The medial coracoclavicular ligament: anatomy, biomechanics, and clinical relevance—a research study

Daniel Moya, MD [a,*], Luciano A. Poitevin, MD [b], Daniel Postan, MD [b], Guillermo A. Azulay, MD [c], Sergio Valente, MD [b], Fernando Giacomelli, Eng [d], Luis A. Mamone, MRI Technologist [c]

[a] Department of Orthopaedic Surgery, Buenos Aires British Hospital, Buenos Aires, Argentina
[b] Department of Anatomy, School of Medicine-University of Buenos Aires, Buenos Aires, Argentina
[c] Department of MRI Technologist, Centro de Diagnóstico Enrique Rossi, Buenos Aires, Argentina
[d] Department of Materials Science, Engineering School-National Technological University, Trenque Lauquen, Argentina

ABSTRACT

Background: The medial coracoclavicular ligament (MCCL), is a structure that shows defined morphologic and histologic features. However, little attention has been paid to the MCCL to date. This study was conducted to (1) determine whether the MCCL is a constant structure, (2) analyze its mechanical properties, and (3) determine its possible role in acromioclavicular (AC) stability.
Methods: AC joints, lateral coracoclavicular ligaments (LCCLs; conoid and trapezoid), and MCCLs were dissected in 30 fresh frozen upper limbs. In 6 of these specimens, we performed a sequential sectioning following the aforementioned order. A 20-N cephalad force was applied to the lateral clavicle at each step, recording the AC distance and coracoclavicular space and their variation. In 6 other specimens, we evaluated the anteroposterior motion of the clavicle following the MCCL section. Biomechanical testing was performed in 8 specimens, comparing the resistance of the MCCL to the LCCLs.
Results: The MCCL in all of the specimens featured a sharp-edge bundle stretching from the coracoid process to the clavicle and subclavius sheath. It showed ligament-like mechanical properties although less tensile resistance than the LCCLs. Once the AC and LCCLs were sectioned, transection of the MCCL determined a significant increase in both cephalad and posterior displacement.
Conclusion: The MCCL is a constant structure with the mechanical behavior of a ligament. It may act as the last container of the coracoclavicular space both in cephalad and posterior directions, precluding additional displacement in the absence of the LCCLs.
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The medial coracoclavicular ligament (MCCL) was first described by Leopoldo Caldani[6,40] in 1802 as the "bicorne ligament." This structure has been classically depicted as a pearlescent yellow bundle of fibers located at the infraclavicular space.[3,4,6-8,10,11,15,21-27,30,33,34,37,40,41] Despite this detailed description, there are few studies on this structure and several of which are contradictory. Moreover, some authors have even stated that they were not able to find the ligament in their dissections.[16]

The physiological and pathophysiological roles of the MCCL have received even less attention than its structural description. It has been described as "an organ having an imprecise function."[33]

Sequential sectioning of the ligaments involved in the acromioclavicular (AC) joint dynamics has been performed to evaluate the joint biomechanics

and instability situations by many authors,[5,12,28,39] but none of these authors have included the MCCL in their studies. This situation is in contrast with the large number of articles published regarding the lateral ligaments (conoid and trapezoid), which have been extensively studied because of their important role in AC stability.[5,9,12,13,17,20,28,32,39]

The purpose of this cadaveric study was to (1) establish the actual prevalence of the MCCL, (2) determine its mechanical properties and (3) evaluate its possible role in AC joint stability. Our hypotheses were the following:

(1) The MCCL has the mechanical properties of a ligament.
(2) It contributes to AC joint stability.

Materials and methods

A cadaveric anatomy study consisting of 3 steps was performed. The first phase consisted of defining the precise anatomy of the ligament. The second involved sequential transections of the ligaments,

* Corresponding author: Daniel Moya, MD, Condarco 4145 (C1419DPK) CABA, Argentina.
E-mail address: drdanielmoya@gmail.com (D. Moya).

followed by the measurement of the AC and coracoclavicular distance both in the cephalad and anteroposterior direction. The third phase consisted of a biomechanical study of the ligament structure. The bodies were bequeathed under the terms of local legal framework and under the directives and rules of the Buenos Aires University School of Medicine.

