavicular ligament; distal clavicle; morphometry; trapezoid line.

ÖZ

Amaç: Articulatio acromioclaviculare yaralanmalarının tedavisinde, ligamentum coracoclaviculare'nin anatomik rekonstrüksiyonu son zamanlarda popüler hale gelmiştir. Bu işlemin doğru şekilde yapılabilmesi için ligamentum coracoclaviculare'nin yapışma yerleri olan tuberculum conoideum ve linea trapezoidea'nın anatomisinin doğru şekilde bilinmesi gerekir. Bu nedenle, bu çalışmada tuberculum conoideum ve linea trapezoidea'nın morfometrisi ile birlikte distal clavicula'nın değerlendirilmesi amaçlandı.
Gereç ve Yöntemler: Bu çalışmada, 77 insan kuru clavicula kemiği (39 sağ, 38 sol) dijital kumpas ve dijital kalınlık ölçer kullanılarak incelendi. Clavicula uzunluğu, distal clavicula kalınlığı ve genişliği, tuberculum conoideum ve linea trapezoidea'nın morfometrik özellikleri incelendi. Ölçümler iki araştırmacı tarafından bağımsız olarak gerçekleştirildi.
Bulgular: Clavicula uzunluğu 138,37±10,69 mm idi. Distal clavicula'nın supero-inferior kalınlığı 9,08±1,69 mm ve antero-posterior genişliği ise 17,70±2,37 mm bulundu. Tuberculum conoideum'un medio-lateral ve supero-inferior boyutları sırasıyla 17,17±3,58 mm ve 7,59±1,38 mm idi. Clavicula extremitas acromialis'i ile tuberculum conoideum'un merkezi arasındaki mesafe 34,43±5,41 mm olarak ölçüldü. Linea trapezoidea'nın medio-lateral uzunluğu 16,69±2,73 mm ve antero-posterior uzunluğu ise 9,61±1,80 mm idi. Clavicula extremitas acromialis'i ile linea trapezoidea'nın merkezi arasındaki mesafe 18,15±2,80 mm olarak ölçüldü.
Sonuç: Bu çalışmadaki ölçümlere göre, ligamentum trapezoideum ve ligamentum conoideum için açılacak tüneller clavicula'nın extremitas acromialis'inden sırasıyla 18 mm ve 34 mm medialde oluşturulmalıdır. Bu çalışmadan elde edilen ölçümler, ligamentum coracoclaviculare'nin anatomik rekonstrüksiyonunda bir kılavuz olarak kullanılabilir.
Anahtar kelimeler: Anatomik rekonstrüksiyon; tuberculum conoideum; ligamentum coracoclaviculare; distal clavicula; morfometri; linea trapezoidea.

INTRODUCTION

The acromioclavicular joint is stabilized by the effects of the coracoclavicular ligaments and the capsule of the acromioclavicular joint. The coracoclavicular ligament restricts the distal clavicle's superior translation relative to the scapula (1,2). The coracoclavicular ligament is used effectively in various sports, particularly those involving significant shoulder activity and contacts, such as lacrosse, weightlifting, hockey, rugby, football, baseball, tennis, volleyball, and swimming (3,4). The coracoclavicular ligament is composed of the conoid and trapezoid ligaments and transmits the weight of the upper limb to the clavicle (5,6). The conoid ligament courses nearly vertically and attaches to the conoid tubercle, which is posteromedial to the trapezoid line. The trapezoid ligament attaches to the trapezoid line and angles anterolaterally away from the conoid ligament (7).

Acromioclavicular joint injuries are common among young athletes who engage in contact and overhead sports (8,9). Several surgical techniques have been described in the literature to treat the acromioclavicular joint (8,10). Recently, there has been a trend toward the anatomical reconstruction of the coracoclavicular ligament using free graft (1,10). Anatomical reconstruction has become popular due to successful clinical outcomes (11). This technique necessitates drilling clavicular bone tunnels and passing the graft through the clavicle and coracoid process of the scapula. The most precise method to restore the normal anatomy of the coracoclavicular ligaments involves creating bone tunnels at the residual stumps of the ruptured ligaments (1,10-12). Creating bone tunnels necessitates accurate morphometry of the conoid tubercle and trapezoid line. Therefore, the present study aimed to evaluate the morphometry of the conoid tubercle and the trapezoid line in order to create bone tunnels accurately for anatomical coracoclavicular ligament reconstructions.

