

Arthroscopically assisted stabilization of chronic AC-joint instabilities in GraftRope™ technique with an additive horizontal tendon augmentation

Gunnar Jensen · Jan Christoph Katthagen ·
Laura Alvarado · Helmut Lill · Christine Voigt

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Abstract

Purpose A chronic symptomatic acromioclavicular joint (ACJ) instability is a possible consequence of an acute ACJ separation. Besides vertical instability a horizontal component of the instability is common in high-grade ACJ separation and clinically relevant; especially, in chronic cases. A new technique of horizontal biologic ACJ augmentation with a transacromial gracilis tendon loop as an addition to the arthroscopically assisted stabilization with the GraftRope™ device is described and first clinical and sonographic results are shown.

Hypothesis The results after arthroscopically assisted single bundle reconstruction of the coracoclavicular (CC) ligaments with an additional horizontal tendon augmentation are comparable to the results of other stabilizing techniques in chronic ACJ instabilities.

Methods A consecutive series of 20 patients with chronic symptomatic ACJ instability was stabilized with this new technique. 16 patients were followed-up clinically and sonographically. Patient satisfaction, visual analogue scale (VAS), simple shoulder test (SST), Constant score (CS) and Taft score (TS) were assessed. Bilateral sonographic measurements were performed to evaluate recurrent instabilities. Complications and concomitant glenohumeral injuries were analyzed.

Results Sixteen patients ($n = 2$ female, $n = 14$ male, median age 40 (21–61) years, follow-up rate 84 %) were evaluated median 13 months (range 4–27 months) after indexed operation. 11 patients had a chronic ACJ instability

after Rockwood type III, and 5 patients after Rockwood type V lesion. 6 patients suffered a recurrent symptomatic instability after operative treatment. 10 patients of the group were primary stabilized with the new technique. 15 of 16 patients were satisfied with the result of the operation at the follow-up examination. The VAS was median 4.6 of 10 points (range 1.1–7.4 points). The SST reached 9 points (range 5–12 points). The adjusted CS was median 84 % (range 46–93 %) and TS median 9 points (range 5–12 points). The sonographic measurements showed a significant difference in the CC distance between the unaffected and the affected side (21.7 vs. 24.8 mm, $p = 0.009$). The acromioclavicular distance was median 11 mm (range 7–17 mm) after resection of the lateral clavicle. Concomitant glenohumeral injuries were arthroscopically detected in seven patients. Postoperative complications occurred in one patient (wound infection). In one case, the clavicular washer was removed due to local paresthesia after healing of the graft.

Conclusions The arthroscopically assisted stabilization of chronic ACJ instabilities with the GraftRope™ device and an additive horizontal tendon augmentation technique leads to good short-term results with a supplementary horizontal stabilization.

Keywords Chronic acromioclavicular joint dislocation · Arthroscopically assisted stabilization · GraftRope™ technique · Horizontal stabilization · Tendon graft · Coracoclavicular ligament reconstruction

G. Jensen (✉) · J. C. Katthagen · L. Alvarado · H. Lill · C. Voigt
Department of Trauma and Reconstructive Surgery,
Friederikenstift Hospital Hannover, Humboldtstraße 5,
30169 Hannover, Germany
e-mail: gunnar_jensen@yahoo.de; gunnar.jensen@ddh-gruppe.de

Introduction

Acute acromioclavicular joint (ACJ) separation is one of the most common shoulder girdle injuries. Most ACJ

injuries occur in male, sportly active adults in their 20s or 30s [30]. Low-grade AC-joint injuries (type Rockwood I and II) are treated conservatively [25]. Currently, there is no consensus about surgical or conservative treatment of Rockwood III injuries [5]. Rockwood IV–VI injuries should be stabilized operatively [5]. For surgical treatment, a variety of techniques was described. In addition to conventional techniques [12, 18, 27], more and more arthroscopically assisted ACJ reconstruction techniques were published [6, 36]. Despite all surgical advances and the good biomechanical understanding of the ACJ complex [9, 11] between 15 and 20 % of all patients treated either operatively or non-operatively for complete ACJ separations develop a chronic symptomatic ACJ instability with complaints, such as pain, weakness and shoulder arm discomfort [41].

The aim of any surgical approach to address the instability of the ACJ should be an anatomic reduction and restoration of normal arthrokinetic. In chronic cases, the healing potential of the ruptured acromioclavicular (AC) and coracoclavicular (CC) ligaments is limited, so that a biologic substitute with an allo- or autograft is necessary. DeBernardino et al. [10] described a new arthroscopically assisted ACJ reconstruction technique using the GraftRope™ System (Arthrex Inc., Naples, FL, USA) to replace the ruptured CC ligaments with a soft tissue graft protected by a subcoracoidal button, non-absorbable sutures and a special clavicular washer. First clinical results were promising.

The majority of modern arthroscopically assisted ACJ reconstruction techniques stabilizes predominantly in vertical direction [2, 38]. Although in chronic cases, the ACJ instability is often multidirectional. Hedtmann et al. [20] showed that in chronic cases a horizontal component of instability that is directed posteriorly is disproportionately frequent.

To address this problem, we have added a transacromial gracilis tendon loop as a component of horizontal stabilization to the established GraftRope™ System.

The aim of the present study is to describe and evaluate the newly developed surgical technique and to assess whether a clinical and sonographically successful stabilization of the ACJ can be achieved.

