Knee Surg Sports Traumatol Arthrosc (2012) 20:1012–1018
DOI 10.1007/s00167-011-1627-5

SHOULDER

Acromioclavicular motion after surgical reconstruction

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Received: 13 September 2010 / Accepted: 14 July 2011 / Published online: 3 August 2011

Abstract
Purpose A retrospective long-term study was carried out to determine whether there was any correlation between the clinical motion of the acromioclavicular joint evaluated by a test we set up using 90° of abduction and 0° of external rotation against resistance [90°/0°RTest] and the cross arm test (compared to the healthy side) and full return to everyday activities after surgical repair.
Methods A clinical and radiographic evaluation was carried out on 51/80 subjects at a 5.4-year mean follow-up, treated for acromioclavicular joint dislocation with an extra-articular artificial loop, between 2000 and 2006.
Results The 25 subjects with ossifications obtained a normal acromioclavicular joint motion, on both the horizontal and vertical planes. There was a correlation between the normal motion of the reconstructed acromioclavicular joint (compared to the healthy side) in these 25 patients and full clinical recovery, whilst there was no correlation between the Constant score, the simple shoulder test, the radiographic evaluation on one hand and the clinical motion of the joint on the other. Two patients had recurrent dislocation. Three had mobilization of the screws without reduction loss, or negative clinical outcome.
Conclusions A postoperative radiographic evaluation should be correlated with a clinical evaluation of the acromioclavicular joint motion (normal, hypermobile, unstable). Normal acromioclavicular joint motion was observed in subjects who developed significant ossifications. The study shows that the clinical evaluation of acromioclavicular joint motion is a simple and trustworthy method to assess the clinical result of a surgical repair.
Level of evidence Diagnostic study investigating a diagnostic test, Level III.

Keywords Acromioclavicular joint · Acromioclavicular joint dislocation · Acromioclavicular stability · Ossifications · Clinical test

Introduction

Approximately 9% of all shoulder traumas are acromioclavicular joint dislocations [27], mainly observed in subjects who practise sports, between 20 and 40 years old. The most common trauma mechanism is falling on the adducted upper arm. The Rockwood [36] Classification divides injuries into 6 types: 2 of which are stable and conservative treatment is the choice, and types 4, 5 and 6 are unstable and, consequently, require surgery [1, 2, 16, 21, 22, 25, 26, 29, 35, 38, 40].

Surgical treatment of type 3 is still controversial and usually reserved to the active subject, i.e., one who carries out regular sports activities and/or heavy manual tasks. However, many other centres use the Tossy [41] classification, which divides injuries into three types, pooling types 4, 5 and 6 together, making comparisons difficult. Moreover, as at time of writing, no single surgical technique has been universally adopted, comparison between the surgical procedure results is difficult. Indeed, there are more than 60 possible surgical procedures [13, 18, 26, 27]. The technique used in this study was a polyester loop that offers rupture loads very close to that of the native acromioclavicular joint complex. However, even if it reaches

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only 30% of its stiffness, it is better than the more elastic tendon grafts [14, 24, 31].

Hypothesis: since, to date, there is no surgical repair of acromioclavicular joint dislocations able to restore the native ligament stiffness, acromioclavicular joint motion is expected to be increased at clinical evaluation, if compared to the healthy side [5, 9, 13, 14, 24, 31, 33]. The aims of this study were also: to verify whether there was any correlation between the clinical motion of the reconstructed acromioclavicular joint detected with a test we set up using 90° of abduction and 0° of external rotation against resistance [90°/0°RTest] and the cross arm test and full return to everyday activities after surgical repair. Correlation between clinical and radiographic results was evaluated. Whether the use of an artificial loop in acromioclavicular joint dislocations might lead to clavicular osteolysis, reduction loss, anterior clavicular displacement, ossification development and/or osteoarthritis was also verified at long-term follow-up.

Materials and methods

The LARS LAC 30 CK technique was used to treat acromioclavicular joint dislocation in 80 subjects (79 men 1 woman) in our centre from 2000 to 2006. A total of 51 subjects, 50 men 1 woman, average age 36 (range 19–65), were available for the long-term follow-up (median follow-up 5 years, range 2–9 years) and were re-investigated both clinically and with plain radiographs. Ten subjects were lost to follow-up, 11 had associated skeletal and/or glenohumeral ligament lesions and 8 were treated by arthroscopy and were not included in our study.

