Anatomic r~~R~~econstruction of the coracoclavicular and acromioclavicular ligaments with semitendinosus tendon graft for the treatment of chronic acromioclavicular joint dislocation provides good clinical and radiological results ~~. A prospective study~~

ha formattato: Tipo di carattere: Grassetto

ABSTRACT

Purpose: To evaluate clinical and radiographic outcomes of anatomical reconstruction of the coracoclavicular and acromioclavicular ligaments with single-strand semitendinosus tendon graft for the treatment of chronic acromioclavicular joint dislocation.

Methods: Patients affected by chronic type III-V acromioclavicular joint dislocations were included. Exclusion criteria were: age under 18 years, concomitant rotator cuff tears, previous surgery to the same shoulder, degenerative changes of the glenohumeral joint, infections, neurologic diseases, patients with a previous history of ligament reconstruction procedures that had required harvesting of the semitendinosus tendon from the ipsilateral or contralateral knee. All patients underwent the same surgical technique and rehabilitation. Primary outcome was the normalized Constant score. Secondary outcomes were: DASH score, radiographic evaluation of loss of reduction and acromioclavicular joint osteoarthritis.

Results: Thirty patients with a mean age of 28.9 ± 8.3 years were included. Mean time to surgery was 12.8 ± 10 months. Mean follow-up was 28.1 ± 2.4 months (range: 24-32). Comparison between pre- and postoperative functional scores showed significant clinical improvement ($p<0.001$). Time to surgery was independently associated with a poorer Constant score ($p < 0.0001$). On radiographs, 4 patients (13.3%) showed asymptomatic partial loss of reduction.

Conclusion: Anatomic reconstruction of coracoclavicular and acromioclavicular ligaments using a semitendinosus tendon graft for the treatment of chronic acromioclavicular joint dislocation provided good clinical and radiological results at minimum-two-year follow-up.

Level of evidence: level III.

Keywords: acromioclavicular, instability, dislocation, coracoclavicular ligament, acromioclavicular ligament, autograft, semitendinosus, reconstruction

INTRODUCTION

Acromioclavicular (AC) joint injuries are common, tending to occur secondary to traumas. They account for a sizeable portion of shoulder injuries [8]. However, since many individuals affected by low-grade injuries, e.g. type I or II according to the Rockwood classification [36], may not seek for medical attention, their true prevalence is unknown. Epidemiological studies showed that most AC joint injuries occur in the third decade of life, and the gender distribution is 5:1 in favor of men [26, 35].

The mechanism of injury leading to AC joint dislocation can be direct or indirect. A direct force on the superior aspect of the acromion process, as can happen subsequently to a fall onto the outer aspect of the shoulder, is the most common scenario [31]. The acromioclavicular capsule-ligamentous structures fail with consecutive loading of the coraco-clavicular (CC) ligaments. According to the Rockwood classification, complete AC joint dislocations, hence grade III to V, are defined as combined AC and CC ligaments disruption, resulting in greater displacement of the clavicle with reference to the acromion [12].

Nonsurgical management is the mainstay of treatment for type I and II injuries, whereas surgery is usually recommended for type IV to VI injuries [14]. The treatment for type III remains instead controversial as no clear treatment algorithm has been established [24].

Because of the distinct functional anatomy of the AC and CC ligaments, several studies provided good results focusing on anatomical surgical techniques that re-create those structures, rather than non-anatomical procedures that aim to improve function and stability regardless of restoration of anatomy of the torn ligaments [49]. Although several anatomic reconstruction techniques are available most of them showed promising results after conducting underpowered studies at short term follow-up [49]. Moreover, no gold standard has been identified yet. In 2014, Saccomanno et al. [37] published a pilot study describing an anatomical reconstruction technique of the AC and CC ligaments using a single-strand autologous

semitendinosus tendon graft for the treatment of type III to V chronic AC joint dislocations. The purpose of the present study was to evaluate the clinical and radiographic results in a larger cohort of patients. The hypothesis of the study was that anatomical reconstruction technique of the AC and CC ligaments using a single-strand autologous semitendinosus tendon graft significantly improves postoperative functional and radiological outcomes.

