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Anatomy of Coracoacromial Ligament

The Association between Coracoacromial Ligament Morphology and Rotator Cuff Tears: A Cadaveric Study

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Abstract:

Purpose: To determine the association between coracoacromial ligament (CAL) morphology and rotator cuff tears.

Materials and Methods: The present study is a prospective cohort study based on the dissection of 172 shoulders from 86 (46 female, 40 male) formalin embalmed European Caucasian cadavers, with a median age of 82 years. The anatomy of CAL was examined, including its morphology and parametric measurements, while the rotator cuff tendons were inspected for the presence of tears.

Results: Gross examination of the CAL in 155 shoulders revealed a variable number of bands as follows: 28 (18%) had one band, 56 (36%) two bands and 71 (46%) three or more bands. Inspection of the rotator cuff tendons showed the presence of tears in 77 (50%) shoulders, of which 37 (24%) were partial and 40 (26%) were full-thickness tears. Statistical analysis showed a significant association ($P < 0.05$) between CAL band number and the prevalence of a rotator cuff tear. A high proportion of rotator cuff tears were observed in shoulders with two (52%) and three or more CAL bands (56%) compared to single band ligaments (29%). Parametric assessment of the CAL in shoulders with rotator cuff tears showed significantly greater ($P < 0.05$) attachment widths and ratios, thicker ligament bands, and larger cross-sectional areas compared to the control group.

Conclusions: Coracoacromial ligaments with more than a single band have a strong association with rotator cuff tears.

Keywords: acromioclavicular joint; coracoacromial ligament; coracoacromial arch; rotator cuff tears; shoulder impingement syndrome; shoulder joint

Introduction:

Subacromial impingement syndrome is the most common form of shoulder joint impingement, being described as friction of the rotator cuff tendon against the undersurface of the acromion, the coracoacromial ligament (CAL), or, sometimes, the acromioclavicular joint, during elevation of the arm. It is usually seen in patients over 40 years of age, causing anterolateral shoulder pain that is worsened by overhead activities. In advanced cases it may lead to a tear in the rotator cuff tendons causing degenerative disease of the shoulder joint (Neer, 1972; Neer, 1983; Michener et al.,2003). Furthermore, the morphology of the coracoacromial arch and the associated degenerative changes may also lead to subacromial impingement syndrome (Burman,1949; Postacchini, 1989; Burns and Whipple, 1993; Masciocchi et al., 1993; Reichmister et al., 1996).

The CAL plays a significant role in development of subacromial impingement syndrome, especially in shoulders without bony abnormalities or articular deformities in the subacromial space or surrounding structures (Uhthoff et al., 1988; Sarkar et al., 1990; Fremerey et al., 2000). As a result of shoulder impingement, the CAL is strained with its thickness narrowing the subacromial space leading to further friction and impingement (Uhthoff et al., 1988; Gallino et al., 1995). Increases in the size of subacromial structures against an unyielding CAL can lead to degenerative changes in the CAL, such as fibrillation, fatty infiltration, microtears (Uhthoff et al., 1988), and spur formation (Neer, 1972; Cone et al., 1984; Aoki et al., 1986; Tada et al., 1990; Miles, 1996; Prescher, 2000; Mahakkanukrauh and Surin, 2003; Ko et al., 2006). However, it is unclear whether geometric or degenerative changes in the CAL are the result or cause of impingement (Uhthoff et al., 1988; Soslowsky et al., 1994; Fremerey et al., 2000). The coracoacromial ligament is commonly resected sequentially during subacromial decompression surgery to relieve the impingement (Neer, 1972).

Anatomy of Coracoacromial Ligament

The CAL is a strong, triangular ligament with its apex arising from the tip of the acromion posteriorly and its base attaching into the lateral border of the coracoid anteriorly. It is bounded superiorly by deltoid and the acromioclavicular joint and inferiorly by the subacromial bursa (Johnson et al., 2005). The literature shows that CAL morphology is variable (Salter et al., 1987; Rockwood and Lyons, 1993; Soslowsky et al., 1994; Edelson and Luchs, 1995); however, the influence of these variations on subacromial impingement and rotator cuff tears is not fully understood. Hence, this study aimed to determine the association between CAL anatomy and degenerative rotator cuff tears in elderly cadaveric shoulders.