Materials and methods

Study design and patient population

This retrospective study was approved by the local institutional review board, and all patients gave their informed consensus before including in the study.

Between October 2008 and April 2010, a consecutive series of 20 patients with a chronic ACJ instability was surgically treated in our level I trauma center.

Inclusion criteria:

- radiologically confirmed chronic symptomatic (>3 weeks after trauma) high-grade ACJ-instability Rockwood type III to Rockwood type V (with static and/or dynamic horizontal instability);
- primary non-operative or operative treatment of acute injury;
- patients age ≥ 18 years;
- monotrauma;
- willing and able to give informed consensus to participate in the study.

Exclusion criteria:

- acute ACJ separations (<3 weeks after trauma);
- a disease process that would preclude accurate evaluation (e.g. neuromuscular, rheumatic, significant psychiatric or metabolic disorders, amputation).

From October 2008 to April 2010, an arthroscopically assisted advanced biologic ACJ reconstruction with vertical stabilization using the GraftRope™ System (Arthrex Inc., Naples, FL, USA) and an additional horizontal stabilization with a transacromial gracilis tendon loop was performed in 20 patients [3 women and 17 men, median age 40 years (range 21–61 years), $n = 14$ Rockwood III injuries, all of them with relevant horizontal instability, and $n = 6$ Rockwood V injuries].

After a median follow-up of 13 months (range 4–27 months), 16 of the initially 20 patients ($n = 2$ female, $n = 14$ male, median age at the time of surgery 40 years (range 21–61 years) could be examined. One patient was excluded due to ipsilateral forearm amputation, one patient was not available and two refused participation at the follow-up examination (84 % follow-up rate).

Diagnostics

The chronic ACJ separation was diagnosed by patient's history, clinical examination and radiographic evaluation of both shoulders. Primary radiological diagnosis included a true anteroposterior and axial view of the shoulder. Bilateral anteroposterior comparison views with 10 kg loads were performed. Rockwood types III and V injuries were differentiated by the CC distance, which was measured between the superior cortex of the coracoid and the inferior cortex of the clavicle on the anteroposterior stress radiographs. A Rockwood III injury was defined by an up to twofold, a Rockwood V injury by a two- to threefold increase in CC distance [34]. A static horizontal instability was assessed in the axial view, and a dynamic instability was evaluated during the physical examination.

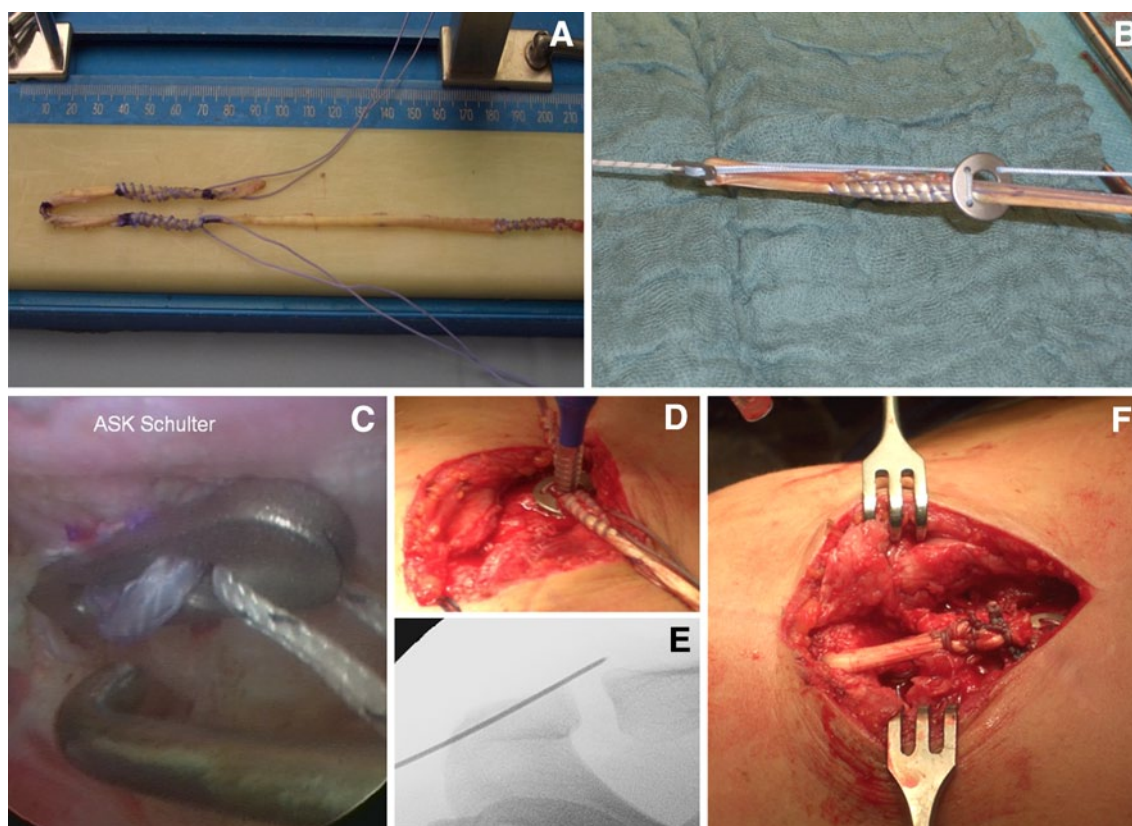


Fig. 1 **a** Gracilis tendon after harvesting and preparation on workstation. The graft should be as long as possible, at least 20 cm. **b** Gracilis tendon after integration into the GraftRope™ system before implantation. **c** Arthroscopic view of the coracoid button after flipping in the desired position at the base of the coracoid base. **d** Insertion of the 5.5 mm Peek Tenodesis screw (Arthrex Inc.,

