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Anatomical Three-Point Coracoclavicular Ligament Reconstruction: A Surgical Technique

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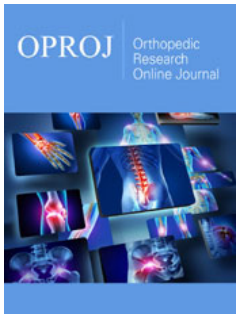
ISSN: 2576-8875



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Submission: September 30, 2022

Published: October 13, 2022

Volume 10 - Issue 1

How to cite this article: Philippe Vial*, Nermine Habib*, Paolo Fornaciari, Mauro Maniglio, Moritz Tannast and Gregoire Thürig. Anatomical Three-Point Coracoclavicular Ligament Reconstruction: A Surgical Technique. Methods of Therapy. Ortho Res Online J. 10(1). OPROJ. 000730. 2022.
DOI: 10.31031/OPROJ.2022.10.000730

Abstract

Introduction: Acromioclavicular joint reconstruction is a frequently performed procedure for high-grade Rockwood injuries. Scientific and commercial interest has led to the development and performance of surgical techniques that more reliably restore horizontal stability to improve patient outcomes. Therefore, we have adopted a modified surgical technique. We present clinical and radiological findings from our experience at a single institution using a three-point anatomical reconstruction of the coracoclavicular ligament. We questioned (i) Quality of reduction, (ii) Complication rate, (iii) Clinical function in terms of ASES, OSS, VAS scores, (iv) Time to return to work.

Materials & Methods: Retrospective analysis of patients with acute ACL dislocation (Rockwood types III-V) from 2015 to 2019. Nineteen patients, with a mean age of 41 years, had a mean clinical and/or radiological follow-up of 20 months. The coracoclavicular distance was measured and compared on preoperative, postoperative, and follow-up radiological images. Clinical assessment was done using the above-mentioned scores. The time required to return to work was recorded.

Results: The difference in coracoclavicular distance was significant between preoperative and postoperative radiographs. Three patients showed secondary displacement of more than 5mm. Clinical evaluation performed at a mean of 20 months showed a median ASES of 98.3, OSS of 48, and VAS of 0. All patients returned to their previous jobs after a mean recovery of 11 weeks.

Conclusion: This study describes an open surgical technique for an anatomic three-point reconstruction of the CC ligaments. All patients resumed their professional activities in a timely manner. It showed promising clinical results and potential benefits. However, long-term studies are needed to show socioeconomic and clinical benefits.

Keyword: Acute acromioclavicular injury; Acromioclavicular dislocation; Coracoclavicular ligaments

Introduction

Acromioclavicular (AC) joint reconstruction is a frequently performed procedure for Rockwood type III or higher according to the classification [1-3]. AC joint reconstruction has been shown to prevent joint deformities and adverse outcomes, including persistent discomfort and secondary AC joint arthritis [4,5].

A multitude of surgical techniques have been described in the treatment of AC joint injuries [6-12]. The most frequently performed procedures are the modified Weaver-Dunn procedure and the anatomic reconstruction of Coracoclavicular (CC) ligaments, which may include a single or double bundle repair technique using an autograft, allograft, or synthetic ligament [13]. Although there are several comparative studies, there is still no clear consensus on which treatment method is preferable [14].

A review by Gowd et al. [3] showed no difference in loss of reduction, complication rate, or the revision rate between open and arthroscopic AC joint reconstruction. Scientific and

commercial interest has led to the development and execution of surgical techniques that more reliably restore horizontal stability to improve patient outcomes.