MATERIAL AND METHODS

A prospective cohort study has been conducted between January 2010 and July 2018. The study was approved by the local Ethic Committee. Each patient signed a written informed consent before entering the study.

Participants

Inclusion criteria were: chronic type III-V AC joint dislocation; persistent pain and discomfort of the affected shoulder with restriction of working and /or sports and/or daily life activities after conservative treatment. AC joint dislocation was considered chronic when at least 2 months from injury occurred. Before surgery, all patients underwent x-rays examination, including antero-posterior and bilateral Zanca views, to assess the type of AC joint dislocation according to the Rockwood classification [36] and a magnetic resonance imaging (MRI) to rule out concomitant rotator cuff pathology and/or degenerative changes of the articular surfaces of the glenohumeral joint.

Exclusion criteria were: age under 18 years, concomitant partial-thickness or full-thickness rotator cuff tears, history of traumatic injuries and/or previous surgery to the same shoulder, degenerative changes of the glenohumeral joint, shoulder infections, and concomitant neurologic diseases. Also,

patients with a previous history of ligament reconstruction procedures that had required harvesting of the semitendinosus tendon from the ipsilateral or contralateral knee were excluded.

Intervention

As previously described in detail [37], AC joint reconstruction was performed by using a single-strand semitendinosus tendon graft passed beneath the coracoid and through two bone tunnels in the clavicle corresponding to the attachment sites of conoid and trapezoid ligament and one tunnel in the acromion through which the lateral end of the graft was looped (from superior to inferior) to re-create the superior and inferior AC ligaments (**Fig. 1**). Initial additional non-biological fixation of CC ligaments was guaranteed by two high strength sutures (one Fiberwire#2 and one Tigerwire#2) which passed through the bone tunnels into the clavicle and around the coracoid together with the graft. The graft was then secured with non-absorbable sutures (**Fig. 2**). Tendon graft was harvested from the ipsilateral knee.

All patients underwent the same postoperative protocol, regardless the use of autograft or allograft. Postoperative protocol as well as timing for return to sport or working activities have been fully described in the previous paper [37].

Outcome measures

All patients underwent clinical and radiographical follow-up at minimum-two-year follow-up.

Primary outcome of the study was the evaluation of global functional status of the operated shoulder by using the Constant-Murley score (CMS) [7]. Secondary outcomes included assessment of disability-related quality of life through the national validated version of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire [33] with the optional modules for working and sports activities (Work-DASK and Sport-DASH, respectively). Radiographic evaluation of loss of reduction of AC joint dislocation, the presence and severity of AC joint osteoarthritis and postoperative complications were also assessed as secondary outcomes.

The CMS is divided into four subscales: pain (15 points), activities of daily living (20 points), range of motion including forward elevation, external rotation, abduction and internal rotation of the shoulder (40 points), and strength. The summary score ranges from 0 (worst result) to 100 (best result). The score was normalized for age and gender, according to normative data [44].

The DASH score is a 30-item self-administered questionnaire concerning the patient's health status. The items explores the difficulties in performing different physical tasks (21 items), the severity of symptoms (5 items), as well as the functional impact on social activities, work and sleep (4 items). The scoring system of the questionnaire is based on a metric scale, ranging from 0 (minimum disability, best result) to 100 points (maximum disability, poorest result). Two 4-item additional modules are available to assess quality of life related to working activities and sports activities.

Radiographic evaluation was performed on antero-posterior (AP) and bilateral Zanca views, consistently with the preoperative radiographic series.

AC joint reduction was graded as follows: “maintained” if no side-to-side difference was seen on the x-rays; “partial loss” if there was a side-to-side difference of less than 100% of the width of the clavicle or “complete loss” if there was evidence of a side-to-side difference of more than 100% of the width of the clavicle [9, 21, 23, 47, 48].