Naples, FL, USA). **e** The transacromial drill wire is placed under fluoroscopic control via the anterolateral portal from caudal–lateral to medial–cranial in the acromion. **f** The long limb of the gracilis tendon is shuttled through the transacromial drill hole and returned subcutaneously. The free ends are sutured together with a #2 FiberWire™

Surgical technique

Arthroscopically assisted GraftRope® technique was described previously [10]. Shortly, under general anesthesia and in beach chair position, with a single shot antibiotic prophylaxis, the injured shoulder and ipsilateral leg were prepared and draped in sterile fashion. First, the gracilis tendon was harvested from the ipsilateral leg, cleaned, whipstitched at its free ends and prepared as shown (Fig. 1). The length should be at least 20 cm. The arm was fixed in a pneumatic arm-holder to hold the arm in the correct position during the crucial reduction and fixation phase of the operation. The anatomical landmarks were drawn in. Three standard arthroscopic portals: posterior, anteroinferior, anterolateral portal were placed. The posterior portal was the initial optic portal. After diagnostic glenohumeral view and possible therapeutic interventions, the arthroscope was placed in the anterolateral portal, which was positioned in line with the upper subscapularis margin through the supraspinatus tendon (SSP) tendon approximately 1 cm

posterior to the anterior border of the SSP. The coracoid undersurface was prepared and the medial–lateral dimension of the coracoid base was exposed by a radiofrequency device. Then, a transverse skin incision (3–5 cm) was made above the lateral clavicle and the ACJ, followed by a sparing open resection of the lateral clavicle with an oscillating saw (about 5 mm). The Clavicle surface was prepared. The ACJ was reduced with the pneumatic arm holder and temporarily fixed with a K-wire under fluoroscopic control.

It is important to drill with a perfectly reduced ACJ to avoid a windshield wiper phenomenon of the bone channels. An anterior cruciate ligament drill guide with an absorbing plate (Arthrex Inc., Naples, FL, USA) was introduced through the anteroinferior portal and placed very precise under the coracoid's base while the drill sleeve was placed on the clavicular surface over the entry point about 3.5 cm medial to the former AC-joint line for the bone tunnel. Then, over a 2.4 mm pin the transclavicular–transcoracoidal 6-mm tunnel was drilled, and the GraftRope™ device was inserted via a nitinol shuttle-wire under

arthroscopic control. Under fluoroscopic controlled ACJ reduction, the clavicle washer was put in place and the FiberWire™ sutures were knotted. The short and long limb of the graft was pulled tight and a 1.1 mm Nitinol guide wire placed through both cortices of the clavicle. Then, a 5.5-mm Peek-Tenodesis screw (Arthrex Inc., Naples, FL, USA) was inserted. As a next step, a transacromial drill wire (2.4 mm) is placed under fluoroscopic control via the anterolateral portal from caudal–lateral to medial–cranial in the acromion. It should exit centrally in the acromion close to the ACJ line. The pin was drilled over cautiously under avoidance of levering movements with a cannulated 4.0 mm drill bit (potential risk of fracture) and a nitinol shuttle-wire was placed in the transacromial tunnel. The long limb of the gracilis tendon was shuttled through this hole. Now, the long limb of the gracilis tendon was returned from the anterolateral portal towards the ACJ subcutaneously with a straight tissue grasper.

Finally, the long and the short limb of the graft were sutured together with a #2 FiberWire™ suture (Arthrex Inc., Naples, FL, USA). The graft position is perpendicular to the joint. If capsule tissue was present, a reconstruction of the former ACJ capsule, especially of the posterior AC ligament was performed. The deltoidtrapezoid fascia was closed accurately over the graft and clavicle washer. Subcutaneous tissue and skin were closed in standardized fashion. After 2 days of surgery, X-rays (true ap- and Y-view) were taken to control and document the AC-joint reduction and the implant position (Fig. 2).