Anatomy

Reviewing the literature on CC ligament anatomy, we introduce a 3-point suspension technique that can better reproduce and reconstruct the acromioclavicular joint. We present our single-institution experience using our novel three-point anatomical reconstruction of the CC ligament. The objective of this study is to investigate:

A. The quality of reduction

B. The rate of complications

C. Clinical function in terms of the American Shoulder and Elbow Society Score (ASES), the Oxford Shoulder Score (OSS), the Visual Analogue Scale (VAS)

D. The time to return to work.

Indications/contraindications

For this single-center retrospective case series, we reviewed all consecutive patients in our database who underwent AC joint stabilization with the aforementioned technique for the treatment of acute, traumatic AC joint dislocation between January 2015 and April 2019. Indications were: (1) age >18 years, (2) an acute AC dislocation of Rockwood type III-VI, (3) clinical and/or radiological follow-up of at least 1 year. Contraindications were: (1) ipsilateral concomitant fractures of the shoulder or clavicle joint, (2) pathological fractures, (3) pretraumatic functional deficit of the ipsilateral shoulder, (4) subacute injury defined as a delay of surgery up to 3 weeks after injury, and (5) patient refusal to participate in the study.

Ultimately, 19 patients (corresponding to 19 shoulders) were included in the study, 18 males and 1 female, with a mean age of 41 years (18-68).

Technique

The patient is placed in a beach-chair position. Disinfection, draping with 3M™ Ioban, and drawing of bony landmarks is performed. The approach uses a 5cm sagittal saber incision at 2cm medial to the AC joint. Special attention is paid to identifying supraclavicular nerve branches. The delto-trapezial fascia is incised longitudinally, if it has not already been traumatically torn, and two periosteal flaps are dissected. Anterior and posterior subperiosteal dissection of the clavicle is performed. The AC joint can be visualized and, if necessary, cleaned of interposed tissue or hematoma.

Identification of the CC ligament interval that is bluntly widened. Exposure of the coracoid process and identification of the CC impression on the coracoid process. A 3.5mm coracoid tunnel is drilled at a 30° angle from posterior to anterolateral with a 20° medial inclination. The coracoid Endo button™ (Smith+Nephew, Andover, MA) is mounted with two Fiber Tapes® (Arthrex, Naples, FL) and passed through the coracoid tunnel. Three clavicular tunnels are performed with a 2.5mm drill in a triangular fashion: two posterior tunnels (1 medial and 1 lateral) and one anterolateral tunnel. The Posterolateral (PL) and Posteromedial (PM) tunnels are drilled from superior to anteroinferior at a 20° angle, and the Anterolateral (AL) tunnel is created from superior to anteroinferior at a slight 0°-5° angle. The PL tunnel is then enlarged with a 3.5mm drill. One Fiber Tape® is passed from caudal to cranial through the PM and PL tunnels, respectively, and the other one through the PL and AL tunnels from caudal to cranial to be knotted over the clavicle (Figures 1-3).

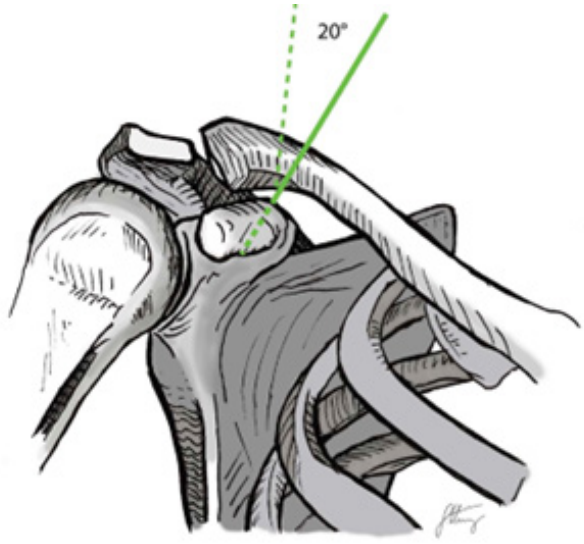

Figure 1: Ventral view of the acromioclavicular joint showing the mediolateral inclination for drilling the coracoid tunnel: (thick green line) angle for drilling.