Dissection technique

Thirty fresh frozen adult male and female upper limbs, either right or left and chosen randomly, were dissected. The skin and subcutaneous tissue of the anterior wall of the axilla were resected. The pectoralis major and deltoid muscles were detached from the clavicle and the acromion. The coracoid process was located as a reference point.

The AC, trapezoid, and conoid ligaments were identified. The pectoralis minor muscle was identified, and the tendon was sectioned 1 cm distal to the coracoid process. The neurovascular fascia behind the pectoralis minor and the MCCL were individualized. The ligament was dissected in situ.

The linear length measurements of the ligament were performed with a caliper accurate to 1/20th of a mm (Fig. 1, *A*). Data were statistically analyzed using the G-stat 2.0 program (G-Stat 2.0 Glaxo Smith Kline, Madrid, Spain), calculating a 95% confidence interval of the measurements obtained.

Sequential sectioning of the ligaments

This experiment was performed in 6 specimens through the cephalic traction of the clavicle using a constant tensile force of 20 N applied 1 cm from its distal edge and measured by a dynamometer (Fig. 1, *B*).

Dissection of the AC joint and the transection of its intrinsic ligaments were first performed; then, a sequential section of the conoid and trapezoid ligaments followed by the MCCL. At each step, a 20-N uniform traction force was applied to the lateral end of the clavicle, the vertical distance between the acromion and the clavicle (from the superior edge of the acromion to the superior edge of the distal clavicle) and the vertical distance between the coracoid and the clavicle (coracoclavicular space) were measured after each cut. We documented the procedure using x-ray images in 1 specimen. We also performed a check test in 2 specimens, measuring the coracoclavicular distance under cephalad traction of the clavicle but reversing the sequential transections.

In 3 other specimens, we performed the same sequential transection protocol: (1) AC ligaments, (2) lateral coracoclavicular ligaments (LCCLs), and (3) MCCL, but in these cases we applied a posterior traction to the clavicle. We also performed a check test in 3 specimens with the following sequence: (1) AC ligaments, (2) MCCL, (3) LCCLs, also applying dorsalward traction at each step.

Tensile strength test

We used the Digimess TC 500 tensile test machine (Digimess, Buenos Aires, Argentina) to assess the strength of the LCCLs and MCCL. The device has 2 clamps (Fig. 2, *A*). The coracoid was attached to the inferior fixed clamp and the distal clavicle to the mobile superior clamp. This last clamp was gradually displaced toward the zenith pulling with a constant speed, determined by the operator. Sternal fixation was performed by means of a Steinmann pin passing through the medial clavicle to a multiperforated iron support. This fixation mimics the sternoclavicular joint and allows the medial end of the clavicle to pivot while the bone is pulled up by the testing machine. Loads were applied with a constant speed of 100 mm/min (Fig. 2, *B*).

Through a connection to a personal computer, we plotted the strength vs. shift in kg/force (kgF) vs. displacement (in mm). The kgF unit is considered equivalent to the Newton unit. Eight trials were conducted: 4 tests included all ligaments, and another 4 tests only used the MCCL after sectioning the conoid and trapezoid ligaments.

Statistical analysis

Statistics data were processed with the G-stat 2.0 and GraphPad Prism 5.0 (GraphPad Software, San Diego, CA, USA) programs. The mean and standard deviation were calculated for the measurement of the AC distance and coracoclavicular space obtained after sequential transections of the ligaments in all the samples after the 3 different procedures (AC, AC+LCCL, and AC+LCCL+MCCL). Differences between the AC+LCCL, and AC+LCCL+MCCL groups were analyzed using the Student *t* test. A 2-tailed *P* value of <.05 was considered to show a significant difference.