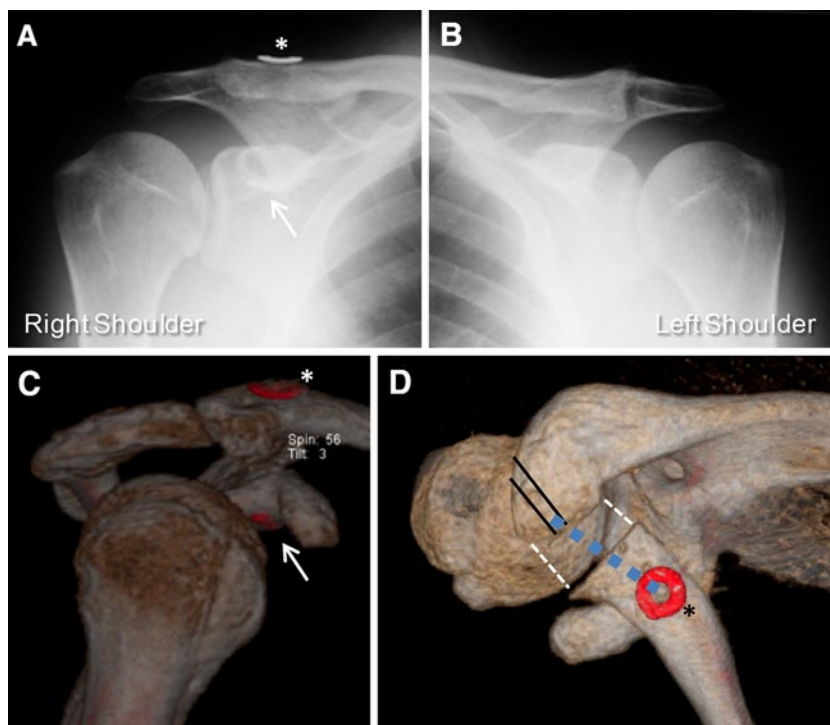
Postoperative management program

After stabilization, shoulders were protected in a sling for 6 weeks. During the first 2 weeks, only passive motions up to a flexion and abduction of 30° were allowed. In the third and fourth week, patients performed active-assistive motions up to a flexion and abduction of 45° and up to 60° in weeks 5 and 6. From the seventh week, a free motion of the shoulder was allowed avoiding the provocation of pain.

Clinical and sonographic evaluation

The follow-up evaluations were performed in a standardized fashion by two examiners (orthopaedic surgeons at the institution), who were not the operating surgeons. The clinical assessment consisted of a structured interview, the evaluation of patient's satisfaction, a 5-part satisfaction scale (1: "excellent" to 5: "poor") for the functional and cosmetic results, the visual analogue scale (VAS), the simple shoulder test (SST) [28] and a detailed physical examination including all elements needed for the assessment of shoulder function according to the Constant score (CS) [8, 23] and the ACJ-specific Taft score (TS) [40]. As a modification, the "radiographic" variables of the TS were evaluated by sonography in this study, because ultrasound is a radiation-free alternative diagnostic tool of the ACJ. In one case, the interview was performed in form of a questionnaire, because the patient was not interested in a follow-up visit. Active shoulder motion was measured.

Fig. 2 **a, b** a.p.-Stress view of both ACJ after stabilization of the right shoulder with the GraftRope™-system and horizontal augmentation in the described technique (*asterisk* clavicle washer, *arrow* coracoids button). **c, d** The 3D-CT reconstruction documents an anatomical vertical and horizontal stabilization and a sparing resection of the lateral clavicle (*asterisk* clavicle washer, *arrow* coracoids button, *black lines* position of transacromial drill tunnel, *white dashed line* ACJ space after resection of lateral clavicle, *blue dotted line* free, extraosseous passage of the horizontal tendon loop)



The range of flexion and of abduction was determined as the angle between the humeral shaft and the midthoracic line. Arm abduction strength was measured as the strength of lateral elevation (90°) in the scapular plane measured in a cuff attachment at the wrist with the Isobex dynamometer (Medical Device Solutions AG, Burgdorf, Switzerland). If 90° of abduction were not achieved, strength was considered to be zero. The age- and gender-adjusted Constant was determined according to Katolik et al. [23]. Complications were assessed and analyzed.

To evaluate the result of the achieved reduction of the ACJ after surgery, we analyzed the postoperative standard anteroposterior radiograph of the operated shoulder. The vertical distance of the inferior border of the acromion and the clavicle was measured. At the follow-up, loss of reduction was analyzed sonographically with the difference of the CC distance in mm from the operated and the contralateral site (Fig. 3). The results of the reduction were categorized into four groups: anatomical: <2 mm; slightly incomplete reduction (after surgery)/slight loss of reduction (at follow-up): 2–4 mm, partially incomplete reduction/partial loss of reduction: 4–8 mm, failed reduction/dislocation: >8 mm [6]. The sonographic examination of the ACJ is a well-described, valid technique and radiation-free imaging [26]. In this study, a standardized bilateral sonographic examination of the AC joint was performed on 15 of 16 patients at the follow-up examination (7.5 MHz linear-array transducer; Sonoline G 20, Siemens Medical Solutions AG, Erlangen, Germany; stand-off medium:

Sonokit (Proxon) Sonogel, Bad Camberg, Germany). First, the width of the ACJ space was measured in a frontal plane from the most lateral cortical reflex of the distal clavicle to the most medial cortical reflex of the acromion. In the next step the CC distance was measured in a sagittal plane with 10 kg weights pulling on the patients arms. The bony landmarks for this measurement were the highest point of the tip of the coracoid process and the bottom edge of the clavicle [13, 29]. In each section, measurement was repeated three times and averaged. The value of the ACJ space width of the unaffected side was subtracted from the value of the operated side to estimate the extent of the lateral clavicle resection.

The horizontal stability of the ACJ was tested during the complete physical examination of the shoulder. For the clinical evaluation, the lateral clavicle was fixed between the fingers of the one hand of the examiner, while the other hand fixed the acromion. The extent of dorsal shift of the lateral end of the clavicle against the acromion was evaluated and differentiated in horizontal stable or unstable [22].

If a radiograph of the operated shoulder was available at follow-up, the width of the drill tunnels was analyzed.

