LockDown

Clinical papers

LockDown

Contents

Introduction

LockDown is proudly built on a unique history and heritage.

LockDown LSSS for ACJ reconstruction, was originally called Surgilig and part of a company dating back to 1924 with an impressive pedigree in innovation borne out of collaboration with clinicians.

The device concept was developed with world-renowned surgeons in the field of shoulder surgery. In the spirit of continual improvement, we have continued to develop and refine the system, via consultation with specialist orthopaedic surgeons. In line with this, we also rebranded the company to LockDown Medical Limited, and the device to the LockDown Shoulder Stabilisation System (LSSS™).

Since its conception, its use across acute and chronic ACJ reconstruction combined with other pathologies has been widely documented. The system boasts more than 20 years of clinical evidence, combined with exceptional patient outcomes, backed up by worldwide clinical use, with thousands of the device implanted each year.

Here, we present to you a sample of clinical papers documenting the use of the LockDown Shoulder Stabilisation System (LSSS™).

Chronic acromioclavicular separation:

The medium term results of coracoclavicular ligament reconstruction using braided polyester prosthetic ligament

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Keywords
AC separation; Coracoclavicular ligament; Reconstruction; Braided polyester prosthetic ligament

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Summary
In this series, we treated chronic acromioclavicular disruption with an artificial coraco-clavicular ligament made from braided polyester (The Nottingham Surgilig). The ligament has a loop at each end and is passed around the coracoid process, threaded through itself, then passed around the posterior aspect of the clavicle and finally anchored to it with a bone screw.

Eleven men with an average age of 39 underwent this procedure. Three patients had previously been operated on using the Weaver-Dunn procedure which had failed. All eleven patients have been reassessed clinically and radiographically at an average of 55 months. Using the Imatani evaluation score, 10 patients achieved a good/ excellent result with the mean Constant score being 92. One patient had fracture of the base of the coracoid after heavy lifting in the early postoperative period which resulted in a poor outcome. Two patients needed an additional operation. In one the lateral end of the clavicle was excised together with removal of the fixation screw, and in the other a subacromial decompression was carried out.

The Nottingham Surgilig is a useful alternative for the treatment of chronic acromioclavicular separation, especially in revision reconstruction when the coracoacromial ligament is no longer available.

Introduction

Disruption of the acromioclavicular joint (ACJ) represents about 3-5% of shoulder girdle injuries and the majority of these acromioclavicular injuries can be successfully treated by simple, non-operative means, particularly in cases of partial disruption.[14,15] However, there remain a significant number of patients who are dissatisfied with the results of conservative management, especially those who are required to use their arm in an overhead position or for demanding activities. The treatment of complete ACJ dislocation is still controversial.[5,6,16]

More than 60 different surgical procedures as well as a variety of conservative measures have been suggested for treatment of this injury.[15] Delbet carried out the first coracoclavicular reconstruction using a single strand of silver wire looped under the coracoid and through a drill hole in the clavicle and most of the coracoclavicular fixations described in the literature have been modifications of Delbet's original procedure.[8] However, simple coracoclavicular circlage causes anterior subluxation of the distal clavicle with malreduction of the ACJ and synthetic material such as wire may wear through the bone and result in failure of reduction.[5] The use of a Bosworth screw requires a second procedure to remove the screw to avoid breakage or migration.[6] Although good results have been reported with Weaver-Dunn coracoacromial ligament transfer,[17] this coracoacromial ligament is not always available, and this procedure by necessity disrupts the coracoacromial arch.

Woven polyester ligaments have been used previously to reconstruct ligaments in the knee joint because of the material's ability to provide a scaffold for tissue ingrowth and its adequate mechanical properties.[3,4,9-12,14] Recently this braided polyester material has been modified into a purpose made ligament with loops on both ends to reconstruct the disrupted coracoclavicular ligament.

In this report, the authors describe a method of reconstruction of the coracoclavicular ligament for chronic symptomatic dislocation of the ACJ using this new ligament and report the medium term results of reconstruction.

Materials and methods

Thirteen patients with chronic complete ACJ dislocation treated by this method were retrospectively reviewed. Two patients were lost to follow-up, and the remaining eleven patients were evaluated clinically and radiologically. All were male with an average age of 39 years (range, 20-61) at the time of the operation. Eight injuries were to the dominant extremity and the right side was involved in seven.

Four patients were injured during a fall, three from bicycle accidents, two during sports activities and two during motor vehicle accidents. All were chronic injuries and the average interval from injury to operation was 18 months (range, 3-36 months). Nine of the injuries were classified as Rockwood grade[14] III and one as grade IV and one as V.

After the initial injury, six patients were treated in a sling, three had a Weaver-Dunn procedure (cases

2, 6, 11), and two did not have any treatment. However, all of these patients continued to suffer from residual shoulder pain, discomfort, weakness and clicking. They all presented to us with obvious deformity of the ACJ and radiographs showed superior migration of distal clavicle above the level of the superior surface of acromion. The length of the non-operative treatment in these patients varied from 9 to 36 months with a mean of 14.4 months, which included anti-inflammatory medication and strengthening exercises (Table 1).

A purpose made braided polyester prosthetic ACJ ligament (Nottingham Surgilig, Surgicraft, Redditch, UK) [Fig. 1] was used in the reconstruction. All operations were performed by two senior authors.

Operative technique

All operations were performed under general anaesthesia with the patient in the deckchair position. A sagittal skin incision was made from the superior margin of the clavicle just medial to the ACJ down to the level of the coracoid process. The deltoid muscle was split in line with its fibres and the trapezius deltoid interval was incised to expose the clavicle and 5-10mm of its distal end was excised.
A curved guide instrument was passed from medial to lateral

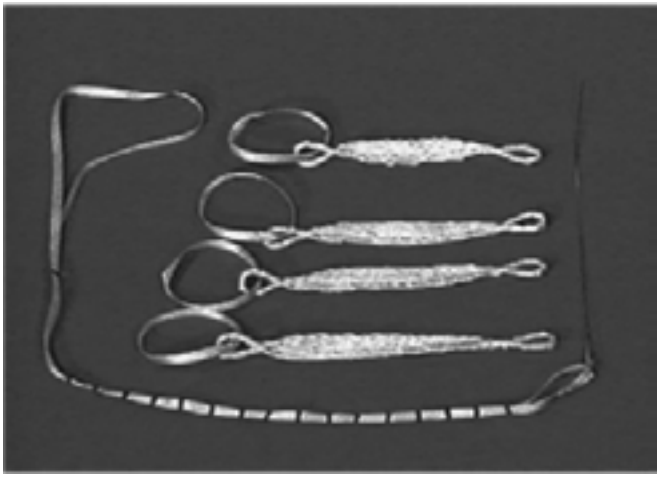

Figure 1: Polyester prosthetic ligament (Surgilig, Surgicraft, Redditch, UK) of different length and the Surgilig length gauge with metal lead.

in order to avoid the brachial plexus and allow the passing of the ligament to be close to the coracoid process [Fig. 2]. After reduction of the clavicle, the appropriate length of the prosthetic ligament was determined by the use of a measuring length gauge [Fig. 1]. The ligament was passed around the coracoid process [Fig. 2] and threaded through one of its loops to afford secure attachment at the base of the coracoid process [Fig. 3]. The free end was then passed from inferiorly round the posterior aspect of the clavicle and finally tensioned, before it was fixed onto the superior or anterior surface of the clavicle with a 3.5 mm bi-cortical screw through the second loop [Fig. 4A and B]. The clavicle was this way held in its manually reduced position.

Postoperatively, the affected arm was placed in a sling for comfort for 10-14 days, after that time, the patients were permitted to mobilise as freely as they were able, but told to abstain from demanding use.

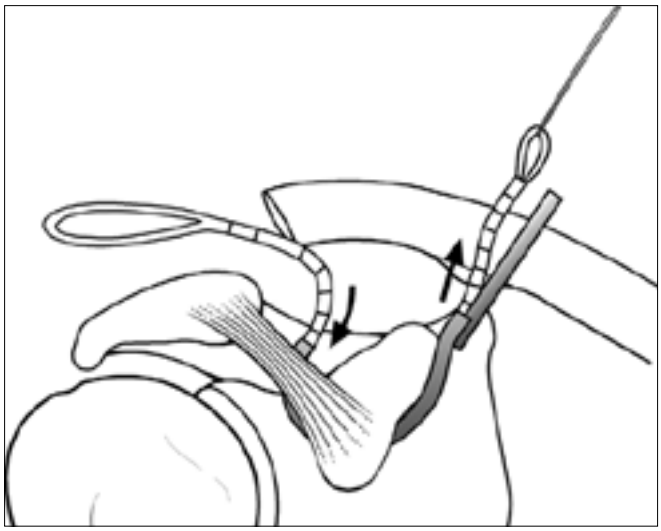

Figure 2: Curved guide passed around the coracoid process from medial to lateral in order to avoid the brachial plexus. The ligament was passed around the coracoid process and then the ligament was threaded through one of its loops to afford secure attachment at the base of the coracoid process.

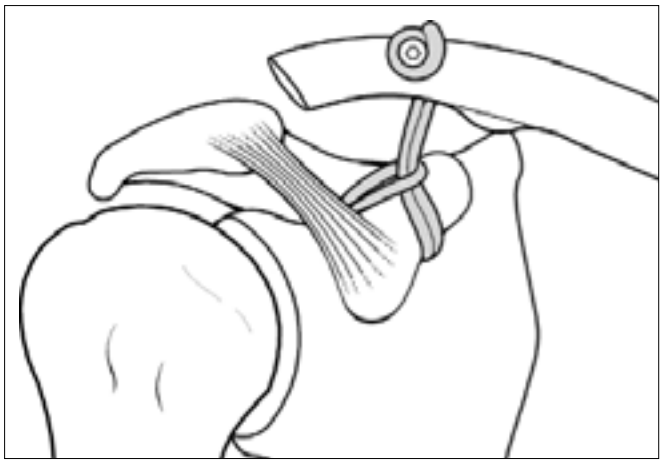

Figure 3: The free end was then passed inferiorly round the posterior aspect of the clavicle and tensioned prior to fixation through the second loop onto the clavicle. The AP (anterior-posterior) view after fixation onto the clavicle.

Follow-up evaluation

All eleven patients were reviewed clinically and radiographically by two doctors who were not primarily involved in the treatment. The functional outcome was assessed using the Constant[1] and Imatani scoring system.[7]

The subjective results were also assessed in terms of patients' satisfaction and the patients were asked whether they would undergo the same procedure again for a similar problem.

Preoperatively and at follow-up, AP, axial radiographs were taken with 10° cephalic tilt view of ACJ. Radiographic analysis of subluxation was graded as mild, moderate and severe (Table 1).[7]

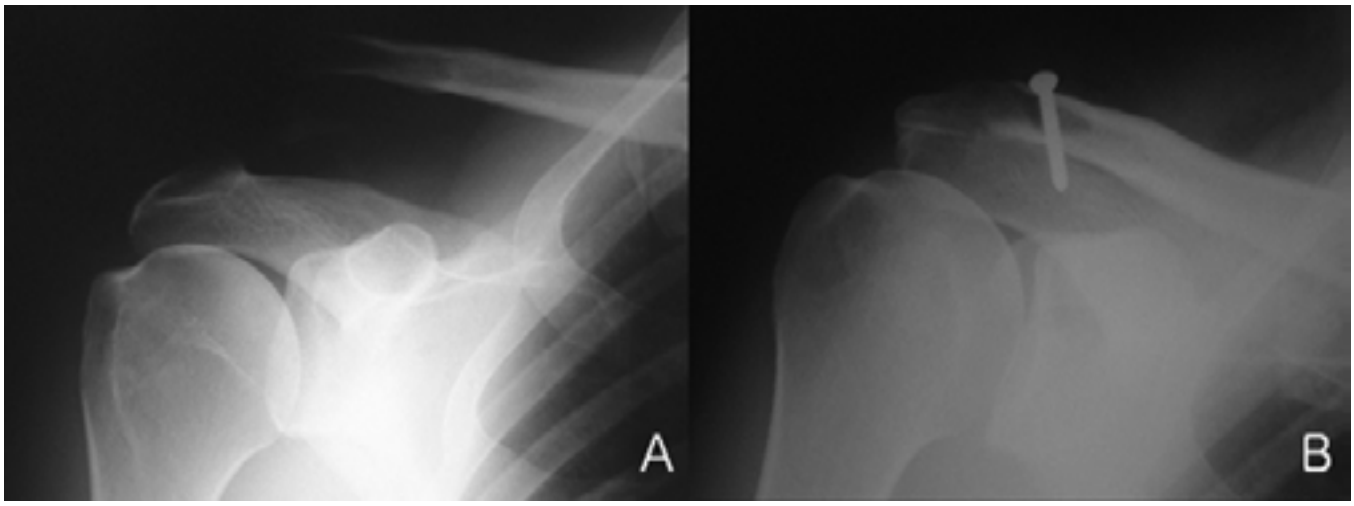

Figure 4: The preoperative (A) and postoperative (B) radiographs of the patient (case number 1).

Table :1 Summary of the patients

Case	Age	Side/ dominance	Cause of injury	Rockwood's grade	Initial treatment	Interval (months)	Occupation	X-ray evaluation	Follow-up (months)	Imatani score	Constant score	Complications and further surgery
1	39	L/ND	Judo	5	Sling	10	Engineer	Minor S/L	50	100	98	No
2	36	R/D	Fall	3	Weaver-Dunn (2)	18	Van driver	Loss of reduction	80	60	64	# Of coracoid
3	46	L/ND	RTA	3	Sling	12	Civil servant	Minor S/L	48	90	97	Calcification of CC ligament
4	61	R/D	Fall	3	Sling	18	Car park attendant	Moderate S/L	60	85	96	ACJ excision at 10 mo
5	37	R/D	Fall from bike	3	No	18	Cleaner industrial	Minor S/L	50	95	96	No
6	42	L/ND	Fall	3	Weaver-Dunn	20	Joiner	Minor S/L	48	85	94	SAD at 8 months
7	20	R/D	Fall	3	Sling (scapular#)	3	Engineer	Minor S/L	48	100	98	No
8	24	R/D	Fall from bike	3	Sling	24	Engineer	Minor S/L	50	95	92	No
9	31	L/D	Football	3	Sling	18	Builder	Minor S/L	78	100	94	No
10	36	R/D	Fall from bike	4	No	19	Mechanic	Minor S/L	50	100	100	No
11	61	R/D	RTA	3	Weaver–Dunn	36	Security Officer	Minor S/L	40	85	87	No
Ave.	39					18			55	90.5	92.3	

D: dominant, ND: non-dominant, Interval: interval between injury and operation, S/L: subluxation, #: fracture, SAD: subacromial decompression.

Results

The mean follow-up period was 55 months (range, 40-80 months). The mean Constant score for the whole group was 92.3 (range, 64-100). Applying the Imatani evaluation system, seven patients were graded as excellent, three as good and one as poor. Table 1 summarises the results.

Pain

Mild occasional pain was present in six patients. However, only the patient who had had a coracoid fracture (case 2) reported constant pain with normal activity. Another patient (case 3) complained of pain when lying on the affected side at night.

Range of motion

In all patients except two, the operation restored a normal range of motion. One patient (case 2) developed a coracoid fracture, which was subsequently treated with a Dewar-Barrington procedure.[2] This patient had restricted elevation to 90˚ and external rotation of 30˚ at final follow-up. The other patient (case 4) had preoperative limitation of 140˚ of flexion related to rotator cuff pathology, which improved to full range after a subsequent subacromial decompression.

Patient satisfaction

Nine of the patients stated that they were satisfied with the procedure, and would undergo the same operation again if a similar problem occurred. One patient was unsure regarding the procedure and another stated that he would not have the surgery again. They were, however, both satisfied with the improvement in strength and power. Nine patients were judged as having a normally appearing acromioclavicular joint without deformity on inspection. Two patients had minimal elevation of the clavicle.

Function

All patients were able to return to their previous level of activity and employment, except one (case 2). Nine of the patients were in manual occupations (Table 1). The mean time to return to work was 5 weeks (range, 2-10 weeks). Two patients returned to work in 2 weeks.

Complications

In one patient, the coracoid process had been eroded by the ligament and a subsequent fracture developed. The patient had received one previous Weaver-Dunn operations, which failed after recurrent trauma. After the implantation of the Nottingham Surgilig, the patient injured the shoulder lifting heavy items in his work place in the early recovery phase, against advice. There was no accompanying erosion of the distal clavicle.

Two patients required further surgery for persistent problems. One patient (case 6) required a subacromial decompression for impingement symptoms at 6 months, and later removal of the screw from the clavicle due to tenderness around the fixation site. The other patient (case 4) underwent trimming of the lateral end of the clavicle at 10 months after stabilisation.

Radiological review

Postoperative radiographs showed minor subluxation in 10 (difference in the distance between the inferior border of the acromion and the clavicle of 2-4mm when comparing the operated side with the healthy side), and moderate subluxation in one (4-8 mm difference). The mean superior migration on weight bearing views was 7mm (range, 2-8mm). Calcification and ossification in the remainder of the coracoclavicular ligaments were noted in one patient (case 3) but the patient was asymptomatic.

Discussion

Most complete acromioclavicular dislocations treated conservatively do not become symptomatic.[5,6,15-17] However, there are some patients who have persistent symptoms after conservative treatment. Some surgeons advocate early operation for ACJ dislocation particularly in manual workers and sportsmen and it has been suggested that the results of early repair are superior to late repair.[6] The weight of evidence, however, is in favour of initial non-operative management. In this series, three patients were treated surgically in the early stage after injury. Our preferred approach is to treat disruption of the ACJ conservatively in the first instance, with operative management being largely reserved for those who remain symptomatic after conservative treatment.

Polyester has been used previously to reconstruct the ligament in the knee. The literature demonstrates that polyester provides a scaffold for tissue ingrowth with minimal synovial reaction[4,12] and sufficient mechanical strength.[3] In this series, we used a braided polyester ligament with loops on both ends.

Many different operative techniques for ACJ injury have been proposed.[5,6,8,13,17] Transfer of the coracoacromial ligament is widely used, with good results being reported in the literature.[17] Guy et al. reported the positioning of the distal clavicle was well maintained with a coracoacromial ligament transfer and a coracoclavicular lag screw.[6] However, using this technique, resisted strengthening exercises should be avoided until after screw removal at 12-24 weeks. Using the artificial ligament we have developed, we were able to allow our patients to return to daily living earlier without long-term immobilisation. The functional outcome of this procedure was very similar to other reports;[5,6,13,15] Constant score of 92 point and 10 patients showed excellent or good results.

One advantage of this technique is that it does not rely on the presence of the coracoacromial ligament, which may be a particular advantage when carrying out revision surgery or when the coracoacromial ligament is deficient such as in patients who had a previous Weaver-Dunn operation or a subacromial decompression. Because the ligament is passed around the clavicle and fixed with a cortical screw through the second loop, the clavicle is free to rotate along the long axis during elevation of the arm without the bone being eroded by the ligament sliding over it. The construct is more physiological because the loop does not interfere with the clavicular motion.

The ligament used has been shown to be able to tolerate enough mechanical strain to allow early postoperative mobilisation. Independent biomechanical testing of this ligament demonstrated that 1 million cycles at 300 N load in a bath of normal saline at 37.8°C caused no more than 1mm elongation.

Two patients were able to return to their manual jobs at 2 weeks after surgery. In addition to the ligament having high initial strength, we identified good tissue ingrowth into the polyester ligament when we removed the screw in the distal clavicle (case 6) where the new ligament remained in situ securely attached on the periosteum of the clavicle. This finding is also reported in previous studies.[8-11]

Examples of the potential complications of this technique are described in this series. The complication of cutting through the coracoid process can happen with any simple coracoclavicular circlage, and we had one such complication leading to a fracture. However, the patient applied a significant load onto the shoulder within the first 3 weeks after the operation against advice. As long as the patient follows the postoperative instruction properly, this complication can probably be avoided.

Two patients required further surgery for persistent problems. One patient (case 6) already had a Weaver-Dunn procedure for stabilisation, but the joint had completely re-displaced such that it was akin to a type III dislocation. The patient had persistent symptoms warranting further surgery. Following his successful operation using this technique, he required a subacromial decompression for impingement symptoms 8 months later, and subsequently removal of the screw from his clavicle due to tenderness around the fixation site. The second patient (case 4) requiring re-operation was a 61-year-old car park attendant who underwent trimming of the lateral end of the clavicle at 10 months after stabilisation as it was impinging on the acromion as its posterolateral corner. In both cases, subjective improvements after the additional surgery were reflected by an improvement in the Constant scores from 42 to 88 and from 68 to 78, respectively.

The limitations of this study are the relative small sample size with retrospective nature of study and no preoperative functional score, thus it is not possible to assess and compare the definite achievement through this procedure. The sample size did not permit an accurate assessment of the time to functional recovery. There was a potential observer bias as the observer could not be blinded. However, we recommend this technique for chronic symptomatic cases of ACJ disruption, especially where the coracoacromial ligament is deficient or absent. Also, this method preserves the coracoacromial ligament whose role is important as a restraint to anteriorsuperior migration of the humeral head in rotator cuff deficiencies. The implant allows very early mobilisation when comparing to other methods, resulting in financial savings and reduction in patient inconvenience, absence from work, etc. At a relatively long follow-up, we have not seen the complications reported in relation to other coracoclavicular ligament implants, and we believe that the Nottingham Surgilig, because of its design and the way it is implanted has advantages which has lead to results that should alleviate the fear of complications commonly associated with the use of artificial ligaments for this indication.

Acknowledgement

We thank Mr. Lyndon Cochrane for his illustrations and photographs of this work.

Conflict of interest

All authors declare that no financial and personal relationships with other people, or organisations, that could inappropriately influence (bias) our work, all within 3 years of beginning the work submitted.

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Preliminary Results of the 'Surgilig™' Synthetic Ligament in the Management of Chronic Acromioclavicular Joint Disruption

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Keywords
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Abstract

Chronic instability of the acromioclavicular joint is relatively common and normally occurs following a fall onto the point of the shoulder. Reconstruction of the joint [Weaver-Dunn procedure] using the coracoacromial ligament is often required in service personnel, and a number of methods to augment this repair have been used. Many of these operative methods require a second operation to remove the metalwork, and in addition can be associated with a failure rate of up to 30%. The 'Surgilig™' was originally designed for use in the revision of failed Weaver-Dunn procedures. However this study evaluates its use in the primary operation, reinforcing the autologous graft, in an attempt to reduce the failure rate.

