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SHOULDER

Why does minimally invasive coracoclavicular ligament reconstruction using a flip button repair technique fail? An analysis of risk factors and complications

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Abstract
Purpose Aim of the present study was to evaluate the risk factors for the failure of coracoclavicular ligament reconstruction using a flip button repair technique and to analyse complications related to this procedure.
Methods Seventy-one patients (3 female, 68 male) underwent surgical treatment using a flip button repair technique for an acute acromioclavicular joint dislocation. The following factors and its impact on clinical and radiographic outcome were assessed: age at trauma, interval between trauma and surgery, degree of displacement (according to Rockwood's classification), coracoid button position, button migration and post-operative appearance of ossifications.
Results Sixty-three patients were available for follow-up. The overall Constant score was 95.2 points (range 61–100 points) compared to 97 points (range 73–100 points) for the contralateral side ($p = 0.05$). Nine patients (14.3 %) needed surgical revision. Inappropriate positioning of the coracoid bone tunnel with subsequent button dislocation was the most frequently observed mode of failure (6 cases, 9.5 %). Button migration into the clavicle was associated with loss of reduction ($p = 0.02$). The patient's age at the time of trauma had a significant impact on the clinical outcome, whereas younger patients achieved better results ($p = 0.02$). The interval between trauma and surgery did not significantly affect the outcome (n.s.).
Conclusion Good to excellent clinical results can be achieved with the presented surgical technique. The age of the patient at trauma had a significant influence on the functional outcome. Furthermore, placement of the coracoid button centrally under the coracoid base is crucial to prevent failure.
Level of evidence IV.

Keywords Acromioclavicular joint dislocation · Coracoclavicular ligaments · Rockwood's classification · Coracoclavicular ligament augmentation

Introduction

Acromioclavicular (AC) joint separations are a common injury particularly in young and active male patients, with up to 12 % of all shoulder girdle dislocations [4]. Surgical treatment is recommended for high-grade lesions type III–VI according to Rockwood [13]. Many surgical procedures have been described to reconstruct the AC joint, indicating the dilemma of no optimal surgical solution. Aim of most of the procedures is to restore the anatomic relations of the lateral clavicle to the acromion. Whereas Kirschner (K) wire and coracoclavicular (CC) screw or sling fixations have been used in former times, currently minimally invasive and arthroscopically assisted procedures have become more popular [2, 3, 10, 18]. The main advantage of these techniques is the minimally invasive approach that

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does not require direct visualization of the coracoid process with subsequently less post-operative morbidity (e.g. pain, scarring). Furthermore, hardware removal is not required. Until now, little is known about complications related to these newer reconstruction techniques.

Furthermore, little is known about the impact of the interval between trauma and operative treatment on acute AC joint separations. It is believed that augmentation with tendon grafts is required if reduction in the AC joint is not accomplished within 3 weeks. However, there is little evidence to support this.

The aim of the present study was therefore to determine risk factors for failure and analyse complications after minimally invasive AC joint reconstruction (MINAR) in acute dislocations in order to improve the surgical technique and to prevent failure in future cases.

Materials and methods

Between 2007 and 2010, 71 patients (68 male, 3 female) underwent surgical reconstruction of the AC joint because of a dislocation Rockwood type III ($n = 23$), IV ($n = 5$) or type V ($n = 43$). An injury during sports ($n = 30$) and a bicycle accident ($n = 18$) were the most frequent mechanisms of trauma. The mean age of the patients at the time of trauma was 39 years (range 17–80 years). The right AC joint was affected in 42 and the left in 31 cases. The mean interval between trauma and surgery was 8 days (range 0–22 days). Patients with previous trauma to the affected shoulder or concomitant lesions to the ipsilateral extremity were excluded from the study.

Preoperative radiological examination included bilateral anterior–posterior (ap) stress radiographs of the AC joint with a 5-kg load on both forearms and an axillary view of the affected shoulder in order to detect any vertical or horizontal instability. Concomitant lesions such as rotator cuff lesions were excluded by clinical examination and ultrasound. No CT or MRI scan was performed preoperatively.

Rockwood type IV and V lesions were mandatory indications for surgery. In type III lesion, both the conservative and operative options were discussed, and the decision was based on the patient's requirements.

Surgical technique

All patients were treated with the same operative technique, the MINAR, originally described by Wellmann et al. [23].