Statistics

Statistical analyses were performed using SPSS (Version 19.0, Chicago, IL, USA). Data were reported as the median (range, minimum–maximum) or mean \pm SD. The relevant data were tested for normal distribution using

Fig. 3 **a** Transducer position for standard frontal plane for measurement of ACJ space. **b** Measurement of the ACJ space (arrow) at follow-up after resection of lateral clavicle (AC acromion, Cl clavicle). **c** Transducer position for standard sagittal plane for measurement of the CC distance. **d** Measurement of the CC distance (arrow) (Co coracoid)

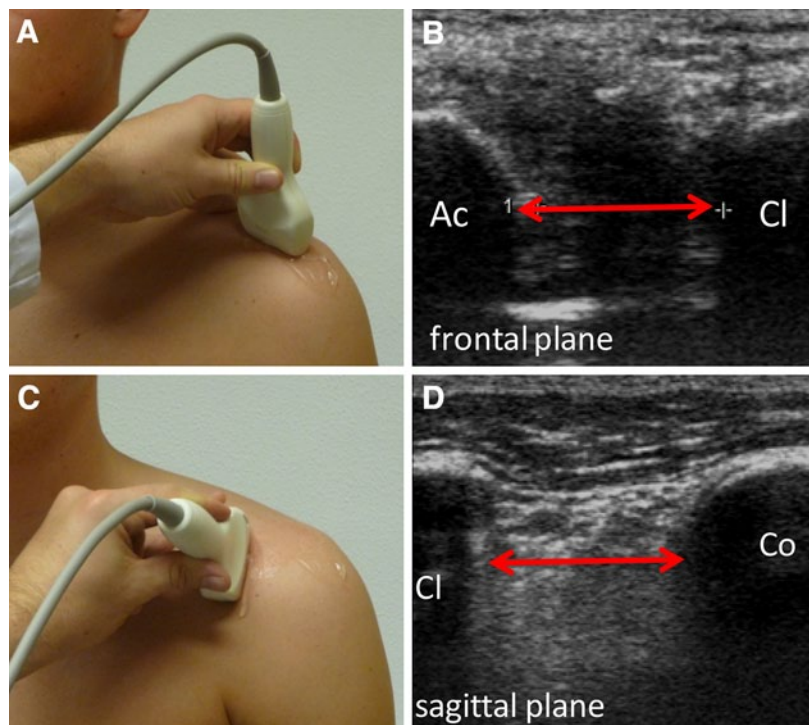


Table 1 Patient data

Nr	Age at accident in years	Gender	Side	Rockwood classification	Prior surgery	Concomitant intraarticular pathology	Interval between accident and surgery in months
1	28	M	N	III	Double-TightRope	None	4
2	37	M	D	III	1: Fixation with clavicular hook plate 2: Weaver–Dunn procedure	None	17
3	38	M	D	III	PDS coracoclavicular sling and temporary K-wire fixation	Partial articular supraspinatus tendon avulsion (<5 mm) involving pulley complex (pulley lesion type Habermeyer II)	6
4	57	M	D	V	None	Partial articular supraspinatus tendon avulsion (<5 mm)	5
5	37	M	D	III	Suture anchor and temporary K-wire fixation	Partial rupture of SSC (Fox and Romeo III/Lafosse III) and LBT (pulley lesion type Habermeyer III)	3
6	60	M	D	III	None	SLAP I	8
7	44	M	D	V	Fixation with clavicular hook plate	Degenerative changes of LBT	13
8	36	F	D	III	None	None	10
9	58	M	D	III	None	None	9
10	56	F	D	III	None	Tendinosis calcarea of SSP	11
11	32	M	D	III	None	None	6
12	31	M	D	III	None	None	89
13	40	M	D	III	Double-TightRope	None	4
14	40	M	D	V	None	None	6
15	53	M	D	V	None	Rupture of SSP (Patte II)	3
16	21	M	N	V	None	None	2

M male, *F* female, *D* dominant, *N* non-dominant

the Kolmogorov–Smirnov test. Subsequently, data of the affected and uninjured side were compared using the Wilcoxon’s test for dependent samples. The level of significance was defined as $p = 0.05$ for all tests.

Results

Eleven patients had chronic ACJ instabilities after acute Rockwood III (all of these with a symptomatic horizontal instability), and five Rockwood V-injuries. The dominant arm was affected in 14 cases. The injury mechanism was a direct trauma to the shoulder ($n = 15$) or an indirect trauma to the elevated arm ($n = 1$).

The median time from trauma to surgery was 6 months (range 2–89 months). In seven patients, concomitant injuries on the affected shoulder were seen (Table 1). Two of them needed reconstruction: $n = 1$ traumatic partial tear of subscapularis tendon (SSC, Fox and Romeo type III/Lafosse type III) with partial rupture of the long biceps tendon (LBT), $n = 1$ tear of the SSP. The other concomitant lesions were gently debrided with a radio frequency

device. The time of surgery amounted to median 116 min (range 61–175 min).

In ten cases, the patients were primary stabilized with the GraftRope™ technique with vertical and horizontal tendon augmentation after failure of a non-operative treatment. 6 patients suffered from persistent symptomatic instability after a primary operative treatment of acute high-grade ACJ lesion (Table 1).

Clinical results

In our collective 15 of 16 patients were satisfied with the results and would repeat surgery. In a 5-part satisfaction scale (1: “excellent” to 5: “poor”), they assessed their cosmetic results with mean 2.1 ± 1.0 and their functional outcome with 2.8 ± 0.9 .

The VAS (scale from 0 to 10) accounts 4.1 ± 2.0 points. The SST showed median 9 points (range 5–12). The adjusted CS was median 84.0 % (range 46.3–93.3 %) and TS median 9 points (range 5–12 points) (Table 2).