MATERIAL AND METHODS

The present study was performed on 88 human dry clavicles which were obtained from the Department of Anatomy, Faculty of Medicine, Hacettepe University. Eleven clavicles with gross deformities were excluded from the study. Eventually, 77 human dry clavicles (39 right sides, 38 left sides) were examined. However, the sex and age of the bones used in the study were not known.

Measurements were performed using a digital caliper (150 mm, Insize 1195 IP 67 Waterproof Digital Calipers) and an outside diameter digital thickness gauge. Before measuring, the caliper and thickness gauge were calibrated. The boundaries of the conoid tubercle and trapezoid line were determined by following the rough footprints of the conoid and trapezoid ligaments. The measurements were carried out independently by two different researchers and an inter-rater reliability coefficient was >0.90 for all the parameters.

This study was performed in line with the principles of the Declaration of Helsinki. Consent to participate is not applicable for this study. Ethical approval for this study was obtained from the Health Sciences Research Ethics Committee of Hacettepe University (21 May 2024, SBA 24/549, 2024/09-18).

The measurements examined in the study were: *i)* the clavicle length: straight distance between the acromial and sternal ends of the clavicle (Figure 1). *ii)* supero-inferior thickness of the distal clavicle, measured from the midpoint between the conoid tubercle and trapezoid line (Figure 2A). *iii)* antero-posterior width of the distal clavicle, measured from the midpoint between the conoid tubercle and trapezoid line (Figure 2B). *iv)* the medio-lateral (Figure 3, EF), and *v)* the supero-inferior (Figure 3, GH) dimensions of the conoid tubercle. *vi)* distance between the clavicle acromial end and the center of the conoid tubercle (Figure 4, Z line). *vii)* a ratio calculated by dividing the distance from the clavicle acromial end to the conoid tubercle by the clavicle length. *viii)* the medio-lateral (Figure 3, AB) and *ix)* the antero-posterior (Figure 3, CD) dimensions of the trapezoid line, *x)* distance between the clavicle acromial end and the center of the trapezoid line (Figure 4, X line). *xi)* a ratio calculated by dividing the distance from the clavicle acromial end to the trapezoid line by the clavicle length. *xii)* distance between the center of the conoid tubercle and the center of the trapezoid line (Figure 4, Y line).

Statistical Analysis

Statistical analysis was performed using IBM SPSS version 21. The variables were assessed by histogram and Kolmogorov-Smirnov/Shapiro-Wilk methods for testing normal distribution. As they were normally distributed, the



Figure 1. Inferior view of the left clavicle. Clavicle length is a straight distance between the sternal and acromial ends of the clavicle. The inferior view of the acromial end includes the conoid tubercle for the conoid ligament and the trapezoid line for the trapezoid ligament

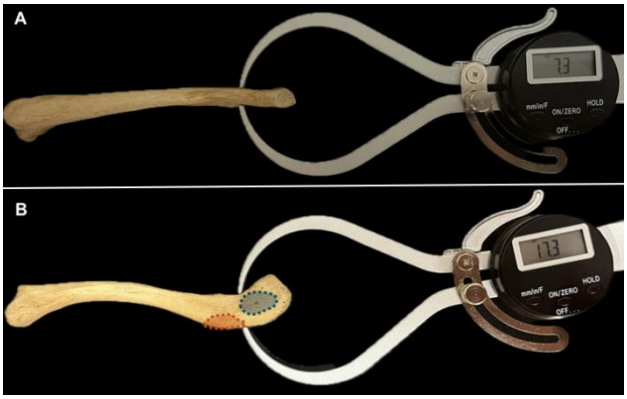


Figure 2. A) Supero-inferior thickness of the distal clavicle, measured from the midpoint between the conoid tubercle and trapezoid line, and **B)** antero-posterior width of the distal clavicle, measured from the midpoint between the conoid tubercle and trapezoid line utilizing an outside diameter digital thickness gauge