Results

Anatomy

Coinciding with Rouvière's classic description,[30] we found that the trapezoid ligament attaches to the most posterior aspect of the medial border of the horizontal part of the coracoid process. The conoid ligament fixes behind the trapezoid to the apex and posterior border of the bend of the coracoid process (between the ascending and the horizontal part). Both origins are contiguous, separated by a bursa.
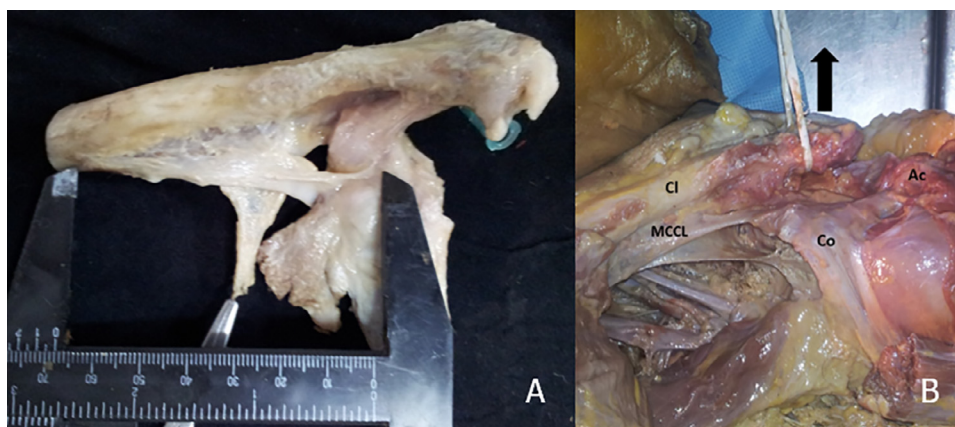
Figure 1 (**A**) Linear length measurement of the ligament. (**B**) Sequential transection of the ligaments under a constant load (left shoulder). *Ac*, acromioclavicular; *Co*, coracoid process; *Cl*, clavicle; *MCCL*, medial coracoclavicular ligament, *black arrow*: cephalic traction.

Figure 2 (**A**) Tensile test machine. (**B**) Tensile strength test.

The MCCL was present in all of the specimens, extending from the coracoid process to the anterior lip of the subclavian channel. Our ligament measurements showed an average length of 59.5 mm. We distinguished a lateral origin at the coracoid process, a body, and a clavicular or medial insertion. We also found 3 fascial expansions.

Coracoid origin

The MCCL originates on the coracoid process ventral to the LCCLs and posterior to the pectoralis minor insertion. It has 2 bundles (Fig. 3, *A*):

1. An anterosuperior bundle originating on the upper surface of the coracoid process, immediately in front of the coracoacromial ligament; and
2. A posteroinferior bundle that is larger than the previous, originating at the medial edge of the coracoid process.

Both bundles form a triangular space with an external base and an internal vertex (Fig. 3, *A*). The pectoralis minor tendon runs through this space to attach to the medial border of the coracoid.

Body

The body of the ligament is formed by the union of the 2 origin bundles. The posterior bundle provides most of the constituent fibers.

Medial insertion

The body runs obliquely upward and inward to attach to the anteroinferior aspect of the clavicle at the level of the junction of the middle third with the medial third. The fibers form an angle of 20° with the bone and fuse with the subclavian muscle sheath (Fig. 3, *B*).

Fascial expansions

1. The medial or costal expansion originates from the body and runs to medial and caudal to attach to the medial end of the first rib. This expansion led to the name "bicorne ligament" in Caldaniś original description. However, it appears more similar to fascia than a ligament. In 20 of 30 cases, this expansion was sickle shaped, with the lateral side being concave. This expansion passes over the subclavian vein, making contact with it and even having adhesions (Fig. 3, *B*).
2. The inferior or pectoral expansion arises from the posterior bundle and the body itself. This expansion has a medial concavity extending toward the back of the pectoralis minor, joining the retropectoralis fascia. Its size and thickness are variable.
3. The superior or clavicular expansion originates from the anterior bundle and the ligament body. We found this expansion in all cases. It runs toward the inferior aspect of the clavicle, where it inserts on the subclavian sheath. This expansion consists of moderately oblique strong fibers running upward and inward, forming an angle between 40° and 60° with the clavicle. The more lateral fibers have the most vertical direction.