The postoperative X-rays (true ap and Y-view) showed that in 15 of 16 patients (94 %), an anatomical reduction of

Table 2 Follow-up results

Visual analog scale (1–10 points)	4.6 (1.1–7.4)
Simple shoulder test (1–12 points)	9 (5–12)
Gender- and age-specific Constant–Murley score (%)	84.0 (46.3–93.3)
Taft score (1–12 points)	9 (5–12)

Table 3 Results of ultrasound examination

	AC distance (unloaded) (mm)	CC distance (10 kg-loaded) (mm)
Uninjured side	4.9 (3.3–8.5)	21.7 (17.2–29.4)
Affected side	11.3 (7.3–16.6)	24.8 (20.3–31.0)
<i>p</i> value		0.009*

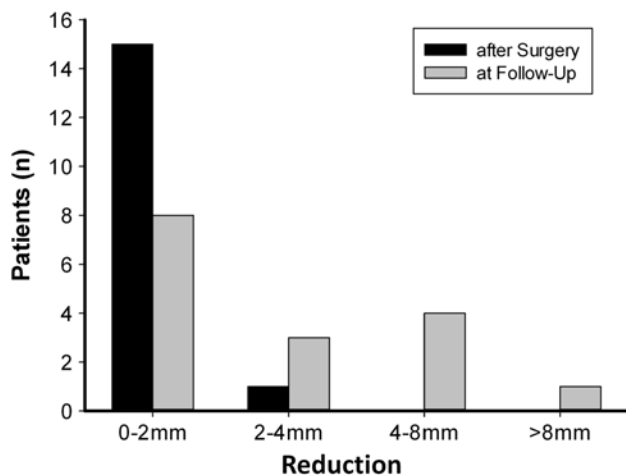


Fig. 4 Overview about the achieved reduction of the ACJ postoperatively (measured at the postoperative a.p.-X-ray; black bars), and at the follow-up examination (ultrasound; grey bars). Anatomical: <2 mm, slightly incomplete reduction (after surgery)/slight loss of reduction (at follow-up); 2–4 mm, partially incomplete reduction/partial loss of reduction; 4–8 mm, failed reduction/dislocation; >8 mm

the AC joint was achieved by surgery. Sonographic follow-up examination of the affected and contralateral AC-joint gave the results in Table 3 and Fig. 4. 15 of 16 patients participated at the ultrasound follow-up. In 7 of 15 patients (47 %), an anatomic reduction could be maintained. Three cases (20 %) presented a slight loss of reduction at follow-up evaluation. In 27 %, a partial loss of reduction was seen and 1 patient showed a recurrent dislocation (7 %).

The CC distance was significant greater at the operated side compared to the contralateral side with a 10 kg loading ($p = 0.009$; Table 3). The difference in CC distance between the affected and healthy side was mean 3.0 ± 2.3 mm. The AC distance after resection of the lateral clavicle was median 11.3 mm (range 7.3–16.6 mm). The

joint space of the contralateral side was median 4.9 mm (range 3.3–8.5 mm). The extent of lateral clavicle resection was mean 6.3 ± 3.9 mm. Clinically, persistent horizontal instabilities were examined in 2 of 15 (13 %) patients.

Complications and revisions

According to the medical records, preoperatively all patients suffered from pressure pain of the ACJ. Postoperatively 10 of 16 patients (63 %) reported that they suffer mild pressure pain and paresthesia over the clavicular washer, or the ACJ. A correlation between pressure pain and remaining CC distance could not be found. 3 of 16 patients (19 %) had a positive cross-body sign at clinical examination. In 1 of 15 patients, a mild ossification of the CC ligaments was observed at the ultrasound follow-up.

In two cases, surgical revision was necessary. One patient had a superficial soft tissue infection after surgery which required revision and removal of the horizontal gracilis tendon loop. In another case, a removal of the clavicular washer was performed in combination with an arthroscopic partial synovectomy of the glenohumeral joint and subacromial arthrolysis due to persistent shoulder pain.

Seven of 16 patients brought X-rays to the follow-up visit. In all of these, a trapezoid-like tunnel widening of the clavicular bone channel of 10.0 mm (range 8.2–10.5 mm) was measured as compared to the direct postoperative radiographs (6 mm drill hole). Implant migration of the Graft-Rope™ button was neither observed via ultrasound in the level of the clavicular cortex nor X-ray.

Discussion

Persistent ACJ instability is a common problem after acute ACJ separations. 15–20 % of the patients with high-grade dislocations type Rockwood III–V develop chronic symptomatic ACJ instability [41]. Unfortunately, the results after delayed surgical treatment in chronic cases are often inferior to early interventions in the acute phase [35].

Moreover, Hedtmann et al. [20] demonstrated that in chronic ACJ instabilities in the majority of patients a relevant horizontal component of instability is evident, which is directed posteriorly and can result in a painful, excessive dorsal translation of the distal clavicle and in abutment of the posterior clavicle into the anterior aspect of the scapular spine [24]. A persisting or recurrent horizontal instability after treatment of an acute ACJ separation is a predictor for significantly inferior clinical results [37]. Gerhardt et al. [16] recommend an additive horizontal AC augmentation in acute ACJ dislocation to prevent a clinically relevant horizontal instability.