Materials and Methods:

The present study is a prospective cohort study based on the dissection and observation of 172 shoulders from 86 (46 female, 40 male) formalin embalmed European Caucasian cadavers, with a median age at death of 82 years (range 53 to 101 years). The cadavers were donated to the Center for Anatomy and Human Identification (CAHID) at the University of Dundee under the Human Tissue (Scotland) Act 2006. Shoulder joints were carefully inspected and selected for this study, in which shoulders with signs of previous surgery, fracture, pathology, or variation were excluded.

Shoulder dissection started with removal of the skin with an anterosuperior incision, followed by detachment of the proximal and distal attachments of deltoid. The clavicle was then removed at the acromioclavicular joint to give a better view of CAL anatomy. Blunt dissection was then used to remove any fatty tissue to expose the CAL and rotator cuff tendons. Demographic data including sex, age, and shoulder side, were collected. In addition, digital photographs were taken for all specimens as reference records.

The current study involved gross examination and parametric assessment. Gross examination enabled morphological CAL classification and the presence of rotator cuff tears based on the description of previous studies, while parametric assessment evaluated changes in CAL dimensions in relation to the presence of rotator cuff tears.

Gross inspection of the CAL was by two of the authors (Alraddadi and Alashkham) independently and categorized as having one, two or three or more bands. In addition, the rotator cuff tendons were evaluated to determine the presence of rotator cuff tears, which were classified morphologically into no-tear tendon, a bursal surface, and full-thickness tears (Snyder, 2003).

Bursal partial tears have bursal-side fraying fibers, fissures or a bursal-side tear, while a full-thickness tear penetrated the whole thickness of the rotator cuff tendon revealing the humeral head. Specimens with partial articular tears and intratendinous tears were excluded from the study as their aetiology was not the result of bursal degenerative changes (Ozaki et al., 1988; Ogata and Uhthoff, 1990; Ogawa et al., 1996; Ko et al., 2006).

Parametric assessment included seven direct measurements of the CAL taken using digital calipers accurate to 0.01 mm. The measurements taken were: attachment widths, lateral and medial lengths (Fig. 1), thickness at the acromial and coracoid attachment sites and middle of the lateral band (Fig. 2). The cross-sectional area of the CAL was calculated at the middle of the lateral band of the ligament. Attachment ratios of the CAL to the acromion and coracoid processes were also calculated: i.e. CAL attachment widths divided by the length of the acromion and coracoid processes, respectively. Each parameter was analyzed according to the presence of rotator cuff tears.

The reliability and repeatability of the measurements taken were assessed at the beginning of the study before full data collection. The reliability measurements of CAL dimensions were taken by the main observer three times at different times of the day. The repeatability test was carried out by two observers in addition to the main observer using the same digital calipers. The results of both tests showed no significant difference between the measurements ($P > 0.05$). The data were collected and analyzed using IBM SPSS statistical software (version 25), with $P < 0.05$ considered as being statistically significant. The statistical analysis was carried out after consultation with a statistics expert. Statistical tests, including the chi-square test, independent samples t-test, and one-way analysis of variance (ANOVA), were conducted to determine relationships between the data collected.

Results:

Seventeen shoulders were excluded from the study due to damage observed either in the CAL or rotator cuff tendons, leaving 155 shoulders (138 bilateral, 17 unilateral). Gross examination of the CAL showed variation in the number of bands present as follows: 28 (18%) had a single band, 56 (36%) two bands, and 71 (46%) three or more bands. The coracoacromial ligament band number according to sex and side are presented in Table 1. A significant difference in CAL band number was observed between males and females, with females having more two band ligaments (45%) than male (25%) and male having three or more bands (55%) than females (38%) (P = 0.034). No difference in the prevalence of single band ligaments was observed between males (20%) and females (17%): there was also no difference between sides (P = 0.881). Interestingly, more shoulders presented with the same CAL morphology bilaterally (124 (90%)) than did shoulders with different morphologies (14 (10%)).