The operation was performed under general anaesthesia with the patient placed in the modified beach-chair position. An oblique 3-cm skin incision was made from the posterior edge of the lateral clavicle towards the tip of the coracoid process. The deltotrapezoid fascia was opened along its fibre course if not already torn. The superior aspect of the clavicle was exposed. Depending on the proportions of the patient's clavicle, the mid-point of the insertions of the CC ligaments is approximately 3 cm away from the lateral edge of the clavicle. Usually, the conoid tubercle can be palpated at the undersurface of the clavicle and serves as a landmark for the clavicle tunnel positioning. After further blunt preparation, the base of the coracoid process could be palpated. A special C-shaped aiming device was placed from medially under the coracoid process to place a K-wire centrally into its base and to protect the neurovascular structures while drilling.

The lateral aspect of the coracoid should not be exposed in order to preserve the coracoacromial ligament. The position of the K-wire was controlled by intraoperative fluoroscopy prior to overdrilling it with a 4.5-mm drill bit. The K-wire and the aiming device were removed. Two flip buttons (FlippTack®, Karl Storz GmbH, Tuttlingen, Germany) were then assembled with a braided non-biodegradable 1.0-mm suture (Ethibond, Ethicon, Cincinnati, OH, USA) in a lifting block fashion. With the use of a custom-made button pusher, the distal flip button was guided through the coracoid drill hole and then flipped into the horizontal position. Using a suture lasso, the proximal button was then shuttled through a 4.5-mm clavicle drill hole placed centrally into the insertion zone of the CC ligaments. By pulling the free ends of the suture and downward pressure on the clavicle, reduction in the AC joint was achieved. The reconstruction was secure by a surgeon's knot and three square knots. The deltotrapezoid fascia was adapted closely, and skin closure was performed with an intracutaneous suture technique.

The affected arm was immobilized in a 15° arm abduction brace (Ultrasling III, Donjoy, Vista, CA, USA) for 6 weeks post-operatively. However, early pendulum exercises were allowed immediately. Passive mobilization was allowed with abduction and forward flexion restricted to 90° after 3 weeks. After 6 weeks, no further restrictions applied to the range of motion and strengthening exercises were started. Return to non-contact sports was allowed 3 months after surgery.

Post-operative radiographs included an ap view of the affected AC joint without any weight loads and a Velpeau view to document anatomic reconstruction in both the vertical and horizontal plane.

Follow-up examination

At an average follow-up of 39 months (range 8–76 months), patients were re-evaluated clinically and radiographically. Clinical examination included the age- and gender-related Constant score [5], the AC joint

instability score introduced by Scheibel et al. [16] and the TAFT score [17]. Abduction strength was measured with an isometric dynamometer (Isobex TM dynamometer, Medical Device Solutions AG, Burgdorf, Switzerland) in 90° of abduction in the scapular plane on both sides. In addition, the subjective shoulder value was used to assess the patients' subjective outcome.

Radiographic evaluation consisted of bilateral ap stress view with a 5-kg load and axillary views of the affected shoulder. The CC distance was measured on the ap views by drawing a vertical line from the tip of the coracoid process to the undersurface of the clavicle with the use of a picture archiving and communication system (PACS, Fa. Siemens, Munich, Germany) and compared to the distances measured contralaterally.

Heterotopic ossifications were classified as none, minor (some ossicles) and major (CC ligaments almost completely ossified).

The following parameters were assessed on its influence on the clinical outcome and loss of reduction:

- age of the patient at the time of trauma
- interval between trauma and surgery
- degree of displacement (according to the Rockwood classification)
- position of the coracoid button (centrally, medially, laterally, anteriorly)
- position of the clavicular button in relation to the lateral edge of the clavicle
- migration of the clavicular button
- alignment of the buttons (perpendicular, out of alignment)
- heterotopic ossifications

Furthermore, the loss of reduction was correlated with the clinical outcome hypothesizing that loss of reduction leads to inferior clinical outcome.

The study has been reviewed by the institutional review board, and all patients gave their informed consent prior to inclusion in the study.

Statistical analysis

The Mann–Whitney *U* test was used to examine the differences in outcome for the following factors: degree of displacement (Rockwood III vs. V lesion), the appearance of ossifications, button position, button migration and alignment of the buttons. The Wilcoxon test was used to detect significant differences in clinical and radiographic outcome between the affected and the contralateral side. The level of significance was set at 0.05.

The Kruskal–Wallis test was performed to determine the influence of the interval between trauma and surgery on the clinical outcome and on loss of reduction.