Radiographic findings suggestive of degenerative osteoarthritis included: joint space narrowing, sclerosis of the lateral aspect of the acromion and hypertrophic spurs on the superior and inferior aspects of both the acromial and clavicular sides of the joint [13, 39]. This outcome was dichotomized (yes or no) according to the presence or absence of AC joint OA [27]. Particularly, the Zanca view allowed an unobstructed view of the joint, by eliminating overlap from the scapula and other tissues seen on standard AP radiographs.

CMS and DASH scores were collected at baseline and at follow-up visits by a fellowship-trained shoulder surgeon. Radiographic outcomes were assessed by an independent orthopaedic surgeon expert in shoulder imaging.

Statistical analysis

Sample size was calculated according to the primary outcome measure (CMS) with the G*Power v. 3.1.9.6 statistical power analysis program [ ]. Because minimal clinically important difference (MCID) is not available for patients with AC joint injuries, we arbitrarily considered as reference standard the minimum changes reported for the treatments of rotator cuff tear that range, according to the literature, between 8 and 10 points [11, 22], and accepted a smaller MCID. Therefore, a 7-point change was arbitrarily considered for the MCID and estimate of change was based on mean (± SD) baseline score reported in a previously published pilot study [37]. Therefore, given an average baseline score equal to 58.5 (SD: 7.1) [37], we estimated a follow-up score of 65.5.

Statistical analyses were performed by using IBM SPSS Statistics 25 software (IBM, Armonk, NY, USA). Normality of data was assessed by Shapiro-Wilk test. Descriptive statistics were reported as mean and standard deviation (SD) for normally distributed continuous data, otherwise median and range were used. Categorical data were expressed as frequency and percentage. Pre- and postoperative clinical outcomes were compared with a two-way paired t-test for normally distributed data, otherwise the Wilcoxon signed-rank test was used. Significance level was set at $p < 0.05$.

Multivariate analysis was performed to determine which variables were independently associated with the primary outcome. A linear regression model was applied for the CMS. All predictors were initially included in the multivariate models, and a stepwise backward-elimination approach at a 5% significance level was applied.

RESULTS

Thirty patients with a mean age of 28.9 ± 8.3 years meeting the inclusion criteria were selected for the present study (**Fig. 3**). Time elapsed from injury to surgery was 12.8 ± 10 months in average. Type-III dislocation was the most prevalent. Fourteen patients were involved in sports activities and

Commentato [PA1]: Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175-191.

completed the Sport-DASH optional module. Descriptive statistics of the study population are reported in **Table 1**.

All patients were available at follow-up. The mean duration of follow-up was 28.1 ± 2.4 months (median: 28, range: 24-32).

Comparison between pre- and postoperative CMS and DASH scores showed significant clinical improvement for all the outcomes (**Table 2**).

Multivariate analysis showed that timing was the only variable independently associated with the outcome with a negative correlation with the CMS (B coefficient: -0.429; $p < 0.0001$). The model explained 42.5% of the variance in the CMS.

A partial loss of reduction was observed in four patients (13.3%). However, none of them showed pain, discomfort or limitation in work or sports activities that required surgical revision. No occurrence of AC joint osteoarthritis was noticed in any case. Postoperative complications consisted of one case of infection (3.3%) that healed with oral administration of antibiotics.

DISCUSSION

The most important finding of this study was that anatomical reconstruction of CC and AC ligaments using a semitendinosus tendon autograft provided good clinical and radiological results with a low radiographic recurrence rate of dislocation at mid-term follow-up.

Although dozens of surgical techniques have been proposed in the last decades, none of them has been proved to be superior yet. Therefore, recent systematic reviews on chronic ACJ injuries tried to categorized them into different classes rather than making single comparisons [3, 49]. Borbas et al. [3] included twenty-seven studies, with level of evidence ranging from II to IV. Surgical techniques were divided in three main groups: non-biological fixations, biological reconstructions by using either allograft or autograft, ligament and/or tendon transfers. The authors showed that, among the level-II

studies, AC joint reconstruction with a tendon graft provided superior clinical and radiological results. Similarly, Xarà-Leite et al. [49] included twenty-eight studies. Surgical techniques were categorized in anatomic and non-anatomic reconstructions. Although significant post-operative improvements could be seen in both groups, the authors highlighted that comparative studies support the use of anatomic reconstruction, thus remarking that it should be considered as a preferable option.