Sequential transection of the ligaments

1. Cephalic displacement:

The average AC distance values under cephalic traction of the clavicle were the following:
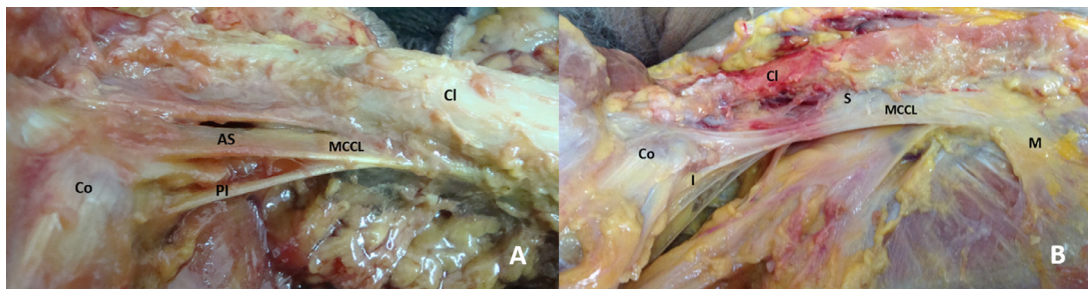
- After the transection of the capsule and AC ligaments: 14.1 mm (Fig. 4, *A*);
- After the transection of the LCCL: 42.5 mm (Fig. 4, *B*); and
- After the transection of the MCCL: 62.6 mm (Fig. 4, *C* and *D*).

The 2-tailed *P* value was <0.0001 comparing the results before and after the transection of the MCCL (Table I).

The coracoclavicular space was also measured under the same circumstances (Table 1) and displayed a final 360% increase in this distance.

The same experiment was documented using a radiographic sequence (Fig. 5). The images clearly show the same changes noticed in the cadavers.

The check test in 2 specimens, under cephalad traction of the clavicle and reversing the sequential transections showed that after resecting the AC ligaments, a moderate upward displacement was evident (from 9.5 coracoclavicular distance to 13.5 mm). Transecting then the MCCL, no further displacement was noticed. Only after transecting the LCCLs was a large superior displacement of the clavicle (43 mm) manifest.

Figure 3 (**A**) Coracoid origin: anterosuperior and posteroinferior bundles (right shoulder). *Co*, coracoid process; *Cl*, clavicle; *MCCL*, medial coracoclavicular ligament; *AS*, anterosuperior bundle; *PI*, posteroinferior bundle. (**B**) Fascial expansions (right shoulder). *M*, medial; *S*, superior, *I*, inferior; *Co*, coracoid process; *Cl*, clavicle; *MCCL*, medial coracoclavicular ligament.
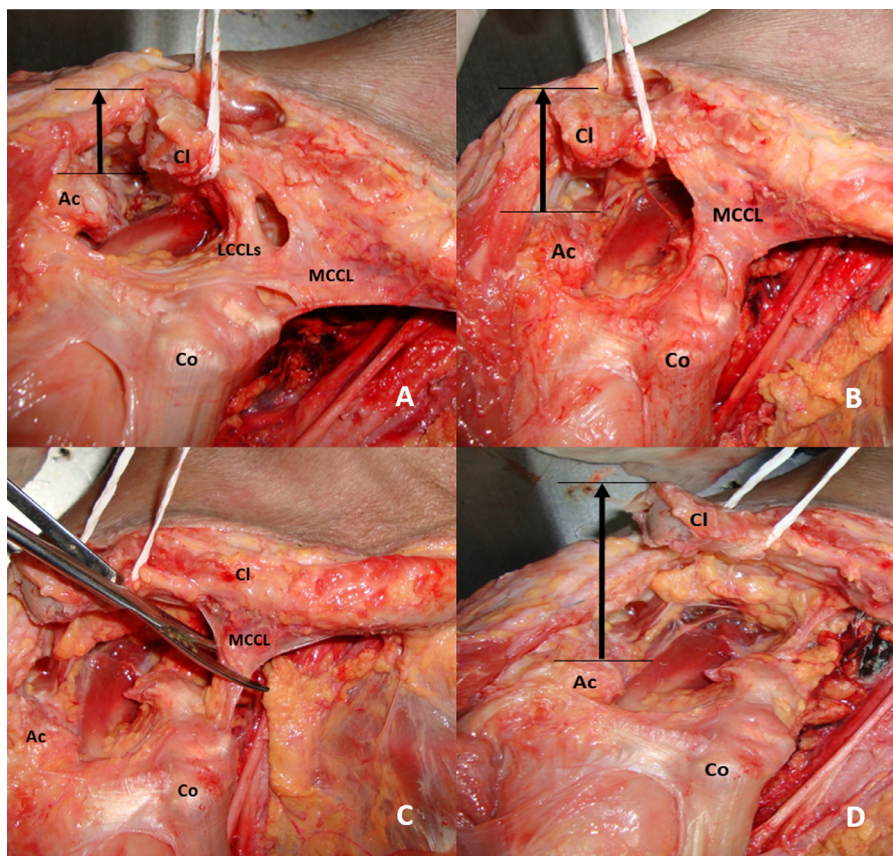
Figure 4 (Right shoulder) (**A**) Transection of the capsule and acromioclavicular ligaments. (**B**) Transection of the lateral coracoclavicular ligaments, showing further increase of the acromioclavicular distance. (**C**) Before and (**D**) after the transection of the medial coracoclavicular ligament (*MCCL*). *Ac*, acromion; *Co*, coracoid process; *Cl*, clavicle; *black arrows*, acromioclavicular distance.