Figure 3. An inferior view of the left clavicle demonstrates the measurements of the trapezoid line and conoid tubercle, **AB)** medio-lateral and **CD)** antero-posterior dimensions of the trapezoid line, **EF)** medio-lateral and **GH)** supero-inferior dimensions of the conoid tubercle



Figure 4. The inferior view of the left clavicle shows the distances between **X)** the clavicle acromial end and the center of the trapezoid line, **Y)** the center of the conoid tubercle and the center of the trapezoid line, and **Z)** the clavicle acromial end and the center of the conoid tubercle

descriptive statistics were reported as mean±standard deviation. The groups were compared using the Student's t-test, and correlation analysis was conducted using Pearson's correlation. A p-value of less than 0.05 was considered statistically significant, and analyses were conducted using a 95% confidence interval.

RESULTS

In the present study, 77 human dry clavicles (39 right sides, 38 left sides) were examined. The mean clavicle length was found to be 138.37±10.69 mm. The mean supero-inferior thickness of the distal clavicle was measured as 9.46±1.36 mm on the right side, 8.69±1.92 mm on the left side, and 9.08±1.69 mm in general. There was a statistically significant difference in supero-inferior thickness of the distal clavicle between sides and right supero-inferior thickness was 0.77 mm thicker than the left side (p=0.044). The mean antero-posterior width of the distal clavicle was found to be 17.70±2.37 mm. Detailed measurements of these parameters were summarized in Table 1.

The mean value of the medio-lateral dimension of the conoid tubercle was 17.17±3.58 mm and the supero-inferior dimension was 7.59±1.38 mm. The mean distance between the clavicle acromial end and the center of the conoid tubercle was found to be 36.70±5.00 mm on the right side, 32.10±4.83 mm on the left side, and 34.43±5.41 mm in general. There was a statistically significant difference between sides and the right side was 4.60 mm longer than the left side (p<0.001). A ratio representing the distance from the clavicle acromial end to the conoid tubercle divided by the clavicle length was calculated as 0.26±0.03 on the right side, 0.23±0.03 on the left side, and 0.25±0.03 in general. There was a statistically significant difference in ratios between sides (p<0.001). Detailed measurements of these parameters were summarized in Table 2.

The mean value of the medio-lateral dimension of the trapezoid line was 16.69±2.73 mm and, the antero-posterior dimension was 9.61±1.80 mm. The mean distance between the clavicle acromial end and the center of the trapezoid line was found to be 18.15±2.80 mm. A ratio representing the distance from the clavicle acromial end to the trapezoid line divided by the clavicle length was calculated as 0.13±0.02. There was no statistical difference between the sides in the measurements of the trapezoid line. The mean distance between the center of the conoid tubercle and the center of the trapezoid line was measured as 18.70±3.11 mm. Detailed measurements of these parameters were summarized in Table 3.

Table 1. Morphometric measurements of the distal clavicle

Measurements	Right (n=39)	Left (n=38)	p	General (n=77)
Clavicle length (mm)	139.44±10.11 (116.77-156.09)	137.27±11.27 (111.40-160.12)	0.375	138.37±10.69 (111.40-160.12)
Supero-inferior thickness of the distal clavicle (mm)	9.46±1.36 (6.58-12.52)	8.69±1.92 (6.40-17.60)	**0.044**	9.08±1.69 (6.40-17.60)
Antero-posterior width of the distal clavicle (mm)	18.19±2.25 (13.50-23.37)	17.20±2.40 (12.63-22.63)	0.065	17.70±2.37 (12.63-23.37)

Table 2. Morphometric measurements of the conoid tubercle

Measurements	Right (n=39)	Left (n=38)	p	General (n=77)
Medio-lateral dimension of the conoid tubercle (mm)	17.80±3.92 (12.20-30.63)	16.52±3.11 (11.10-23.42)	0.115	17.17±3.58 (11.10-30.63)
Supero-inferior dimension of the conoid tubercle (mm)	7.71±1.31 (4.36-10.20)	7.47±1.45 (4.74-10.27)	0.443	7.59±1.38 (4.36-10.27)
Distance between the clavicle acromial end and the center of the conoid tubercle (mm)	36.70±5.00 (24.55-48.11)	32.10±4.83 (23.26-41.24)	**<0.001**	34.43±5.41 (23.26-48.11)
Distance from acromial end to conoid/clavicle length	0.26±0.03 (0.19-0.32)	0.23±0.03 (0.18-0.29)	**<0.001**	0.25±0.03 (0.18-0.32)