Gross inspection of the rotator cuff tendons revealed tears in 77 (50%) of specimens, of which 37 (24%) were partial tears and 40 (26%) were full-thickness tears. The prevalence of tears according to sex and side are shown in Table 2. A significantly higher number of tears were observed in females (50 (60%)) than males (27 (38%)). In contrast, males (62%) had more no-tear cuff tendons than females (40%) (P = 0.007). Further analysis showed that both types of tear were more likely to be observed significantly in females compared to males (P = 0.018). In terms of shoulder side, there was no difference in the presence of tears or tear types between the right and left shoulders (P > 0.05). However, when the rotator cuff tears presented, they were seen more frequently bilaterally (54 (39%)) than unilaterally (14 (10%)). Furthermore, more shoulders (40 (29%)) showed the same type of tear than did those with different tear types (14 (10%)).

Specimens with cuff tears were significantly older (P =0.004, 83.87 ± 8.6 years) than those with no-tear rotator cuff tendons (79.56 ± 9.9 years). In terms of the type of tear, those with full-thickness tears (86.15 ± 6.7 years) were significantly older than those with no-tear rotator cuff tendons. However, the age of those with partial tears (81.41 ± 9.8 years) showed no difference from that of those with full-thickness tears or no-tear rotator cuff tendons ($P = 0.001$).

Analysis of the normative data showed a significant association between the band number of the CAL and the rotator cuff tears ($P = 0.042$) (Table 3). Shoulders with two and three or more band ligaments showed significant rotator cuff tears: 29 (52%) and 40 (56%), respectively. A strong association was also seen in shoulders with a single band ligament, which showed more no-tear rotator cuff tendons (71%) than tendons with tears (29%). In contrast, there was no association between the CAL band number and tear type ($P = 0.076$). Moreover, shoulders with more than one CAL band showed significant numbers of rotator cuff tears: 69 (54%) compared to 58 (46%) ($P = 0.014$). Furthermore, according to tear type, specimens with more than a single CAL band showed significant partial and full-thickness tears: 33 (26%) and 36 (28%) ($P = 0.047$).

The means and the associated standard deviations of CAL morphology parameters according to sex and side are presented in Table 4, and according to the rotator cuff tear are shown in Table 5. In specimens with rotator cuff tears, the CAL had wider acromion and coracoid attachments than those without tears ($P < 0.05$). The lateral and medial lengths of the CAL were the same in both types of tear, with CALs in specimens with rotator cuff tears thicker at the acromion and middle of the lateral band than in those without rotator cuff tears ($P > 0.05$, $P < 0.001$, $P = 0.024$). The thickness of the lateral and medial bands at the coracoid attachment did not show any difference between specimens with and without rotator cuff tears ($P > 0.05$). Comparing CAL cross-section area at the midpoint of the lateral band showed a significant difference between those with and without rotator cuff tears ($P = 0.007$). In addition, specimens with rotator cuff tears were characterized by significantly higher acromion and coracoid attachment ratios than shoulders with no-tear rotator cuff tendons ($P < 0.01$).

Comparing CAL morphology parameters in relation to the type of rotator cuff tear revealed similarities between no-tear and torn tendons. Comparing specimens with no-tear tendons and partial tears, CALs in specimens with full-thickness rotator cuff tears had significantly greater values for acromial width and thickness, medial and middle band thickness, and cross-sectional area ($P < 0.05$). Specimens with full-thickness tears also had significantly wider coracoid attachment, thicker lateral band, and higher acromial and coracoid attachment ratios than those with no-tear cuff tendons ($P < 0.05$). However, no difference in CAL morphology was observed between those with no-tear and partial tear tendons, except in the CAL coracoid attachment ratio. Shoulders with partial tears had significantly higher coracoid attachment ratios than those with no-tear cuff tendons ($P = 0.019$).

Discussion:

The current study found a strong association between rotator cuff tears and CAL morphology, with more rotator cuff tears observed in specimens with CALs consisting of two and three or more bands, while specimens with a single band CAL had the lowest number of rotator cuff tears. In contrast, previous studies (Pieper et al., 1997; Kesmezacar et al., 2008) have reported no association between CAL band number or morphology and rotator cuff tears. However, Kesmezacar et al. (2008) highlighted the relationship between rotator cuff tears and CALs with more than one band. Pieper et al. (1997) also assumed that a third band caused further impingement on the rotator cuff tendons.