Type 3 dislocation was observed in 38/51 patients, type 4 in 11 and type 5 in 2; 18/51 had been visited in other centres and then referred to ours for further evaluation surgery. Sports accidents accounted for 47% of the injuries, 37% were road accidents and 16% were due to falls. Surgery was carried out within the first 3 weeks post-trauma in 34 subjects, i.e., acute lesions, whilst surgery was done later in the remaining 17 with chronic lesions (range 3 weeks–2 years).

Although to date there are no evidence-based medical guidelines as to whether type 3 lesions should be treated conservatively, or operated on, literature recommends that surgery be carried out only in particularly active patients and/or those who have manual occupations involving the handling of heavy loads [10, 16, 26]. The patients were informed, and the final decision left to them. The technique of choice was an extra-articular loop fixed into the clavicular bony tunnels with 2 titanium interference blunted-thread screws (4.7 mm × 15 mm length).

Radiographic evaluation

Presurgical diagnostic imaging was carried out: radiograph with comparative bilateral Zanca projection, followed by stress views of the acromioclavicular joint with 5 kg weights strapped to the wrists and axillary projections [37]. The same imaging was repeated at the follow-up, to investigate:

- *clavicular osteolysis around the screws:*
  - type 0 $\leq$the screw diameter so as to insert the ligament
  - type I >the screw diameter
  - type II in the presence of screw migration
- *acromioclavicular reduction : comparative radiology of the healthy side:*
  - type A: the same as the contralateral side
  - type B: sub-dislocation with a dislocation of less than 50% of the clavicular thickness
  - type C: sub-dislocation with a dislocation of more than 50% of the clavicular thickness
  - type D: acromioclavicular joint separation recurrency
- *anterior clavicular displacement:*
  - A: the same as the contralateral side, the anterior displacement is not evidenced on the axillary projection
  - B: with anterior displacement, or rotation that differs from the contralateral side
- *ossifications* (Figs. 1, 2, 3)