The technique used in the present study combined the advantages of a biological enhancement by using a tendon graft with an anatomic reconstruction aiming to provide restoration of both CC and AC ligament complex.

Nowadays, the principles of CC and AC ligaments reconstruction using tendon grafts for chronic AC joint instability are well established. Biomechanical studies clarified the importance of their combined reconstruction in order to address both vertical and horizontal instability [28, 40].

Although most of the "anatomic" reconstructions still address only the vertical component of instability, clinical attention was recently focused also on horizontal instability. After Scheibel et al [38] showed posterior radiographic instability in roughly 43% of patients following arthroscopic CC reconstruction, subsequent studies ascertained that an additional AC stabilization improves clinical outcomes [2, 17]. Recent clinical studies focusing on reconstruction of both CC and AC ligament complex in chronic AC joint injuries described slight modifications to the present technique [5, 20, 29, 43, 46]. Most of them [5, 29, 43, 46] secured the reconstructed CC ligaments by using anchors in the clavicle tunnels, whereas Kibler et al [20] used 5 No. 2 PDS sutures. In the belief that the free tendon graft needs to be protected during the healing and remodeling process by means of temporary non-biological stabilization, the authors of the present paper thought that two high-strength non-absorbable sutures could be strong enough to ensure primary fixation, thus overcoming the need for anchors. This choice potentially reduces costs and hardware-related complications, such as infections, hardware failure and/or need for removal, osteolysis and late clavicle fractures [7, 18, 19, 25, 34, 45, 50].

Certainly, what really differed in the present study compared to previous ones was the reconstruction of the AC ligament complex. From an anatomical standpoint the AC ligament complex is composed of anterior, posterior, superior, and inferior components [41]. Recently, Nakazawa et al [30] divided the complex into 2 parts: superoposterior (SP) and antero-inferior (AI). The SP bundle was consistent and ran obliquely from the anterior part of the acromion to the posterior part of the distal clavicle, whereas the AI bundle was thin and narrow. Subsequently, Morikawa et al [28] found that the superior half of this complex is the most important for both posterior and rotational stability. Therefore, most techniques are basically focused on the reconstruction/reinforcement of the superior or SP AC ligament [5, 20, 29, 43, 46]. On the contrary, the present technique aimed to be as much anatomic as possible by trying to reconstruct both the SP and the AI bundles.

Furthermore, the present paper, consistently with some previous studies [5, 43], debunks the myth of distal clavicle excision (DCE) in the treatment of chronic AC joint dislocation. In this series, none of the patients complained of AC joint pain and no signs of OA of the AC joint were observed at follow-up, even if the DCE was never performed. In support of the present findings, the literature showed higher revision rates associated to reconstruction procedures performed with DCE [15]. As a matter of fact, it's authors' preference not to perform the DCE nor in acute neither in chronic cases if the AC joint reduction can be achieved without much difficulty in order to respect AC joint anatomy and biomechanics as much as possible.

An upcoming issue is surely how to specifically evaluate functional outcomes after an AC joint reconstruction. Some AC joint specific scores, such as the Taft score [42], the acromioclavicular joint instability (ACJI) score [38] and the Nottingham clavicle score [6] are available. However, the ACJI [38] and the Nottingham clavicle [6] scores were not feasible when the present study started, whereas the Taft score [42] was not in widespread usage yet. Therefore, we preferred to rely on the most commonly used ones in order to be consistent with previous studies. Although not specific for the AC joint, the CMS remains the most widely used [49], therefore it was chosen as primary outcome. A MCID was arbitrary set based on metrics available for rotator cuff tears in order to overcome the

issue of a specific AC joint score and to demonstrate that the present technique can reach substantial clinical outcomes. Similarly, in a recent study, Muench et al [29] applied the American Shoulder and Elbow Surgeons (ASES) score minimum changes from rotator cuff tears [10] to AC joint. The ASES score could not be used in the present study because its national version was published later [32] than the beginning of the present study.