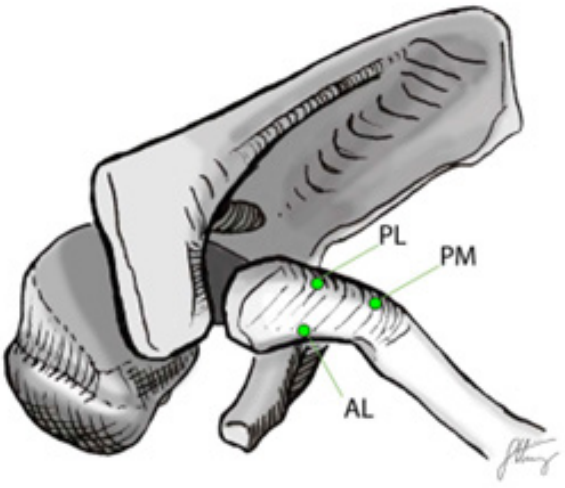

Figure 2: Cranial view of the acromioclavicular joint showing tunnel positioning: (AL) anterolateral tunnel, (PL) posterolateral tunnel, (PM) posteromedial tunnel.

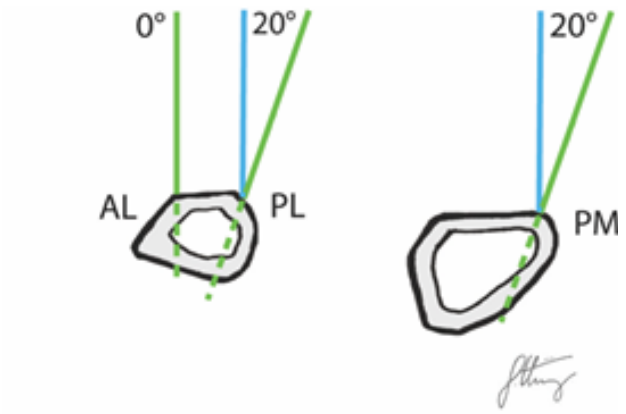

Figure 3: Sagittal cuts of the clavicula showing angle to drilling: (AL) Anterolateral Tunnel, (PL) Posterolateral Tunnel, (PM) Posteromedial Tunnel, (green line) angle for drilling, (blue line) coronal reference line.

Aftercare: The shoulder is immobilized with a sling. Mobilization under the guidance of a physical therapist in the postoperative period is allowed by enabling active abduction/anteversion up to 90° without weight-bearing for 6 weeks. Then, physical therapy is prescribed to regain full range of motion and strengthening. Heavy lifting and overhead activities were limited until 12 weeks postoperatively.

Expected outcomes

Clinical analysis: Clinical follow-up was done at 6 weeks and at 3, 6, and 12 months. Clinical outcomes were documented using the American Shoulder and Elbow Society Score (ASES), the Oxford Shoulder Score (OSS), and the Visual Analogue Scale (VAS) in all patients at their last clinical follow-up. Time to return to work, complications, and revision rates were also determined. Surgical time and complications such as infection or neurovascular injury were also documented.

Radiological analysis: Radiographs of the clavicle (anteroposterior and tangential views) were collected before surgery, in the immediate postoperative period, and at 12-month follow-up. CC distance (CCD) was measured in the tangential views of the preoperative radiographs. The same distance was also measured in the immediate postoperative period and in the final radiographs. The radiographs were analyzed by two examiners (G.T. and N.H.). A loss of reduction was defined as an increase in CCD of more than 5mm on postoperative radiographs. Complications such as bone erosion, fractures, button dislocation, and heterotopic ossification were also documented.

Statistical analysis: Statistical analysis was performed using SPSS version 23.0 software (SPSS, Chicago, Illinois). The Wilcoxon Signed-Ranks test was used for qualitative data analysis. The significance level was set at $p \leq 0.05$.

Ethics: Informed consent was obtained from all patients, and all investigations were conducted in accordance with research ethics principles. The study was approved by the Ethics Cantonal Committee (CER-VD 2019-00092).

Results

Nineteen patients (corresponding to 19 shoulders) were included in the study, 18 males and 1 female, with a mean age of 41 years (18-68). Patients had a mean clinical and/or radiological follow-up of 20 months (10-37) after AC stabilization. The mean time to surgery was 13 days (5-21) (Table 1). Of the 19 patients operated, 7 had a Rockwood III type lesion, 2 had a Rockwood IV type lesion, and 10 had a Rockwood V type lesion (Table 2). The surgery was performed by 4 surgeons (consultant level) with a mean time of 62 minutes.