We prospectively followed up the Modified Weaver Dunn procedures using Surgilig™. The post-operative x-rays were reviewed at six weeks, three months and then six months to assess the radiological success of the procedure. Our patients were discharged at six months.

We have performed this procedure in 11 patients. One of the 11 patients was excluded from the study as the Surgilig™ graft was used in addition to a hook plate. The remaining ten patients have all reached the six-month post-operative time with no incidence of radiological failure of the graft. After six months they were discharged from clinic follow-up as the coracoacromial graft had sufficient strength to no longer rely on the augment for mechanical stability of the joint. All 10 patients had a good clinical and radiological result. One patient even had inadvertent stress/weight-bearing x-rays taken at six weeks, with no discernable detrimental effect to outcome.

Although a small study, these initial results for primary fixation of acromioclavicular joint disruption with Surgilig™ are extremely encouraging. The results suggest that Surgilig™ should continue to be used in its current role. As patient numbers increase, a follow-up study to evaluate these preliminary findings should be conducted.

Introduction

Acromioclavicular joint (ACJ) disruption (Figure 1) is a common military injury, which usually occurs following a fall onto the point of the shoulder [1]. It has been reported that ACJ disruption accounts for 3-5% of all shoulder girdle injuries [1]. Although there is some debate regarding exactly which ACJ disruptions should be treated operatively, it is generally accepted that the majority of ACJ injuries are successfully treated conservatively [1]. Unfortunately some patients fail conservative management, either due to persistence of symptoms or worsening of ACJ separation. These patients require secondary reconstruction to provide definitive stabilisation of the joint [7].

Historically, the injuries requiring operative fixation, underwent a Weaver-Dunn procedure. This was first described in 1972, and involved excision of the lateral end of the clavicle and transfer of the coracoacromio ligament to supplement the deficient acromioclavicular and coracoclavicular ligaments [2]. Copeland described a modified technique in 1995, which included reinforcement of the ligament with a PDS loop, to reduce the failure rate of ligament transfer alone [3]. A number of other augments have been used, including ethibond, vicryl tape or plates and screws. They are all short-term measures offering stability to the joint whilst the main coracoacromial ligament graft heals, and therefore strengthens. Many of these methods still had significant failure rates. (figure 2), or required a second operation to remove the plate and/or screws used.

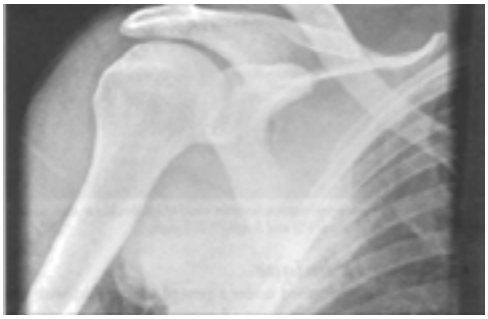

Fig. 1 A typical x-ray showing acromioclavicular joint disruption

In 2001 a synthetic ligament known as Surgilig™ was developed by the Nottingham shoulder unit [4]. This was initially used in revision ACJ stabilisation operations. More recently this method has gained popularity as the primary operation, where it appears to have a lower failure rate than other augments. This study intends to assess the early results of the use of Surgilig™ at Frimley Park Hospital.

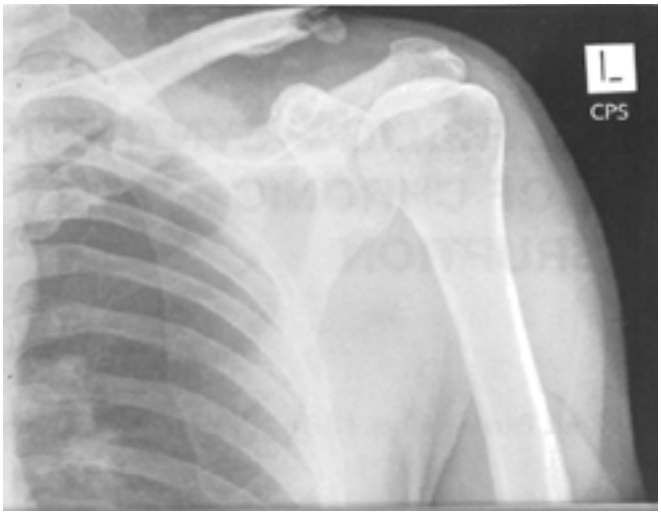

Fig. 2 A post-operative x-ray showing a failed acromioclavicular joint reconstruction

Materials & Methods

Between February and November 2007 we performed 11 procedures using Surgilig™ (manufactured by Surgicraft Ltd and distributed by Plus Orthopaedics UK Ltd). The indication for surgery was a displaced acromioclavicular joint with loss of function. Our cut-off for the degree of displacement was greater than 50% of vertical dislocation (which equates to grade 3 on the Rockwood score). Our patients were followed up to the 6 month point post-operatively when they were discharged from Consultant care. The two senior authors (JC, PR) performed all operations.

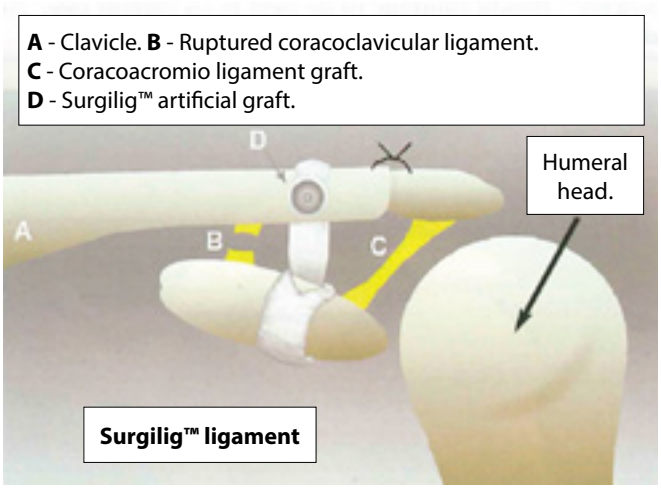

Fig 3. Diagrammatic representation [anterior view] of left shoulder to show position of the coracoacromio ligament [C] and Surgilig™[D] grafts.

Operative technique

The operation is performed under a general anaesthetic, with the patient in the deck chair position. A saggital skin incision is made from a point just medial to the ACJ to the coracoid process. The clavicle and acromiocalvicular joint are identified. The lateral one centimetre of the clavicle is excised, and a recess created in the distal portion with a burr. The acromial end of the coracoacromial ligament is detached and then re-inserted into the recess at the

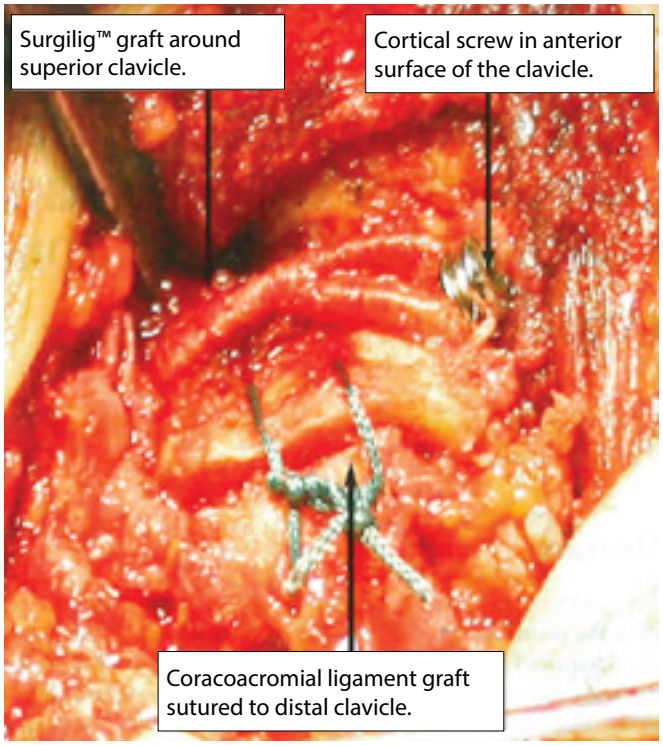

Fig 4. Operative photograph showing Surgilig™ and anchored around clavicle with a cortical screw in the anterior surface. [Looking medially along superior border of the clavicle].

lateral end of the clavicle. The coracoacromial ligament graft is held in place with a suture through the clavicle. Surgilig™, a braided polyester prosthetic with a loop at either end of the graft, is passed around the coracoid process using a curved introducer and then threaded through itself. The free end is then passed around the posterior aspect of the clavicle before being attached to the anterior aspect of the clavicle with a bone screw (Figures 3 and 4). Post-operatively the limb is immobilised in a sling for six weeks following which time a period of rehabilitation is recommended prior to the return of normal duties.

Posterior-anterior radiographs were taken at the following times post-operatively:

1. Prior to discharge
2. Six weeks
3. Three months
4. Six months, when follow-up is completed

Results

Eleven patients underwent acromioclavicular joint stabilisation using Surgilig™ between 8th February 2007 and 7th November 2008. Of these patients, one had Surgilig™ used in addition to a hook plate, and therefore was excluded from analysis in this study. There were no intra, or post-operative complications. Of the 10 patients remaining, none experienced failure of the graft when assessed radiologically as outlined in our methodology, and all returned to their pre-injury level of activities.

Figure 5 shows post- operative radiographs of the Surgilig™ used successfully on the right side, with the left side included for comparison. There is no disruption to the ACJ even on weight loading of the joint. We have not experienced any complications to date with the use of Surgilig™, but continue to monitor our use of this implant.

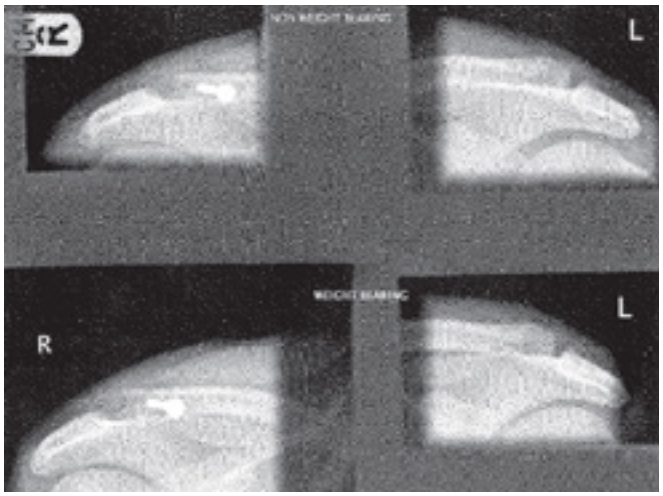

Figure 5. Port-operative x-rays of a Surgilig™ graft used on the right side [note the screw in the clavicle] and the normal left side for comparison. This patient even had inadvertent stress weight-beating views.

Discussion

From a military perspective, given the age and activity level of military patients, reconstruction of a chronic ACJ dislocation is a relatively common procedure. The functional level that is required post-operatively necessitates a secure augment to the coracoacromio ligament. Military patients benefit from treatment with a single definitive operation. As a group that is so transitory, fixation involving two operations would often require the handover of clinical care as the patient is moved to a new geographical location. It would also require a second period of downgrading and rehabilitation thus prolonging the time of eventual return to active duty.

The use of Surgilig™ in the modified Weaver Dunn procedure has proved beneficial in revision ACJ stabilisation surgery, failed conservative management and even in acute cases [5] . Regardless of the indication for its use, the functional outcome with Surgilig™ has allowed early mobilisation of the affected limb, and early return to full function [6], making it a highly desirable option for use in active people.

A number of methods are available to augment the 'classical' Weaver Dunn, including a hook plate, a plate and screws, or just screws alone [6]. All these methods increase the strength and durability of the fixation. However the real benefit of using Surgilig™ is that it offers secure fixation of the AC joint without the need for a second operation. In contrast, a hook plate can be used to provide a similar secure fixation; however it does require a second operation to remove the plate, necessitating a second in-patient admission.

Although we prospectively followed-up these patients, and therefore had no control group to directly compare our results against, we are confident that more traditional methods of fixation would have displayed a higher failure rate. The authors believe that the complication rate with the previous methods of fixation [ethibond suture, vicryl tape and hook plate] was high [see Figure 2], and this is supported by published evidence [7]. As the results with Surgilig™ have proven it to be so effective, we believe that it would now be unethical to proceed with a randomised control trial.

A potential criticism of our study could be that we relied on radiological evidence and the patients' report of return to all activities as the only outcome measures. Numerous clinical and/or functional shoulder scores exist, such as the Constant-Murley and the Imatani [8,9] scores. However with our particular patient group, a group of motivated and active service personnel, the authors believe they would have scored highly even pre-operatively and therefore would have made conclusions based on functional scores difficult to interpret and potentially misleading. It was felt that to use symptomatic and radiological evidence only would provide more accurate results. Indeed, all of our patient group have returned to full military duties, indicating a very high functional outcome.

In contrast to other units we still use Surgilig™ as an augmentation implant, and continue to rely on the coracoacromial ligament to provide long term mechanical stability. A study from Jeon et al in South Korea advocates the use of Surgilig™ alone, and reports good results over a period of 55 months [10]. We feel that as the prosthesis is artificial, we would expect it to ultimately fail. If used solely then the strength and functionality of the joint would be reliant on scar tissue exclusively. The authors believe that it is more prudent to use Surgilig™ as an augment to the coracoacromio ligament, so that strength to the acromioclavicular joint is provided by the graft augment in the early stage whilst the coracoacromio ligament achieves full tensile strength. This theory is supported by published biomechanical evidence [11] . Anecdotally the authors have seen failures of the sole use of Surgilig™ without coracoacromial ligament transfer, in service personnel operated on at other centres.

We advise our patients to keep the arm immobilised in a sling for six weeks, after which time mobilisation can begin. We would expect that formal rehabilitation could begin at three months post-op as accepted scientific belief suggests that ligaments heal in three months and therefore the coracoacromial ligament will have achieved full strength. We expect, and have found with our military patients that they can be medically upgraded at five to six months after the operation. Unlike a hook plate or plate and screws, there is no requirement for a planned period of future downgrading/ operation/rehabilitation to facilitate removal of the graft.

Conclusion

This study suggests very positive early results for the use of Surgilig™ in primary acromioclavicular joint disruption. The benefit of a single definitive operation would be particularly useful in a military setting, although the reduction in in-patient time and duration of rehabilitation it has clear advantages for the wider NHS setting. Although we have not experienced any complications so far in this initial study, we remain vigilant to any complications that may arise. We are extremely encouraged by the results so far, and feel that after the six-month post- operative time frame we would expect the transplanted coracoacromial ligament to deliver almost all of the mechanical strength stabilising the ACJ. The authors believe that the use of Surgilig™ warrants further study, with particular attention to a longer period of follow-up, and studying a larger patient group.

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Stabilization of acromioclavicular joint dislocation using the ‘Surgilig’ technique

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Conflicts of Interest
None declared

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Background Disruption of the coracoclavicular ligaments may be associated with dislocation of the acromioclavicular joint, resulting in pain and functional disability. The Surgilig (Surgicraft Ltd, Redditch, UK) is a synthetic ligament used to reconstruct the ligaments, thereby stabilizing the joint.

Methods Between 2004 and 2009, 50 patients with acromioclavicular joint dislocation were reconstructed using the Surgilig system. Five patients were lost to follow-up; hence, 45 patients underwent review. Patients were evaluated clinically and radiologically at an average of 26.9 months (range 6 months to 60 months) postoperatively using the Oxford, University of California, Los Angeles (UCLA) and Simple Shoulder scoring systems.

Results The mean Oxford score was 45.31 (SD 4.52, range 35 to 48), the mean UCLA score was 31.38 (SD 5.07, range 11 to 35) and the mean Simple Shoulder score was 10.92 (SD 1.7, range 6 to 12). Ninety-one percent of patients were completely satisfied with the procedure and outcome. Few complications were encountered, with no recorded infections. However, one patient underwent early revision for persistent instability. Six patients had the screw removed at a later stage as a result of local skin irritation. Removal of the screw did not result in recurrent instability.

Discussion The present study is the largest reported mid-term results using the Surgilig technique, and appears to be successful for treating both acute and chronic injuries, with high patient satisfaction and excellent functional results.

Introduction

Acromioclavicular joint (ACJ) injuries commonly result from a direct force, generally occurring from a fall onto the tip of the shoulder with the arm adducted. They comprise 3% to 5% of all shoulder injuries [1]. Disruption of the acromioclavicular ligaments alone after such trauma may result in inferior subluxation (i.e. the acromion is driven anteroinferiorly) of the ACJ. Larger forces can lead further to rupture of the coracoclavicular ligaments, resulting in the complete dislocation of the ACJ, with long-term pain and functional disability.

ACJ injuries were classified by Tossy et al. [2] and Allman [3] as incomplete (Grades I and II) and complete (Grade III). Neviaser [4] subdivided Grade III injuries into IIIA (reducible) or IIIB (irreducible) depending on the effect of upward force on the elbow, suggesting the latter type required operative treatment. Whereas, Rockwood[5] expanded the original classification by subclassifying Grade III injuries into four types, resulting in a total of six types (I to VI).

We use Rockwood's classification to describe injury patterns in our study [5].

The treatment for ACJ disruption varies according to the grade of injury. In general, there is a consensus that Types I and II are treated conservatively with analgesia, a short period of support in a broad arm sling, followed by early mobilization [1]. However, the evidence suggests that Types IV, V and VI comprise injuries that have a poorer outcome if conservatively managed and operative intervention is required [1,6].

The ideal treatment of the Type III injury remains controversial and practice varies between centres and individuals. Most Type III injuries are currently treated conservatively [7]. A series of retrospective studies showed no outcome differences between operative and non-operative groups. Furthermore, the patients treated non-operatively returned to full activity sooner than surgically treated groups [8,9]. Exceptions to this include those individuals who perform repetitive or heavy lifting, those who work with their arms overhead, and thin patients who have prominent ACJ. These patients may benefit from surgical repair [10,11].

Surgical repair can be divided into six main types:

- Acromioclavicular fixation: intra-articular repair with Kirshner wires [12], hook plates [13].
- Coracoclavicular fixation: Bosworth screws [14], Cerclage
- Distal clavicular excision [15].
- Distal clavicular excision and coracoacromial ligament transfer: Weaver-Dunn [16].
- Coracoclavicular ligament reconstruction using soft tissue: free tendon grafts, dynamic muscle transfer [17].
- Coracoclavicular ligament reconstruction using prosthetic ligament: Surgilig [18], Tightrope.

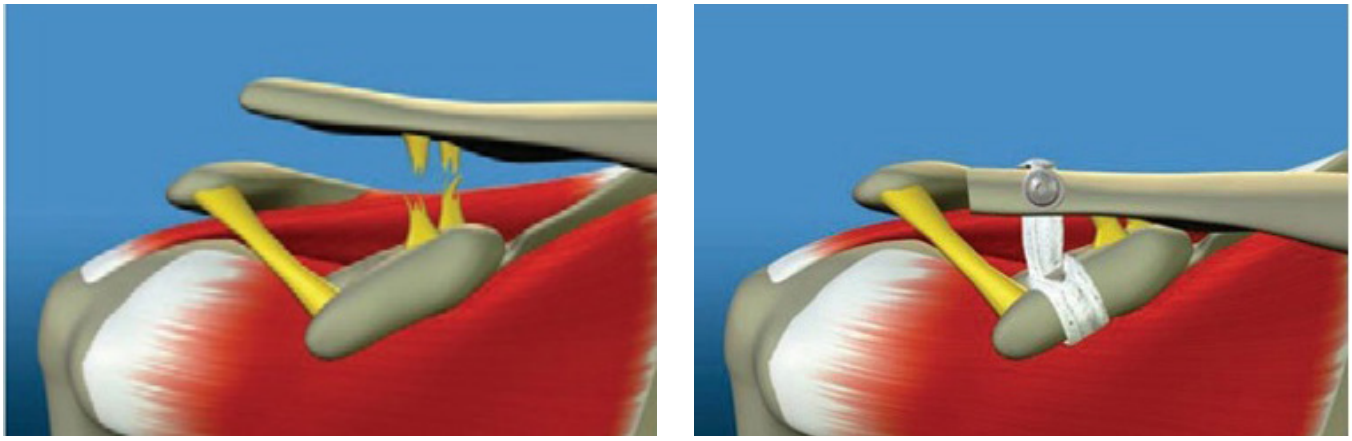

Fig. 1 (A) Acromioclavicular joint (ACJ) dislocation and coracoclavicular (CC) ligament rupture. (B) Surgilig: ACJ stabilization (CC ligament reconstruction).

We report our experience and medium-term results with the use of the Surgilig (Surgicraft Ltd, Redditch, UK) prosthetic ligament for ACJ reconstruction.

Materials and Methods

In this prospective cohort study, 50 patients with Type III to V ACJ injuries, who consented for surgical management, were treated using the Surgilig prosthetic ligament. The ligament utilizes a braided synthetic polyester ligament with loops on both ends to reconstruct the disrupted coracoclavicular ligaments by securing the distal clavicle to the coracoid, thus providing strong biocompatible fixation (Fig. 1).

Operative technique

All operations were performed by the two senior authors, under general anaesthesia with the patient in the supine position, with head-up tilt. A vertical skin incision was made from above the clavicle just medial to the ACJ to the level of the coracoid process. The deltoid muscle was split in line with its fibres and the trapezius deltoid interval was incised to expose the lateral clavicle. The distal 5 mm to 10mm of clavicle was excised. The base of the coracoid was identified and a curved guide instrument was carefully slid adjacent to and around the bone from medial to lateral to allow the Surgilig to be seated close to the coracoid.

The instrument was then used to feed the Surgilig Length Gauge around the coracoid. This measuring tape was then looped around the coracoid in the same manner as the proposed ligament, and passed up and behind the lateral end of the clavicle. The clavicle was reduced to its normal alignment and the appropriate length was determined.