2. Posterior displacement:

In the specimens in which a posterior traction to the clavicle was applied, we found a progressive posterior displacement during the sequential sectioning. Starting with a mean coracoclavicular distance of 9 mm, there was no significant change after sectioning the AC capsule, but there was a marked increase after LCCL sectioning, reaching 20 mm. This displacement increased to 31 mm after sectioning the MCCL. The check test series with the sequence (1) AC ligaments, (2) MCCL, and (3) LCCLs, started from an initial coracoclavicular distance

of 9 mm. Almost no increase in posterior translation of the clavicle was noticed after step 2) (only 1 mm). After step 3), a large posterior displacement was noticed, reaching 35 mm, averaging a total of 289% posterior displacement.

Tensile strength test

The mechanical strength test featured the following breaking sequence pattern:

1. Stress on the superior fascial expansion;
2. The expansion breaks from lateral to medial;

Table I
Measures (in mm) of the acromioclavicular and coracoclavicular spaces after each sequential section

Specimen	Acromioclavicular distance			Coracoclavicular space				
	AC	AC+LCCLs	AC+LCCLs+MCCL	IM	T	AC	AC+LCCLs	AC+LCCLs+MCCL
1	14	41	61	10	13.5	19.7	25	42
2	13	43	63	9	13	18	32	58
3	16	43	64	11	14	19	31	44
4	15	42	62	11	14.5	20.5	28	44.8
5	14	44	60	10	15	19.5	29.6	46
6	13	42	66	9	16	21	32	46
Average	14.1	42.5	62.6	10	14.5	19.5	29.6	46
SD	1.1	1	2.1	0.81	1.11	1.11	2.727	6.324
Increase, %						45	95	196	360