Table 1: Patient demographics.

Variable	n	Nr. (range)
Patients included	19	
Follow-up from (months)		20 (10-37)
Time to operation (days)		13 (5-21)
Male	18	
Female	1	
Age (years)		41 (18-68)
Surgical time (minutes)		62 (40-119)

Table 2: Acromioclavicular dislocation according to rockwood classification.

(n = 19)	n
Type III	7
Type IV	2
Type V	10

Quality of reduction

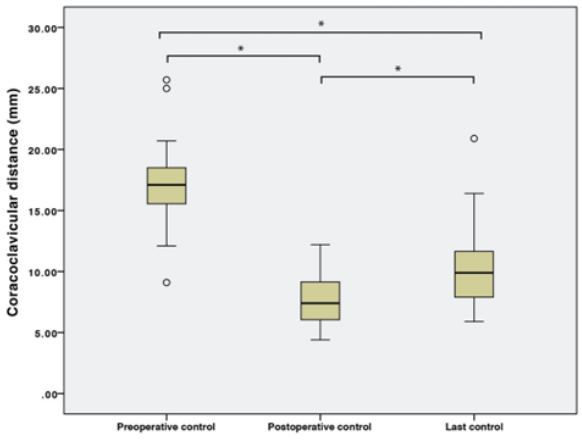

Figure 4: Coracoclavicular distance at preoperative, postoperative and last control; (*) significant, (°) outliers.

The mean preoperative coracoclavicular distance was 17.2mm (±4, range 9.1-25.7) while the postoperative distance was 7.6mm (±2.2, range 4.4-12.2) and on the last one 10.6mm (±3.6, range 5.9-20.9). Because the data was skewed for one of the variables,

a Wilcoxon Signed-Ranks Test was performed, and the output indicated that postoperative scores, Mdn = 7.4, were statistically significantly lower than preoperative scores, Mdn = 17.1, Z = -3.823, p < .000, that the last control scores, Mdn = 9.9, were statistically significantly lower than preoperative scores, Mdn = 17.1, Z = -3.662, p < .000, and that postoperative scores, Mdn = 7.4, were statistically significantly lower than the last control scores; Mdn = 9.9, Z = -3.824, p < .000. (Figure 4).

Complications

Three patients showed a secondary displacement of more than 5mm. Two of which presented with secondary dislocation of the Endo button. One of the cases was diagnosed at 6 weeks after surgery. The patient was asymptomatic and clinical examination showed no instability; therefore, revision surgery was not necessary. The second case presenting with Endo button dislocation was at 5 months postoperatively after additional trauma. Clinical examination showed anteroposterior instability. Revision surgery was performed with reconstruction using a palmaris longus graft. After rehabilitation, the patient returned to work.

The third patient presented with a loss of reduction secondary to bone loss at the clavicular site, without Endo button dislocation. Clinically, the patient showed no signs of instability and resumed all his usual activities, so no further action was taken. Heterotopic ossifications were visualized in 6 patients: all asymptomatic. No cases of infection or neurovascular injuries were reported (Table 3).

Table 3: Complications.

Type	Total	Treatment	
		Surgical	Conservative
Secondary Displacement	3	1	2
- Secondary dislocation of the Endo button	2		1
-Revision surgery (Sink III)		1	
- Clavicular bone erosion	1		
-Conservative treatment (Sink I)			1
Heterotopic Ossifications (Sink I)	6		6

Clinical analysis

The median ASES was 98.3 (44-48; 10th-90th percentile), OSS 48 (44-48; 10th-90th) and VAS 0 (0-3; 10th-90th) (Table 4). The detailed analysis is shown in (Figure 5). The patient with the lowest scores (ASES 63, OSS 36, VAS 5) was the patient who sustained additional trauma mentioned above, requiring revision surgery with a palmaris longus graft and with a total follow-up of 19 months.