Table 3. Morphometric measurements of the trapezoid line

Measurements	Right (n=39)	Left (n=38)	p	General (n=77)
Medio-lateral dimension of the trapezoid line (mm)	17.29±2.80 (12.01-23.41)	16.08±2.54 (10.48-20.45)	0.051	16.69±2.73 (10.48-23.41)
Antero-posterior dimension of trapezoid line (mm)	9.82±1.87 (4.86-13.68)	9.39±1.73 (5.98-13.24)	0.292	9.61±1.80 (4.86-13.68)
Distance between the clavicle acromial end and the center of the trapezoid line (mm)	18.66±2.41 (14.13-25.30)	17.62±3.09 (11.93-25.28)	0.101	18.15±2.80 (11.93-25.30)
Distance from clavicle acromial end to trapezoid line/clavicle length	0.13±0.02 (0.11-0.17)	0.13±0.02 (0.09-0.16)	0.150	0.13±0.02 (0.09-0.17)
Distance between the center of the conoid tubercle and the center of the trapezoid line (mm)	18.58±3.05 (13.32-27.48)	18.82±3.20 (10.06-25.60)	0.738	18.70±3.11 (10.06-27.48)

There was a significant moderate and positive correlation between the medio-lateral dimension of the conoid tubercle and the medio-lateral dimension of the trapezoid line ($r=0.447$, $p<0.001$). While no significant correlation was found between the supero-inferior dimension of the conoid tubercle and the antero-posterior dimension of the trapezoid line ($r=0.125$, $p=0.278$).

DISCUSSION

Acromioclavicular joint injuries commonly affect young athletes and are often caused by direct trauma to the lateral aspect of the shoulder or acromion process with the arm in adduction (6). Acromioclavicular joint injuries can also be caused by falling on an outstretched hand or elbow (13). More than 60 surgical procedures have been identified for treating acromioclavicular joint injuries, and their application is supported by hundreds of biomechanical and anatomical investigations (14). Anatomical reconstruction of the coracoclavicular ligaments has become popular in recent years due to successful clinical outcomes. With this technique, the residual stumps of the ruptured ligaments are punctured, and synthetic materials or grafts are inserted through them to restore the coracoclavicular ligaments as distinct anatomical structures (15).

Traditionally, in the anatomical reconstruction technique, trapezoid and conoid tunnels are created 25 and 45 mm medial to the lateral edge of the clavicle, respectively (6,16). After some failures were reported with this technique, it was suggested that clavicular tunnels should be placed according to the "tunnel ratio". This ratio is calculated by dividing the distance from the lateral edge of the clavicle to the center of the conoid tubercle/trapezoid line by the total clavicular length (1). In this surgical technique, it has been reported that using a ratio of 0.20-0.25 for the conoid tunnel and a ratio of 0.13-0.16 for the trapezoid tunnel provides higher survival (17). Clavicular tunnels placed outside of these ratios have been related to the failure of this technique (17,18). Anatomical reconstruction by creating clavicular tunnels requires accurate knowledge of the distances and ratios of the conoid tubercle and trapezoid line, and therefore, in this study, the morphometry of the conoid tubercle and trapezoid line was evaluated in detail.

Clavicle Length: The clavicle length was measured as 150 mm by Boehm et al. (19), 141.3 mm by Chahla et al. (20), 139.9±9.4 mm by Xue et al. (21) on 172 cadaver shoulders, 149.4±10.3 mm by Bernat et al. (22), 149±9.1 mm by Rios et al. (1), 148.57±12.63 mm by Ominde et al. (23) on 180 human dry clavicles, 156.87±9.75 mm on males and 145.79±7.95 mm on females by King et al. (24). In the present study, the clavicle length between the sternal and acromial ends was measured as 138.37±10.69 mm and no difference was found between sides. The clavicle length found in the present study was in accordance with the previous studies (Table 4).