In relation to the number of CAL bands, Pieper et al. (1997) reported the incidence of rotator cuff tears in 34.4% with one band, 44.6% with two bands, and 27.8% with three bands. Kesmezacar et al. (2008) stated that the incidence of rotator cuff tears depends on the morphology of the CAL ligament: being 39%, 28%, 44%, 0% and 56% with Y-shaped, broad band, quadrangular, V-shaped ligament, and multiple band ligaments, respectively. In contrast, Kesmezacar et al. (2008) did not detect any relationship between CAL morphology and rotator cuff tears, but they observed a significant prevalence of rotator cuff tears in shoulders with CALs composed of more than one band ligament. In comparison to Pieper et al. (1997), the current study detected fewer rotator cuff tears in specimens with one or two band CALs and more tears in specimens with three or more bands. In agreement with Kesmezacar et al. (2008), the current study also observed a lower incidence of rotator cuff tears in specimens with a single band CAL. Moreover, a higher incidence of rotator cuff tears was observed in specimens with CALs composed of more than a single band. Therefore, the current study found a significant prevalence of rotator cuff tears in shoulders with multiband of CALs.

Morphometric assessment of CALs in specimens with rotator cuff tears showed significantly greater attachment widths, thicker ligament bands at the acromion attachment and midpoint of the lateral band, as well as a greater cross-sectional area. Previous studies have reported that larger cross-sectional areas characterize shoulders with rotator cuff tears at the midpoint of the lateral band compared to those without tears (Soslowsky et al., 1994; Fremerey et al., 2000). According to Burns and Whipple (1993), CAL thickening in shoulders with subacromial impingement syndrome and rotator cuff tears may decrease the subacromial space for rotator cuff expansion. Increasing CAL thickness and cross-sectional area may accentuate the degenerative changes of the ligament due to the expanded subacromial structures, as suggested by Uhthoff et al. (1988). In addition, increasing CAL attachment width may lead to increased degenerative changes, as acromial spurs are strongly associated with rotator cuff tears (Neer, 1972; Fealy et al., 2005). The present study, therefore, suggests further investigation to assess the correlation between the CAL parameters and acromial spur size in shoulders with rotator cuff tears.

However, the current study revealed no differences between the length of the lateral and medial CAL bands in relation to rotator cuff tears. A similar result has been observed by Wu et al. (2010, 2012), who reported no difference in CAL length between tear and no-tear groups or between symptomatic and asymptomatic shoulders. In contrast, other studies have reported shorter CAL lateral bands in shoulders with rotator cuff tears (Zuckerman et al., 1992; Soslowsky et al., 1994; Fremerey et al., 2000; Kesmezacar et al., 2008). However, these studies, except that of Zuckerman et al. (1992), had small sample sizes. The current study assumes that CAL shortening, as previously mentioned, implies an increase in the bony contribution to the coracoacromial arch. Ossification of the attachment sites of the CAL should not be taken into account when determining

CAL length. Hence, the current study found no difference in CAL length between shoulders with and without rotator cuff tears.

The current study found no difference in lateral and medial band thickness at the coracoid attachment between shoulders with and without rotator cuff tears. However, differences were apparent when thickness was compared according to tear type. Shoulders with full-thickness tears had thicker lateral and medial bands at the coracoid attachment site than shoulders without tears. Furthermore, the current study found significantly thicker acromial attachments of the CAL in shoulders with rotator cuff tears. Previous studies have reported no difference in medial band dimensions between no-tear and degenerated shoulders (Neer, 1972; Soslowsky et al., 1994; Kesmezacar et al., 2008). Nevertheless, other studies have suggested that pathological changes involve all parts of the CAL (medial and lateral bands) when rotator cuff tears are present (Salter et al., 1987; Zuckerman et al., 1992; Pieper et al., 1997; Fremerey et al., 2000; Fealy et al., 2005). The highest pressure recorded was underneath the acromion, centered at the anterolateral border of the acromion, during active internal rotation and horizontal abduction of the shoulder, producing a bulge in the CAL (Burns and Whipple, 1993; Hyvönen et al., 2003; Wang et al., 2009; Yamamoto et al., 2010). Thus, the CAL is more likely to develop parametric changes at the acromial attachment than the coracoid attachment in shoulders with rotator cuff tears.