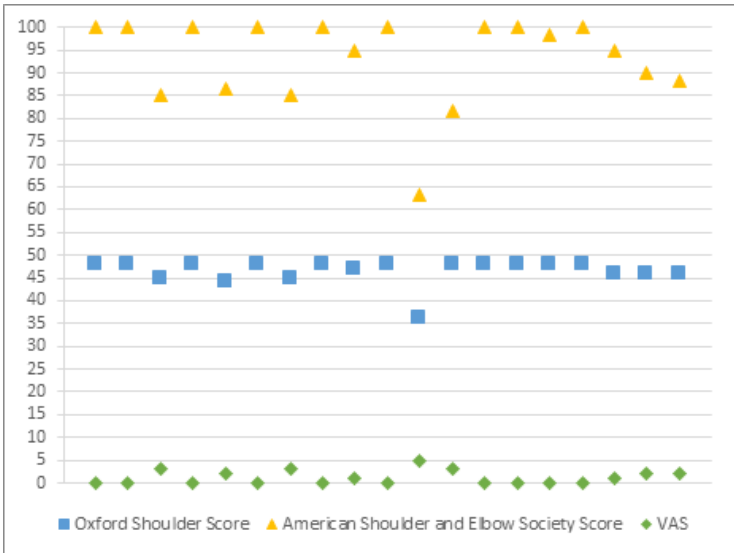

Figure 5: Scores.

Table 4: Scores.

(n = 19)	Median	10th	90th
Oxford Shoulder Score (0-48)	48	44	48
ASES (0-100)	98.33	81.7	100
VAS (0-10)	0	0	3

Return to work

Ten patients were manual workers and nine of them had office jobs. The mean recovery time was 11 weeks (5-20). At 6 weeks, eight patients (41.2%) returned to their previous occupation. At 12 weeks, seven more patients (78.9%) returned to their jobs, and at 20 weeks, the final four patients (100%) returned to work. One of the patients was a retiree, so the return to work was considered when he resumed all his daily activities. It was particularly noted that patients with an office job returned to work at 6 weeks after surgery, whereas manual workers at 12 to 20 weeks after surgery (Figure 6).

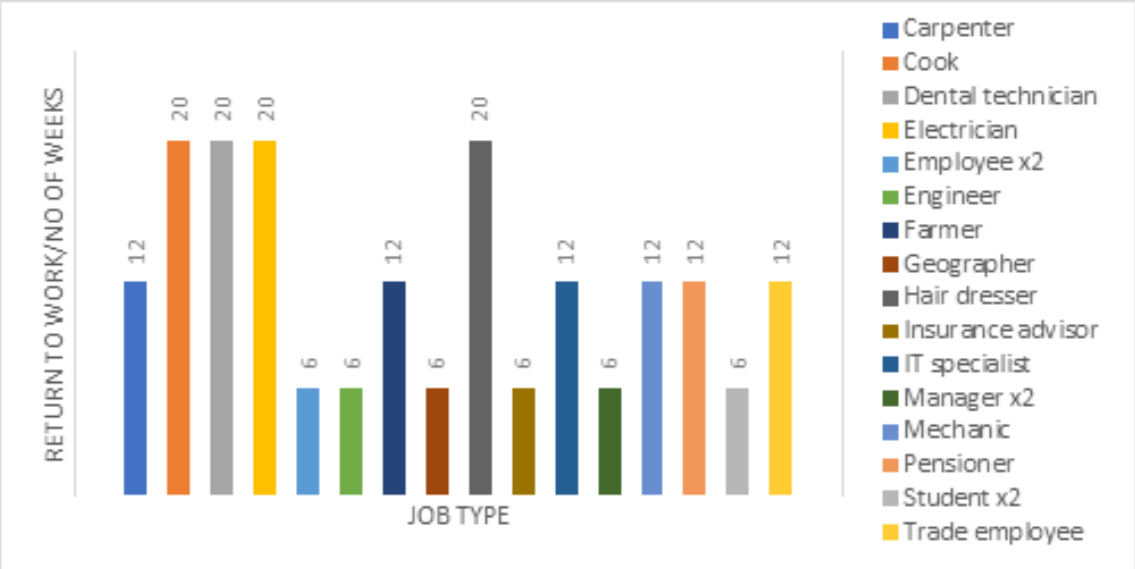

Figure 6: Time after surgery needed to return to employment.