The Surgilig was then 'daisy chained' to the Surgilig Length Gauge and passed around the base of the coracoid. The hard loop on the ligament was threaded through the soft loop, so that the soft loop sat on the superior aspect of the coracoid. The Surgilig was tensioned to the coracoid using a Loop Tensioner and the free end (hard loop) passed inferiorly around the posterior aspect of the clavicle. This was then fixed to the anterosuperior surface of the clavicle with a 3.5mm bi-cortical screw and accompanying washer. Postoperatively, the arm was supported in a sling for 4 weeks and then mobilized with supervised physiotherapy.

All 50 patients were reviewed clinically and radiographically by the two senior surgeons.

Anteroposterior, lateral and axillary view radiographs were taken pre-operatively and post-operatively (Fig. 2).

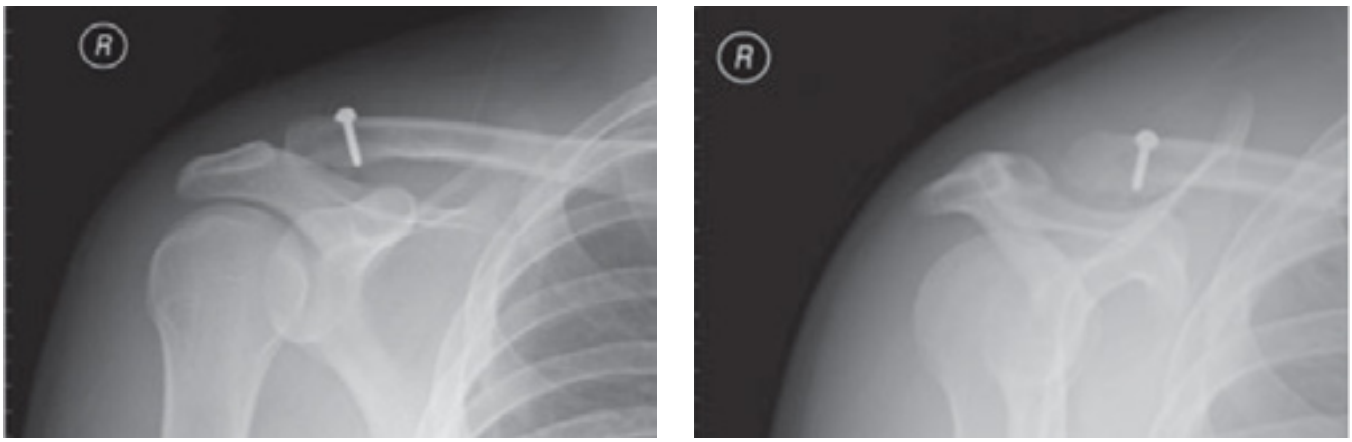

Fig. 2 (A) Postoperative anteroposterior view radiograph showing a reduced and Surgilig stabilized acromioclavicular joint (ACJ) dislocation (B) Postoperative lateral scapular view radiograph showing a reduced and Surgilig stabilized ACJ dislocation.

Anteroposterior radiographs were taken with a 10˚ cephalic tilt view of the ACJ. Radiographic analysis of postoperative clavicle migration on the AP radiographs was measured in millimetres using the measuring tool from the Picture Archive Communication System (PACS) software (Centricity, GE Medical Systems).

Functional outcome was assessed using the University of California, Los Angeles (UCLA), Oxford and Simple shoulder scoring systems. The subjective result of surgery was assessed in terms of patients' satisfaction, with patients being asked whether they would undergo the same procedure again for a similar problem.

Results

We have evaluated the medium-term clinical outcomes in a cohort of 50 patients treated with a Surgilig reconstruction of acromioclavicular injuries. Five patients were lost to follow-up, leaving 45 for review. This group had a mean age 37.6 years (range 19 years to 67 years), and consisted of 32 males and 13 females. Sixteen of the injuries were classified as Rockwood Type III, four as Type IV and 25 as Type V.

Seventeen of the cases were treated within 2 weeks of the original insult, whereas 28 were treated at a longer time interval. The average interval from injury to operation was 7.2 months (range 0.5 months to 120 months).

The mean follow-up period was 26.9 months (range 6 months to 60 months). The mean UCLA score for the whole group was 31.38 (SD 5.07, range 11 to 35). The mean Oxford Score was 45.31 (SD 4.52, range 35 to 48). The mean Simple score was 10.92 (SD 1.7, range 6 to 12).

Forty one of the patients stated that they were satisfied with the procedure, and would undergo the same operation again if a similar problem occurred. Four patients were not satisfied. Two had residual pain (one of these patients had an outstanding compensation claim), one patient was unhappy with the cosmetic appearance, and one patient was unhappy with both the cosmetic appearance and ongoing pain.

The majority of patients (n=32) showed no migration of the clavicle, when comparing immediate postoperative radiographs with those taken at latest follow-up. Migration was defined as the difference in coracoclavicular distance when comparing post- operative radiographs. Migration was noted in 13 cases. In this minority group, the mean migration was 6.3mm (range 3mm to 9mm).

Seven patients required further surgery. One patient required an early revision because the Surgilig displaced within the first week. Six patients ultimately required removal of the screw because ofskin irritation. This was usually performed at approximately 9 months postoperatively and did not result in recurrent instability.

Discussion

ACJ dislocation is a common injury and, given the number of different surgical procedures that have been described for its treatment, no single technique has been demonstrated to be ideally suited. Although there appears to be consensus that Type IV to VI injuries should be surgically managed, the management of Type III injuries still causes debate, with some centres advocating immediate surgery, whereas others suggest a conservative approach and intervention at a later date should the patient remain symptomatic.

In the present study, our preferred protocol involved initial non-operative treatment of Type III injuries, with analgesia and physiotherapy, and consideration of the surgical option if the shoulder remains painful and there is functional loss beyond 6 months after the injury. We treated all Type IV and V injuries operatively. A proportion of Type V injuries in our series were not immediately surgically treated. These cases had been initially managed elsewhere or had alternative initial advice in Accident and Emergency departments and hence had considerable delay in their presentation to our unit.

Over 60 different surgical procedures have been suggested for treating ACJ dislocations [2].

Amongst those described, the Mumford and Gurd technique involves simple distal clavicular excision and is mainly indicated for symptomatic Type II subluxations [15,19].

In the Modified Phemister technique, the ACJ is reduced and internally fixed with unthreaded Kirschner wires through the acromion, joint and lateral clavicle [12]. There is a risk of wire loosening and migration until they are removed at 8 weeks postoperatively and reduction can be lost soon after wire removal. In the Modified Bosworth technique, the ACJ is reduced, and fixation achieved by drilling a Bosworth screw from the clavicle into base of coracoid, followed by coracoclavicular ligament repair with sutures [14]. Again there is risk of migration, loosening with erosion of bone, which sometimes leads to fracture of the weakened clavicle.

The Hook Plate technique has the disadvantage of a larger incision, a reduced range of movement postoperatively as a result of impingement symptoms from the subacromially placed 'hook' and the necessity of a second procedure to remove the implant [13].

More recently, the modified Weaver–Dunn technique has been very popular for treating symptomatic ACJ dislocations [16]. This involves excising the distal clavicle. Next, the coracoacromial ligament, along with a sliver of acromion at its attachment, is freed and sutured to the remaining distal clavicle through the intramedullary canal, to achieve reduction. Although good results have been reported, the coracoacromial ligament is not always present, and this procedure unavoidably disrupts the coracoacromial arch. Recent biomechanical studies have stressed the importance of preserving, where possible, the subacromial arch and specifically the coracoacromial ligament for shoulder stability [20]. Release of the coracoacromial ligament can lead to increased glenohumeral joint translation and laxity [21]. Additionally, transection of this ligament removes the buffer between the acromion and the rotator cuff, which may lead to subacromial symptoms and cuff pathology [22]. Although it is accepted that the original Weaver–Dunn technique has had various modifications, especially in higher-grade injuries,

which require combined coracoclavicular ligament reconstruction or fixation, the use of a corocaoacromial ligament sparing artificial ligament may therefore confer an anatomical advantage.

Augmentation cerclage techniques for the reconstruction of the coracoclavicular ligament include PDS [23], Merselene [24] and carbon fibre [25] and these have been associated with the risk of the device cutting through the bone and failure of reduction. In our series, we did not see any evidence of coracoid erosion or fracture, although we accept that this has been described in earlier smaller series with shorter follow-up [18].

Recently, all-arthroscopic or arthroscopic-assisted techniques have been described to achieve reconstruction; however, the results so far have limited numbers with only short-term follow-up [26–28]. Some studies include cases with intact acromioclavicular ligaments, allowing arthroscopic excision of symptomatic ACJ without any underlying or resulting instability. All these studies cite high patient satisfaction with cosmetic appearance. Interestingly, however, only two of our series (4%) were concerned regarding their cosmesis after surgery.

The overall success rate in ACJ reconstruction surgery is approximately 90%, as reported in various studies [1,6,16,29]. In the case of late reconstruction, the success rate has been reported at approximately 78% [6,29]. In the present study, the use of the Surgilig in ACJ disruptions has yielded comparable, if not better, overall results compared to the other techniques of early and/or late reconstructions reported in the literature, with comparatively less adverse effects [18,30].

A single patient had recurrent instability warranting early revision surgery in our series. This was considered to be a failure of technique because the Surgilig slipped from behind the clavicle as a result of inadequate positioning and tensioning. By performing an oblique cut to the distal clavicle, thereby preserving more posterior bone, and with increased experience of using the implant, no subsequent failures were observed.

Six patients elected to have the screw removed at least 9 months after surgery as a result of irritation or prominence beneath the skin. However, we found that the prosthetic ligament appeared to allow tissue ingrowth because, whenever the screw in the distal clavicle was removed, the new ligament remained in situ, securely attached to the periosteum of the clavicle. This finding is also reported in previous studies [30]. Additionally, no recurrent displacement or instability of the clavicle occurred. Despite requesting removal of these screws, most of these patients remained satisfied with their surgery.

A minority of 13 patients showed migration of the clavicle postoperatively. None had an appearance greater than a Type II injury position on postoperative radiographs and only two patients had concerns with cosmesis. We found no correlation between migration and pain, grade or chronicity of injury. We accept that it was not possible to completely standardize the radiographic views and there is a potential observer bias in the radiographic analysis. There were no cases of postoperative infection or re-operations as a result of impingement of the lateral end of the clavicle on the acromion, as previously described in other series [18]. Also, unlike previous studies, none of our patients reported any untoward reactions to the synthetic materials used for reconstruction [31].

Despite a good sample size, the limitations of the present study include the lack of pre-operative functional scores, thereby making it difficult to assess and compare the definitive improvement after the procedure. We accept that the heterogeneity of our cases, in terms of grades and chronicity, makes it difficult to make clear conclusions on a specific classification subgroup.

Conclusions

The present study provides the largest reported medium-term results using the Surgilig technique. We have been successful in treating both acute and chronic injuries, with high patient satisfaction and excellent functional results. So far, there has been sparse evidence on the use and longer-term outcomes of this implant for treatment of ACJ injuries [18,30]. We have not had any significant complications or adverse reactions outlined in previous studies. The implant appears inherently strong and allows preservation of the coracoacromial ligament. We conclude that this technique is a safe, simple and reproducible method of reducing and stabilizing the acromioclavicular joint.

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Acromioclavicular joint dislocation: diagnosis and management

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Abstract

We present a review of the literature with respect to the anatomy, biomechanics, classification, diagnosis and rationale for contemporary management of both acute and chronic acromioclavicular joint dislocations. Both conservative and surgical management are discussed.

Introduction

Injuries to the acromioclavicular joint (ACJ) are common [1], accounting for between 3% and 5% of all shoulder girdle injuries [2] and up to 50% of shoulder injuries in athletic individuals [3]. The majority of these occur in males (five males to 10 males : one female) [4] in their 20s, often during contact sports [2].

Joint anatomy and biomechanics

The articulation of the acromion and the distal clavicle represents a diarthrodial joint with four planes of motion: anterior/posterior and superior/inferior. The ACJ is surrounded by a capsule and has intra-articular synovium and an articular cartilage interface. The hyaline cartilage becomes fibrocartilage by age 17 years on the acromial side of the joint and by age 24 years on the clavicular side [3].

A meniscal homologue is present within the joint. As we age, the meniscal homologue degenerates rapidly and is no longer functional after the fourth decade [5]. The average size of the adult ACJ is 9mm by 19mm but is subject to wide variations. The true articular portion of the distal clavicle varies in both location and size. Articular cartilage can cover the entire distal clavicle or it can cover a smaller percentage, which complicates the fixation and treatment of ACJ injuries.

Stability at the ACJ is achieved through a combination of both static and dynamic stabilizers. There are four AC ligaments: superior, inferior, anterior, and posterior. The ACJ capsule and the AC ligaments resist movement of the distal clavicle primarily in the horizontal plane (anterior to posterior direction) with respect to the scapula. Resistance to posterior translation is important because instability of the distal clavicle in the posterior direction can lead to abutment with the spine of the scapula.

The coracoclavicular (CC) ligament complex is the primary restraint to vertical (superior to inferior) translation at the ACJ, although it has significant influence in the horizontal plane as well. This complex is comprised of the conoid and trapezoid ligaments (Fig. 1). In addition to stabilizing the ACJ in the vertical plane, the CC ligaments also strengthen the AC articulation and mediate scapulohumeral motion by attaching the clavicle to the scapula. The radiographical anatomical distance between the coracoid and the clavicle has been found to range between 1.1cm and 1.3cm. This anatomical distance is important when reviewing radiographs of a suspected ACJ injury and when trying to restore normal functional anatomy during reconstruction of the CC ligaments.

Fukuda et al. determined that, with small displacements at the ACJ, the AC ligaments are the primary restraint to posterior (89%) and superior (68%) translation of the clavicle [4]. As displacement at the ACJ increases, the AC ligaments maintain their role in resisting posterior translation but the conoid ligament becomes the primary restraint to superior (62%) translation. The trapezoid ligament primarily functions to restrain compression at the ACJ with both small and large displacements, making it an important factor when considering operative reconstruction.

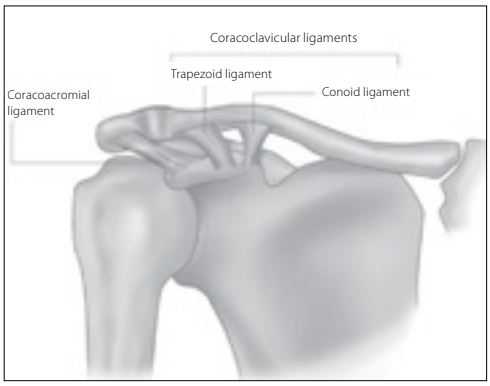

Fig. 1 Schematic of the anatomy of the ligaments around the acromioclavicular joint.

Normal co-ordination of movement of the shoulder girdle requires coupling of scapulothoracic and glenohumeral movement. For this coupling to be effective then the integrity of the sternoclavicular and acromioclavicular joints must be maintained. During abduction of the shoulder, there is 15° of protraction, 21° of upward rotation and 22° of posterior tilting of the scapula relative to the clavicle at the joint. In addition, during normal shoulder movements of elevation and abduction, the clavicle is seen to rotate up to 45° about its own axis. However, in

relation to the acromion, the clavicle only rotates between 5˚and 8˚. This accounts for the normal and full range of shoulder movement allowed following a coracoclavicular arthrodesis using a lag screw [2].

Mechanism of injury

A force applied either directly or indirectly through the ACJ can result in injury. Direct force to the acromion with the arm adducted across the body, such as in a fall onto the shoulder tip, is the most common mechanism[6]. The force applied results in movement of the acromion inferiorly and medially, whereas the clavicle remains stabilized by the supports of the sternoclavicular joint [7]. The failure of the ACJ support occurs sequentially with increasing force. The AC ligament and the joint capsule fail first, followed by failure of the CC ligament and finally failure of the deltotrapezial fascia [2]. Indirect trauma to the ACJ is usually caused by a fall onto the outstretched upper limb, with the force being directed superiorly causing the stabilizing structures of the joint to fail in the same sequential manner.

Classification

The degree of ACJ and ligamentous disruption is related to the degree of force applied across the joint. Rockwood published a six-type classification as a modification of the original Tossey and Allman system [2]. This classification is now the accepted and most commonly used one (Fig. 2).

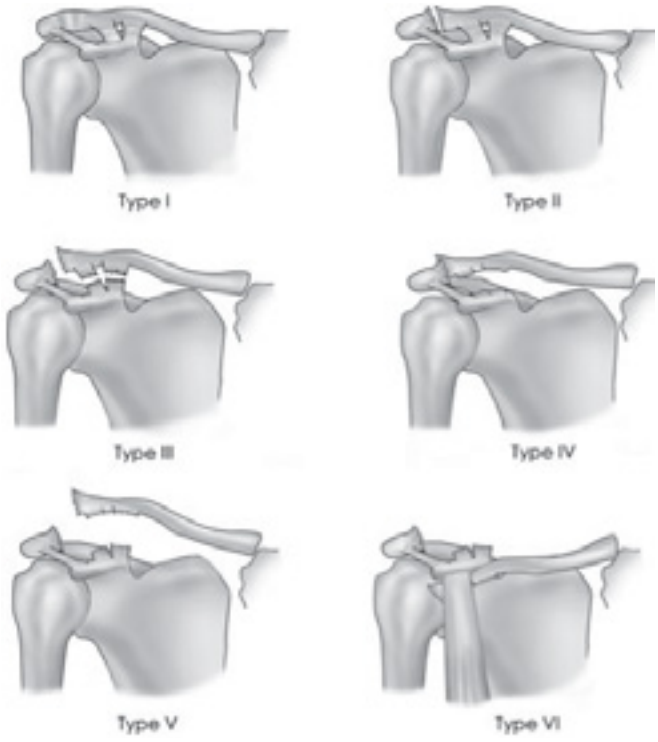

Fig. 2 Schematic of the Rockwood [2] classification of acromioclavicular joint dislocations.

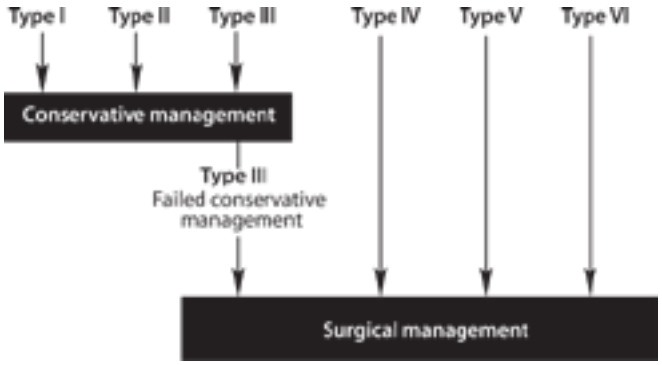

Fig. 3 Treatment algorithm for acromioclavicular joint dislocations based on the Rockwood classification.

Type I This represents a sprain of the AC ligaments and presents as pain in the region of the ACJ with no visible deformity or radiographical abnormality. The patient may have a degree of swelling over the ACJ but no tenderness on palpation of the CC interspace because the CC ligaments are intact.

Type II Here, a rupture of the AC ligaments causes horizontal instability of the distal clavicle. The CC ligaments are sprained but intact and, in most instances, the distal clavicle should be stable vertically. Unlike type I injuries, the patient will present with tenderness in the CC interspace and radiographs may demonstrate a widened ACJ and some vertical displacement of the distal clavicle and increased CC distance.

Type III Patients with a type III injury have an unstable distal clavicle both horizontally and vertically with up to 100% translation relative to the acromion. The swelling over the ACJ may be accompanied by an abnormal shoulder contour representing the superiorly displaced distal clavicle, which should be easily reducible with adequate analgesia.

Type IV In the type IV injury, with the AC, CC ligaments and the deltopectoral fascia disrupted, the clavicle displaces posteriorly through or into the trapezius muscle producing, in some cases, a prominent acromion anteriorly. Critically, the distal clavicle will be irreducible with increased CC interspace and a posterior displacement of the clavicle seen on axillary lateral radiographs.

Type V Type V injuries represent more extensive damage to the deltopectoral fascia, allowing the distal clavicle to displace significantly (100% to 300% of the CC distance). The distal clavicle appears subcutaneously and will not be reducible by direct superior pressure or by upward pressure on the ipsilateral elbow.

Type VI In this rare injury, the distal clavicle displaces inferiorly into a subacromial or subcoracoid position. This is a high energy injury, usually resulting from hyperabduction and external rotation following a significant fall. Additional injuries should be carefully looked for during a secondary survey.

Diagnosis

Injury to the ACJ should be considered in any patient presenting with pain in the vicinity of the acromion or the lateral portion of the clavicle following shoulder trauma. Clinical examination requires adequate exposure to allow the glenohumeral joint, ACJ and lateral end of the clavicle to be visualized and palpated easily. The patient should sit or stand with the affected limb unsupported to allow any deformity to become apparent or be exaggerated by the weight of the arm.

The patient should next be asked to demonstrate the range of passive and active movement of the affected shoulder. Localized pain at the ACJ is indicative of ACJ pathology and discomfort may be accentuated by abduction and cross-body adduction (Scarf test) or by O'Briens' active compression test. The displacement of the distal clavicle present in types IV to VI injuries is sufficient, in some cases, to cause traction injury to the brachial plexus. Therefore, the examination should be completed by performing a thorough neurovascular examination of the affected limb because of the possibility of arterial or brachial plexus injuries associated with clavicle fractures and ACJ dislocations.

Radiographical evaluation

Radiographical evaluation should include a standard anterio-posterior view of the clavicle and acromion, an axillary lateral and a 10˚ to 15˚cephalic incline view (Zanca view). Radiographs of the affected shoulder should be accompanied by images of the unaffected shoulder to provide comparison of the normal CC distance. If, on examination, the radiographs demonstrate a dislocation of the ACJ without increase in CC distance, a coracoid fracture should be suspected and investigated by either a Stryker notch view or by shoulder computerized tomography (CT).

At present, there is not a role for routine investigation of ACJ injury by CT or magnetic resonance imaging.