The current study also found significant differences in CAL attachment ratios between shoulders with no-tear and torn tendons. Shoulders with rotator cuff tears were characterized by higher attachment ratios to both the acromion and coracoid processes. A significant relationship has been reported between the CAL band number and the attachment site of the ligament to acromion and coracoid processes (Alraddadi et al., 2017). Increasing number of bands is associated with extension of the ligament attachment sites onto the medial side of the acromion and medial end of the coracoid. Hence, the current study found that shoulders with rotator cuff tears had a higher attachment ratio of CAL extending medially at the acromion and coracoid processes.

One limitation of the current study was that the specimens were from aged cadaveric donors. Degenerative rotator cuff tears are the most common type of tear in older individuals, often resulting in chronic impingement and degenerative disorders of the rotator cuff tendons (Woertler, 2009). Nevertheless, the present study found that individuals with rotator cuff tears were older than those without tears. A further limitation was that the dominant hand, medical history, and occupation of the donors were not available, therefore comparisons between these factors was not possible. The current study, however, recommends that future studies include prospective intraoperative or imaging investigations and include younger individuals, to enable the association between CAL morphology and rotator cuff tears to be examined. Finally, the current study findings may help in understating the anatomy of the CAL and its variable attachment sites. Additionally, the parametric changes of the CAL in shoulders with rotator cuff tears may be used as secondary evidence to confirm the tear and determine the ligament release during the subacromial decompression.

Conclusion:

The current study observed that CAL morphology is associated with the incidence of rotator cuff tears. Gross examination showed a significant incidence of rotator cuff tears in relation to the number of CAL bands. The CAL also showed significant differences between specimens with and without rotator cuff tears. Notwithstanding these observations, the cause of this relationship could not be determined. Further studies are therefore recommended to clarify the cause of the relationship between CAL morphology and the incidence of rotator cuff tears.

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Tables:

Table 1: Prevalence of CAL band number according to sex and side

CAL Band Number	N = 155 (%)	Sex		Side	
		Male n = 71(%)	Female n = 84 (%)	Right n = 71 (%)	Left n = 84 (%)
One Band	28 (18)	14 (20)	14 (17)	12 (17)	16 (19)
Two Bands	56 (36)	18 (25)	38 (45) *	25 (35)	31 (37)
Three + Bands	71 (46)	39 (55) *	32 (38)	34 (48)	37 (44)

* P < 0.05

Table 2: Presence of rotator cuff tears according to sex and side

Rotator Cuff Tendon	N = 155 (%)	Sex		Side	
		Male n = 71 (%)	Female n = 84 (%)	Right n = 71 (%)	Left n = 84 (%)
No-Tear	78 (50)	44 (62) *	34 (40)	35 (49)	43 (51)
Tear	77 (55)	27 (38)	50 (60) **	36 (51)	41 (49)
Partial	37 (24)	11 (15)	26 (31) *	14 (20)	23 (27)
Full-Thickness	40 (26)	16 (23)	24 (29) *	22 (31)	18 (22)

* P < 0.050, ** P < 0.010

Table 3: Pearson's chi-squared test to evaluate the association between the CAL band number and rotator cuff tears.

Rotator Cuff Tendon	N = 155 (%)	CAL Band Number		
		One Band n = 28 (%)	Two Bands n = 56 (%)	Three Bands n = 71 (%)
No-Tear	78 (50)	20 (71) *	27 (48)	31 (44)
Tear	77 (55)	8 (29)	29 (52) *	40 (56) *
- **Partial Tear**	37 (24)	4 (14)	11 (20)	22 (31)
- **Full-Thickness Tear**	40 (26)	4 (14)	18 (32)	18 (25)

* P < 0.050

Table 4: Means and associated standard deviation (V) of CAL morphology parameters and the frequency of distribution according to sex and side.