Discussion

In arthroscopic and open CC reconstruction techniques, construct stability depends on a fixation point on the inferior base of the coracoid. Different combinations can be used, either a metal button, or a ring with biological graft or synthetic material around the base of the coracoid [15-18]. Even though the Weaver JK et al. [19] procedure has been considered the gold standard since its description in 1972, in recent years, the general surgical trend has shifted away from non-anatomic reconstructions towards more anatomic reconstructions [20-28]. A systematic review was able to show significantly better results of anatomic versus non-anatomic reconstruction [28]. Postoperative dislocation and last follow-up compared with preoperative dislocation showed a significant reduction in CCD. Although the loss of reduction at last follow-up showed statistical significance, it is still in concordance with the literature (Table 5.1).

Table 5.1: Review of the literature.

Author	Year	Mean Age of Patient (years)	Mean Follow-up (Months)	Technique	n =?	Rockwood Type	Time to Surgery (Days)	CCD Pre-op (mm)	CCD Post-op (mm)	CCD Last Follow up (mm)	Loss of >5mm
Chernchujit B et al. [11]	2006	(23-54)	18	Arthroscopic suture anchors, fiber wires and small titanium plates	13	IV-V	2-12	n.a.	n.a.	n.a.	1
Greiner et al.	2009	35.3±10.2 (15-56)	70 (30-121)	PDS-cerclage reconstruction	50	III-V	0-21	n.a.	n.a.	2.2±2.8 (contralateral comparison)	10 (20%)
Murena et al. [64]	2009	33.3 (20-54)	31 (24-48)	Arthroscopic double flip button	16	III-V	4.3 (2-10)	n.a.	10 (6–16)	10 (6–16) stress view	4 (25%)
Shin et al. [41]	2009	39.7 (18-56)	27.8 (24-40)	2 suture anchors and coracoacromial ligament transfer	29	V	6.8 (1-21)	16.9± 4.3	6.2± 2.6	7.6±3.1	3-5 (10-17%)
Scheibel et al. [43]	2011	38.6 (18-66)	26.5 (20.1-32.8)	Arthroscopic Endo button	28	III & V	7.3 (0-18)	22.1 (14-36)	8.9 (4-19)	13.6 (5-27)	n.a

Lädermann et al.	2011	33.6± 8.9 (18-55)	54 ±2.5 (2-10.5)	AC and CC cerclages (Ethibond 6)	37	III-V	4,8 ±5.1 (0-20)	n.a.	n.a.	2.8±3.1 (-3-10) (contralateral comparison)	9 (24%)
Sandmann et al.	2012	39 (18-71)	32 (24-58)	PDS-cords (2loops CC and AC Suture)	33	III-V	5 (0-9)	19.1 ±4.18	9.0± 3.84	12.2± 3.12	5 (15%)
Kraus et al. [44]	2013	37.7 (18-66)	24	Arthroscopic double tight rope V-shaped	15	V	n.a.	20.5 (14-25)	n.a.	13.9 (5-19)	n.a
		40.9 (21-59)	24	Arthroscopic double tight rope parallel	13	V	n.a.	23.6 (14-36)	n.a.	13.4 (6-27)	n.a
Shin et al. [34]	2015	45.4 11.9 (30-66)	25.6 (24-32)	Single adjustable Loop-length suspensory	18	III-V	6.1 (1-14)	16.1 ±2.7 (11.2-21.0)	7.3± 1.4 (5.1-10.5)	10.5±2.5 (7.7-15.5)	6 (33%)
Katsenis et al.	2015	35.5 (20-71)	42 (36-49)	Open one endo button 2 tunnels	50	IV-V	n.a.	12.8 (9.5-15)	n.a.	9.2 (8.7-10.2)	n.a
Struhl et al. [16]	2015	45.7 (25-55)	72 (27-144)	Double Endo button	9	III-V	13 (4-25)	n.a.	n.a.	7.7±2.9	n.a