Supero-Inferior Thickness of Distal Clavicle: The thickness of the distal clavicle is crucial to predict how much graft will be in the clavicle tunnels and to design a more appropriate interference screw for anatomical reconstruction technique. The supero-inferior thickness of the distal clavicle was found to be 11.4±1.6 mm by Rios et al. (1), 10.09±2.36 mm by Ominde et al. (23), and 10.31 mm by Daruwalla et al. (25). King et al. (24) examined 418 clavicles and measured the clavicle height at the middle of the acromial third as 10.56±1.96 mm on males and 9.74±1.65 mm on females. In the present study, the supero-inferior thickness at the midpoint between the conoid tubercle and trapezoid line was measured as 9.08±1.69 mm, which was consistent with the literature (Table 4). When determining the graft length and tension, it is needed for approximately 1 cm of the graft to be positioned within the distal clavicle tunnel.

Antero-Posterior Width of Distal Clavicle: The lateral aspect of the distal clavicle is relatively narrow and rectangular in shape. Renfree et al. (26) evaluated 41 clavicles and measured the antero-posterior width of the distal clavicle as 26.7±2.7 mm in males and 21.5±2.7 mm in females. Rios et al. (1) analyzed 120 human dry clavicles and measured the antero-posterior thickness as 19.2±2.8 mm. Daruwalla et al. (25) evaluated 27 human clavicles and measured the acromial width as 21.24 mm on the left and 21.91 mm on the right side. King et al. (24) examined 418 clavicles using CT imaging and found the clavicle width at the middle of the acromial third to be 18.26±3.04 mm in males and 15.14±2.53 mm in females. Antero-posterior width of the distal clavicle was measured as 17.70±2.37 in the present study, and thus this result was convenient with the studies performed by Rios et al. (1) and King et al. (24). Our result was narrower than the studies done by Daruwalla et al. (25) and Renfree et al. (26). Differences in distal clavicle width measurements across studies may be due to differences in geographical regions and measurements methods.

Conoid Tubercle: The conoid tubercle is the prominent eminence placed on the lateral part of the clavicle inferior aspect. It serves as an attachment point for the conoid ligament and is situated between the trapezoid line and the subclavius muscle groove (5). Morphometric features of the conoid

tubercle are important for the anatomical coracoclavicular reconstruction. Takase (27) dissected 40 shoulders of 20 cadavers and measured the sagittal (medio-lateral) dimension of the conoid ligament footprint as 17.4 mm and the coronal (antero-posterior) dimension of the conoid ligament footprint as 5.4 mm. Harris et al. (28) dissected 24 shoulder specimens and measured the width of the conoid ligament footprint as 20.6±3.6 mm. Xue et al. (21) performed a dissection on 172 shoulders and measured the medio-lateral dimension of the conoid ligament as 13.1±2.2 mm, and antero-posterior dimension 6.0±1.4 mm. Rios et al. (1) dissected 19 fresh-frozen cadaveric shoulders and measured the width of the conoid ligament footprint as 25.3±4.9 mm. In the present study, the medio-lateral dimension of the conoid tubercle was measured as 17.17±3.58, similar to the studies of Xue et al. (21), Takase (27), and Harris et al. (28). Our result was lower than Rios et al. (1)'s study. This difference may be due to the difference in geographical regions and measurement methods. Cadaveric studies, of course, give more precise results in the measurements of ligaments, while only the footprints of the ligaments can be measured in human dry bone studies. Therefore, we only measured the footprints of the ligaments in the present study and this is a limitation. In the present study, the supero-inferior dimension of the conoid tubercle was found to be 7.59±1.38 mm in accordance with previous studies (Table 5).