An interesting finding of the present study was that timing was the only variable independently associated with the outcome, showing a negative correlation with the CMS. Probably a step backward in the biomechanics is needed to try to give an interpretation to this finding. The AC joint stabilizes the scapula in relation to the clavicle: as the clavicle rotates upward, the scapula rotates downward, and AC joint motion thereby decreases, thus defining the "synchronous scapulo-clavicular motion"[16]. This synchrony is coordinated by CC and AC ligament complex. Therefore, AC joint instability due to a complete loss of ligamentous suspension has disabling consequences, especially in a chronic setting where compensative mechanisms already took hold, resulting in scapular dyskinesia [1, 16]. Gumina et al [16] in a previous study including 34 patients affected by chronic type III dislocation showed that 70.6% of them had scapular dyskinesia. Subsequently, Carbone et al [4] in a series of 24 patients affected by chronic type III dislocation and scapular dyskinesia showed that a tailored rehabilitation protocol could result in positive improvements of shoulder function within 6 weeks. However, the authors also noticed that an extended rehabilitation time in non-respondent patients seemed to be worthless. Recently, Kibler et al. [20] showed a complete resolution of scapular dyskinesia, at rest and with motion, in a series of 15 patients affected by chronic type III to V AC joint dislocation who underwent a biological reconstruction of CC and AC ligaments. However, nor timing to surgery was clearly defined nor a sample size calculation was attempted neither a multivariate analysis to understand which factors influenced the outcome was conducted by Kibler et al [20] , thus probably making a difference with the present study. Although a specific clinical evaluation of scapular dyskinesia was not performed in the present study, it was noticed that mean time elapsed from injury to surgery was about a year,

therefore it's authors' opinion that residual periscapular muscle fatigue and scapular dyskinesia could explain the association with timing and poorer CMS.

Finally, the evaluation of radiographic loss of reduction remains a major challenge. As already highlighted by previous studies [29, 43], the correlation between loss of reduction and clinical outcomes is still unclear. Moreover, a shared definition of the subject is still lacking. In the present series, although four patients out of 30 showed a partial loss of reduction compared to the contralateral side, no impairs in functional recovery could be noticed. Further studies focused on this topic are needed to clarify the issue.

Even though the technique proposed in the current study showed several advantages over previously described non-anatomic techniques and provided promising clinical and radiological results at a mid-term follow up, some limitations of the study should also be taken into account. Although the sample size was calculated based on the primary outcome, making the present findings clinically substantial and consistent with the study design, a lack of a control group still remains a limitation. Moreover, the MCID chosen may be not appropriate for the AC joint. Lastly, AC joint functional scores as well as clinical evaluation of scapular dyskinesia were not taken into account, thus making the results possibly less specific.

The results of the present paper strongly remark the importance of anatomy and biology, even in the chronic setting. Anatomic reconstruction of AC joint by using an autologous tendon graft and an hardware-free technique increases the chance of an healing response and optimizes clinical and radiological results, while minimizing costs and risk of complications.

CONCLUSIONS

Anatomical reconstruction of CC and AC ligaments using a semitendinosus tendon graft for the treatment of AC joint dislocation provided good clinical and radiological results at minimum-two-

year follow-up. The surgical technique used in the present study demonstrated a safe, effective and viable option for surgical management of chronic type III-V AC joint dislocations.

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FIGURE LEGENDS

Fig. 1: A single-strand semitendinosus tendon graft was passed beneath the coracoid and through two bone tunnels in the clavicle corresponding to the attachment sites of conoid and trapezoid ligament (**A**). The lateral end of the graft was passed through a bone tunnel in the acromion and looped from superior to inferior to re-create the superior and inferior AC ligaments (**B**).

Fig. 2: The graft was secured over the clavicle with non-absorbable sutures.

Fig. 3: Flowchart of patients included into the study.