The role of stress views

Historically, stress views of the ACJ were recommended to differentiate between type II and III injuries. However, a prospective randomized trial looking at this has not shown stress views to be of benefit. Bossart et al. presented 83 pairs of radiographs, taken with and without weights, in a blinded manner to a staff radiologist[8]. In only three cases (4%) did the weights cause the injured coracoclavicular distance to increase and thereby unmask a grade 3 injury not evident on plain radiographs. In several cases, the weights actually caused the injured and uninjured CC distance to decrease.

The evidence does not support stress views and we do not recommend their routine use.

Treatment of the acute ACJ injury

Treatment of ACJ disruption has long been debated and remains controversial [9,10]. The goal of treatment, whether non-operative or surgical, is to return the patient to their pre-injury level of function, with a pain-free, strong, functionally stable and mobile shoulder and no restriction of activities (Fig. 3).

Treatment of type I injuries. Low energy Rockwood type I or II ACJ injuries are usually managed non-operatively. Although various complex devices for reduction and immobilization of the distal clavicle are available, a simple sling or shoulder immobilizer is reported to reduce stress across the AC and CC ligaments [11,12].

Type I injuries are a ligamentous sprain and the ACJ is stable. These patients should be treated with simple analgesia and simple sling for 7 days to 10 days or until pain subsides [2].

Treatment of type II injuries. Patients with type II injuries may require up to 2 weeks of immobilization. Following resolution of symptoms, a period of focused rehabilitation aiming to restore painless passive and active range of movement should be undertaken. Following this, physiotherapy should aim to restore strength and endurance to the shoulder girdle musculature. Contact sport and heavy overhead activity should be avoided for a period of up to 3 months.

Type II injuries produce a greater disruption to the stability of the ACJ in the horizontal plane than type I injuries [13]; consequently, patients with type II injuries often go on to complain of chronic ACJ symptoms of pain and clicking on exercise and almost 50% of patients with ACJ injury will develop ACJ osteoarthritis [13]. Evidence of early degenerative change may be present on radiographs and this patient group may benefit from excision of the distal clavicle (Mumford procedure) if symptoms persist [14].

Treatment of type III injuries. Conservative management yields 97% of good to excellent results at more than 12 years follow-up [15]. It has been demonstrated that patients with good shoulder function pre-injury, such as labourers and athletes, will recover adequate shoulder strength and endurance to return to pre-injury activities despite a slight but quantifiable reduction in these measures [16]. These decreases in strength and endurance, together with chronic symptoms of pain or clicking on activity, have suggested a need for targeted and supervised rehabilitation regimens in conservative management of types III ACJ injury [17,18], especially in subjects with high levels of shoulder function and strength required for employment or sporting activity [16]. It has also been suggested that avoidance of prolonged immobilization is key to successful conservative management [19].

It is suggested that young patients with high functional demands are relative indications for operative treatment of acute type III, although no definitive evidence exists in the literature to support this. What is evident is that patients treated conservatively experience fewer complications and return to work or sporting activity sooner than those managed surgically [20]. The current recommendation is for a trial of conservative treatment initially. Surgery is only considered if the patient has residual pain, loss of function, or inability to perform at previous levels of activities following 3 months of functional rehabilitation.

Types IV to VI. Operative treatment is an accepted method of management of types IV to VI injuries because of the associated morbidity of a displaced clavicle [21]. There are five basic types of

surgical procedures described for treatment of these injuries. These include:

- Primary repair of the ACJ.
- Fixation of clavicle to coracoid
- Anatomic coracoclavicular reconstruction
- Distal clavicle excision with soft tissue reconstruction (Weaver–Dunn)
- Arthroscopic suture fixation

Primary joint repair. Closed or open reduction of the disrupted ACJ followed by fixation with smooth/threaded Kirschener wires is the historical description of primary fixation of the ACJ. This operative technique is now discouraged because there are case reports of migration of pins into the lungs and mediastinum [22,23].

A hook-plate is a clavicular small fragment AO plate with a hook engaging below the acromion. It can be used in the treatment of displaced ACJ dislocations. Its function relies upon the lateral end of the plate, which is shaped to fit beneath the acromion, with the rest of the plate being securely fixed to the lateral third of the clavicle with screws. This requires an open approach and reduction and the plate to be removed 6 weeks to 8 weeks following the original procedure. Reconstruction of the CC ligament at the time of hook-plate insertion is performed by some surgeons [24], with the aim being to support the ligamentous repair by maintaining the reduction of the ACJ. The hook-plate can be useful in the treatment of patients with afracture dislocation of the clavicle [24]. Drawbacks to its use include the need to remove the implant before resumption of full overhead shoulder activites. Retained hook-plates can potentially cause acromial erosion as well as being a potential cause of impingement, rotator cuff tears and shoulder stiffness. In addition, there are case reports of retained plates causing stress shielding and osteolysis in the clavicle and periprosthetic clavicular fractures have occurred [25].

Fixation of clavicle to coracoid. Fixation of the clavicle to the coracoid, as described by Bosworth, using a single screw provides robust and secure reduction of the ACJ (Fig. 4A). It has been noted that the CC screw provides the most biomechanically solid fixation of all major techniques currently described and is advocated in surgical treatment of acute ACJ dislocation when used in conjunction with a ligamentous reconstruction [2]. The screw should be removed at 2 months to 3 months postoperatively.

Anatomic coracoclavicular reconstruction. The Nottingham Surgilig (Surgicraft, Reddich, UK) is a braided polyester ligament with loops at either end that has been designed to reconstruct the coracoclavicular ligaments for chronic symptomatic ACJ disruptions [26] (Fig. 4B). The technique requires open reduction of the ACJ but with specialized instruments and represents a simple and reproducible procedure that does not require staged removal. Short-term outcomes in military patients were positive with no complications or failures noted in 10 patients who were able to return to pre-injury performance levels at 6 months [27]. In civilian patients, one of 11 patients experienced rupture of the ligament after 6 months, with 82% patient satisfaction at 24 months follow- up [28]. At 5-year follow-up, the mean Constant score was 92.3 in 11 patients treated with the Nottingham Surgilig, one patient developed coracoid osteolysis, and another developed impingement symptoms attributed to the clavicular screw, which was later removed [29].

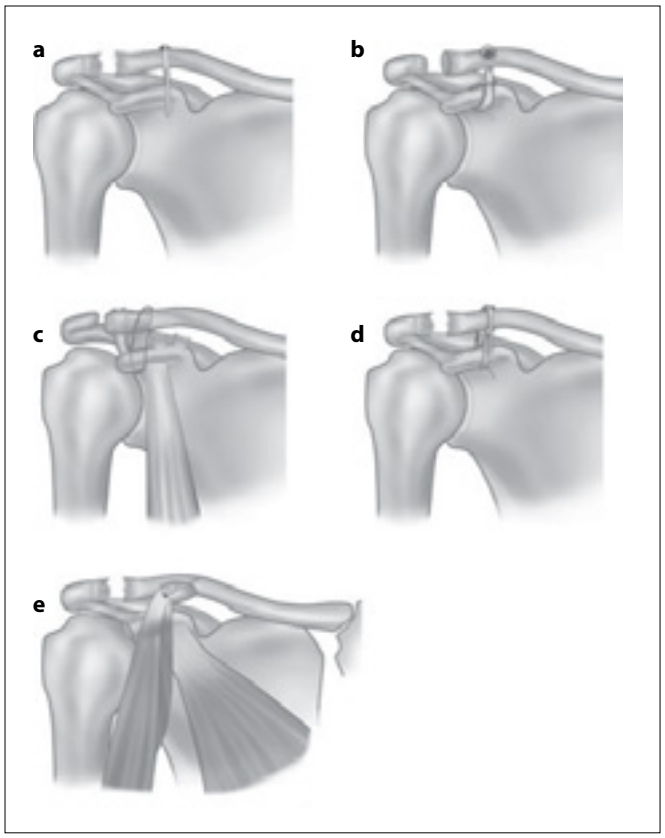

Fig. 4 Schematic of the options for surgical management of acromioclavicular joint dislocations. (a) Screw fixation. (b) Surgilig fixation. (c) Weaver–Dunn reconstruction. (d) Semitendinosus reconstruction. (e) Dynamic muscle transfer.

Other materials have been described for use as slings to reduce ACJ dislocations. Polydiaxone (PDS) has been described but was associated with a sterile discharging sinus in one of six patients treated with this product [30]. Dacron slings have had similar worrying results, with one paper quoting 14 of 19 patients having developed fissures in the clavicle at the point where the graft crossed the bone [31], and another with 28% unsatisfactory results and erosion of the clavicle in 21% [32].

Distal clavicle resection. Resection of the distal clavicle, as described independently by Mumford [33] and Gurd [17], has been applied to the patient with ACJ dislocation presenting acutely or late. The technique, originally described as an open approach, has been modified to employ minimally invasive arthroscopic instruments with good functional outcomes [14,34]. Currently, there is a lack of comparative evidence for the two approaches. The key factor in the use of distal clavicle resection is careful patient selection. In intact CC ligaments (grade 2), the risk of increasing instability

following distal clavicle excision may be low, although of concern in grade 3 injuries. In grade 3 injuries by definition, there is no contact between both ends of the joint. Indeed, in patients with ruptured CC ligaments or concomitant instability, the distal clavicle osteotomy may compromise stability provided by the capsular remnant and delto-trapezial fascia, leading to further instability [35].

For symptomatic arthritis following a chronic ACJ dislocation, the safe area for resection without compromising stability was defined by Stine and Vangness [36] In their cadaveric study, they determined the amount of bone that could be removed without destabilizing the ACJ. Their recommendation for ACJ resections were that a 5mm to 7mm piece of bone may be taken, with 2mm to 3mm removed from the acromial size and 3mm to 4mm from the clavicular side. Doing so will not disrupt the stabilizing ligaments of the ACJ after distal clavicle resection.

Distal clavicular excisions can be performed as open or arthroscopic procedures. The residual superior capsular restraints and the overlying delto-trapezial fascia may be injured during the direct open approach to the joint, which can potentially exacerbate the patient's symptoms of instability. This might explain why patients appear to achieve better results from arthroscopic excisions.

Arthroscopic suture fixation. As surgical techniques evolve, many surgeons are combining many of the previously mentioned techniques with the use of the arthroscope to provide minimally invasive, arthroscopic interventions. The introduction of the arthroscope into the shoulder joint by lateral or posterior subacromial portals allows for direct examination of the glenohumeral joint for loose bodies, labral tears and chondral injuries, as well as rotator cuff lesions. This approach also allows for subacromial pathology to be addressed via the same portals.

Simple resection of the distal clavicle, as described using the Mumford technique, can be carried out arthroscopically. Several variations of the technique have been described [34,36,37], although complete resection of the distal clavicle and elevation of the inferior aspect of the ACJ capsule appears to be important in the reduction/elimination of pain. Loose bodies can be difficult to remove via this technique; however, unless these are particularly large, they are not associated with significant postoperative continuation of symptoms [37].

Reconstruction of the coracoclavicular ligament by the Weaver – Dunn technique [38] or by use of PDS sutures and a semitendinosus tendon graft via the arthroscopic technique with mini-open incision [39] has been described with good functional results. Similar techniques using non-absorbable materials such as the Graftrope system are also described [40].

These less invasive techniques are reported to allow anatomical, solid reconstruction of the coracoclavicular ligaments with less soft tissue dissection and associated morbidity of open techniques [39]. The use of bioabsorbable fixation avoids the need for metalwork and associated complications of migration, infection and future removal.

Treatment of the chronic ACJ injury

Many chronic ACJ injuries are asymptomatic. Treatment is tailored towards the symptoms that the patient has. Surgery is often offered for instability. A number of different surgical techniques have been described for this, which have enabled good results using a number of different grafts such as a semitendinosus autograft [41] in one series and an Achilles tendon allograft in another [42]. A criticism of many of these studies describing new techniques is that they are limited to very small numbers, and the results achieved in the hands of other surgeons may vary.

A recent prospective study showing the findings of two surgeons treating a young cohort of fit military patients with persistent symptoms of ACJ instability [27] found that that a modified Weaver – Dunn procedure augmented with the use of a surgilig yielded good results at 6 months follow-up in a series of 10 chronic cases. In this series, all patients returned to full operational duties, had minimal symptoms and were discharged after 6 months. Presently, there is no clear consensus regarding the best treatment for instability following a chronic ACJ injury and more research is needed.

Summary

The current literature supports conservative treatment for Rockwood classification injuries types I and II. Higher-grade injuries types IV, V and VI should be treated by surgical management acutely using one of the previously described techniques.

The literature supports an initial trial of conservative treatment in the type III injury group. We acknowledge there does exist a subset of younger patients for whom demanding overhead work or sporting activity prompts careful consideration for surgical intervention on a case-by-case basis if functional rehabilitation fails.

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Modified Weaver-Dunn procedure versus the use of a synthetic ligament for acromioclavicular joint reconstruction

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Key words:
acromioclavicular joint; dislocations; reconstructive surgical procedures

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ABSTRACT

Purpose

To compare the subjective outcome of acromioclavicular joint (ACJ) reconstruction using the modified Weaver-Dunn procedure versus the Surgilig synthetic ligament.

Methods

55 patients aged 19 to 72 (mean, 42) years underwent ACJ reconstruction of Rockwood grade 3 (n=38), grade 4 (n=8), and grade 5 (n=9) using the modified Weaver-Dunn procedure (n=31) or the Surgilig synthetic ligament (n=24), based on the surgeon's preference. The mean period from injury to surgical treatment was 39 months. Subjective outcomes were assessed before and after surgery using the Oxford Shoulder score and Nottingham Clavicle score. The time required to return to work and sports was also recorded.

Results

After a mean follow-up period of 40 months, the mean Oxford Shoulder scores improved from 28 to 42 in the Weaver-Dunn group (p=0.009), and from 26 to 45 in the Surgilig group (p=0.007), whereas the respective mean Nottingham Clavicle scores improved from 53 to 81 (p=0.047) and from 51 to 93 (p=0.023). The Surgilig group achieved significantly better postoperative Oxford Shoulder score (p=0.008) and Nottingham Clavicle score (p=0.007), and could also return to work (14 vs. 6 weeks, p<0.001) and sports (25 vs. 12 weeks, p<0.001) sooner than the Weaver-Dunn group. Three patients in the Weaver- Dunn group and one patient in the Surgilig group had persistent pain and/or functional deficit with evidence of ACJ dislocation.

Conclusion

Chronic ACJ reconstruction using the Surgilig synthetic ligament achieved better Oxford Shoulder score and Nottingham Clavicle score and earlier return to work and sports, compared with the modified Weaver-Dunn procedure.

Introduction

Acromioclavicular joint (ACJ) disruptions account for around 12% of injuries to the shoulder girdle in the general population and 40% of all shoulder injuries in athletes. The Rockwood system[1] classifies these injuries into 6 grades, based on the extent of distal clavicular displacement and AC ligament and coracoclavicular (CC) ligament injuries, and the integrity of the deltoid and trapezius muscles. Most ACJ injuries can be successfully managed by non-operative methods,[2,3] such as use of anti-inflammatory drugs, ice packs, and protecting the arm in a sling for 2 to 4 weeks until the pain subsides. However, those who need to adopt an overhead position of the arm or in high-demanding work activities may prefer operative treatments.[2] These can be classified into 4 types: (1) primary direct fixation of the ACJ (with screws, sutures, pins, hook-plates, and even plates across the joint), with or without ligament reconstruction or repair,[4] (2) primary CC fixation (with wire, screw, conjoint tendon or synthetic suture), with or without augmentation of AC ligament reconstruction,[5,6] (3) excision of the distal end of the clavicle (as in the Mumford procedure), with or without CC ligament reconstruction; or repair with suture or coracoacromial ligament transfer (as in the Weaver-Dunn method),[4,7] and (4) dynamic muscle transfer of the conjoint tendon, with or without excision of the distal end of the clavicle.[8]

The optimal operative method for ACJ reconstruction remains controversial. The modified Weaver-Dunn method is one of the most popular methods.[9,10] It involves excision of the distal end of the clavicle and transferring of the coracoacromial ligament to the distal end of the clavicle, using the ligament as a substitute for the ruptured CC ligament. The CC fixation is then usually augmented with an absorbable braided Vicryl suture.

The use of a synthetic ligament – Surgilig (Surgicraft, Redditch, UK) – to bring the acromion toward the clavicle enables a near anatomic reconstruction of the ACJ and hence healing of the AC ligament. It is made of braided polyester, which has a minimal foreign body reaction and acts as a scaffold for tissue ingrowth.[11] It consists of 2 loops at either end (Fig. 2). The hard loop is for screw fixation, whereas the soft loop facilitates looping the Surgilig through itself after passing

it around the coracoid process. The Surgilig provides a strong but non-rigid support for the ACJ and enables clavicular rotation during elevation of the arm.[11]

This study aimed to compare the subjective outcome of ACJ reconstruction using the modified Weaver-Dunn procedure versus the Surgilig synthetic ligament.

Materials and methods

Between May 1999 and May 2009, 55 patients aged 19 to 72 (mean, 42) years underwent ACJ reconstruction of Rockwood grade 3 (n=38), grade 4 (n=8), and grade 5 (n=9) using the modified Weaver-Dunn procedure (n=31) or the Surgilig synthetic ligament (n=24), based on the surgeon's preference. Patients with multiple injuries or mental illness were excluded.

All patients had chronic shoulder pain and weakness interfering with activities of daily living. Most had involvement of the dominant arm. They had undergone conservative management using a sling for 2 weeks followed by range-of-movement exercises and physiotherapy at week 2, and shoulder girdle strengthening exercises at weeks 6 to 8. The mean period from injury to surgical treatment was 39 months. The diagnosis was based on clinical (injury history, symptoms) and radiographic (the 10º cephalic tilted view, the Zanca view,[12] and the axillary lateral view) assessment.

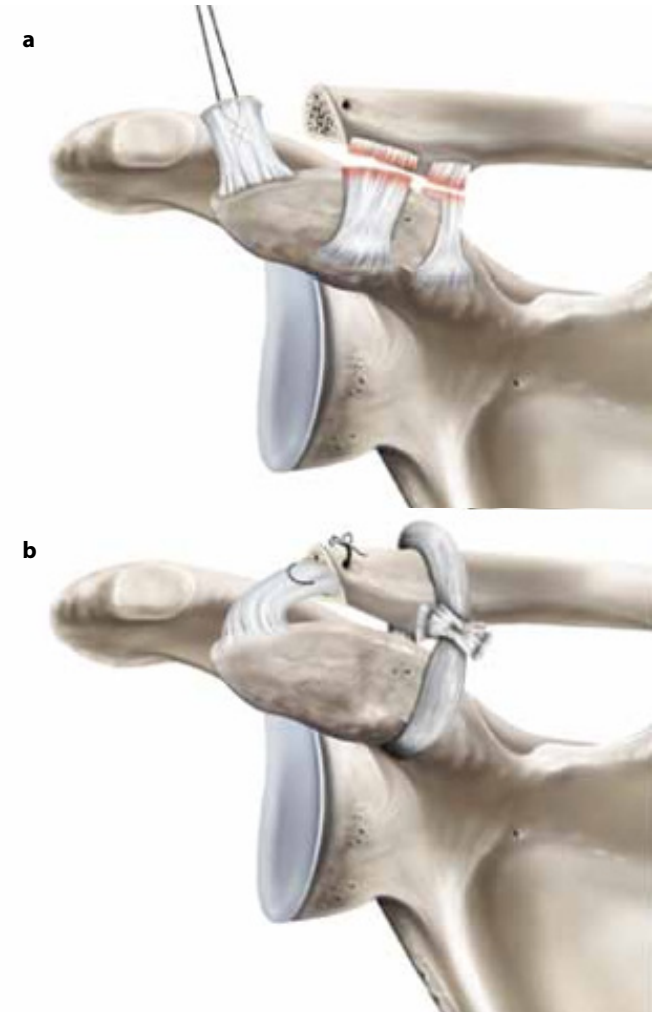

Fig. 1 (a) Detachment of the coraco-acromial ligament with a sliver of bone, and (b) the Weaver-Dunn procedure.

The modified Weaver-Dunn procedure was carried out in the beach-chair position. About 10 mm of the lateral end of the clavicle was excised. The coracoacromial ligament was then carefully removed from the acromion with its bony attachment to facilitate bone-to-bone healing with the lateral end of the clavicle. The repair was reinforced by a CC Vicryl braided suture sling passed around the coracoid process and tied over the clavicle (Fig. 1).

The length of the Surgilig was determined before insertion. The most commonly used lengths were 10, 11, and 12 cm. The Surgilig was passed around the coracoid process, and then the hard loop was passed through the soft loop, and then the Surgilig was passed around the back of the clavicle and fixed with a 3.5 mm bicortical screw, with the Surgilig being fully tensioned (Fig. 2).

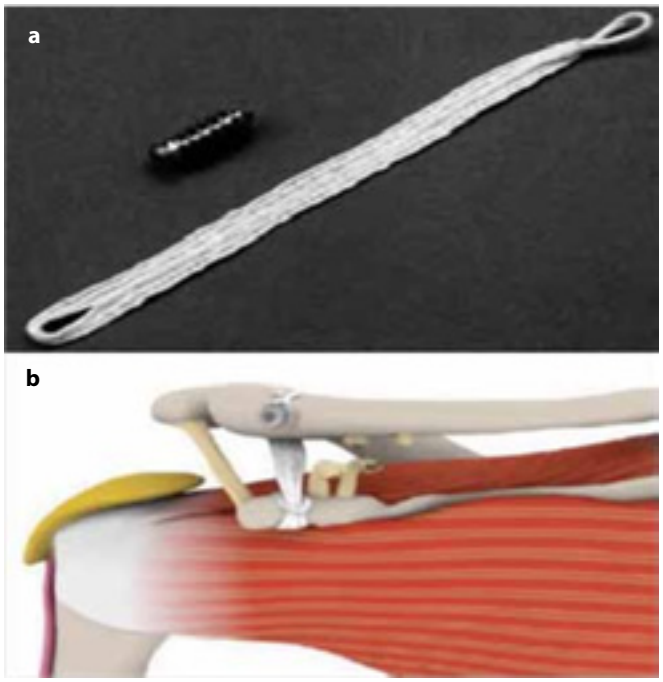

Fig. 2 (a) The fixation screw and the Surgilig synthetic ligament with loops at both ends, and (b) the Surgilig in place with an intact coraco-acromial ligament.