type 1 ossifications free-bodies within the clavicular-coracoid space

type 2 ossifications attached to either the clavicular or coracoid

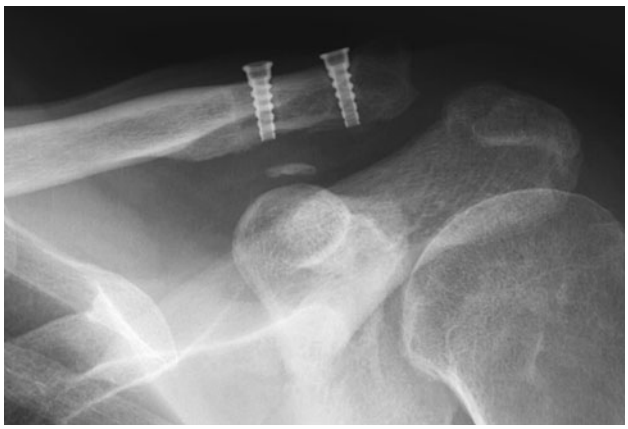

Fig. 1 Type 1 ossifications

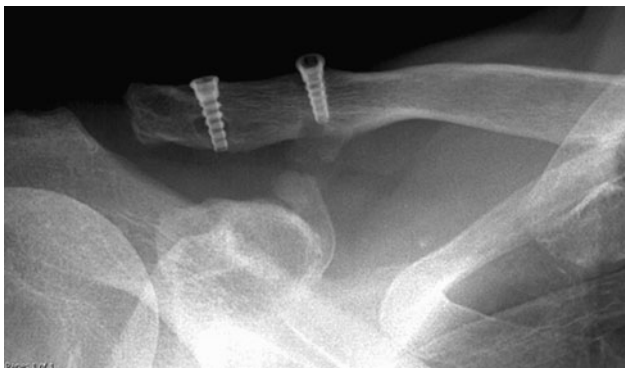

Fig. 2 Type 2 ossifications

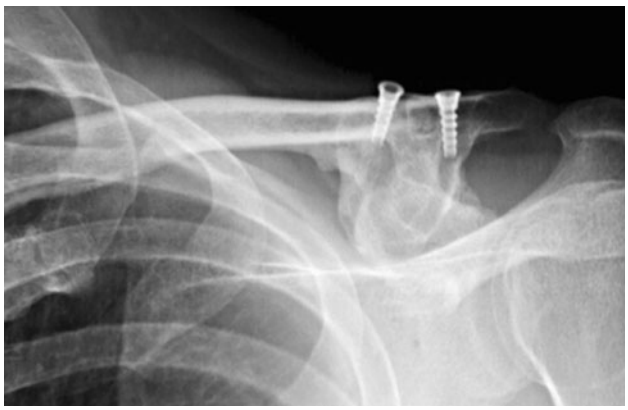

Fig. 3 Type 3 ossifications

type 3 the formation of a bony fusion bridge between the clavicular and coracoid

– acromioclavicular joint *osteoarthritis:*

type 0 the same as the contralateral side
type I >of the contralateral side

Clinical evaluation

Acromioclavicular joint *motion*: The cross arm test was used to evaluate the acromioclavicular joint motion on the horizontal plane; our 90°/0°RTest (Fig. 4) was used to evaluate the acromioclavicular joint motion on the vertical plane:

Normal	motion on both planes the same as on the healthy contralateral side
Hypermobile	only one test positive
Unstable	both tests were positive

When the pain in any of these tests was in association with radiographically confirmed osteoarthritis, it was considered suggestive for symptomatic acromioclavicular degeneration.

Fig. 4 90° of abduction and 0° of external rotation against resistance test [90°/0°Rtest]

Constant score

Simple shoulder test The objective/subjective clinical evaluation was carried out by 2 independent investigators. Particular attention was paid to whether the patient was able to carry out the same level of sports activities and the same tasks in the workplace as before surgery.

The surgical positioning of the screws varied in as much as some were positioned vertically and others obliquely, according to the surgeon's personal preference. Likewise some screws were placed more laterally and others more medially.

Post-surgery, the shoulder was kept in a Donjoy UltraSling for an average of 20 postoperative days. Passive elevation was allowed up to 90° after 20 days, so as to promote a gradual recovery of the articulation activity; full range of motion was permitted at 1 month and weight-lifting at 2. Permission for sports activities was given only after 3 months.

Statistical analysis

All computations were done with *statistica software version 7.0*. The radiographic results were compared using the chi-square test, and Student *t* test was used for the clinical results. $p < 0.05$ was considered statistically significant.

Results

Radiographical evaluation

Acromioclavicular joint reduction

At comparative radiology, it was observed that 25 patients had a type A reduction, 17 a type B, 7 a type C and 2 had

type D. When a comparison was made between lesions and operating times, a statistically significant difference ($p < 0.05$) was observed in the outcome of the acromioclavicular joint, i.e., our data showed that more than 61% of subjects operated in the acute phase (within 3 weeks) had a type A reduction at radiographic follow-up, compared to 23% of subjects operated in the chronic phase (>3 weeks).

Ossifications

Ossifications type 1 in 8, 2 in 9 and 3 in 16 were observed at follow-up in a total of 65% of the subjects. Noteworthy was that clinical stability was strongly influenced by the development of the ossifications, i.e., 100% of subjects with type 2 or type 3 ossifications had a stable acromioclavicular joint, whilst only 1 of those with type 1 or no ossifications obtained the same result ($p < 0.001$).

An interesting significant finding was that subjects with type B or C sub-dislocation had a stable acromioclavicular joint when in association with type 2 or 3 ossifications ($p < 0.001$).

The development of ossifications had a significant correlation with postoperative shoulder immobilization timing, e.g., 29 subjects were immobilized for more than 3 weeks and 22 for a shorter period. The presence of ossifications predominated in subjects with an immobilization period of >than 3 weeks: 86% versus 36% ($p < 0.05$).

Clavicular osteolysis around screws

No radiographic evidence of osteolysis was observed in 33 subjects at follow-up, whilst 14 had type I and 3 type II. The study evidenced a significant correlation between the presence of osteolysis and the acromioclavicular joint motion, i.e., more than 65% of subjects without osteolysis in either of the 2 screws had a normal acromioclavicular joint motion, versus 26% with any grade of osteolysis ($p < 0.001$). There was no osteolysis at the coracoid level.

Osteoarthritis

The osteoarthritis level was the same as that in the contralateral healthy shoulder in 32 subjects, whilst 19 had a more serious level in the operated shoulder. It was observed that those with a hypermobile and/or unstable reduction had developed less osteoarthritis (12%), as opposed to those with a good clinical stability (>61%) in the operated shoulder ($p < 0.001$) and osteoarthritis. The anterior clavicular displacement was type A in 17 subjects and type B in 34, the former having a significant correlation with the development of osteoarthritis (>65% versus 24%, $p < 0.05$).