CAL Parameters	Mean ± V (mm) n = 155	Sex		Side	
		Male n = 71	Female n = 84	Right n = 71	Left n = 84
Acromial Width	16.69 ± 4.0	17.78 ± 3.9	15.77 ± 4.0	16.77 ± 4.2	16.62 ± 3.9
Coracoid Width	31.58 ± 8.4	34.33 ± 8.5	29.25 ± 7.7	31.84 ± 8.3	31.36 ± 8.6
Lateral Band Length	38.50 ± 5.7	41.98 ± 5.5	35.55 ± 3.9	38.76 ± 5.9	38.27 ± 5.8
Medial Band Length	33.25 ± 4.5	35.00 ± 4.6	31.76 ± 4.0	33.44 ± 4.9	33.09 ± 4.2
Acromial Thickness	1.99 ± 0.6	2.10 ± 0.7	1.89 ± 0.6	2.04 ± 0.8	1.95 ± 0.5
Middle Thickness	1.07 ± 0.3	1.08 ± 0.3	1.06 ± 0.3	1.09 ± 0.3	1.05 ± 0.2
Lateral Band Thickness at Coracoid	1.3 ± 0.3	1.28 ± 0.3	1.23 ± 0.3	1.33 ± 0.3	1.19 ± 0.3
Medial Band Thickness at Coracoid	0.88 ± 0.4	0.84 ± 0.4	0.91 ± 0.4	0.91 ± 0.4	0.85 ± 0.4
Cross Sectional Area	12.08 ± 4.9	13.15 ± 4.7	11.18 ± 4.9	12.26 ± 5.2	11.93 ± 4.6
Acromion Attachment Ratio (%)	96 ± 26	98 ± 27	94 ± 25	95 ± 25	97 ± 26
Coracoid Attachment Ratio (%)	73 ± 19	73 ± 18	73 ± 19	74 ± 18	73 ± 19

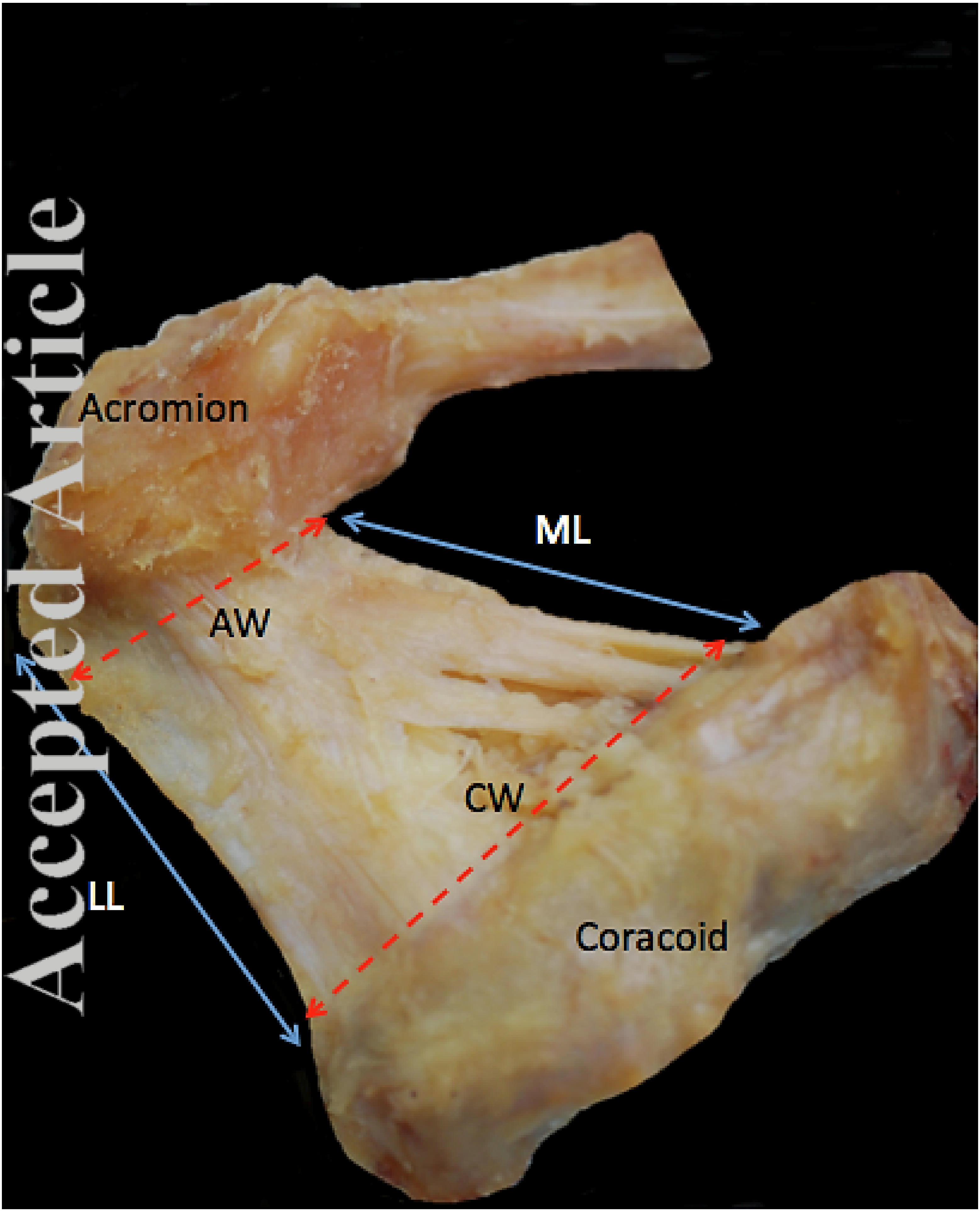
Table 5: Comparison of CAL morphology according to the presence of rotator cuff tears (independent samples t-test) and tear type (one-way ANOVA).