A regression analysis was performed to evaluate the effect of the patient's age and the radiographically detected loss of reduction on the clinical outcome.

Statistical analysis was performed with the use of PASW 18.0 (SPSS, Chicago, IL, USA).

Results

Sixty-three of 71 patients were available for a complete follow-up. The remaining eight patients refused to take part in the study for personal reasons. However, they could be reached by phone to acquire information on the status of their shoulder, possible re-dislocations and surgical revision.

The functional results are illustrated in Tables 1 and 2.

Radiographic results

The average CC distance on the bilateral ap stress view at the last follow-up was 11.1 mm (range 8.7–14.1 mm) on the affected side and 9.7 mm (range 8–12.5 mm) on the unaffected side. This difference was statistically significant ($p = 0.009$).

A loss of reduction in more than half of the clavicle thickness was seen in 18 patients (28 %), and five of them showed a complete loss of reduction analogue to a Rockwood V lesion. However, loss of reduction was not associated with a worse outcome (n.s.).

Table 1 Functional results of all 63 patients with an average follow-up of 39 months

Score	Affected shoulder	Unaffected shoulder	*p* value
CS	95.2 (61–100)	97 (73–100)	0.005
ACJI	90.8 (69–100)	92.4 (79–100)	n.s.
TS	10.8 (3–12)		
SSV	90 % (70–100)	100 %	

CS Constant score, *ACJI* Acromioclavicular joint instability score, *TS* TAFT score, *SSV* subjective shoulder value

Table 2 Functional results of 38 patients with a follow-up of at least 2 years

Score	Affected shoulder	Unaffected shoulder	*p* value
CS	91.7 (61–100)	97.1 (73–100)	0.005
ACJI	84.5 (69–100)	89.5 (79–100)	0.005
TS	10.5 (3–12)		
SSV	90 % (70–100)	100 %	

CS Constant score, *ACJI* Acromioclavicular joint instability score, *TS* TAFT score, *SSV* subjective shoulder value

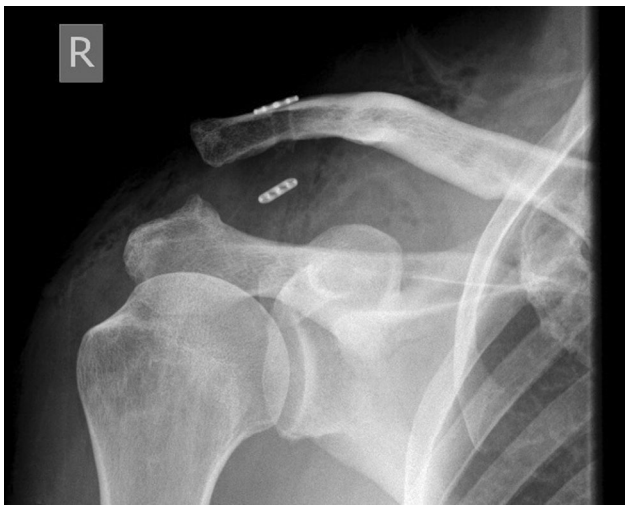

Fig. 1 The coracoid button was placed too far laterally. A marginal fracture of the lateral cortex led to a pull-out of the button with subsequent dislocation and early failure four days after surgery

Signs of static posterior instability could be seen in 11 patients on the axillary view. Again, no impact on the functional outcome could be seen (n.s.).

The mean distance from the lateral edge of the clavicle to the centre of the single clavicular bone tunnel was 25.6 mm, indicating a bone tunnel position slightly laterally from the anatomic insertions.

Heterotopic ossifications of the CC ligaments were detectable in seven patients (11 %) with four of them presenting with minor and three of them with major ossifications. The appearance of ossifications had no influence on the clinical outcome (n.s.).

Surgical revisions

Nine of 63 patients (14.3 %) required surgical revision because of symptomatic recurrent instability ($n = 8$) or a wound infection ($n = 1$). In six cases (9.5 %), an inadequate position of the coracoid bone tunnel too far laterally led to a breakage of the lateral coracoid cortex and subsequent failure of the reconstruction (Figs. 1, 2). However, the integrity of the coracoid was preserved. In two cases, the coracoid bone tunnel was placed too far anteriorly, resulting in symptomatic anterior. In five patients, failure occurred within 10 days post-operatively. These patients had surgical revision using either the same procedure with now correct placement of the bone tunnels. The remaining three patients were revised at a later stage (6, 8 and 14 months after the initial operation) and underwent lateral clavicle resection and augmentation of the CC ligaments using an autologous semitendinosus tendon graft.