Clinical evaluation

Acromioclavicular joint motion

A normal acromioclavicular joint motion, on both the horizontal and vertical planes, was observed in a total of 26 subjects, 19 had acromioclavicular joint hypermobility and 6 an unstable acromioclavicular joint. There was no significant correlation between the radiographic reduction of the acromioclavicular joint and the clinical stability. Patients with a normal acromioclavicular joint motion returned to the same level of every day activity they had before surgery.

The Constant score and simple shoulder test gave superimposable significant results (Tables 1 and 2). Clinical results in our cohort are not related to the preoperative Rockwood dislocation type, or postoperative radiologic findings, in agreement with Larsen and Rawes et al. [22, 35].

Discussion

The most important finding of the study was that there was no correlation between the Constant score, the simple shoulder test or the radiographic evaluation and normal acromioclavicular motion, whilst there was a correlation between the normal motion of the reconstructed acromioclavicular joint (compared with the contralateral healthy side) in 25 patients and full clinical recovery. Indeed, 90°/0°RTest and cross arm test detected a normal acromioclavicular motion only in patients who returned to their everyday work and sports activities at the same level as before surgery. Literature reports that acromioclavicular

Table 1 Clinical results (according to treatment timing)

	Acute treatment ($n = 34$)		Chronic treatment ($n = 17$)	
	Mean	SD	Mean	SD
Constant score	97	6.1	91	15.1
Simple shoulder test	11	1.1	10	2.1

Table 2 Clinical results (by age)

	Patients aged ≤45 years ($n = 38$)		Patients aged > 45 years ($n = 13$)	
	Mean	SD	Mean	SD
Constant score	96	6.0	89	17.1
Simple shoulder test	11	1.3	10	2.01

joint stability on the coronal plane depends mainly on the coracoclavicular ligaments, whilst the superior and inferior portion of the articular acromioclavicular joint capsule has a fundamental role on the transversal plane [11, 23]. This is in agreement with Debski et al. [8], who reported that in the presence of a sectioned articular acromioclavicular joint capsule, coracoclavicular ligaments do not suffice for clavicular distal portion anteroposterior stability. Klimkiewicz et al. [20] also reported the same results when the lateral portion of the clavicle was resected. Dawson's recent paper discusses the contribution the acromioclavicular joint capsule lends to acromioclavicular stability on the anteroposterior plane and concludes that it has a 3-fold importance at this site over the vertical plane [7].

International literature is in agreement as to there being no type of isolated synthetic, bio-reabsorbable or tendinous loop able to restore the native coracoclavicular and/or acromioclavicular ligament complex stiffness, which ranges from 60.8 to 115 N/mm [5, 9, 13, 14, 24, 31]. In order to investigate these data further, acromioclavicular joint clinical stability was evaluated, bearing in mind that the stability would not have reached the same level as that of the original complex stiffness.

Our data showed that a correct evaluation of the surgical outcome is a must and is to include not only radiographic documentation but also an accurate clinical evaluation, so as to make a dynamic quantification of the stability on both the vertical and horizontal planes. There are various tests that may be used in the clinical evaluation, including the dedicated acromioclavicular joint score [1, 17], isokinetic muscle testing to evaluate the strength and endurance [43] or the generic range of motion, as well as a strength and pain evaluation [6, 22]. However, none of the aforementioned tests, including the Constant score and the simple shoulder test, are able to provide a conclusive stability evaluation, either alone, or together. Indeed, conventional score systems are based more on pain and articular range of shoulder motion than on acromioclavicular joint motion, or return to previous activities. This study evidenced no correlation between the high average Constant score/simple shoulder test score results on the one hand and full recovery to everyday tasks and/or sports on the other. This was evidenced by the fact that 19 subjects with type A or B acromioclavicular reduction and a high Constant score and/or simple shoulder test score had a hypermobile acromioclavicular joint and were obliged to change their routine lifestyle. Only 26/51 had the same motion as that of the healthy contralateral joint. When postoperative motion was investigated, the 90°/0°RT gave a correct evaluation of the vertical plane motion, due to increased maximum strength in the lever arm. The horizontal motion was evaluated by the cross arm test as it is able to evidence any posterior clavicle dislocation, whilst the shoulder is stressed anteriorly.