AC, acromioclavicular ligaments; *LCCLs*, lateral coracoclavicular ligaments (trapezoid and conoid); *MCCL*, medial coracoclavicular ligament; *IM*, initial measure; *T*, under traction before sectioning; *SD*, standard deviation.
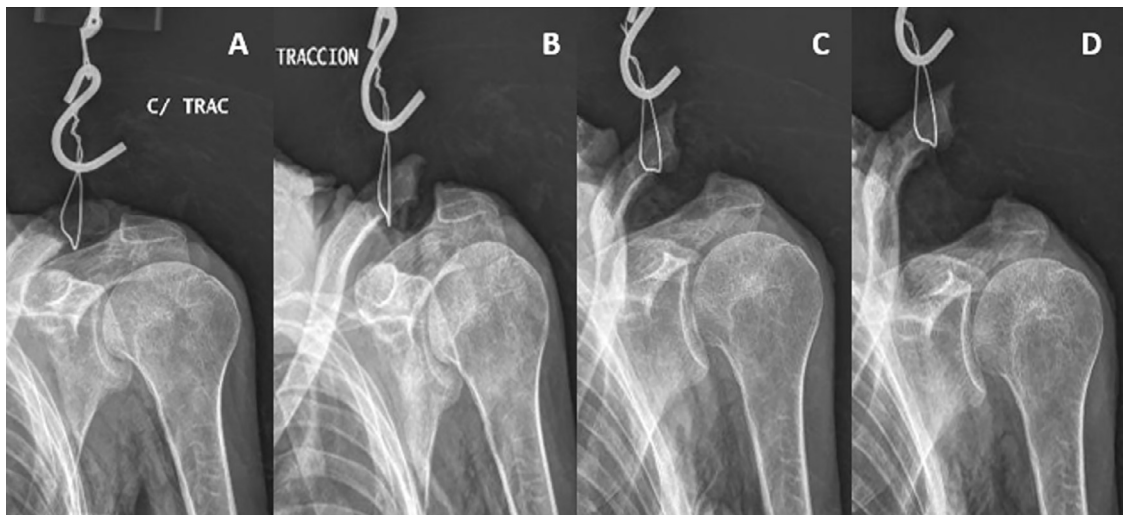
Figure 5 Sequential transection of the ligaments under x-ray control. (**A**) Intact capsule and ligaments under traction. (**B**) After the transection of the capsule and acromioclavicular ligaments. (**C**) Transection of the lateral coracoclavicular ligaments (conoid and trapezoid). (**D**) After transection of the medial coracoclavicular ligaments. Notice the additional increase in acromioclavicular distance.

3. Progressive detachment of the MCCL from lateral to medial, which is a delamination process (release of layer upon layer of a composite material); and
4. Total detachment of the medial end of the MCCL from the clavicle.

The mechanical strength curves of the 4 isolated MCCLs are superimposed in Fig. 6, *A*. For comparison, Fig. 6, *B* shows the curves from 4 specimens that include all of the ligaments (conoid, trapezoid, and MCCL).

- Both sets of curves showed stepped or jagged patterns that were more marked in the case of the complete ligament system where the trapezoid and conoid ligament predominate.
- When the MCCL was analyzed separately, it always featured curves that suggested an elastic deformation (the original dimensions are recovered when releasing the load). After reaching the maximum strength, the ligament broke without presenting plastic deformation. The average of the maximum force in these test conditions was 6.56 kgF.
- Conversely, in most of the curves including the complete ligament system, we observed deformation after reaching the values of maximum force, so we can infer they underwent a plastic or permanent deformation. This means that after removing the acting force, the dimensions did not return to their original predeformation values. The average of the maximum force in these test conditions was 24 kgF.

Discussion

Our results suggest that (1) the MCCL seems to be a constant structure and (2) that it may play a role in AC stability, acting as the last restrainer of the coracoclavicular space in the absence of the LCCLs both in the cephalic and posterior direction. These findings confirm our initial hypothesis. Strikingly, some specific anatomic studies of the coracoid ligaments do not even mention the MCCL.[5,9,12,13,17,28,31,32,36,39] Klassen et al,[16] in their work on the surgical anatomy of the AC and coracoclavicular ligaments, mention the MCCL but say that they were not able to find it in their dissections.

We found the ligament bilaterally and symmetrically in all of our specimens. Our findings are consistent with several other descriptions.[3,4,6-8,10,11,15, 21-27,30,33,34,37,40,41] The MCCL is a true "hand-fan" of fibers, whose apex converges at the coracoid process and whose axis constitutes the body of the ligament. Recently, Azulay et al[2] found the MCCL in all cases in a consecutive series including 7 volunteers studied by magnetic resonance imaging.