A complete coracoid fracture was observed in one case. However, the patient was free of symptoms and did not require surgical revision.

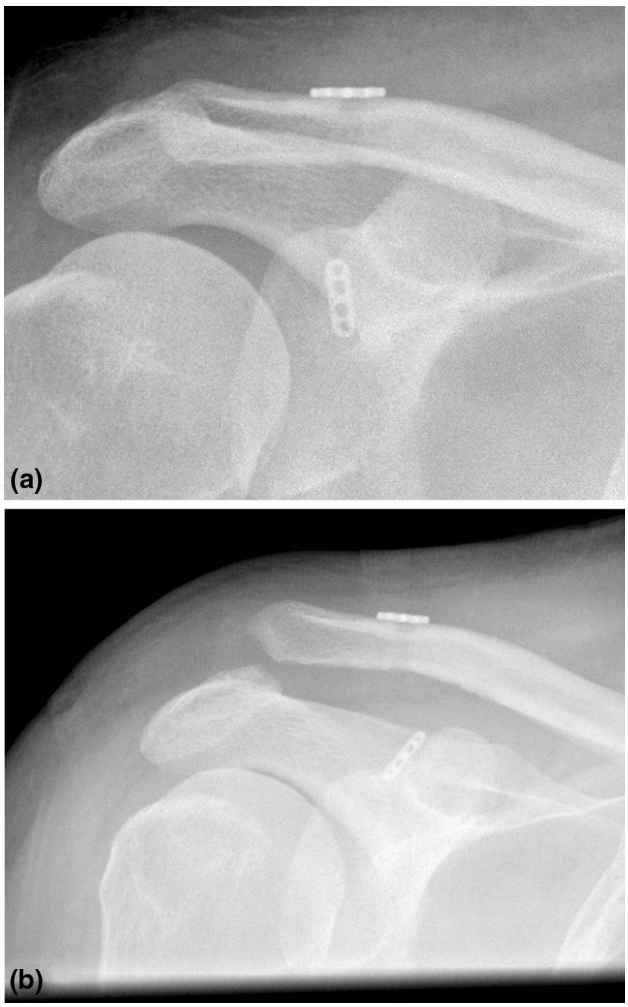

Fig. 2 A 37-year-old patients underwent MINAR. Although reduction in the AC joint could be achieved, inadequate position of the coracoid button is observable on the post-operative X-ray (**a**). Subsequently, the button dislocated and the reconstruction failed 3 months after surgery (**b**)

Factors with significant impact on the outcome

The following factors had a significant impact on the clinical and/or radiographic outcome:

- age of the patient at the time of trauma with younger patients achieving superior outcomes ($p = 0.02$)
- coracoid bone tunnel position: the coracoid bone tunnel was placed laterally in 11 patients, centrally in 40 patients and medially in 12 patients. Of the 11 patients with a lateral coracoid bone tunnel position, seven had a failure of the reconstruction with six of them requiring surgical revision
- migration of the clavicular button (seen in 11 cases, 17.5 %): migration of the flip button into the clavicle bone after perforation of the cortex was associated with a significant loss of reduction ($p = 0.02$; Fig. 3)