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Rehabilitation protocol of the 2 groups was identical. The arm was placed in a sling for 2 weeks, followed by exercise regimen to mobilise the arm aiming to attain full range of movement and function by week 6. Patients were advised to refrain from heavy lifting (>5 kg) for the initial 6 weeks.

Subjective scores can better reflect a patient's quality of life than some clinical objective assessment.[13,14] Subjective outcomes were assessed before surgery and after a mean of 40 months using the Oxford Shoulder score[2] and Nottingham Clavicle score. The former consists of 12 questions related to function, disability, and pain; scores range from 0 to 48 where 0 to 19 indicates severe dysfunction, 20 to 29 moderate dysfunction, 30 to 39 mild dysfunction, and 40 to 48 satisfactory function. The latter comprises 10 questions related to pain and activities of daily living; scores range from 20 (severe dysfunction) to 100 (satisfactory function). The Pearson correlation coefficient between the 2 score systems was 0.918 (p=0.01).

The Wilcoxon signed rank test was used to compare pre- and post-treatment scores and improvement in each group. The Mann-Whitney *U* test was used to compare outcome scores between the 2 groups. A p value of <0.05 was considered statistically significant.

Results

Generally, less severe ACJ injuries were treated with the Weaver-Dunn procedure and more severe ACJ injuries with the Surgilig synthetic ligament: grade 3 (25 vs. 13), grade 4 (4 vs. 4), and grade 5 (2 vs. 7).

After mean follow-up periods of 47 (range, 9–108) months in the Weaver-Dunn group and 30 (range, 7–108) months in the Surgilig group, the respective Oxford Shoulder scores improved from 28±11 to 42±10 (p=0.009) and from 26±9 to 45±7 (p=0.007), whereas the respective mean Nottingham Clavicle scores improved from 53±12 to 81±23 (p=0.047) and from 51±11 to 93±13 (p=0.023). The Surgilig group achieved significantly better postoperative Oxford Shoulder score (p=0.008) and Nottingham Clavicle score (p=0.007), and could also return to work (14 vs. 6 weeks, p<0.001) and sports (25 vs. 12 weeks, p<0.001) sooner than the Weaver-Dunn group.

Failure was defined as persistent pain of visual analogue score of ≥5 and functional deficit with evidence of ACJ dislocation. Three patients in the Weaver-Dunn group and one patient in the Surgilig group had failure. The latter had a mid-substance rupture of the synthetic ligament following a fall onto the affected side at week 8. All failures were revised with the Surgilig synthetic ligament. Superficial infection occurred in 3 patients in the Weaver-Dunn group and 4 patients in the Surgilig group; all were successfully treated with antibiotics. None had deep infection.

Discussion

For chronic grade-3 ACJ injuries, non-operative treatments have achieved good results, with 80% to 90% satisfaction rates.[15,16] However, up to 50% of patients treated non-operatively have residual pain and weakness.[17,18] Surgery for acute injuries is associated with the risk of early failure and complications. Surgery for acute grade-3 ACJ injuries results in overtreatment and unnecessary financial costs in patients who might have otherwise done well.[19–21] There is not enough evidence to support primary operative treatment for acute ACJ injuries in general. Even manual labourers and throwing athletes can achieve good outcome after non-operative treatment.[16,22] In our hospital, surgery was indicated in patients who failed non-operative treatment and had symptoms affecting activities of daily living.

Modifications of the Weaver-Dun procedure have achieved good outcome for acute and chronic ACJ dislocations.[7,21,23–25] Transfer of the coracoacromial ligament may be associated with the risk of ongoing pain, instability, and recurrent subluxation because of stretching or failure of fixation of the re-attached CC ligament.[7] The Weaver-Dunn procedure has only 30% of the strength and 10% of the stiffness of the intact ligaments, and failures occur mainly at the suture that attaches the transferred coraco-acromial ligament.[26] The mean laxity after reconstruction was 42mm in an anteroposterior plane and 14 mm vertically, compared with 8mm and 3mm, respectively, in intact ligaments.[27] This can be improved by augmentation of the CC suture. Newer suture materials such as Fiberwire (Arthrex, Naples [FL], USA) and more anatomic techniques may achieve better load to failure.[23,27,28]

The tensile strengths of the CC ligament and the CC sling from Fiberwire are 500 N and 483 N, respectively,[29] whereas the pullout strength of the Surgilig is in excess of 1700 N.[11] Therefore, the Surgilig enables more aggressive rehabilitation and earlier mobilisation of the shoulder, compared with other surgical methods.[9,11,30,31] The Surgilig is more cost-effective in terms of reduction in off-work time.[10] The Surgilig enables non-rigid fixation of the ACJ while maintaining reduction and normal motion at the ACJ; the movement of the clavicle is not restricted and it can freely rotate during elevation of the upper extremity without causing erosion of the bone.[10] In addition, preserving the coraco-acromial ligament enables its role for shoulder stability as a buffer between the acromion and the rotator cuff muscles.[9,28,29] This is in contrast with the modified Weaver-Dunn procedure where the coraco-acromial ligament is sacrificed.

ACJ reconstruction using the Surgilig synthetic ligament has become popular for treating acute and chronic complete ACJ separation.[10,11] The Surgilig is recommended as the primary treatment for ACJ dislocation, as it provides permanent protection to the damaged CC ligament.[10,11] In a study of 11 patients with chronic complete ACJ dislocation treated with the Surgilig and followed up for a mean of 55 months, 10 achieved good-to-excellent results with a mean Constant-Murley score of 92 out of 100, and the remaining one had a score of 64 who had sustained a fracture at the coracoid process secondary to lifting heavy weight early.[16] In another study of 11 patients with chronic complete ACJ dislocation followed up for 24 months, the mean Constant-Murley score was 83.1 out of 100, and 82% of patients were satisfied with their outcome.[3]

Although some patients have a reaction to the synthetic material used in CC ligament reconstruction,[21] none of our patients had tolerance problems or synovial reaction to the Surgilig™, similar to that in other studies.[10,11] Postoperative morbidity was low in our patients, owing to the limited use of hardware. Superficial wound

infection is not uncommon owing to the extensive soft-tissue damage and foreign body reaction to non-absorbable materials.[32–34] Other complications associated with the Surgilig include coracoid fracture, screw loosening in the clavicle, and distal clavicular osteolysis.[10,11,35]

Limitations of our study included non-randomisation, a small sample size, no objective assessment (although radiographic appearance does not correlate with the clinical outcome[22]), and possible observational bias owing to lack of blinding.

Conclusion

Chronic ACJ reconstruction using the Surgilig synthetic ligament achieved better Oxford Shoulder score and Nottingham Clavicle score and earlier return to work and sports, compared with the modified Weaver-Dunn procedure.

Disclosure

No conflicts of interest were declared by the authors.

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The biological response to a failed extra-articular polyester ligament used for AC Joint reconstruction at the shoulder girdle

A retrieval analysis of five cases

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A retrieval analysis of five cases

The LockDown device (previously called Surgilig) is a braided polyester mesh which is mostly used to reconstruct the dislocated acromioclavicular joint. More than 11 000 have been implanted worldwide. Little is known about the tissue reaction to the device nor to its wear products when implanted in an extra-articular site in humans. This is of importance as an adverse immunological reaction could result in osteolysis or damage to the local tissues, thereby affecting the longevity of the implant.

We analysed the histology of five LockDown implants retrieved from five patients over the last seven years by one of the senior authors. Routine analysis was carried out in all five cases and immunohistochemistry in one.

The LockDown device acts as a scaffold for connective tissue which forms an investing fibrous pseudoligament. The immunological response at the histological level seems favourable with a limited histiocytic and giant cell response to micron-sized wear particles. The connective tissue envelope around the implant is less organised than a native ligament.

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The LockDown device (previously called the Nottingham Surgilig; LockDown Medical Ltd, Redditch, United Kingdom) is a braided polyester scaffold type of mesh which has mostly been used for reconstructing the dislocated acromioclavicular joint (ACJ).[1-3] It is made of polyethylene terephthalate (Dacron, initially marketed by DuPont, Wilmington, Delaware) and manufactured using a patented weaving technique. Over 11,000 have been implanted worldwide.[4] LockDown is the implant most commonly used in the United Kingdom to reconstruct a Rockwood type III[5] acute ACJ injury (BESS Survey, 2013).[6] The short- and medium-term results are promising,[1-3] but little is known about the reaction of the tissues to the device and to its wear products when implanted in an extra-articular location in humans.

The concept of using an artificial ligament to replace a live structure is not new. Attempts to replace the anterior cruciate ligament (ACL) were first made in the early part of the 20th century.[7] Artificial ligament grafts manufactured from polyethylene terephthalate for reconstruction of the ACL appeared to be very promising in the late 1980s but their popularity was soon compromised by problems, one of which was mechanical failure due to repetitive loading over time.[8-14] There may also be a further problem in the form of osteoarthritis developing secondary to debris from the artificial ligament.[15]

Their failure led to the adoption of scaffold-type ligament implants on the basis that these implants generate the ingrowth of connective tissue. After initial load-sharing, the newly ingrown tissue ultimately takes over the mechanical role of the artificial ligament.[16,17] All these materials are manufactured from different types of polyester similar to polyethylene terephthalate.

Tissue ingrowth into a braided polyester scaffold-type ligament is generally accepted to occur in animals:[18,19] its clinical use has been particularly successful in aortic vascular grafts which have repeated stresses applied to them with every heartbeat.[20] Data about the biological behaviour of braided polyester ligaments in humans are mostly derived from its use in intra-articular sites, particularly the knee.[9,21-23] Whether connective tissue grows into the polyester ligaments used for ACL reconstruction is controversial.[10,12,13,24-29] Osanai, Tsuchiya and Sugawara[30] have reported good results and good quality tissue ingrowth into a polyester device in an extra-articular location, when reattaching muscles to a tumour endoprosthesis.

In this paper we describe the type of tissue reaction which occurs to the LockDown ligament and its wear products. Our aim was to see whether the connective tissue ingrowth into a polyester scaffold which occurs in animal models also occurs in an extra-articular location in humans. The type of wear products that are generated and the immunological response to them are of key importance for the survival of a joint replacement,[31-39] and might have a comparable effect on the long-term survival of the LockDown device.

Table I. Patient data on explanted LockDown cases

Patient	Age at explantation (yrs)	Female(F) male (M)	Past medical history	Survival of explanted artificial ligament (mths)	Type of acromio-clavicular join injury (Rockwood[5])	Number of failed operations before implantation of Surgilig	Reason for failure of the Surgilig requiring its removal
1	38	F	None	14	III	0	Trauma
2	36	F	None	3.5	III	2	Low-grade infection
3	50	F	None	7	V	3	Trauma
4	31	M	Phenylketonuria	18	V	0	Implant stretching
5	34	M	None	10	Sternoclavicular joint subluxation	3	Surgical error

Fig. 1 Photograph showing the LockDown device (formerly known as the Nottingham Surgilig). The left side end of the device is called the 'soft loop end', the other is the 'hard loop end'.

Patients and Methods

All LockDown (Surgilig) revision cases of the Nottingham Shoulder and Elbow Unit, United Kingdom, have been recorded in a designated database. The patient data are summarised in Table I.

The LockDown device (Fig. 1) has two ends, the 'soft loop end' and the 'hard loop end'. When reconstructing the ACJ, the hard loop end is passed through the soft loop end then around the coracoid then the hard loop end is passed behind the clavicle and secured to its anterior surface with a screw (Fig. 2).

To remove the device, the securing screw is removed from the clavicle. As the device will have become strongly adherent to the posterior surface of the clavicle, it is peeled off with a knife. It is then followed down to the coracoid. The device at this stage is cut at the level it goes through the soft loop for two reasons: the LockDown has a thick envelope of connective tissue around it which does not fit through the soft loop when unhooking the device from the coracoid. The device is also strongly adherent to the coracoid and does not slide out from underneath the coracoid. The soft loop end is eventually separated from the coracoid with a periosteal elevator.

The technique of sternoclavicular joint stabilisation using LockDown is described elsewhere[6] and involves passing the LockDown device around the first rib, then passing the hard loop through the soft loop and finally anchoring the hard loop to the medial end of the clavicle with a screw.

All five explanted ligaments were fixed in formaldehyde, and underwent routine histological processing. Histological analysis was carried out by the same experienced musculoskeletal histopathologist (TAM) within a few days of explantation, specifically for this study.

Each of the explanted prostheses was sectioned transversely in several areas. In one patient (2) longitudinal sections were also taken.

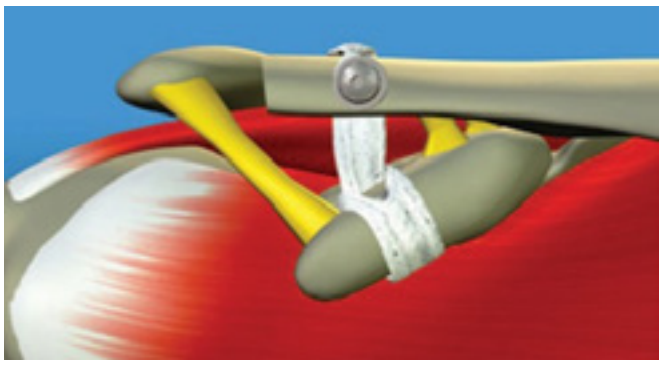

Fig. 2 Diagrammatic representation of the LockDown device for stabilisation of acromioclavicular joint. The hard loop end is passed around the coracoid and then through the soft loop end, than the hard loop end is passed behind and over the top of the clavicle and finally secured to the anterior surface of the clavicle with a screw (reproduced with permission from Mandaco 569 Ltd[4]).

However, these gave less useful histological information than the transverse sections. Sections of 3 µ thickness were prepared and stained with haematoxylin and eosin. These were then examined by visible and polarised light microscopy. Immunohistochemistry was carried out in one retrieval (patient 1) for smooth muscle actin, CD34, CD31, leucocyte common antigen (CD45) and a macrophage marker (CD68).

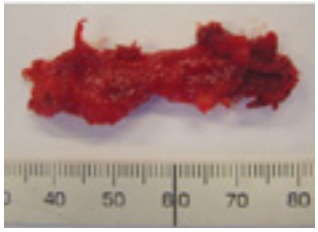

Fig. 3 Photograph showing the connective tissue envelope around the artificial ligament.

Fig. 4 Photograph showing that the connective tissue ingrowth into the space between the braids is present.

Results

In one patient (3), the LockDown ligament had ruptured at the edge of the hard loop where it had been connected to the braided ligament. In the other patients, the macroscopic structure of the artificial ligament was intact apart from mild stretching of the section passing through the soft loop in patients 1 and 4. In all patients there was a thick connective tissue envelope around the implant.

Figure 3 shows a typical specimen in which the thick outer capsule is clearly visible. In Figure 4 the capsule has been peeled off the surface of the prosthesis. Connective tissue has grown into the interstices of the braids. The illustrations only show the hard loop end of the explants as they had been divided to facilitate retrieval.

Microscopically, each device was surrounded by a thick pseudocapsule of collagenous fibrous tissue which invested the whole structure. The separate braids of the device were also separated by similar but less well organised fibrous tissue, mostly towards its outer surface (Fig. 5). Only fibrin penetrated between the individual fibres of the braids except for some limited fibrous ingrowth to a limited degree on the outer surface of the device (Figs 6 to 8).

The detailed structure of the reaction was similar in each case. The outer fibrous pseudocapsule consisted of collagen fibres separated by fibroblasts and scattered inflammatory cells, most of which were histiocytes (Figs 6, 8, and 9). The immunohistochemistry undertaken on the specimen retrieved from patient 1 did not express any smooth muscle actin in the mesenchymal suggesting that, at least in this example, the cells had a fibroblastic rather than myofibroblastic phenotype. Accordingly this probably represented a mature fibrous 'scar' type response without any ongoing organisation.

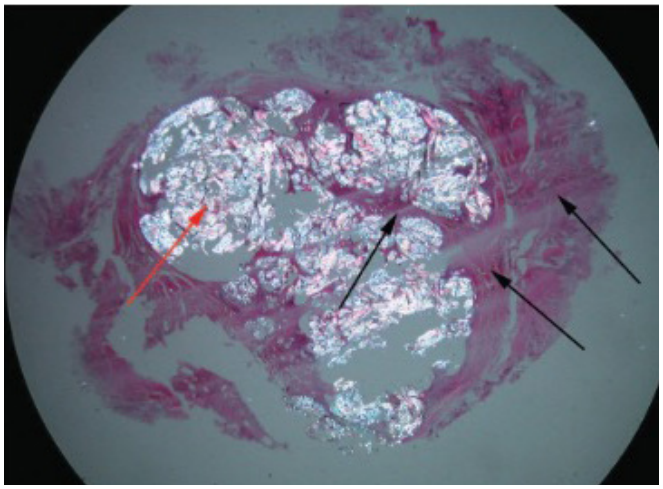

Fig. 5 Low magnification image of the cross section of an explanted LockDown, under polarised light. Polyester is birefringent (red arrow). Some of the braids are missing as they fell out during tissue preparation. Connective tissue between the braids and a thick connective tissue pseudocapsule can be observed (black arrows, original magnification × 40).

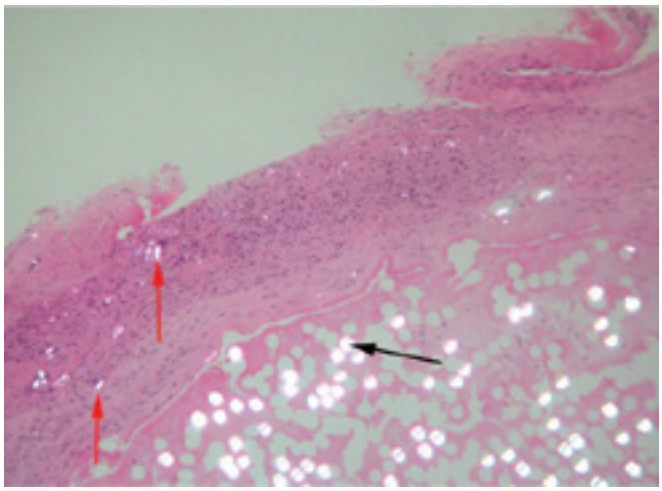

Fig. 7 Low magnification image of the same field seen here under polarised light. The individual polyester fibres (black arrow) can be clearly seen (some have fallen out in preparation) as well as tiny birefringent micro-particles of polyester wear debris in the pseudocapsule (red arrows; original magnification × 100).

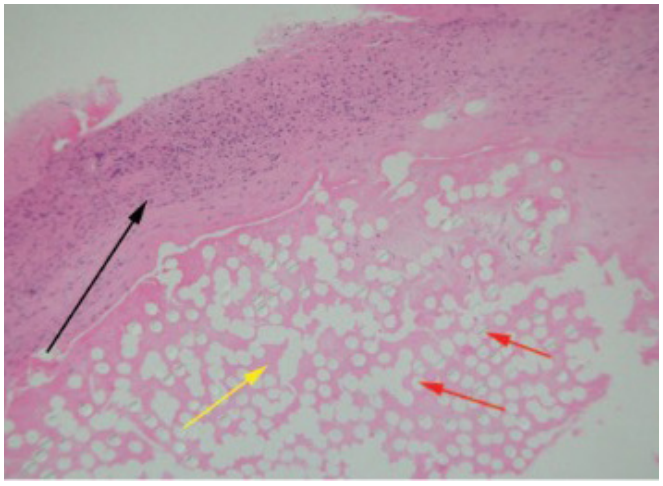

Fig. 6 Low magnification image showing the outer investing fibrous pseudocapsule (black arrow). Beneath is a layer of thick fibrin surrounding the braid seen here as a collection of individual polyester fibres (red arrows). Only pink fibrin extends between these individual fibres (yellow arrow; original magnification × 100).

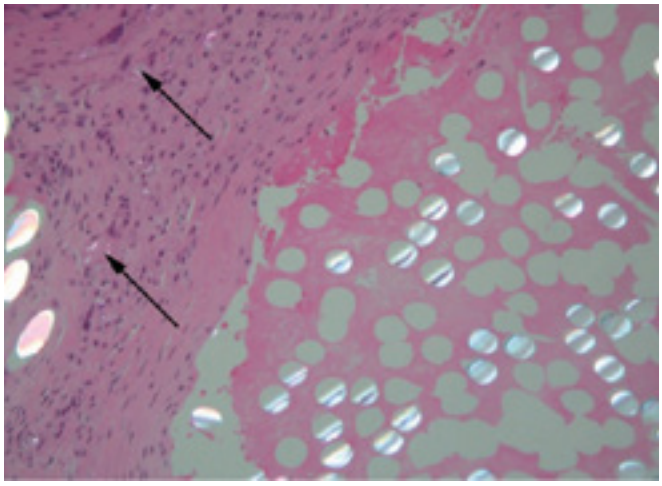

Fig. 8 A higher power view from the interface between the pseudocapsule and the polyester braid under partially polarised light. The right side of the picture shows the individual fibres of the polyester braids with only fibrin between the fibres. On the left side is the fibrous pseudocapsule. The far left shows connective tissue ingrowth among splayed fibres, amongst which a few foreign body giant cells are visible (black arrows).

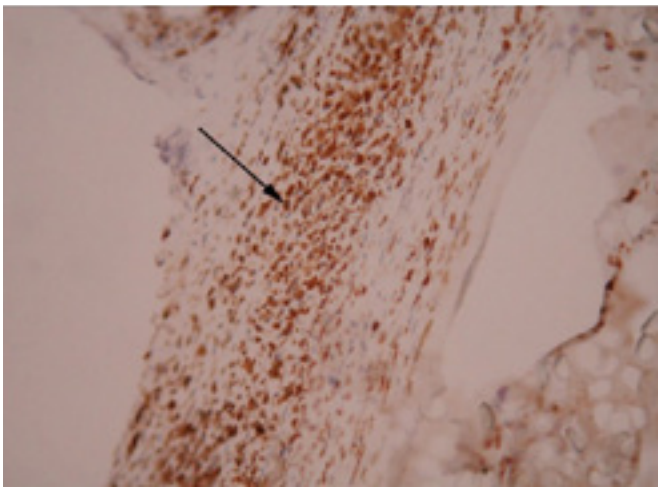

Fig. 9 Immunohistochemistry for the macrophage marker (CD68) showing numerous histiocytes within the pseudocapsule due to the presence of wear debris. Original magnification × 200.