According to Vallois and Thomas,[40] Caldani was the first to describe the MCCL in 1802. Because of having 2 bundles like horns, the Italian anatomist named it "bicornuate."[6] We do not agree with
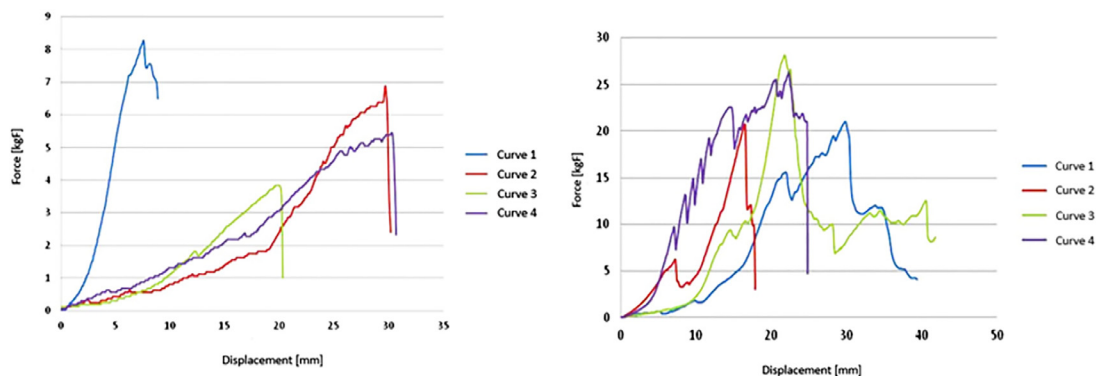
Figure 6 (**A**) Mechanical strength curves of the 4 isolated medial coracoclavicular ligament tests. Each curve corresponds to a different specimen. (**B**) Mechanical strength curves of the 4 specimens including all of the ligaments (conoid, trapezoid, and medial coracoclavicular ligament).

the name "bicornuate" because the medial fascial expansion (found in two-thirds of our specimens) is not a true ligament bundle from a morphologic point of view.

Blandin,[3] Cruveilhier,[8] Henle,[15] Paturet,[21] and Poirier et al[22] alternately described the MCCL as a fibrous formation with a medial insertion on the clavicle merging with the anterior sheath of the subclavius muscle fascia. Several authors[3,4,6,8,10, 15,22-27,33,35, 37,41] consider that the ligament is not dependent on the neighboring structures. Among them, Poitevin et al[27] made a detailed description of the anatomic arrangement of the MCCL. Bourgery,[4] Eisler,[10] and Testut and Latarjet[37] recognized only a sternocostal bundle.

The ligament was referred to using other names, such as the anterior coracoclavicular ligament by Henle,[15] the horizontal coracoclavicular ligament by Soulie as mentioned by Souteyrand-Boulanger,[33] and the anticum coracoclavicular ligament[33]. In our opinion, it should be referred to as the medial coracoclavicular ligament because we have found it steadily extended from the coracoid process to the underside of the clavicle and subclavian sheath. We also intend to differentiate this structure from the LCCLs (trapezoid and conoid).

The MCCL has been described as "an organ having an imprecise function."[33] However, some anatomic and histologic studies define it as a true ligament in relation to the coracoclavicular fascia and with a morphologic pattern that mimics its lateral counterpart.[7,35] Even its location is consistent with its possible ligamentary function.[7]

Our biomechanical findings are consistent with the histologic description by Stimec et al.[35] These authors describe a central area of parallel collagen-fiber bundles and the presence of cartilage at the coracoid attachment. Its small diameter is compensated for by the torsion of its fibers in the middle third, which significantly increases its tensile strength.[35] These histologic features show an adaptation to the compressive and shear forces.[19]

Poitevin[23-25] described the MCCL's possible involvement in thoracic outlet syndrome, and its presence has also been suggested to possibly hinder subcoracoid cerclage techniques[18] and coracoid osteotomy procedures, such as the Latarjet.[9] However, we have not found any reference to its possible role in containing the coracoclavicular space in absence of the LCCLs.

Rockwood's classic description of AC injuries[29] states that the difference between type III and type V AC separations is the degree of increase in the coracoclavicular space. The AC ligaments and LCCLs are torn completely, resulting in dislocation of the AC joint. Compared with the normal shoulder, the coracoclavicular interval may be widened by up to 100% in type III injuries and between 100% and 300% in type V. The author[29] attributes this difference to greater muscle detachment of the deltoid and trapezius. There is no mention of the MCCL as a factor that may influence the degree of displacement.