The loss of ligamentous suspension of the shoulder girdle after complete ACJ dislocation leads to an antero-lateral rotation of the shoulder girdle and a functional imbalance. Gumina et al. [19] report an incidence of 70.6 % of scapular dyskinesia in patients with chronic ACJ dislocation. Of these, 58.3 % showed an SICK (Scapular malposition, Inferior medial border prominence, coracoid pain and malposition, and dyskinesia of scapular movement) scapular syndrome.

Therefore, the aim of any surgical approach to address instability of the ACJ should be an anatomic reduction and resuspension of the scapula, so that the distal clavicle serves as a stable fulcrum of the shoulder girdle to restore normal arthrokinetics.

In chronic cases, the regenerative capacities of the capsuloligamentous structures of the ACJ are limited, so that a biologic tissue augmentation is necessary to archive satisfying results. The majority of surgical techniques using tendon allografts [32, 38, 21] or modifications of the Weaver–Dunn procedure [2] stabilize predominantly the CC complex, but not the ACJ capsule.

In this context, Fukuda and co-workers [15] showed the important role of the ACJ capsule and its ligaments to prevent posterior subluxation of the distal end of the clavicle. About 80 % of the horizontal stability in this direction is provided by the intact posterolateral AC ligaments, as Klimkiewicz et al. [24] demonstrated in further biomechanical studies of the ACJ complex.

To address this clinically relevant problem, we have added a transacromial gracilis tendon loop, which is made with the excess graft material, to the previously described GraftRope™ System to reinforce/reconstruct the ACJ capsule. To our knowledge, we are the first who present clinical data of a transosseous transacromial ACJ reconstruction technique. In our collective only 13 % of the patients showed mild persistent horizontal instability while clinical testing, indicating a successful horizontal stabilization. Furthermore, 81 % of the patients showed no discomfort at cross body-action manoeuvre.

Carofino and Mazzocca [7] describe a technique of reinforcement of the ACJ capsule done with the excess graft material after reconstruction of the CC ligaments using a semitendinosus autograft. The graft material is sutured to the periosteum and remaining ACJ capsule tissue. To our experience, especially in chronic cases, this tissue is often of poor quality.

Alternative surgical approaches to address the problem of persistent horizontal instability in ACJ reconstruction have been described recently. Freedman and co-workers [14] and Gonzalez-Lomas et al. [17] describe, i.e. the use of an intramedullary free tissue graft. Shu et al. [39] presented a reverse coracoacromial ligament reconstruction technique to augment the ACJ capsule. So far, there is only biomechanical data available.

For reconstruction of the CC ligaments, the GraftRope™ system was used. It was first described by DeBerardino et al. [10]. Besides the surgical technique, the authors showed early clinic results of ten patients with a 6-month follow-up. In this case series, all patients have returned to their normal pre-injury level of activity. No complications have been documented and all have maintained the intraoperative reduction in the ACJ- and CC space.

The GraftRope™ system shows a good biomechanical primary stability as comparable to the native CC ligaments and superior to modified Weaver–Dunn procedures [3]. The system enables the surgeon to implant a combined device with the potential of an arthroscopically assisted one-step procedure. It joins the advantages known for primary fixation devices (e.g. high primary stability, easy handling, and arthroscopic procedure) with the advantages of adding biologic material to the reconstruction (e.g. ingrowth of tendon graft into bone tunnels, improved secondary stability, reconstruction of “native” ligaments) [3].

In our collective, we could observe a secondary loss of reduction in some cases with a significant greater CC distance as compared to the contralateral side, although no movement of the clavicle washer or coracoid button was seen. Therefore, suture rupture of the FiberWire™ might be the reason [31]. In this context, we could observe trapezoid-like tunnel widening of the clavicular bone channel in the patients where postoperative X-ray was present at the follow-up examination. Owing to the multidirectional movement of the distal clavicle during shoulder motion the suture might rub against the bone tunnels leading to tunnel widening, wear and cutting of the suture. The presence of four FiberWire™ sutures in the same drill tunnel like the tendon graft might have negative consequences for graft healing. The surgical technique for ACJ reconstruction in chronic cases described by Scheibel et al. [38] using different drill tunnels for the temporary fixation device and graft passage might be beneficial. In this context, we did not observe any lateral clavicle or acromial fracture associated with the GraftRope™ System and the newly added transosseous transacromial tendon loop. The incidence of distal clavicle tunnel widening and associated fracture is unknown. So far only a few case reports exist in the literature. Turman et al. [44] report about three cases of lateral clavicle fractures out of seven patients after CC ligament reconstruction with a tendon graft.

In our case series, the lateral clavicle was sparingly resected in all patients. The fact, if the lateral clavicle resection should be done or not is controversially discussed. Most modifications of the Weaver–Dunn procedure require lateral clavicular resection for fixation of the transposed ligament-bone-block [46]. At the majority of other CC-reconstruction techniques the lateral clavicle is traditionally resected to prevent possible future osteoarthritic

degenerations of the ACJ and further pain [30]. Beitzel et al. [4] demonstrate in a biomechanical study that sequential resection of the distal clavicle increases horizontal translation and should therefore be performed only sparing and not exceed 5–10 mm. The extent of the lateral clavicle resection in our data was mean 6.3 ± 3.9 mm (detected via ultrasound from the difference of the ACJ space of the affected minus the contralateral side).