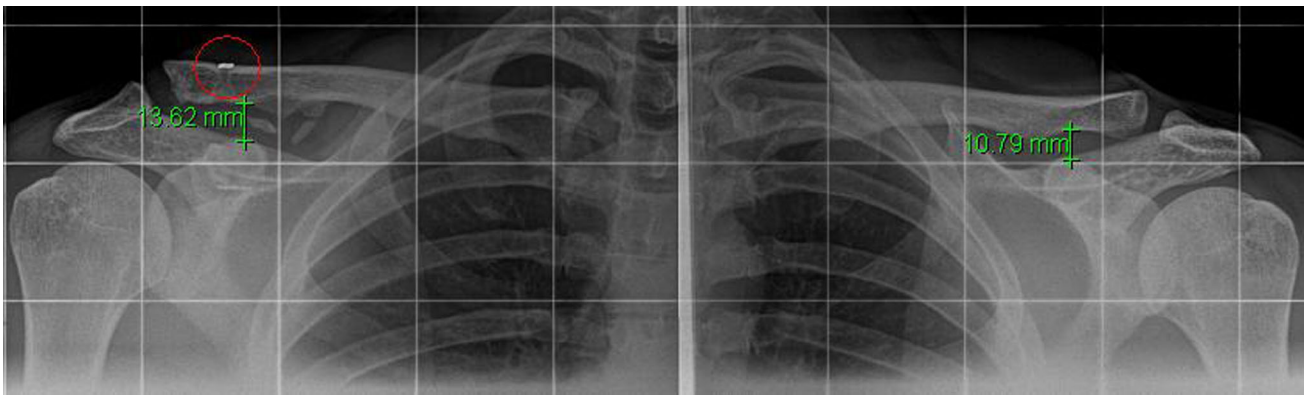

Fig. 3 Migration of the clavicular button with penetration of the superior cortex of the clavicle leads to an increased CC distance compared to the uninjured contralateral side. Note some minor ossifications within the CC ligaments

- button alignment: if clavicular and coracoid buttons were not perpendicular to each other (13 of 63 cases), loss of reduction was higher (11.9 vs. 10.6 mm)

Neither the type of the lesion (Rockwood III vs. IV vs. V) nor the interval between trauma and surgery had an impact on clinical and radiographic results (n.s.). However, with every day of delay between trauma and surgery, the mean Constant score decreases by 0.032 points.

Discussion

The most important finding of the study is that the overall results of this surgical procedure are very satisfying with a mean age- and gender-related Constant score of 95 points on the affected shoulder (91 points after a 2-year follow-up). These results are comparable to those achieved with similar surgical techniques [11, 16, 18, 19]. The principle of this procedure is to approximate the stubs of the torn CC ligaments and preserve the reduction in the AC joint until ligaments have healed. Although this technique is more anatomic than others widely used such as CC slings, hook plates or the Weaver–Dunn procedure, it does not strictly respect the anatomic insertions of the conoid and trapezoid ligaments. In the in vitro setting, the use of two sutures with one in the course of each CC ligament restores the anatomy and biomechanical properties of the native ligaments more closely [21]. However, in a biomechanical study by Beitzel et al. [1], the biomechanical properties of a reconstruction using one clavicular and one coracoid tunnel exceeded those of the native CC ligaments. Thus, the proof of the superiority of double-bundle reconstructions with regard to the clinical results and patient's satisfaction has not been shown yet. Scheibel et al. [16] reported on clinical and radiographic results of 28 patients treated with the double ThightRope® device (Fa. Arthrex, Naples, FL, USA) for an acute AC joint dislocation. After a mean follow-up of 26.5 months, patients achieved a Constant score of 91.5 points (range 84–100 points). The final CC distance was 13.6 mm (range 5–27 mm). Both the functional and radiographic results are similar to those reported in the present study (CS 95 points, CC distance 11.1 mm, respectively). Thus, no patient in the study by Scheibel required surgical revision in contrast to nine patients (14.3 %) in the present study. However, the number of patients in the present study is considerably higher (63 vs. 28), and the follow-up period is longer (39 vs. 26.5 months).

To our knowledge, this is the first study that attempts to determine specific factors with an impact on clinical and radiographic results after minimally invasive AC joint repair. Indeed, failure modes and complications of different surgical techniques have been widely described but not assessed systematically so far. The most important finding of the present study is the negative impact of malpositioning of the coracoid bone tunnel on the outcome after MINAR. If the coracoid button is not placed centrally under the coracoid base, failure of the reconstruction is likely to occur. Seven of the 11 patients with the coracoid button placed laterally to the centre of the coracoid base had an early failure of the reconstruction because of button dislocation and required surgical revision. Considering a biomechanical study by Ferreira et al. [8], who found higher peak loads to failure for centre–centre and centre–medial drilling of the coracoid bone tunnel in cortical button reconstructions, these clinical findings must be expected if lateral tunnel malpositioning exists.

Similarly, anterior malpositioning occurred in two patients and led to anterior clavicle subluxation. This condition has been described for coracoid sling procedures [9]. Both lateral malpositioning and anterior malpositioning are due to inadequate use of the C-shaped aiming device. It is crucial to place that device centrally under the coracoid base in order to obtain a central bone tunnel.

Intraoperative fluoroscopy may facilitate this step of the operation. In addition, a slightly longer incision towards the coracoid process would allow direct visualization of its base and could facilitate central bone tunnel placement. Using arthroscopically assisted procedures, coracoid bone tunnel malpositioning may be completely avoided as the position of the tunnel can be directly visualized. However, all complications related to coracoid tunnel and button malpositioning presented in this series occurred during the first 18 months this technique has been used, indicating a steep learning curve for this procedure.