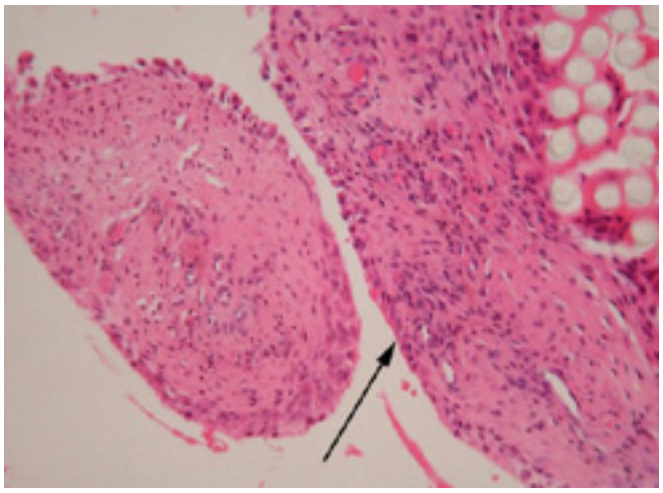

Fig. 10 Neosynovium without active inflammation, possibly resulting from movement (black arrows) original magnification × 200.

Immunohistochemistry delineated a surprising number of vessels in this outer fibrous pseudocapsule. Polarised light confirmed the collagenous nature of this fibrous tissue but, as expected, did not show the regular periodicity of native mature structures such as ligament or tendon.

Within the pseudocapsule were a small number of foreign body giant cells and a variable numbers of histiocytes arranged around either birefringent debris from disrupted fibres, or apparently whole fibres splayed out from the edge of the outer braids (Figs 8 and 9). A few lymphocytes were present but no polymorphs or active granulation tissue were identified in any of the cases.

Beneath the outer pseudocapsule was a discontinuous layer of fibrin, which in some areas formed a membrane-like structure around some of the braids (Fig. 8). The device consists of a number of woven braids, each of which consists of numerous individual polyester fibres. These braids were each invested by fibrous collagenous tissue similar to the outer pseudocapsule but of variable, and generally lesser, thickness. Generally, the inner fibrous layer was restricted to the outer inter-braid areas.

Only fibrin was present between the central parts of each of the braids and between the individual polyester fibres which constitute the braid: there was no evidence of cellular ingrowth or organisation within the tight braided material (Fig. 8).

In patients 2, 3, 4 and 5, areas of neosynovium were present but no acute inflammation was seen (Fig. 10).

Discussion

In each retrieval specimen, the explanted polyester ligament was surrounded by an investing layer of mature vascularised fibrous tissue which formed a thick 'pseudoligament'. Similar tissue was observed between the individual braids to a lesser extent, mostly on the outer surface. Only fibrin was able to penetrate between the individual polyester braids deep within the device, probably because of the tightness of the braids. A lack of penetration of tissues other than fibrin is also seen with woven polyethylene terephthalate (Dacron) vascular grafts.[30] This appears to be a feature intrinsic to the material when implanted. Overall, the investing connective tissue 'pseudoligament' around the device and similar tissue between the outer braids had a well-organised structure but not the collagen structure of a true ligament.

Some evidence of wear of the LockDown device could also be seen. Some of the outer polyester fibres can become detached and can splay at the edges. This could be due to minor damage to the device during implantation, the result of long-term wear, or both. Some of these splayed fibres had become incorporated into the outer connective-tissue capsule. Evidence of fibre fragmentation and wear was also apparent as micron-sized polyester particles in the pseudocapsule. This was of a variable degree and associated with a phagocytic histiocytic and giant-cell response. Synovial tissue is formed in some cases possibly as a response to movement. No polymorph component was seen in any of the cases, despite a clinical suspicion of infection in two. There was no evidence of a Type IV hypersensitivity reaction, confirming that the polyester fibres are biologically inert. Overall, the biological response appears favourable, reparative and compensatory and does not seem to affect the immune response. This favourable tissue reaction with a strong outer pseudocapsule suggests that when implanted in humans, a braided polyester scaffold may do better in an extra- than in an intra-articular location.

Our study suffers from several limitations, firstly the limited number of retrieved specimens available for analysis. However, we included all those seen in our tertiary referral centre, between 2006 and 2013. Second, only failed implants were analysed and it is always possible that the histological picture could be different in the surviving LockDown ligaments. However, in two patients the only reason for revision was because of further significant injury to patients with otherwise functioning prostheses. On histological analysis, all five implants showed similar features. This supports our view that the histological findings are representative of all functioning implants. We acknowledge that immunohistochemical analysis

was only performed on one specimen and extrapolation must be undertaken with caution.

A recent review of the management of Rockwood grade III acromioclavicular joint dislocation concluded that the restoration of the anatomical stability of the joint with autograft or certain synthetic grafts was an acceptable form of treatment.40

In conclusion, the LockDown device has now been used for over 15 years, with over 11,000 implanted world-wide, mainly for AC Joint stabilisation. Very few have been explanted. As for all surgical operations, failures occur for technical-surgical reasons, or due to re-injury or mechanical failure of the device. Mechanical failure of the LockDown device has been remarkably rare. On the strength of our limited investigations, this study has demonstrated that there are very few adverse findings from the implanted LockDown which appears to retain its strength long-term because of fibrous on-growth, with some limited in-growth into the device. We conclude that it is justifiable to continue using this product for extra-articular reconstruction at the ACJ and also in our one example at the sternoclavicular joint.

G. Kocsis: Collated the material for the paper, Transported specimens to the histology laboratory, Collaborated with T. McCulloch and wrote the first draft of the paper.

T. A. McCulloch: Carried out all the histological preparation and analysis of the specimens, Wrote the histological parts of the paper and corrected the drafts and the proofs.

D. Thyagarajan: Carried out two of the surgical retrieval operations, Transported specimens to the histology laboratory, Corrected the various drafts of the paper.

W. A. Wallace: Was the co-inventor of the Nottingham Surgilig, now called LockDown, Carried out three surgical retrieval operations, Corrected the various drafts of the paper, Completed the final editing of the proofs.

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Stabilisation for the disrupted acromioclavicular joint using a braided polyester prosthetic ligament

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Key words:
acromioclavicular joint; shoulder dislocation

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ABSTRACT

Purpose
To report outcomes of 21 men who underwent stabilisation for the disrupted acromioclavicular joint (ACJ) using a braided polyester prosthetic ligament.

Methods
21 men aged 23 to 76 (mean, 43) years underwent stabilisation for the disrupted ACJ of Rockwood type 3 (n=12), type 4 (n=1), and type 5 (n=8) using a braided polyester prosthetic ligament.

Results
The mean time from injury to surgery was 6.8 (range, 0–19) months. The mean follow-up duration was 30 (range, 7–67) months. The mean Constant Score was 86.8 (range, 62–100), and the mean individualised Constant Score was 88.5 (range, 68–100). The mean Oxford Shoulder Score was 43.1 (range, 28–48). The mean abduction power of the operated side was 82% (range, 31%–97%) that of the normal side. 20 patients were satisfied with the procedure. One patient was dissatisfied who developed scapulothoracic bursitis. One patient required arthroscopic subacromial decompression for impingement. One patient sustained a redislocation following a fall at 6 weeks and declined further surgery.

Conclusion
The braided polyester prosthetic ligament achieved good outcome for patients undergoing stabilisation for the disrupted ACJ.

Introduction
Acromioclavicular joint (ACJ) injuries occur more frequently in men aged <35 years and account for 12% of shoulder girdle injuries.[1,2] The mechanism of injury involves a direct blow to the shoulder tip in the adducted arm (particularly during contact sports such as rugby, wrestling, and hockey).[3] Forces applied to the lateral aspect of the shoulder lead to inferior and medial displacement of the scapula and clavicle. As the clavicle and the distance of inferior displacement are limited by the first rib, the force is redirected to the acromioclavicular (AC) and coracoclavicular (CC) ligaments. Greater forces can lead to complete disruption of the AC ligament and then the CC ligament, and even the muscular attachments of the deltoid and trapezius. This can lead to inferior subluxation of the acromion to the distal clavicle, as the supporting structures are disrupted.

According to the Rockwood classification,[4,5] there are 6 types of ACJ injury. Type 1 is a simple sprain. Type 2 involves a disrupted AC ligament but an intact CC ligament. Type 3 involves disruption of both AC and CC ligaments. Type 4 involves disruption of both ligamentous complexes, with posterior displacement of the clavicle through the trapezius fascia. Type 5 involves a greater level of disruption of both AC and CC ligaments; the deltotrapezial fascia is torn from the lateral attachments to the clavicle. Type 6 is caused by extreme hyperabduction, in which the clavicle is inferiorly displaced to a subcoracoid or subacromial position, with high risk of neurovascular compromise.

In terms of radiographic appearance, type 1 shows normal appearance; type 2 shows some widening of the ACJ but with a normal CC distance; type 3 shows further disruption of the ACJ with 20% to 100% increase in the CC distance; type 4 can be missed on anteroposterior view but can be seen on axillary view; and type 5 shows >100% increase in the CC distance (Fig. 1).[5,6] Weightbearing views (5 kg weight applied to both normal and injured sides) can maximise displacement to differentiate types.

In terms of treatment, types 1 and 2 can be treated conservatively with immobilisation in a broad arm sling until symptoms subside.[5] Type 3 can be treated conservatively or operatively; both achieve similar patient satisfaction.[7] Types 4 to 6 with or without failure in conservative treatment can be treated operatively.[2] Operative treatments include fixation across the ACJ with Kirschner wires (Phemister technique[8]) or a hook plate,[9] fixation of the clavicle to the coracoid process with extra-articular techniques (Bosworth screw fixation[10]), transfer of the coracoacromial ligament to reconstruct the CC ligament (Weaver-Dunn procedure[11]), and use of prosthetic materials (non-absorbable sutures around the coracoid,[12,13]

suture anchors,[14] and CC screw[15]) to augment the ligament transfer or to reconstruct the CC ligament (the TightRope[16] [Arthrex, USA], and the LockDown[17] [Lockdown Medical, Reddich, UK]). The LockDown prosthetic ligament is a double braided polyester mesh with loops at either end (Fig. 2). It has been used for revision of the failed Weaver-Dunn procedure, augmentation of the Weaver-Dunn procedure, and stabilisation of the disrupted ACJ.[17–20] This study reports outcomes of 21 men who underwent stabilisation for the disrupted ACJ using the Lockdown polyester ligament.

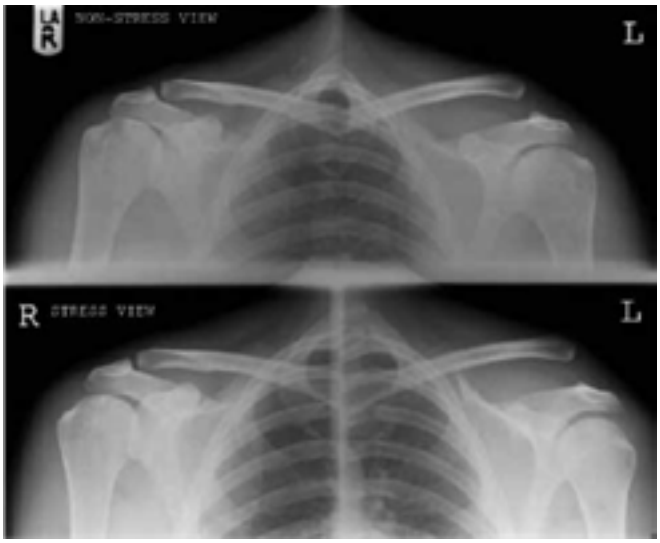

Fig. 1 The Rockwood type 5 acromioclavicular joint disruption of the left shoulder.

Materials and methods

Between 2005 and 2011, 21 consecutive male patients aged 23 to 76 (mean, 43) years underwent stabilisation for the disrupted ACJ of Rockwood type 3 (n=12), type 4 (n=1), and type 5 (n=8) using the Lockdown prosthetic ligament. Patients with type 3 ACJ injury had first undergone 3 months of conservative treatment and physiotherapy; one of these patients opted for surgery after one month. Two patients with type 5 injury had delayed surgery; one had delayed referral and another opted to avoid surgery initially.

Fig 2 The Lockdown prosthetic ligament is a double braided polyester mesh with loops at either end.

Patients were placed in the beach-chair position, and a vertical (shoulder strap) incision was made over the clavicle. The periosteum was split and the lateral 1cm of the clavicle excised.[21] The clavicle was reduced, and the measuring guide was passed around the coracoid process from medial to lateral, using the blunt-ended curved trochar. The appropriate-size prosthetic ligament was passed around the coracoid process. The soft loop was tightened around the base, and the hard loop was looped over the clavicle from posterior to anterior and fixed with a 3.5mm bicortical screw with a washer (Fig. 3). Appropriate tension was applied through the loop to reduce the clavicle, with a slight over-correction (2–3mm) of the clavicle position relative to the acromion. The wound was then closed in layers.

The postoperative protocol was standardised and involved 4 weeks of immobilisation in a Polysling, followed by physiotherapist-guided mobilisation, with an aim to restart light activities at 8 weeks and return to sports at 12 weeks.

Functional outcomes were assessed using the Constant Score[22] and the Oxford Shoulder Score.[23] The isometric abduction power was assessed using an electronic spring balance, with the arm held in 90° of abduction in the scapular plane. Scores were compared to that of the contralateral side. An individualised relative Constant Score was calculated after adjusting for the contralateral side score. Patient satisfaction was assessed by asking patients whether they would undergo the procedure again. Radiographs were assessed for evidence of fracture, loosening, or redislocation. Redislocation was defined as a vertical displacement of >50% at the ACJ.

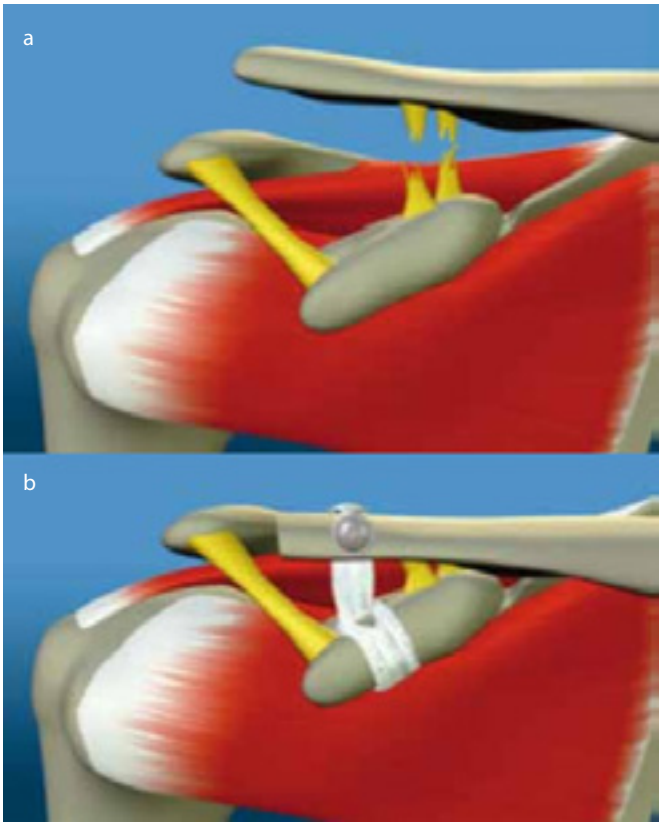

Fig. 3 (a) Rupture of the coracoclavicular ligaments, and (b) reduction of the acromioclavicular joint and fixation with the Lockdown prosthetic ligament.

Results

The mean time from injury to surgery was 6.8 (range, 0–19) months. The mean follow-up duration was 30 (range, 7–67) months. The mean Constant Score was 86.8 (range, 62–100), and the mean individualised Constant Score was 88.5 (range, 68–100). The mean Oxford Shoulder Score was 43.1 (range, 28–48). The mean abduction power of the operated side was 82% (range, 31%–97%) that of the normal side (Table 1).

Table 1 Patient characteristics and outcomes

Sex/Age (years)	Injured side	Rockwood type	Initial management	Time from injury to surgery (months)	Follow-up (months)	Postop Oxford shoulder score	Post-op Costant Score			Post-op abduction strength (kg)		Post-op strength (% of normal)
							Injured side	Normal side	Individualised	Injured side	Normal side	
M/63	Left	3	Sling	3	18	46	82	98	83.7	8.24	10.5	78.5
M/64	Left	3	Sling	18	41	41	80	100	80	5.76	7.5	76.8
M/30	Left	5	Sling	1	32	47	90	98	91.8	9.83	10.19	96.5
M/48	Right	5	Sling	7	16	32	62	90	68.9	6.52	11.33	57.5
M/59	Right	3	Sling	1	53	48	90	100	90	10.62	12	88.5
M/66	Left	5	Sling	0	42	47	92	100	92	7.84	9.18	85
M/39	Left	5	Sling	15	41	28	68	100	68	6.73	9.94	67.7
M/76	Left	4	Sling	0	40	47	87	92	94.6	5.78	7.16	80.7
M/43	Left	5	Sling	1	13	45	95	100	95	11.69	12.3	95
M/41	Left	5	Sling	11	7	40	81	90	90	6.24	8.5	73.4
M/52	Left	3	Sling	6	36	43	90	100	90	9.03	11.2	80.6
M/44	Right	3	Sling	6	29	30	70	95	73.7	3.64	11.64	31.3
M/23	Left	3	Sling	5	21	44	90	100	83.7	9.48	11.8	80.3
M/51	Left	5	Sling	4	7	45	90	100	90	10.9	11.7	93.2
M/27	Left	3	Sling	17	67	45	95	100	95	10.4	11.2	92.9
M/43	Left	3	Sling	3	13	46	93	100	93	10.51	11.5	91.4
M/27	Left	3	Sling	6	23	44	87	100	87	10.8	11.6	93.1
M/26	Left	3	Sling	19	53	48	100	100	100	14.1	15	94
M/30	Right	5	Sling	1	13	46	91	100	91	11.5	12.6	91.3
M/27	Left	3	Sling	10	42	47	95	100	95	13.9	15	92.7
M/26	Left	3	Sling	9	21	46	95	100	95	12.6	13.3	94.7

Table 2 Comparison of various acromioclavicular joint reconstruction techniques

Technique	Advantages	Disadvantages
Weaver-Dunn procedure	Widely used	Sacrifice of the coracoacromial ligament; lower strength and stiffness than native ligament; may require augmentation
Clavicle hook plate	Strong construct	Plate impingement may necessitate plate removal
Bosworth screw	Low cost, readily available	Bicortical fixation; risk of coracoid fracture or screw loosening or breakage; may require screw removal
TightRope	No sacrifice of the coracoacromial ligament	Risk of coracoid fracture or soft tissue irritation
Lockdown prosthetic ligament	No sacrifice of the coracoacromial ligament; enables soft-tissue ingrowth; good tensile strength	Soft tissue irritation may necessitate screw removal

20 patients were satisfied with the procedure. One patient was dissatisfied who developed scapulothoracic bursitis. One patient required arthroscopic subacromial decompression for impingement. One patient sustained a redislocation following a fall at 6 weeks and declined further surgery. No patient had wound infection or clavicular/coracoid process fracture, or required implant removal for irritation.

Discussion

Most ACJ dislocations can be treated conservatively with good outcomes.[7] Surgery is indicated for more severe disruptions (Rockwood types 4 to 6) and failed conservative management.[5] Patients with high physical demand jobs or jobs that require overhead work, or athletes or soldiers are suitable for early reconstruction for type 3 injuries.[24,25] There are various methods of surgical stabilisation for ACJ disruption (Table 2). Fixation across the ACJ with a hook plate may result in impingement or require implant removal.[9] The Weaver-Dunn procedure (transfer of the coracoacromial ligament to reconstruct the CC ligament) may not provide sufficient stability, as the coracoacromial ligament only provides 30% of the strength of the intact CC ligament.[26] A CC screw improves strength and stiffness of the construct,[15,26,27] but is associated with coracoid fracture, screw cut-out, and screw removal. Other methods include coronoid cerclage sutures and suture anchors.[12,14] Sacrifice of the coracoacromial ligament for transfer is

associated with increased instability of the glenohumeral joint.[28,29] The coracoacromial ligament acts as a buffer between the acromion and the rotator cuff; the risk of cuff pathology may theoretically increase following its removal.[30] Use of a prosthetic ligament avoids disruption of the coracoacromial arch and is useful when the coracoacromial ligament is deficient or unavailable (in revision surgery). Stabilisation with CC cerclage sutures or suture anchors with polyethylene or polydioxanone has achieved comparable strength to that of the native CC ligament in cadaveric testing.[12,14,26] Transfer of the coracoacromial ligament without augmentation results in the weakest strength and stiffness, compared to other surgical options. The stiffness of the Bosworth screw construct is similar to native ligaments when fixation is bicortical.[26] The strength of TightRope is comparable to that of the CC cerclage sutures or suture anchors. The tensile strength of the Lockdown prosthetic ligament is greater than both the native CC ligament and the TightRope.[31]

The success rates for ACJ reconstruction have been around 90%.[2,11,13,27] For late reconstruction, the rate is about 78%.[13,27] The Lockdown prosthetic ligament has been used in conjunction with the Weaver-Dunn procedure.[18] The Lockdown prosthetic ligament encourages soft tissue ingrowth[17] and thus is thought to prevent late failure. There is no loss of reduction after screw removal at a minimum of 9 months, owing to soft tissue ingrowth.[17,20] The Constant Score may be biased when used in a heterogeneous group, in particular given the high weighting for the strength component.[32,33] To correct this bias, the relative Constant Score to account for age is used.[34] In our study, the strength and Constant Score of the affected side were compared to those of the non-affected side. This gave a measure of proportional strength and an individualised Constant Score, which is a more reliable measure of shoulder function in heterogeneous groups.[33]

One limitation of this study was the potential for observer bias, as the observer involved in clinical assessment also involved in the operative procedure.