In our consecutive series, the 16 patients followed-up reached median 84 % (range 46–93 %) at the gender and age-specific CS and median 9 points (range 5–12 points) at the ACJ-specific TS, which represents a good clinical result. Our data are in accordance with the results of Tauber et al. [41]. In a prospective randomized clinical trial, a modified Weaver–Dunn procedure was compared to a semitendinosus graft as CC-ligament reconstruction. The semitendinosus graft group reached significant better results with a mean CS of 93 ± 7 points at a mid-term follow-up of mean 37 months than the modified Weaver–Dunn procedure with a mean CS of 81 ± 8 points.

Only a few clinical studies report exact measured CC distances from 11.4 ± 4 to 14.9 ± 6 mm after ACJ reconstruction in cases of chronic instability [35, 41]. In our study, the measured CC distances were greater in general with mean 22.7 ± 4 mm of the uninjured and 24.8 ± 4 mm of the injured side. This is a result of the use of different diagnostic tools: radiographic versus sonographic measurements. The absolute values of the sonographic and radiologic measured CC distance are not directly comparable due to different anatomic points of reference (measured distance with radiographic evaluation from under surface of clavicle and highest point of convex upper surface of coracoid process; measured distance with ultrasound: deepest point of clavícula and highest point of the tip of the coracoids process) and a different projection plane [13]. Owing to interindividual differences, a norm distance for the sonographic measured CC distance does not exist. The reference value for ultrasound measurement was the unaffected contralateral shoulder [26]. We prefer sonographic controls of the CC distances, because this is a valid and radiation-free method with a high inter- and intraoperator reliability [45]. In the present study, a difference in the CC-distance in the sonographic stress view of mean 3.0 ± 2.3 mm between the affected and unaffected side was measured. Sluming [45] defined the limits of agreement between radiological and ultrasound measurement of the difference in the CC distance of the unaffected and operated side and showed that there is a mean difference of 0.38 mm in the absolute value between both techniques. This means that the difference of the CC distance of the unaffected and operated side measured by ultrasound as in the present study should be comparable to other studies using radiological examination techniques. Unfortunately, a valid ultrasound

technique to evaluate and quantify persistent dynamic horizontal instability has not been described. Radiologic evaluation of a persistent dynamic horizontal instability, such as the Alexander stress view, needs an intact lateral clavicle as prerequisite [1]. However, there is no evidence how much overlap of the clavicle with the acromion is still to be tolerated because no graduation of this stress view exists. Tauber et al. [42] describe a functional radiographic technique for the evaluation of dynamic horizontal instability with the determination of the gleno-acromio-clavicular angle. So far, this technique is valid only for acute ACJ separations. Furthermore, the influence of lateral clavicle resection for the measurement of this angle has not been analyzed. A static horizontal instability can be visualized with the axillary view, but comparably with the Alexander view, there is still a lack of evidence how much posterior translation of the clavicle against the acromion should be tolerated. For this reason, the horizontal instability was tested clinically in our study.

One important advantage of the described arthroscopically assisted procedure is the possibility of a diagnostic glenohumeral joint inspection and possible therapeutic interventions in case of concomitant injuries. In patients with high-grade AC-joint separations in 15–20 % traumatic intraarticular lesions, like partial tears and one complete tear of the M. supraspinatus or M. subscapularis as well as SLAP lesions types (I) II–IV, were found and arthroscopically treated [33, 43]. In our study, a higher percentage (7/16 patients; 44 %) of intraarticular concomitant pathologies could be observed. Thereof, some are more related to degenerative changes (1 tendinosis calcarea, 2 intraarticular lesions of LBT), others are more likely of traumatic character (e.g. partial rupture of subscapularis tendon). In some cases it was difficult to distinguish between traumatic and degenerative changes due to longer time spans between trauma and surgery in our collective. The higher percentage of concomitant pathologies and, in some patients, longer history of shoulder pain, including the previous surgery might be an explanation for postoperative discomfort in some patients despite successful stabilization of the ACJ.

To our knowledge, this study is the first, which describes a novel surgical technique of a transacromial tendon augmentation of the ACJ to address the clinically relevant problem of persisting horizontal instability, which is especially common in chronic ACJ instabilities. Moreover, short-term clinical results are presented, indicating a supplementary horizontal stabilization.

The present study is the largest therapeutic case series of CC-ligament reconstruction using the GraftRope™ system. It points out, that a successful vertical stabilization can be achieved, although we found indices of possible hardware-associated problems, i.e. trapezoid-like tunnel widening.

A limit of the study is the retrospective approach. We decided to measure the CC and AC distance sonographically because it allows precise, valid and radiation-free assessment of the ACJ. After lateral clavicle resection, the often used Alexander view for the assessment of horizontal instability is not adequate because of the missing contact of acromion and lateral end of the clavicle, so that evaluation of this parameter was performed clinically. In addition, only 7 of 16 patients brought X-rays to the follow-up examination, so that we could only describe the phenomenon of tunnel widening. Further information about the incidence and clinical relevance cannot be derived.

Conclusion

The arthroscopically assisted stabilization of chronic ACJ instabilities with the GraftRope™ device and a newly described, additive transacromial horizontal tendon augmentation may lead to good clinical and sonographical short-term results including a supplementary horizontal stabilization. It represents an innovative approach and reproducible technique using the excess graft material to address the clinically relevant problem of persistent horizontal instability. The results of our study are comparable to other stabilizing techniques in chronic ACJ instabilities. Further studies are necessary to assess the longevity to the stabilization.

Conflict of interest There is no conflict of interest.

Ethical standard Approval by the local ethics committee (Hannover Medical School, Hannover Germany): 10 October 2011; No. 1207-2011.

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