The origins of the coracoclavicular ligaments with respect to the distal end of the clavicle are crucial for successful anatomical reconstruction of the coracoclavicular ligaments. The distance from the clavicle acromial end to the center of the conoid tubercle has been examined by several authors. This distance was found to be 35.0±5.9 mm by Rios et al. (1), 35.7±3.4 mm by Xue et al. (21), 39.52±5.93 mm by Ominde et al. (23), and 36.6±0.9 mm by Zhu et al. (29). The ratio calculated by dividing the distance from the clavicle lateral edge to the conoid tubercle by the length of the clavicle was found 0.24 by Rios et al. (1), 0.25 by Xue et al. (21), and 0.27 by Ominde et al. (23). In the present study, this distance was measured as 34.43±5.41 mm and the ratio was found to be 0.25±0.03, similar to the previous studies (Table 5). According to the measurements of the present study, for making reconstruction of the conoid ligament in as an anatomical position as possible, the conoid tunnel on the clavicle should be created 34 mm medial from the acromial end of the clavicle and at a ratio of 0.25.

Trapezoid Line: The trapezoid line is the narrow ridge found on the lateral part of the inferior face of the clavicle. It serves as an attachment point for the trapezoid ligament and extends anterolaterally from the conoid tubercle (5). Morphometric properties of the trapezoid line are important in performing successful anatomical reconstruction. Medio-lateral dimension of the trapezoid ligament was found to be 11.8±1.0 mm by Rios et al. (1), 14.7±2.0 mm by Xue et al. (21), 18.5 mm by Takase (27), and 21.7±4.0 mm by Harris et al. (28). In the present study, medio-lateral dimension of the trapezoid line was measured as 16.69±2.73 mm, similar to the studies of Xue et al. (21) and Takase (27). Our result was wider than Rios et al. (1)'s study and narrower than the study of Harris et al. (28). This discrepancy might result from different measurement techniques and conducting studies in different geographic locations. Antero-posterior dimension of the trapezoid ligament was found to be 8.2±2.5 mm by Xue et al. (21), and 15.4 mm by Takase (27). In the present study, the antero-posterior dimension of the trapezoid line was found to be 9.61±1.80 mm (Table 6) in accordance with the study of Xue et al. (21).

Accurate knowledge of the trapezoid ligament attachment sites is required for successful anatomical coracoclavicular ligament reconstruction. The distance between the clavicle acromial end and the center of the trapezoid line was found to be 24.9±3.8 mm on dry clavicles and 25.9±3.9 mm on cadaveric shoulders by Rios et al. (1), 21.8±2.7 mm by Xue et al. (21), 17.96±3.42 mm by Ominde et al. (23), and 21.7±1.1 mm by Zhu et al. (29). In the present study, this distance was measured as 18.15±2.80 mm, similar to the previous studies (Table 6). Our result was lower than the study of Rios et al. (1). The ratio calculated by dividing the distance from the clavicle acromial end to the trapezoid line by the length of the clavicle was found to be 0.17 by Rios et al. (1), 0.15 by Xue et al. (21), and 0.12 by Ominde et al. (23). The ratio was found to be 0.13±0.02 in the present study in accordance with the previous studies. According to the measurements of the present study, for making reconstruction of the trapezoid ligament in as an anatomical position as possible, the trapezoid tunnel on the clavicle should be created 18 mm medial from the acromial end of the clavicle and at a ratio of 0.13.

Table 4. Length, thickness, and width of the clavicles in previous studies

	n	**Method**	**Clavicle length** (mm)	**Supero-inferior thickness of the distal clavicle** (mm)	**Antero-posterior width of the distal clavicle** (mm)
Rios et al. (1)	120	Dry clavicles	149.0±9.1	11.4±1.6	19.2±2.8
Boehm et al. (19)	36	Cadaver shoulder	150	-	-
Chahla et al. (20)	10	Fresh-frozen shoulder	141.3	-	-
Xue et al. (21)	172	Cadaver shoulder	139.9±9.4	-	-
Bernat et al. (22)	68	Cadaver shoulder	149.4±10.3	-	-
Ominde et al. (23)	180	Dry clavicles	148.57±12.63	10.09±2.36	-
King et al. (24)	101 male 108 female	Computed tomography	156.87±9.75 145.79±7.95	10.56±1.96 9.74±1.65	18.26±3.04 15.14±2.53
Daruwalla et al. (25)	27	Cadaver clavicles	-	10.31	21.58
Renfree et al. (26)	41	Cadaver clavicles	-	-	24.1±2.7
Present study	77	Dry clavicles	138.37±10.69	9.08±1.69	17.70±2.37