In addition, preoperative function was not assessed using the same assessment scales, and thus improvement in functional scores was not known. Further randomised controlled studies are needed to demonstrate superiority of one surgery modality over another.

Conclusion

The Lockdown prosthetic ligament achieved good outcome for patients undergoing stabilisation for the disrupted ACJ.

Disclosure

No conflicts of interest were declared by the authors.

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Acromioclavicular joint reconstruction using the LockDown synthetic implant

A study with cadavers

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Dislocation of the acromioclavicular joint is a relatively common injury and a number of surgical interventions have been described for its treatment. Recently, a synthetic ligament device has become available and been successfully used, however, like other non-native solutions, a compromise must be reached when choosing non-anatomical locations for their placement. This cadaveric study aimed to assess the effect of different clavicular anchorage points for the Lockdown device on the reduction of acromioclavicular joint dislocations, and suggest an optimal location. We also assessed whether further stability is provided using a coracoacromial ligament transfer (a modified Neviaser technique). The acromioclavicular joint was exposed on seven fresh-frozen cadaveric shoulders. The joint was reconstructed using the Lockdown implant using four different clavicular anchorage points and reduction was measured. The coracoacromial ligament was then transferred to the lateral end of the clavicle, and the joint re-assessed. If the Lockdown ligament was secured at the level of the conoid tubercle, the acromioclavicular joint could be reduced anatomically in all cases. If placed medial or 2cm lateral, the joint was irreducible. If the Lockdown was placed 1cm lateral to the conoid tubercle, the joint could be reduced with difficulty in four cases. Correct placement of the Lockdown device is crucial to allow anatomical joint reduction. Even when the Lockdown was placed over the conoid tubercle, anterior clavicle displacement remained but this could be controlled using a coracoacromial ligament transfer.

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High grade (Rockwood IV and V)[1] acromioclavicular joint (ACJ) dislocations are thought to result from disruption of the acromioclavicular (ACL) and coracoclavicular (CCL) ligaments. The optimal treatment of such injuries remains controversial. Both arthroscopic [2,3] and open techniques to reconstruct the CCL and/or ACL have been described, with synthetic [4,5] and biological ligaments,[6] tendon transfers, [7-10] the Weaver–Dunn procedure[9,11] and fixation with a Bosworth screw[12] or hook plate.[1,13] The Lockdown implant (Mandaco 569, Redditch United Kingdom, Lockdown previously called the Nottingham Surgilig) is a synthetic ligament which has increasingly been used for this purpose with encouraging published clinical results.[4,14,15]

The implant restores congruity to the ACJ by looping around the base of the coracoid before passing posterior to and over the reduced clavicle, culminating in fixation with a screw through the clavicle's anterosuperior surface. To date, the optimal clavicular anchorage point for the LockDown implant has not been described. In biomechanical terms, it is logical to suppose that a fixation point that is too medial will be inadequate to reduce the ACJ and one which is placed too lateral risks malpositioning of the lateral end of the clavicle resulting in fixation in an anteroinferiorly-displaced position.

The CCL and ACL act as the two anchorage points between the scapula and the clavicle, permitting the former to swing in a single fixed plane. After Rockwood IV or V injuries are subsequently fixed with a Lockdown ligament, only one of these restraints is restored and so it is possible for the scapula to move relatively freely in most planes. Simultaneous transfer of the coracoid end of the coracoacromial ligament (CAL) can enable stabilisation of the ACJ by reconstructing the anterior ACL, which is a modification of the technique described by Neviaser[16] in 1951.

The aims of our study were to assess the effect of different sites of fixation of the Lockdown ligament, relative to the conoid tubercle, and of restoring the ACL using a modified Neviaser technique proposed by two of the authors (RT, JJC-C. The outcome measures were reducibility and stability of the ACJ. We also sought to assess the variability within our measurements between the anatomical landmarks with which we were working.

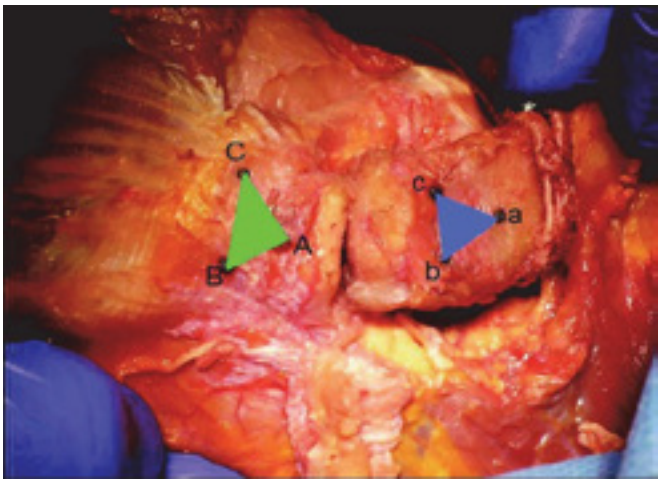

Fig. 1 Photograph showing an example of the geometric reference triangles situated on the acromion (green triangle) and on the clavicle (blue triangle).

Materials and Methods

This cadaveric study was carried out on seven fresh-frozen shoulders in a regional cadaveric surgical training facility. All specimens included the upper trunk, head and neck with intact ACJs and sternoclavicular joints. The cadavers were aged between 48 and 61 years, three were male, one female, and no cases had had prior shoulder surgery. The ACJ was exposed and the relative positions of the clavicle and acromion were determined using a trigonometric method. In short, three fixed points on the superior surface of the lateral end of the clavicle were marked with metal pins to form a reference triangle. A similar triangle was created on the acromion, just lateral to the ACJ (Fig. 1). By measuring the distances between all six points, we were able to define the position of each triangle relative to the other. These were recorded in all experiments and all measurements were made with an electronic caliper with 0.01mm accuracy (Digital LCD Caliper Vernier Gauge, Trixes, Guangdong, China). The ACJ was considered 'unstable' when the distal clavicle was mobile, with minimal force applied by the surgeon.

Four possible anchorage points for the artificial ligament were marked on the clavicle: at the conoid tubercle (CT), hence mirroring the in vivo attachment of the conoid ligament, 1 cm lateral to the CT, 2cm lateral to CT and 1cm medial to CT. The conoid tubercle is located posteroinferiorly, and corresponds to the junction of the flattened lateral clavicle with the triangular-shaped medial two thirds.[1] The 1cm spacing of the sites was to avoid fracture from more densely-spaced drill holes.

The ACJ was reconstructed with the Lockdown ligament by the manufacturer's published technique[17] with identical replication of the steps at each site of attachment. To achieve reduction, one surgeon applied a craniocaudal force to bring the clavicle level with the acromion in the axial plane as in clinical use, while another used the system's sizing device to select the correct length. After reconstruction, distances between the pins of the two reference triangles were measured and, if the joint was not congruent, an attempt was made to reduce the ACJ into an anatomical position. Following experiments on the Lockdown repair alone, the anterior ACL was reconstructed using the CAL with the CT used as the site of attachment in each case. The CAL was detached from its coracoid insertion, keeping its acromial attachment, and the graft was translated anteriorly and fed through the most laterally drilled hole in the clavicle (2cm lateral to the CT) using transosseous sutures (Taranu-Candal (TC) transfer).

Statistical analysis

In order to estimate measurement error, three authors (RT, PRPR, JJC-C) performed nine repeated measurements of three different distances of the same shoulder configuration, a total of 27 measurements. The means of the nine measurements for the three distances were 33.45mm (SD 0.152), 29.57mm (SD 0.172) and 27.8mm (SD 0.095), respectively. We used these 27 measurements because it allowed us to find significant differences between SDs of 0.15 and 0.20 with a power of 80%. We also wanted to calculate the effect of this variability on distance, elevation and azimuth estimation, and therefore we undertook 1000 simulations for each one of the seven shoulders, using a model based on the real anatomical measurements (Table I) with the addition of a random error obtained from the normal distribution (mean 0 and SD 0.15mm) to each real measurement. When all error estimation models were processed, the mean of the estimated errors was 0.45mm for distance, 2.66º for elevation, and 0.91º for azimuth. Finally we derived the 95% confidence interval (CI) using the residuals from the Matlab (solve) routine (R2011b, MathWorks, Natick, Massachusetts) and it was $\pm 3.8 \times 10^{-6}$. Further measurements were obtained and analysed by using a one-way analysis of variance (ANOVA) of the differences. A p-value of < 0.05 was considered significant.

Results

In all seven shoulders it was observed that if the Lockdown ligament was secured at the level of the CT the ACJ could be passively reduced anatomically. If the ligament was placed medial to it, the ACJ was found to be irreducible. If the Lockdown ligament was placed 2cm lateral to the CT, the ACJ remained displaced with the clavicular articular surface lying inferior, anterior and significantly medial to its acromial counterpart. If the Lockdown device was placed 1cm lateral to the CT the ACJ could be reduced with some difficulty in four cases but was irreducible in the other three shoulders.

Despite reduction of the ACJ using the Lockdown ligament over the CT, anterior instability remained. The coracoid end of the CAL was transferred to the lateral clavicle in five shoulders, which then rendered the ACJ stable.

Table I. Distances, elevation angles, and azimuth angles, for different surgical procedures, between the centre of the triangle located in the acromion (reference point) and the centre of the triangle located in the clavicle

	Distance between centroids (mm)							Elevation (°)							Azimuth (°)						
Shoulders	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Anatomical	30.9	30.4	37.3	25.4	35.7	34.0	26.5	-9.2	-6.6	-3.8	-12.8	0	-3.4	-5.1	-12.6	-8.4	0.23	14.8	-2.7	-7.4	6.6
All ligaments cut	37.3	39.2	44.8	31.1	46.4	40.6	32.5	-6.3	0	0	0	-2.6	0	-14.6	-10.9	-12.8	5.6	22.1	5.0	7.8	3.9
Conoid tubercle +2 cm lateral	45.2	43.2	48.1	44.0	35.8*	39.3	33.4	-14.1	0	-1.0	-18.4	-3.2*	-2.5	-9.1	-49.9	-35.7	-21.7*	-11.5*	-20.6	-25.1	-52.2
Conoid tubercle +1 cm lateral	44.2	41.3	42.7	41.4	33.0	40.4	31.0	-10.6*	-10.4	-6.3	-16.2	-6.9	0	0*	-48.4	-35.7	-27.9	-19.2	-20.2	-20.4	-33.0
Conoid tubercle	43.2	41.0	40.4	42.3	33.5	40.1	30.2	-17.1	0	-2.4*	-13.6*	-18.0	-3.3*	-10.9	-51.8	-39.6	-33.0	-19.7	-20.0	-22.4	-33.6
Conoid tubercle –1 cm medial	42.2	45.0	38.2*	37.2*	34.4	38.7	32.7	-6.9	0	-10.4	-22.9	-6.1	-5.5	-11.6	-53.2	-44.7	-33.5	-28.2	-21.8	-24.8	-61.8
CT with Taranu-Candal transfer	28.7*	30.6*	X	X	29.9	34.5*	26.5*	-19.1	-8.6*	X	X	-4.7	-19.5	0*	-24.5*	-26.2*	X	X	-16.9*	-19.1*	-23.0*

* Values that are closer to the anatomical measures (without taking into account the row 'All ligaments cut')

Using trigonometric analysis of our measurements (Table I) we found that once both CCL and ACL were cut, the clavicle became only modestly subluxed, despite being grossly unstable. It adopted a resting position superiorly and posteriorly, which changed to a more marked inferior and anterior dislocation when stabilised with the Lockdown implant, regardless of the chosen anchorage point. This abnormal position was mostly corrected by the CAL transfer to the lateral end of the clavicle (Fig. 2) and this conferred a statistically significant improvement in displacement compared with the use of the Lockdown ligament inserted 2cm lateral to the CT ligament ($p = 0.035$).

Discussion

More than 100 different fixation techniques have been described for acute and chronic dislocation of the acromioclavicular joint.[1] In 1972, Weaver and Dunn[11] proposed the reconstruction of CCLs by transferring the acromial side of the CAL to the lateral end of the clavicle and, more recently, the availability of synthetic ligaments has offered an alternative to the traditional Weaver-Dunn procedure.[2,5] Most techniques described focus on correcting the superoinferior translation of the clavicle, but there is lack of clinical data pertaining to anteroposterior (AP) translation following surgical reconstruction of the CCL. The long-term impact on shoulder function or degeneration of the ACJ in the presence of chronic anterior subluxation or dislocation, are not known. In a medium-term report, Fauci et al[6] presented good clinical outcomes at four years in the context of radiologically demonstrated subluxation, or dislocation of the ACJ.

Preliminary results of the Lockdown implant have reported encouraging short- and medium-term clinical results.[4,5,14] While around 90% of Lockdown ligament procedures are successful, it may be that malreduction and persistent instability will lead to cosmetic and functional issues in some patients.[14] Further development of the surgical technique, such as identification of ideal location of fixation, may address these remaining issues.

We reduced the superoinferior translation by reconstructing the CCL with the artificial Lockdown ligament. Invariably, this resulted in an anterior clavicular translation, irrespective of the clavicular anchorage point of the artificial ligament, due to a relatively more anterior coracoid placement of the artificial ligament, rather than the original coracoid insertion of the conoid ligament. Anatomically, the conoid ligament inserts on the coracoid at the most posterior and dorsal aspect of the coracoid angle, described by Harris et al[18] as the conoid apophysis. In contrast, the Lockdown ligament is hooked around the horizontal pillar of the coracoid, anterior to the vertical pillar and conoid apophysis. By restoring the superoinferior position, the clavicle will inevitably be pulled anteriorly by the AP component of the vector force applied by the Lockdown device.

Importantly, we observed that the clavicular anchorage point permitting passive anatomical reduction of the ACJ was level with the insertion of the conoid ligament in the mediolateral axis. If placed too medial the ACJ was irreducible, while if too lateral the clavicle remained displaced anteriorly, medially and inferiorly towards the coracoid, suggestive of a similar vector effect in the coronal plane.

In this experiment, reconstruction of both of the CCL and anterior ACL were necessary in order to maintain anatomical reduction of the ACJ without application of external force. This is consistent with several previous studies,[19-21] which suggest that reconstruction of both CCL and ACL may be superior to CAL transfer alone. Neviaser[16] described reconstruction of the superior ligament of the ACJ with the CAL released from its coracoid attachment; this technique has been criticised by some who question its biomechanical efficacy as the reconstructed ligament is orientated perpendicular to the craniocaudal force vector.[22] We used a modified Neviaser technique to reconstruct the anterior ACL, aiming to prevent AP instability. The broad CAL insertion onto the coracoid allows the surgeon to harvest a thick ligament which can be attached to the lateral end of the clavicle using transosseous sutures.

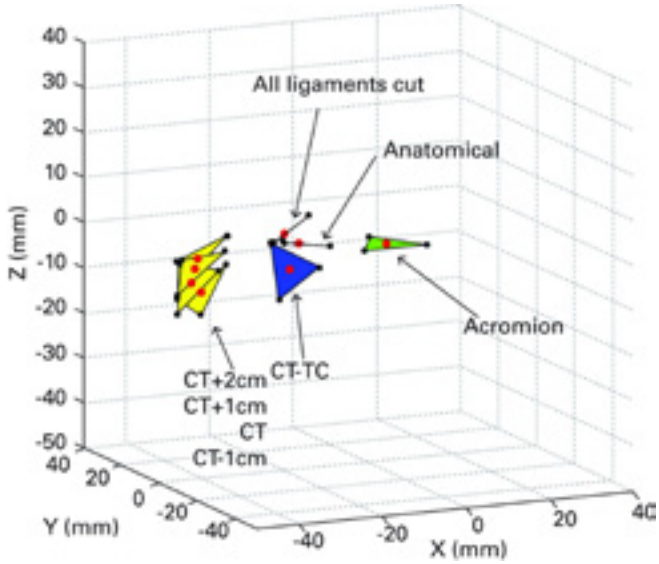

Fig. 2 Graph demonstrating the position of the clavicle in relation to the acromion (green triangle) in three dimensions. The yellow triangles correspond to the similar positions adopted by the lateral end of the clavicle after the insertion of the Lockdown ligament with all four different anchor points. The position is improved with the coracoacromial ligament transfer (CT-TC; Conoid tubercle anchor point with Taranu-Candal transfer.

It is important to note that although after division of the CCL and ACL the ACJ became grossly unstable, the resting position of the lateral end of the clavicle exhibited only modest superior and posterior displacement (Fig. 2). This is clearly a limitation of a cadaveric study where the absence of muscular forces such as those contributed by trapezius may give an underestimate of the degree of displacement one may expect to see *in vivo*. We did not, therefore, use this initial resting displacement for scientific comparison.

Excision of distal clavicle is recommended in the Lockdown operative technique to reduce acromioclavicular impingement[17] and pain from secondary arthritis, although the benefit of this has been questioned by some authors.[23] Neither pain nor impingement were outcome measures that bore relevance to our experimental study, and reduction was not affected by the remaining length of the clavicle.

We acknowledge the limitations of this study; it is observational and cadaveric and we did not carry out biomechanical testing of the combined ligamentous reconstruction. The principal aim, which was to determine the optimal clavicular insertion of the artificial ligament, was achieved but the significant anterior displacement following reduction of superoinferior translation may require an AP stabiliser. The novel CAL transfer fulfilled this function in our cadaveric study, but further *in vivo* trials are required before it can be recommended for clinical use.

The ligaments of the ACJ, capsule and deltotrapezial fascia were excised to simulate a high-grade tear, where both capsule and fascia are commonly injured. Having excised these tissues, we were not able to formally repair them as part of the reconstruction; this resulted in some loss of biofidelity as further stability of the ACJ may be achieved by imbricating these structures in an *in vivo* repair.

We are aware that experimental variability was introduced by the manual application of the reduction force when sizing the LockDown ligament. However, this reproduces normal surgical practice when choosing the appropriate ligament size as recommended by the manufacturer's manual.[17]

In conclusion, correct placement of the LockDown device at the level of the conoid tubercle is crucial to allow anatomical joint reduction. Additional measures such as coracoacromial ligament transfer may be used to address any residual anterior instability of the clavicle, and further work is encouraged to investigate clinical use of this technique.

Supplementary material

Further information and original material pertaining to experimental and trigonometric methods used in this study are available alongside the online version of this article at www.bjj.boneandjoint.org.uk

Author contributions:

R. Taranu: Study design, data collection, writing the paper.
P. R. P. Rushton: Data collection, writing the paper.
I. Serrano-Pedraza: Developed the trigonometric method used for the analysis of the data, wrote part of the paper, performed the statistical analysis.
L. Holder: Data collection and surgical procedure.
W. A. Wallace: Co-Inventor of the LockDown device, experience of using LockDown in over 100 patients, provided advice on both the experimental method and the analysis of results.
J. J. Candal-Couto: Senior author, study idea and design, carried out study, data analysis and writing of paper.

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Current practice in the management of Rockwood type III acromioclavicular joint dislocations

National survey

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Abstract

Purpose:
Our aim was to conduct this survey among consultant shoulder surgeons in the United Kingdom to document the current management of Rockwood type III acromioclavicular joint (ACJ) injuries.

Methods:
British Elbow and Shoulder Society Research Committee-approved online survey was used and 137 responses were collected within 3 months.

Results:
One hundred percent of responders would treat type III injuries conservatively initially. Routine physiotherapy would be offered by 86% of surgeons. The patient's factors that influence the decision to consider surgery are pre-injury functional demand, current functional deficit, pain and patient request for surgery. Across all groups the mean time to surgical intervention from injury was 3.8 months. About 45% of all consultants would use the same technique for all cases and there were differences between the varieties of techniques used by surgeons, depending on their degree of experience. LockDown was the most widely used technique in all groups of patients. This was followed by Ligament Augmentation & Reconstruction System (LARS), hook plate and Arthroscopic TightRope/DogBone technique for acute injuries. LARS, modified Weaver–Dunn and ACJ resection were used most commonly after LockDown for delayed cases.

Conclusion:
Our survey revealed the current trends in clinical practice to treat symptomatic Rockwood type III ACJ injuries, but it also confirmed the controversial and complex management differences, which vary among shoulder surgeons in the United Kingdom.

Introduction

Acromioclavicular joint (ACJ) dislocation is a common injury seen in orthopaedic practice and accounts for up to 12% of shoulder injuries.[1] It is most commonly seen in younger male patients who participate in contact sports, and the spectrum of injury encompasses from minor sprains and subluxations to complete dislocations with rupture of the surrounding soft tissue structures. The ACJ injuries were classified by Rockwood into six separate types, according to the severity of the injury.[2] Although this is still the commonly used classification system, recent studies have suggested an overall lack of reliability of the Rockwood classification of ACJ dislocations and of decisions regarding their treatment.[3,4]

Less severe (types I, II and III) ACJ injuries are more common,[2] with recent studies suggesting that of those who present to hospital, the most common are type III injuries.[5] The treatment of ACJ injuries can be broadly stratified by the severity of the injury, with type I and II injuries almost universally treated conservatively with expected return to painless full range of motion few weeks after the injury.[6] There is also consensus that type IV, V and VI injuries should be treated surgically.[7]

The treatment of type III injuries is less clear, with current evidence suggesting that both conservative and surgical treatment have similar outcomes.[8,9] There is no clear consensus on the management of these injuries and no randomized controlled trials to support clinical decisions. Most of the studies in the literature support nonoperative management for most patients; however, other factors must be considered, including the patient's occupation and physical demands as well as the age of the injury. Overhead athletes and manual labourers place high demands on their shoulders, prompting some surgeons to consider acute surgical treatment for these patients. The only advantage to operative intervention consistently borne out in the literature is an increased probability of anatomic reduction, but there is no correlation between reduction and improvement in pain, strength or motion, however. On the other hand, these patients are usually able to return to full sport with no deficits if appropriate rehabilitation is emphasized, and for those patients who fail conservative management, a multitude of surgical techniques exist to reconstruct the ACJ. This survey was therefore carried out in 2014/2015 to document the clinical practice of shoulder surgeons in the United Kingdom (UK) when treating the controversial Rockwood type III injuries and to determine what factors influence their decisions.