Despite attempts to recreate the native anatomy of the CC ligament with reconstruction procedures, loss of reduction is still a major problem [29,30]. In a study by Tsou [31] on CC fixation, the failure rate was 32%. Rush [32] reported a reduction loss of 39% [33]. Cook [33] reported that intraoperative reduction was lost in an average of 80% of patients, while 40% required revision and only 50% had good or excellent results. Shin [34] demonstrated that causes of failure included residual horizontal instability and excessive stress of the suture button on the bone causing osteolysis of the clavicle.

Because long-term radiographic studies with different techniques have shown a high rate of partial loss of reduction ranging from 11% to 53% [32,35-43], a slight over-reduction of 2-3mm at the time of surgery is recommended to achieve anatomic reduction thereafter [43-45]. Three cases were found with a loss of reduction of more than 5mm. Two were asymptomatic and did not need further treatment. The third experienced re-injury 5 months after the primary surgery and needed revision surgery. Regarding horizontal stability, an emerging concept is to address not only vertical instability, but also persistent horizontal instability of the AC joint. Studies have shown that persistent horizontal instability after surgical reconstruction is associated with inferior outcomes, both because of clinical instability [46], and because of pain related to the amount of anteroposterior translation [47].

Although AC ligaments and the surrounding muscles are important for horizontal stability, the CC ligaments also play an important role in providing stability in both planes. Debski et al. [48] demonstrated that in cases of complete AC ligament rupture, the conoid ligament is the main restraint against anterosuperior loading and the trapezoidal ligament is the main restraint against posterior loading. In a Magnetic Resonance Imaging (MRI) study, in addition to the AC joint capsule, the trapezoidal ligament has been shown to limit posterior translation and the conoid ligament to limit anterior translation [49].

As described in anatomical reference texts such as Testut [50] and subsequent clavicle anatomy literature the shape of the footprint on the clavicle of the ligaments is "L", with the anteroexternal ligament, commonly the trapezoid defect developing in the sagittal plane [51-53]. For this reason, the addition of a third tunnel just anterior to the PL tunnel can recreate a condition more similar to the original anatomy and allow for better biomechanics. Several studies have discussed CC ligament reconstruction techniques focusing on clavicular attachments rather than coracoid insertions [18,26]. However, a biomechanical study by Hislop et al. [54] reported that failure occurred more frequently at the clavicle (15/22 [68.2%]) probably because the cortex of the lateral clavicle is weaker than that of the coracoid because the lateral clavicle has a metaphysis composed of cancellous bone. Other drilling techniques such as transacromial-transclavicular carry the risk of fracture of the coracoid or lateral clavicle, or of nonanatomic reconstruction [55] and therefore must be applied with care.

Although double-tunnel techniques for CC fixation were introduced to minimize the loss of reduction of the single-tunnel technique [38,42,56-58] they have been associated with an increased risk of clavicle and coracoid fracture. In the technique described by Rush et al. [32], the incidence of coracoid fractures is 11%. Several studies have suggested smaller drill holes and sufficient bone bridging to prevent this complication [32,38,56,58,59]. Meticulous attention to surgical technique can also help minimize the risk of clavicle fracture, and adequate visualization of the coracoid is

essential [58]. Preoperative measurement of the total length of the clavicle is recommended to place the PM tunnel at a point between 20% and 25% of the total length of the clavicle and the lateral (trapezius) tunnel at a point less than 16% of the total length of the clavicle [38]. This series demonstrates that drilling three small clavicular and one coracoid hole with sufficient bony bridging does not result in an increased risk of fracture.