A normal acromioclavicular joint motion was observed in 25 subjects with type 2, or 3 ossifications, as a bony fusion bridge had formed between the clavicle and the coracoid. They reported having returned to their same level of sports activities and every day activities in the workplace, whatever the reduction type. Conversely, 15 subjects with type 1 or no ossifications had a hypermobile/unstable acromioclavicular joint. Ossifications were observed to increase the stiffness of surgical reconstruction and are, therefore, positively correlated ($p < 0.001$) with a normal acromioclavicular joint motion. This gives a significant value to what was affirmed by Larsen [22] who noted that ossifications were more common in patients with excellent results. The longer postoperative shoulder immobilization adopted by our protocol differs from that proposed in the LARS postoperative care indications, i.e., a few days immobilization with return to sports activities at 4–6 weeks. Moreover, we observed that 3-week immobilization and return to sports activities after a minimum of 3 months could well favour the development of ossifications.

The 3- to 4-week postoperative immobilization allows for a mechanical pause that may well stimulate a correct scarring of the soft tissues and cellular ingrowth of the new ligament [42]. Unlike the first synthetic loops in Dacron®[4], the polyester used in this study did not provoke any adverse reactions to foreign bodies, or infections, clavicle and/or coracoid fractures [15, 30, 32]. Neither was there any neurovascular injury during the passage of the loop around the coracoid process.

The study cohort had a very high overall incidence of ossifications (65% of subjects). This may be due to a combination of factors, such as the transportation of bone fragments carried over by drilling [19] and/or a bone morphogenic protein [BMPs] process that, when the shoulder is at rest, favours calcium deposition in the soft tissues. These factors may pool, leading to the formation of the bony fusion bridges observed on the radiographs.

It would seem that the mechanical function of the new ligament in this cohort leads to scarring that repairs the soft tissues. Indeed, although 3 patients had screw migration and the ligament was no longer anchored, there was no loss of reduction. Moreover, there were no cases of reduction loss, apart from the 2 recurrences, which occurred before the onset of soft tissue repair.

Clavicular fixation of the extra-articular loop is the weak point of this type of reconstruction [10, 24, 28], in as much as literature reports stress fractures of the clavicle due to a "cheese-wire effect" [10, 14, 30]. To date, there is no clear-cut explanation as to why such a small number of clavicular osteolysis was observed. Type A reduction and/or no anterior clavicular displacement seem to predispose subjects to osteoarthritis, in agreement with Calvo et al. [3],

whilst osteoarthritis is a rare finding in Type B, or C reductions and/or in the presence of anterior displacement/rotation.

The surgical extra-articular loop is, therefore, able to modify force transmissions at the acromioclavicular joint level, leading to osteoarthritis degeneration. None of the subjects in this study had symptomatic osteoarthritis, in agreement with other authors' findings [12, 34, 39]. However, there are some limiting factors in this study: firstly, subjects with different Rockwood grade dislocations were compared; secondly, as no intra-articular examination was carried out, some associated pathologies may have been missed, e.g., slap lesions that might have influenced the clinical results; thirdly, 8 of the 10 patients lost to follow-up declined to come for examination as they were asymptomatic; fourthly, a longer follow-up would allow for the evaluation of any degenerative changes in the acromioclavicular joint. However, the data obtained in this study show that the restoration of normal acromioclavicular motion after extra-articular repair depends on the development of grade II, or III ossifications: when surgical repair of the acromioclavicular joint is also associated with the reconstruction of the coracoclavicular ligaments, good clinical results can be expected.

Conclusions

Although the outcome of the surgical acromioclavicular repair was not correlated either to radiographic or to clinical score (the Constant score, the simple shoulder test), this study demonstrated that there was a correlation between the normal acromioclavicular joint motion evaluated by the 90°/0°RTest and the cross arm test and the patients' return to everyday activities and sports at the same level as before surgery. Ossifications type 2 or 3 were present in more than 96% of the cohort with a normal acromioclavicular joint motion. It was observed that the ossifications enhanced the stiffness of the surgical repair and improved clinical outcome. There was no clear scientific explanation for the high percentage of ossifications observed (65%), or for the low incidence of clavicular osteolysis (34%). The best results were observed in the younger subjects and those with acute lesions.

Conflict of interest The authors declare that they have no conflict of interest.

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