CAL Parameters Mean ± V (mm)	Cuff Tendon			Tear Type		
	No Tear n = 78	Tear n = 77	P	Partial n = 37	Full-thickness n = 40	P
Acromial Width	15.66 ± 4.1	17.73 ± 3.7	0.001	16.56 ± 3.0	18.81 ± 4.1	0.000
Coracoid Width	29.90 ± 9.4	33.27 ± 7.0	0.012	32.78 ± 8.1	33.72 ± 5.8	0.039
Lateral Band Length	39.04 ± 5.8	37.94 ± 5.6	0.233	37.70 ± 5.8	38.18 ± 5.4	0.459
Medial Band Length	33.22 ± 4.5	33.27 ± 4.6	0.942	34.08 ± 4.3	32.53 ± 4.8	0.330
Acromial Thickness	1.78 ± 0.4	2.19 ± 0.8	0.000	1.98 ± 0.7	2.38 ± 0.8	0.000
Middle Thickness	1.02 ± 0.2	1.11 ± 0.3	0.024	1.05 ± 0.2	1.17 ± 0.3	0.010
Lateral Band Thickness at Coracoid	1.21 ± 0.3	1.29 ± 0.3	0.099	1.23 ± 0.3	1.35 ± 0.3	0.081
Medial Band Thickness at Coracoid	0.83 ± 0.4	0.92 ± 0.4	0.208	0.79 ± 0.3	1.03 ± 0.4	0.013
Cross Section Area	11.04 ± 4.1	13.14 ± 5.4	0.007	11.07 ± 3.5	15.04 ± 6.2	0.000
Acromion Attachment Ratio (%)	90 ± 28	101 ± 21	0.008	98 ± 19	104 ± 23	0.016
Coracoid Attachment Ratio (%)	68 ± 21	78 ± 15	0.001	78 ± 18	79 ± 12	0.005

Figure Legends:

Figure 1: Superior view of the coracoacromial arch showing measurement of the width and length of the CAL. Acromial width (AW) was taken between the anterolateral and anteromedial corners of the acromion and included any medial or lateral extension beyond these points. Coracoid width (CW) was taken from the lateral tip of the coracoid process to as far as the ligament extended medially and included any spaces between ligament bands. Lateral length (LL) was taken from the anterolateral corner of the acromion to its insertion on the lateral tip of the posterior aspect of the coracoid process. Medial length (ML) was taken from the anteromedial corner of the acromion to its insertion on the posterior aspect of the coracoid as the ligament passed medially.