Cook et al. [7] found a significant impact of the clavicular bone tunnel position on the failure rate after CC ligament reconstruction with two clavicular bone tunnels. Given the fact that comparability is limited because of the different surgical techniques (one vs. two clavicular bone tunnels), we could not confirm this in the present study. Rios et al. [12] described a mean distance from the lateral edge of the clavicle to the trapezoid insertion centre of 25.9 mm and of 35 mm to the conoid insertion centre. In the present study, the mean distance from the lateral edge of the clavicle to the centre of the single clavicular bone tunnel was 25.6 mm, indicating a bone tunnel position slightly laterally from the anatomic insertions. However, failures on the clavicular side were not seen. Nonetheless, positioning of the clavicular bone tunnel out of the anatomic insertion centre of the CC ligaments may lead to misalignment of the clavicular and coracoid bone tunnel (seen in 13 of 63 cases). This misalignment may cause a wear in the strands leading to failure of the suture. This assumption is supported by the fact that misalignment of the bone tunnels was associated with an increased loss of reduction compared to those cases in which the bone tunnels were applied perpendicularly to each other.

The discrepancy between the absent correlation between loss of reduction and a worse functional outcome is due to the fact that only those patients, who presented with a loss of reduction equal to a Rockwood V lesion, were clinically symptomatic and required revision. A loss of reduction equal to a Rockwood II–III lesion may have been clinically asymptomatic and was therefore associated with a good functional outcome.

Still, unknown is the impact of the interval between trauma and surgery on the outcome after reconstruction of an acute AC joint dislocation. There are only a few studies that focus on this topic. Weinstein et al. [22] reported on better results in patients treated surgically within 3 weeks after an acute AC joint dislocation. However, a significant difference could only be detected between patients treated within 3 weeks and those who had surgery after 3 months. Similarly, Rolf et al. [14] found better results for patients treated within 10 days by the use of CC sling and additional K-wire transfixation compared to late surgery after 215 days. Von Heideken et al. [20] observed the same differences in two groups of patients treated within 4 weeks and after 4 months, respectively. However, in both studies, two different surgical techniques were applied in the two groups.

In the present study, no significant influence of the interval between trauma and surgery on the clinical and/or radiographic outcome could be detected. Although there was no distinct cut-off, the results of the Constant score decreased by 0.032 points with every day of delay, indicating that early surgery may lead to better results. All operations were performed within 3 weeks. The authors believe that later reconstruction with the same surgical technique is not reasonable as the ligament stubs undergo atrophy over time, making approximation of the stubs and ligament healing less likely. In patients who present with symptomatic AC joint instability that exists longer than 3 weeks, we therefore recommend augmentation of the CC ligaments using an autologous gracilis tendon graft.

Some limitations apply to this study. Although prospective data acquisition (radiographs, post-operative follow-up examinations) was used, the study design was retrospective and the follow-up period was inconsistent. However, results of a subgroup of 38 patients who completed a follow-up of 2 years are presented to overcome this limitation.

Dynamic horizontal instability was not assessed properly with standard axillary views. Only static horizontal instability could be detected reliably. Therefore, the effect of persistent or recurrent dynamic horizontal instability on the clinical follow-up has to remain unclear. Furthermore, the usability of the AC joint instability score in this study is limited as it originally requires an Alexander view instead of an axillary view to evaluate horizontal instability.

A potential strength of the study is the fact that it deals with a consecutive series of patients that were treated with a single surgical procedure. In comparison with similar studies in literature, the number of patient is high and the follow-up period is, despite its inconsistency, quite long [6, 15, 16, 18]. Only one study by Venjakob et al. [19] describes mid- to long-term results of a similar technique with a mean follow-up of 58 months. Furthermore, the outcome measures are validated quite well, making a comparison to other studies on operative treatment of acute AC joint dislocation feasible.

Conclusion

Minimally invasive AC joint reconstruction using a single flip button repair technique may lead to excellent clinical outcomes. Although the CS decreases with every day of delay, an acute AC joint dislocation can be treated safely

with this surgical technique within 3 weeks after trauma. The age of the patient at trauma had a significant influence on the functional outcome. Furthermore, placement of the coracoid button centrally under the coracoid base is crucial to prevent failure.

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Conflict of interest W.P. is a consultant for the Karl Storz Company. The other authors report no conflict of interest.

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