The sequential sectioning of the ligaments involved in AC dynamics has been done by many authors[5,12,17,28,39] to evaluate the joint biomechanics and instability situations, but none of these studies included the MCCL. All of the authors[1,5, 12,14,17, 28,29,38,39] agree that there is a correlation between the anatomic damage and the degree of instability.

In our work, the sequential sectioning of the AC ligaments, LCCLs, and the MCCL, when maintaining cephalic traction from the clavicle, revealed that the MCCL became tight only after the LCCLs were severed. Finally, sectioning of the MCCL itself produced a significant cephalad displacement of the clavicle. The figures of our sequential sectioning are comparable with Rockwood's description. To our knowledge, we are the first group to assess its contribution to containing the coracoclavicular space.

However, we also found a significant increase in posterior translation of the clavicle when sectioning the MCCL after the LCCLs were sectioned. This could also imply a physiopathologic role to the MCCL in type IV AC separations.

Our biomechanical study showed that the MCCL displays a more elastic behavior than the trapezoid and conoid ligaments, which appear to undergo plastic deformation before their rupture. This may be because the MCCL fibers are reoriented during the deformation process to increase strength and directly break without undergoing plastic deformation.

The staggered break pattern presented by the isolated MCCL specimens that were subject to constant traction (Fig. 7, *A*) was comparable to the specimens of the complete ligament system, although this one was more resistant. This type of break pattern is typical and maintains the resistance of the assembly until a complete break. This behavior confirms our view that the MCCL is a true ligament even though its strength is 27% of the trapezoid and conoid ligaments (Fig. 7, *B*).

The main limitations of this study are the small number of specimens and the difficulty of extrapolating cadaveric findings to clinical outcomes. Several dynamic stabilizers (pectoralis major, pectoralis minor, and deltotrapezial fascia) were removed. These structures may provide as much stability to the AC joint as the MCCL. However, the studies of sequential sections on which the AC separation classifications in use are based were performed in the same way.

Despite these limitations, in our interpretation, the structure first described by Caldani may act as a real ligament, being an AC secondary stabilizer in both cephalad and posterior directions once the LCCLs are injured.

The participation of the MCCL in the vertical and horizontal stability of the AC joint could justify its repair or reconstruction in case of AC type IV and type V separations. However, because it behaves as a secondary stabilizer of the clavicle, we believe repairing the LCCL is more important. In any case, we consider that it would be necessary to confirm the presence of this lesion in cases of marked increase of the coracoclavicular distance in a future clinical study.
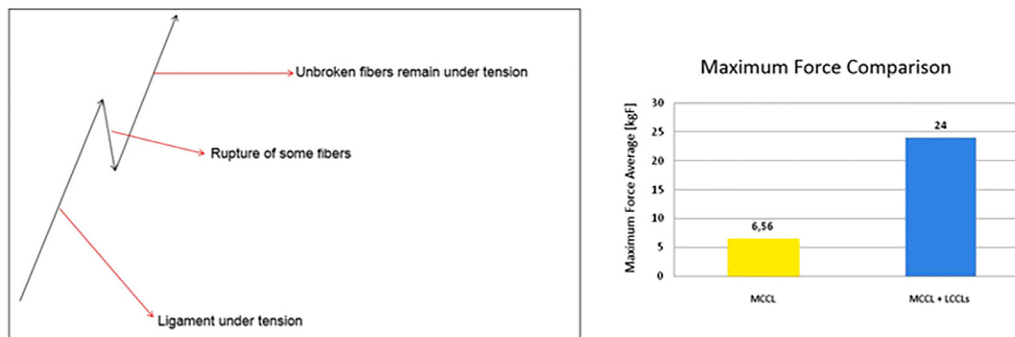
Figure 7 (**A**) Ligament staggered rupture pattern. (**B**) Medial coracoclavicular ligament (*MCCL*) has 27% the strength of the lateral coracoclavicular ligaments (*LCCLs*).

Conclusion

Our findings suggest that the MCCL is a constant structure with mechanical characteristics of a ligament that may act as the last restraint of the coracoclavicular space both in cephalad and posterior direction, precluding an additional displacement in the absence of the LCCLs.

Disclaimer

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