Figure. 2: Medial cut view of the coracoacromial arch showing the measurement of thickness (superior–inferior) of the CAL at the acromial attachment (AT), middle of the ligament (MT), and coracoid attachment (CT).



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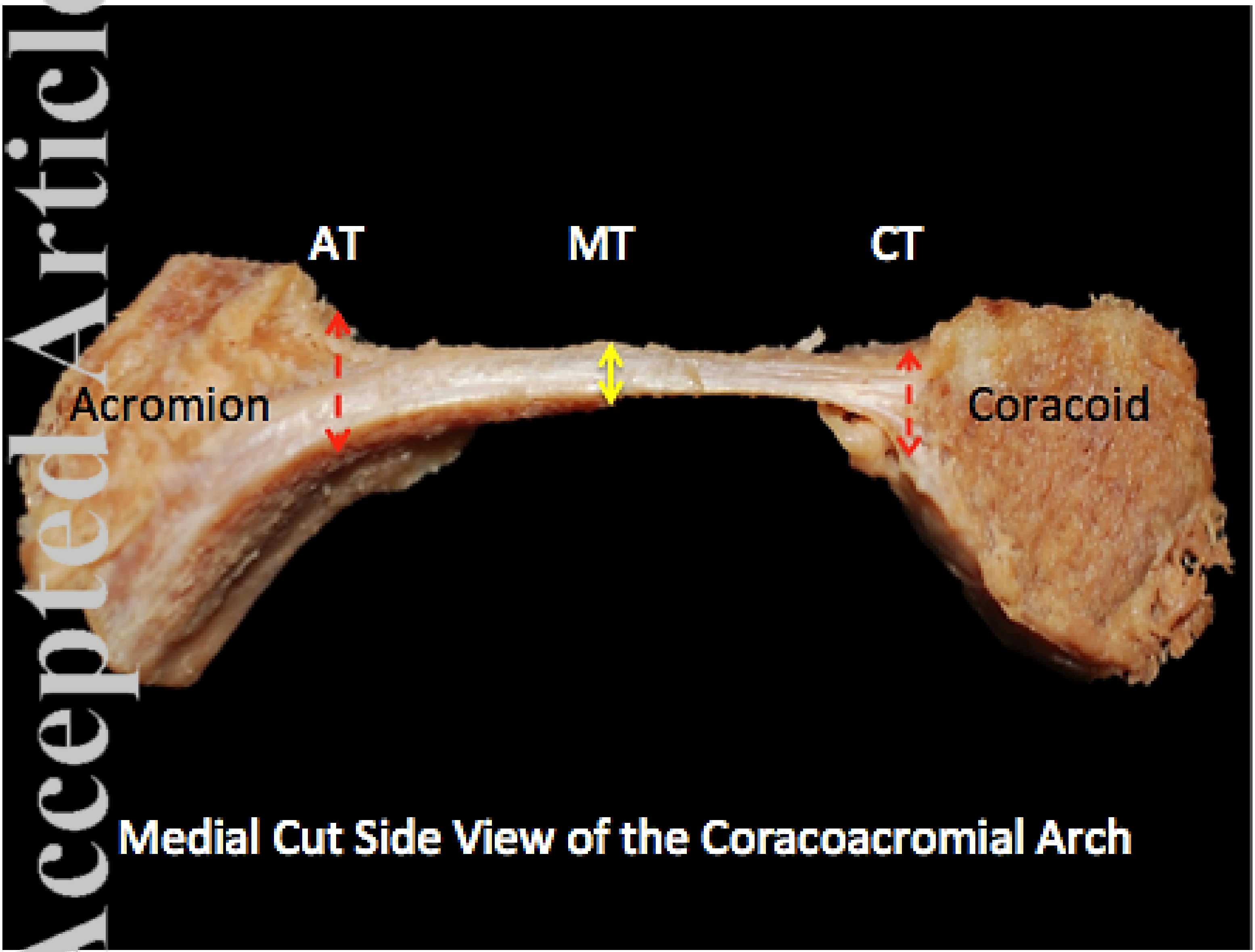

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