In this study, clinical outcome was measured using the ASES, the OSS, and the VAS. The ASES is based on patient responses to questions regarding joint pain, instability, and activities of daily living. It has been shown to be a valid score with excellent reliability and responsiveness. One limitation, however, is that higher functioning patients may experience ceiling effects due to the response structure [60]. The second clinical score is the OSS, a score directed at self-assessment of shoulder pain and function, with the advantage of being easy to read, understand, and interpret, and an internal consistency/cross-sectional reliability comparable to that of the DASH and limited by its rather weak validity and usability for research [61]. We also clinically assessed the patients using the VAS which is presumed to produce ratio-level data [62]. We decided to use it to avoid the possible problems caused by the use of noncontinuous, ordinal scales [63] This study shows similar results to those cited in the literature (Table 5.2).

Table 5.2: Review of the literature (2nd part).

Author	Complications	Return Normal Life (Months)	Constant Score (0-100)	ASES (0-100)	VAS (0-10)	SSV (%)	DASH (100-0)	Taft Score (0-12)	ACJI (0-100)	UCLA (2-35)
Chernchujit B et al. [11]	Post-traumatic recurrent deformity	0.5-4	95 (75-100)	-	-	-	-	-	-	-
Greiner et al.	n.a.	n.a.	91.7±8.7 (62-100)	-	-	92±10.7	5±8.8 (0–42)	-	-	-
Murena et al. [64]	n.a.	3.2 (3–4)	97 (82-100)	-	-	-	-	-	-	-
Shin et al. [41]	n.a.	3.1 (2.6-4.3)	96 (88-100)	-	-	-	-	-	-	-
Scheibel et al. [43]	n.a.	n.a.	91.5 (84-100)	-	-	95.1 (85-100)	-	3.8 (3-4)	79.9 (45-100)	-
Lädermann et al.	1 irritation 1 plexus lesion	n.a.	96±7.7 (63-100)	-	0.8±1.5 (0-6)	-	7± 10.8 (0-61)	-	-	-
Sandmann et al.	3 total rerupture 2 reoperated	n.a.	94.3±7.1 (73-100)	94.6±9.7 (64-100)	0.5±0.6	-	3.46±6.6 (0-32)	-	-	-
Kraus et al. [44]	n.a.	n.a.	92.4 (84-100)	-	-	96.2 (85–100)	-	10.5 (7-12)	75.9 (45-100)	-
	n.a.	n.a.	90.5 (84-98)	-	-	93.9 (85-100)	-	10.5 (7-12)	84.5 (64-100)	-
Shin et al. [34]	3 clavicular erosions 1 lat. clavicular fracture 1 clavicular button failure	n.a.	97.5±3.4 (88-100)	-	-	-	-	-	-	-
Katsenis et al.	n.a.	n.a.	93.04 (84-100)	-	-	-	-	-	-	-
Struhl et al. [16]	n.a.	n.a.	98.8±1.1	98.6±1.5	-	-	-	-	-	34.1±1.6

In the literature, not many studies address the issue of return to work as before surgery [41,64]. In a society where resources are finite and surgeries must also be justified in correspondence with a recovery of productive capacity, this parameter seems very relevant. An interesting finding of the present study is the very high overall rate (100%) of early return to work with an average recovery time of less than 12 weeks. This is particularly important for patients in an active population facing surgery for AC dislocation, such as manual workers. One limitation of our study is the small sample size and the fact that it was performed retrospectively. Another limitation

is that radiological controls were performed with conventional radiography leaving a margin of error in the measurements. It is also difficult to compare different clinical scores with those used in a multitude of studies. The ASES has been shown to have a high correlation with Constant-Murley (CS), the University of California Los Angeles (UCLA) and the Simple Shoulder Test (SST) scores. The results obtained with this modified technique showed very good scores that are similar to those reported in the literature (Tables 5.1. & 5.2.). In our opinion, this could be due to the reproduction of a more accurate biomechanics by obtaining an anatomical reconstruction.

Conclusion

The study describes an open surgical technique for an anatomic three-point reconstruction of the CC ligaments. All patients were able to resume their professional activities in a timely manner. It showed promising clinical results and potential benefits. However, long-term studies in a larger population are needed to show socioeconomic and clinical benefits.

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