Table 5. Measurements of the conoid tubercle in previous studies

	n	Method	Medio-lateral dimension of the conoid tubercle (mm)	Supero-inferior dimension of the conoid tubercle (mm)	Distance between the clavicle acromial end and the center of the conoid tubercle (mm)	Distance from acromial end to conoid/clavicle length
Rios et al. (1)	19	Cadaver shoulder	25.3±4.9	-	35.0±5.9	0.24±0.03
Xue et al. (21)	172	Cadaver shoulder	13.1±2.2	6.0±1.4	35.7±3.4	0.25
Ominde et al. (23)	180	Dry clavicles	-	-	39.52±5.93	0.27
Takase (27)	40	Cadaver shoulder	17.4	5.4	-	-
Harris et al. (28)	24	Cadaver shoulder	20.6±3.6	-	-	-
Zhu et al. (29)	40	Cadaver shoulder	-	-	36.6±0.9	-
Present study	77	Dry clavicles	17.17±3.58	7.59±1.38	34.43±5.41	0.25±0.03

Table 6. Measurements of the trapezoid line in previous studies

	n	Method	Medio-lateral dimension of the trapezoid line (mm)	Antero-posterior dimension of the trapezoid line (mm)	Distance between the clavicle acromial end and the center of the trapezoid line (mm)	Distance from acromial end to trapezoid/clavicle length
Rios et al. (1)	120	Dry clavicles	-	-	24.9±3.8	0.17±0.03
	19	Cadaver shoulder	11.8±1.0	-	25.9±3.9	0.17±0.02
Xue et al. (21)	172	Cadaver shoulder	14.7±2.0	8.2±2.5	21.8±2.7	0.15
Ominde et al. (23)	180	Dry clavicles	-	-	17.96±3.42	0.12
Takase (27)	40	Cadaver shoulder	18.5	15.4	-	-
Harris et al. (28)	24	Cadaver shoulder	21.7±4.0	-	-	-
Zhu et al. (29)	40	Cadaver shoulder	-	-	21.7±1.1	-
Present study	77	Dry clavicles	16.69±2.73	9.61±1.80	18.15±2.80	0.13±0.02

There is limited knowledge in the literature about the distance between the conoid tubercle and the trapezoid line. Chahla et al. (20) dissected 10 fresh-frozen cadaveric shoulders and measured the distance between the centers of the trapezoid and conoid ligament attachments as 16.2 mm. In the present study, the distance between the center of the conoid tubercle and the center of the trapezoid line was found to be 18.70±3.11 in accordance with the study of Chahla et al. (20). According to the present study, there should be a distance of 18 mm between the conoid and trapezoid tunnels to make an anatomical reconstruction.

Study Limitations

The present study has some limitations inherent to a human dry bone design. Since the present study was performed on dry bone, measurements were taken from clavicles devoid of soft tissue, making it difficult to know exactly where the ligament was attached. Consequently, the footprints of ligaments would not be entirely precise in comparison to cadaveric research. The anatomical structures on the human dry clavicles may have been eroded because they are also used in student education. The other limitation is that this study was conducted with bones of unknown age and sex. Therefore, the effects of age and sex on the measured parameters could not be evaluated. Finally, this sample from a south-Mediterranean population may not be generalized. Further studies performed on cadavers and radiologic images should be planned for evaluating these sex, age, and geographical differences in distal clavicle morphometry.

CONCLUSION

Morphometric features of the distal clavicle are significant for anatomical reconstruction of the coracoclavicular ligament. According to our measurements, the conoid tunnel should be created 34 mm medial from the lateral edge and at a ratio of 0.25. The trapezoid tunnel should be created 18 mm medial from the lateral edge and at a ratio of 0.13 to achieve a successful anatomical reconstruction of the coracoclavicular ligaments. The distance between the tunnels to be created for the conoid and trapezoid ligaments should be 18 mm. The measurements obtained in this study can be used as a guide for coracoclavicular ligament reconstruction.

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