Materials and methods

A one-page, web-based survey was created using a survey creation tool (http://www.surveymonkey.com, supplement online link with questionnaire). Approval for the study was gained from the British Elbow and Shoulder Society (BESS) Research Committee. The survey link was sent via email to all consultant members of BESS, which was kept open for a 3-month period.

The survey questions included clinical experience (number of years as a consultant surgeon), the preferred method of differentiating between Rockwood type III and IV injuries, the preferred treatment protocol for type III injuries and the indications for surgery and the preferred procedure for symptomatic patients. The responding surgeons were invited to provide this information for different patient subgroups: overhead athlete, collision athlete, young (<35 age) male, young (<35 age) female, male or female (35–65 age) with high functional demand and elderly (>65 age) patients.

Results

Overall, the survey received a response from 137 consultant surgeons (response rate: 30%). Of these, 51% had at least 10 years of experience in shoulder surgery.

Table 1: The time for physiotherapy referral after type III ACJ injury.

Patients referred for physiotherapy	Percentage
Immediately	29
At 1 week	3
At 2 weeks	24
At 3 weeks	8
After 3 weeks	8
Only if persisting stiffness	14

ACJ: acromioclavicular joint.

Table 2: The patients' factors that influence the decision to consider surgery.

Patients' factors	Percentage
Functional demand	51
Current functional deficit	38
Level of pain	22
Patient request for surgery	22
Cosmesis	13

Diagnosis and initial management

It was found that 86% of surgeons made a differentiation between Rockwood type III and IV injuries based upon clinical examination. This was also confirmed by some form of radiograph imaging to assist in the diagnosis (axillary radiograph – 48%, AP radiograph – 43%, Zanca view radiograph – 13% and lateral Y view radiograph – 10%).

One hundred percentage of all responders indicated a preference to treat type III injuries conservatively initially. This was indicated to be with sling immobilization for a period of up to 4 weeks in 90% of all acute injuries, with a slightly shorter period of time for elderly patients (> 65 age). Routine physiotherapy would be offered by 86% of surgeons surveyed for injuries in the acute setting and 14% of responders would never refer their patients for physiotherapy (Table 1).

Surgical intervention

With regard to consideration to proceed with surgery, there were a number of factors that seemed to influence the decision-making process (Table 2). The factors that seemed to have the largest bearing were pre-injury functional demand, current functional deficit, pain and patient request for surgery. The age, gender and hand dominance of the patient had no significant bearing on whether or not surgery was offered.

Surgeons were then asked to specify their treatment plans for different patient subgroups and no immediate surgical intervention was advocated in any group. Across all groups, the mean time to surgical intervention from injury was 3.8 months (Table 3).

Table 3: Decision to proceed with surgical treatment

Subgroup	Mean time to surgical treatment from injury, months
Symptomatic acute type III injuries (within 3 weeks)	
Athletes (overhead or collision)	2.9
Younger patients (<35 age)	3.3
Middle-aged (35–65 age)	3.8
Older patients (>65 age)	4.7
Symptomatic delayed type III injuries (after 3 weeks)	
Athletes (overhead or collision)	2.6
Younger patients (<35 age)	3.3
Middle-aged (35–65 age)	4.2
Older patients (>65 age)	5.4

There was no difference in the way in which overhead or collision athletes were treated or any difference between males and females. There was a slight difference between the mean time to surgical treatment for acute injuries (i.e. <3 weeks) and delayed cases (>3 weeks) across all patient subgroups.

It was evident that consultants who had less than 10-year practice had a tendency towards earlier operative intervention compared to those who had 10 or more years of experience.

Surgical technique

Forty-five percentage of responders surveyed said that they would use a single technique for all cases of ACJ instability, regardless of whether they were acute or not. The remaining 55% stated that they would use a different technique for acute and delayed cases. LockDown ACJ Ligament (previously called the Nottingham Surgilig; LockDown Medical Ltd, Redditch, UK) was the most widely used technique in all subgroups of patients. In the acute setting, the second most popular surgical technique was Ligament Augmentation & Reconstruction System (LARS, Arc sur Tille, France), followed by Arthroscopic TightRope/DogBone device (Arthrex,

Naples, Florida, USA) and clavicular hook plate (DePuy Synthes; Table 4). Techniques were similar across all subgroups of patients in the acute setting. For patients who presented with a delayed injury (>3 weeks), LARS was the second most popular technique, followed by an open Weaver–Dunn (WD) technique with modifications. This was the same across all patient groups, with the exception of patients over the age of 65 years, where an arthroscopic ACJ excision was the third most popular choice (Table 5).

There were differences between the varieties of techniques used by surgeons, depending on their degree of experience. As already mentioned, consultant surgeons who had been in independent practice for less than 10 years on average opted for surgical intervention in all non-acute cases 1 month earlier than their colleagues who had practiced for 10 years or more. The surgeons with greater than 10-year experience (group A) tended to use a single technique more frequently than those with less experience (group B). There was a tendency towards newer techniques in the less experienced group, perhaps reflecting changes in training and recent developments in technology (Table 6).

Discussion

The management of Rockwood type III ACJ injuries remains controversial. There is no clear consensus as to whether these injuries should be managed conservatively or by operative intervention.[1,10] Interestingly, the ISAKOS Upper Extremity Committee has provided recently a more specific classification of this shoulder pathologies to enhance the knowledge of, and clinical approach to, these injuries.[11] They suggested the addition of type IIIA (stable ACJ without overriding of the clavicle on the cross-body adduction view and without significant scapular dysfunction) and type IIIB (unstable ACJ with therapy-resistant scapular dysfunction and an overriding clavicle on the cross-body adduction view) injuries to a modified Rockwood classification.

In an earlier survey, in the 1970s, the department heads of all approved US orthopaedic training programmes were polled. The results of this questionnaire revealed that there was a preference for surgical treatment of these injuries; however, they used the Tossy classification, which probably included injuries type IV and V of Rockwood classification.[12] Although in the 1990s, the fixation between the clavicle and coracoid became more accepted than fixation across the ACJ, another survey of Cox et al. found different results. There was a dramatic reversal in treatment choices of the surveyed US orthopaedic programme residency directors and orthopaedic surgeons, with 72% and 86%, respectively, advocating non-operative treatment for type III ACJ injuries.[13] This is a view that was supported later by McFarland et al., who surveyed all US major league baseball team orthopaedists, 69% of whom would treat throwing athletes initially conservatively but 31% would offer immediate surgery.[14] Our survey also supports the current view of the majority of clinicians that these difficult injuries can be managed conservatively, at least in the initial period.

However, a survey of Brazilian orthopaedic surgeons showed that there is no consensus in the selection between traditional and surgical treatment for 386 (80.7%) respondents, with the most important factor for selecting a given treatment method being the patient's level of sports practice and age.[15] Another recent survey of all members of the American Orthopaedic Society for Sports Medicine (AOSSM) and approved Accreditation Council for Graduate Medical Education (ACGME) orthopedic programme residency directors showed that 81% of AOSSM members and 86% of the directors would continue to treat uncomplicated type III ACJ separations conservatively.[16]

Table 4. Surgical techniques for acute (<3 weeks) type III ACJ injuries.

Most frequent techniques for subgroups	Number1	Number 2	Number 3
Athlete	LockDown (34%)	Hook plate (14%)	LARS (13%) Arthroscopic TightRope/DogBone (13%)
Young (<35 age)	LockDown (27%)	LARS (17%)	Hook plate (9%)
Middle-aged (35–65)	LockDown (26%)	LARS (12%) Hook plate (12%)	Arthroscopic TightRope/DogBone (11%)
Elderly (>65 age)	LockDown (22%)	LARS (10%) Hook plate (10%) Open Weaver–Dunn (10%)	Mumford (8%)

ACJ: acromioclavicular joint; LARS: Ligament Augmentation & Reconstruction System.

Table 5. Surgical techniques for delayed (>3 weeks) type III ACJ injuries.

Most frequent techniques for subgroups	Number1	Number 2	Number 3
Athlete	LockDown (37%)	LARS (24%)	Open Weaver–Dunn (20%)
Young (<35 age)	LockDown (35%)	LARS (24%)	Open Weaver–Dunn (21%)
Middle-aged (35–65)	LockDown (38%)	LARS (21%)	Open Weaver–Dunn (17%)
Elderly (>65 age)	LockDown (21%)	LARS (18%) Open Weaver–Dunn (18%)	Arthroscopic ACJ resection (10%

ACJ: acromioclavicular joint; LARS: Ligament Augmentation & Reconstruction System.

Table 6: Different surgical techniques by the clinical experience of the surgeons.

Technique	Group A (> 10 years), %	Group B (< 10 years), %
Single technique for all cases	58	32
LockDown	26	34
LARS	15	20
Arthroscopic TightRope/DogBone	10	18
Modified Weaver–Dunn	24	15
ACJ resection	14	5
Hook plate, Bosworth screw, Dacron, PDS tape	11	8

ACJ: acromioclavicular joint; LARS: Ligament Augmentation & Reconstruction System; PDS: polydioxanone.

The factors that led surgeons to surgery in our survey related primarily to the patients' premorbid function, current functional deficit and, to a lesser extent, patients' preference. As mentioned, it is suggested that patients have a trial of conservative management for a period of 1–3 months before consideration of surgery.[1,8,10,14] Mean time to surgery for our surveyed group was 3.8 months with no difference between the timing of the injury or any patient subgroups. Functional deficit, after initial conservative management, appears to be an accepted indication for surgical intervention.[1,8,10,14] Early surgery may well be easier, especially within the 'acute' period (i.e. within 3 weeks), as anatomical reduction of the joint is more readily enabled.[10] However, immediate intervention without a trial of conservative management for type III injuries may well lead to unwanted complications, which may not have existed had surgery not been undertaken.[10,17] There also appears to be a paucity of evidence, based upon systematic reviews, that the outcomes from early operative intervention are superior to conservative management, in the acute period.[18,19] In type III ACJ injuries, each patient and pathology must be carefully analysed to ensure that the correct treatment option is chosen.[17] Broadly speaking there is support, from a number of studies, for the initial conservative management of these injuries.[1,8,10,14] A systematic review was carried out by Spencer favoured conservative over surgical management.[18] This is in contrast to a more recent systematic review by Korsten et al., the outcome of which suggested a possible benefit from surgery in young more active patients.[8] Our survey has shown that 100% of clinicians would choose to treat type III injuries conservatively. The recent Cochrane review also suggested that there is insufficient evidence from randomized controlled trials to determine when surgical treatment is indicated for acromioclavicular dislocation in adults, in current practice.[20]

Interestingly, we found a trend for earlier surgical intervention for surgeons who had been practicing for less than 10 years. Consultants who had been independently practicing for less than 10 years (group B) offered surgery for delayed presentations (i.e. > 3 weeks) 1 month earlier, compared to those who had been practicing for greater than 10 years (group A). We hypothesize that this may reflect a more 'aggressive' approach by more recently appointed surgeons, compared to practice by more senior colleagues who have more experience of management and its subsequent outcomes. This difference in clinical practice also seems to be reflected in the choice of surgical technique. There were a greater variety of techniques used by consultants who had practiced for less than 10 years. This may well be as a result of recent developments in arthroscopic shoulder surgery, new advances in technology and changes to training within the UK. Other authors have already observed that younger surgeons may be more likely to adopt newer techniques without evidence of superior results. There is certainly an intrinsic attraction towards newer technologies or techniques and surgeons may perceive certain pressures to offer these.[21] On the other hand, the greater experience of surgeons could mean that they are correct to be less optimistic about the results and continue to use reliable, reproducible and well-established techniques.

There is good evidence in the literature for all the surgical techniques that were identified within the survey.[22–29] LockDown and LARS techniques represented the first and second most popular techniques, for both acute and delayed injury groups. Helfen et al. also proved that due to inconsistent study designs, there is no evidence for a general superiority of any of the open or arthroscopic procedures.[30] Randomized controlled studies are necessary to demonstrate whether arthroscopic techniques show a potential benefit, in terms of a better functional outcome.

The limitations of this study are that it is a survey without statistical analysis, which carries a low power in terms of evidence and the conclusions we can draw from it. The response rate was low, which potentially limits generalizability, and could have been higher, to add further weight to our findings. The questionnaire was deliberately designed as a simple one-page survey in an attempt to increase response rates, but the selection bias towards those most likely to respond to this voluntary internet-based questionnaire means that respondents may not be representative of the entire population of shoulder surgeons. One of the strengths of our study was to provide an insight into the current trends in the management of type III acromioclavicular injuries in the UK. It demonstrates a consensus opinion that initial management of these injuries should be conservative and on average for a period of 3 months, before surgical intervention is offered. This is in keeping with the current evidence provided in the literature. Surgery, when offered, is tailored to the individual needs of the patient, as demonstrated by a wide variety of surgical techniques employed. The surgical techniques being used are again supported by evidence that appears to show good overall outcomes. However, the level of evidence to support a number of these techniques is inadequate for meaningful conclusions to be drawn. There is a clear need for further research into the individual techniques themselves, both in terms of the long-term outcomes and their superiority over each other. The undertaking of randomized controlled trials in the future is likely to be key in adding further clarity to the effective management of these controversial ACJ injuries.

Conclusion

Our survey revealed the current trends in clinical practice to treat symptomatic Rockwood type III ACJ injuries, but it also confirmed the controversial and complex management differences, which vary among shoulder surgeons in the UK. The reasons for this variation are understandable, in the context of our current knowledge and evidence. Further studies, with proper methodologies, are warranted for providing evidence regarding the effectiveness of surgical therapy versus conservative treatment as well as for addressing the best surgical and conservative method for treating Rockwood type III ACJ injuries.

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Operative Versus Non-operative Treatment of Grade III Acromioclavicular Joint Dislocations and the Use of SurgiLig:

a Retrospective Review

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SUMMARY

Background

Acromioclavicular joint dislocations are common shoulder girdle injuries. The treatment of grade III acromioclavicular joint dislocations is controversial. Furthermore, the literature on the use of the Surgilig™ synthetic ligament for reconstruction of dislocations is sparse.

Material and methods

This retrospective review aimed to establish whether operative treatment was superior to non-operative treatment in grade III acromioclavicular joint dislocations treated at our institute over a 5-year period. We also reviewed the effectiveness of reconstruction with Surgilig™ after acute and chronic dislocations across all grades of acromioclavicular joint dislocations.

Results

Twenty-five patients completed full follow-up with grade III dislocations. The mean follow-up in the operated group was 3.56 years and in the non-operated group this was 3.29 years. The mean Oxford Shoulder Score (OSS) in the operated group was 39.8, whereas the mean OSS in the non-operated group was 45.9 (p=0.01). The mean pain score in the operated group was 2.2, and in the non-operated group this was 1.6. The mean satisfaction score in the operated group was 8.2 and that in the non-operated group was 7.8. There was no statistically significant difference in pain or satisfaction scores. In respect to the cohort treated with Surgilig™ synthetic ligament, 22 patients across all grades of dislocations had this procedure performed. The mean post-operative Oxford Shoulder Score (OSS) was 40.

Conclusions.

1. Non-operative treatment is not inferior to operative treatment for grade III acromioclavicular joint dislocations. The data from this study demonstrated that the non-operated group had superior Oxford Shoulder Scores that were statistically significant. 2. Additionally, the use of the Surgilig™ ligament appears to be effective in treating both chronic and acute acromioclavicular joint dislocations.

Background

Acromioclavicular joint dislocations generally arise from a fall onto the point of the shoulder with the arm adducted and they account for 9% of all shoulder girdle injuries [1]. There is a preponderance of these injuries in the young athletic population [2]. This is particularly the case in high impact sports such as American Football and Rugby League [3].

The treatment of most grades of acromioclavicular joint dislocations is well established. There is general agreement that Rockwood grade I and II injuries are best treated non-operatively and grade IV to VI injuries benefit from operative management [2]. The treatment of grade III injuries, however, remains controversial [4- 8]. In grade III acromioclavicular joint dislocations the acromioclavicular and coracoclavicular ligaments are both disrupted, resulting in up to 100% displacement of the acromion relative to the clavicle [9].

There is a paucity of randomised controlled trials and prospective comparative studies looking at the treatment of grade III acromioclavicular joint dislocations [6]. Much of the existing literature is level 4 evidence with case series forming the bulk of this group [2,4]. The few randomised control trials that are available have demonstrated no difference in outcome with operative or non-operative treatment [10,11]. In fact, these studies showed a shorter rehabilitation period in the non-operated group [10,11]. Meta-analyses of the existing literature have drawn similar conclusions but have also alluded to the lack of good quality studies, making comparison between the treatment groups difficult [12].

It is the policy of our unit to treat every patient with a broad arm sling and to mobilise as comfort allows for a period of 6 weeks. The patients are then reviewed with a view to either continuing non-operative management or suggesting operative treatment dependent on the recovery. We have found that this period of 6 weeks is sufficient time to allow those who will manage with non-operative treatment to demonstrate a response.

For patient with higher grade injuries or those whom failed conservative management of grade 3 injuries, we use surgical intervention. One of the surgical techniques we have used is the Surgilig™ synthetic ligament to treat acute and chronic acromioclavicular joint dislocations in our institution since 2005. The Surgilig™ was developed in 2001 by the Nottingham shoulder unit and is an artificial coracoclavicular substitute ligament made from braided polyester [13]. The ligament is passed around the coracoid process and the loop from one end of the ligament is passed through the other and then around the clavicle, where it is an- chored with a screw [13]. Braided polyester has been used as an artificial ligament in other joints because of the mechanical properties of the material and the propensity to allow tissue ingrowth [13]. Again, the majority of the existing literature on the use of the Surgilig™ reports small case series where the ligament was used to reconstruct the acromioclavicular joint in chronic injuries and revision cases [13-15]. Little is known about the use of this device in the acute setting.

The purpose of this study is to present the clinical outcomes of patients with acromioclavicular joint dislocations at our institution. We focussed in particular, on the outcomes of operative versus non-operative treatment for grade III injuries and on the outcomes of patients treated with Surgilig™ synthetic ligament reconstruction across all grades of acromioclavicular joint dislocations. The study analysed consecutive patients presenting to our institute over a 5-year period.

Material and methods

This was a retrospective study evaluating the treatment of patients presenting to our institute with acute acromioclavicular joint dislocations over a 5-year period (January 2005 to December 2010). These patients with acute acromioclavicular joint dislocations were assessed both clinically and radiologically and graded according to Rockwood's classification at initial presentation [9]. Those with acromioclavicular joint dislocations of grade IV and above were offered surgery. Those with grade II and III injuries were given a 6-week trial of conservative treatment during which they were given a broad arm sling and instructed to mobilise as pain allows. This was followed by physiotherapy and strengthening exercises until the second follow-up. At 6 weeks, the patients were assessed clinically. Those who felt they had a meaningful improvement in their symptoms which would not interfere with their occupation and hobbies continued with non-operative treatment. The remainder were given the option of operative treatment.

Rockwood grade III patient cohort

We included 54 consecutive patients with acute grade III acromioclavicular joint dislocations. We excluded patients with chronic injuries, those with associated shoulder girdle injuries and those with previous acromioclavicular joint injuries.

All but one of the 54 patients with a type 3 injury had an initial course of non-operative treatment. They were given a broad arm sling and instructed to mobilise as pain allows, followed by physiotherapy and strengthening exercises for 6 weeks until the second follow up. One patient underwent acute fixation with the TightRope device.

The vast proportion of the operated group was treated with a SurgiLig™ reconstruction, with a smaller number being treated with a modified Weaver-Dunn technique, and one patient was treated with a TightRope™ technique, mentioned above. After sugery, the operated group followed the same rehabilitation programme as the non-operated group.

Of the 54 patients with a type 3 dislocation, 29 were treated non-operatively and 25 operatively. However, in the non-operated group, 15 patients could not be contacted, 2 had dementia and could not comply with the follow-up assessment, 1 refused to participate and 1 had died from an unrelated cause. In the operated group, 9 patients could not be traced and 1 did not wish to be included in the study. This left an eventual cohort of 25 patients with 10 in the non-operated and 15 in the operated group.

Surgilig™ synthetic ligament treatment group

Of the patients treated with the Surgilig™ device, we identified 34 patients who were eligible for inclusion. Unfortunately, 2 patients opted out and 10 could not be traced. This is a frequent problem in a university town where many of this group of patients are young students who move on after completing their studies. This left twenty-two patients who underwent reconstruction of the acromioclavicular joint with Surgilig™.

Operative technique for patients treated with Surgilig

A "bra-strap" incision is made from just posterior to the acromioclavicular joint to the coracoid. The clavicle and acromioclavicular joint are then identified. A 10mm segment of the distal end of the clavicle is usually excised to avoid any post-operative impingement. A measuring guide is first passed in the same way the ligament will be to gauge the required length. The braided polyester ligament comes in various sizes in increments of 1cm.

The braided ligament has one loop at each end and is passed around the base of the coracoid using an introducer. The soft loop is initially passed through the hard loop and then anchored into the clavicle with a bone screw, reducing the clavicle to its normal alignment. A bicortical screw is used to secure the ligament into the distal end of the clavicle.

Patient outcomes and follow up

The case notes of all individuals were then reviewed and a telephone follow-up questionnaire performed. The Oxford Shoulder Score (OSS), Pain score and Satisfaction score were recorded during this assessment. The Pain and Satisfaction scores were designed based on a scale to quantify post-treatment pain and satisfaction. Pain was subjectively graded from 0 to 10 based on frequency and severity during activities of daily living and performance of hobbies (0 being no pain with 10 being painful all of the time). Satisfaction was similarly scored on a scale of 0 to 10 (0 being totally dissatisfied and 10 being extremely satisfied). Qualitative data was also collected by asking patients to describe the course of their injury and recovery.

Statistical analysis

Data was collated in Microsoft Excel 2016 and analysed using Stats direct statistical software version 3.1.4. The dataset was analysed for normality; when found to be from a non-parametric distribution, it was analysed using a Mann Whitney U Test. Statistical significance was established at the P<0.05 level.

Tab. 1. Patient demographics for the operated and non-operated groups

	Operated Group	Non-operated Group
Number of patients	15	10
Males	14	10
Females	1	0
Mean age (years)	38.5 (16-67)	36.8 (18-62)
Mean Followup (years)	3.56	3.29

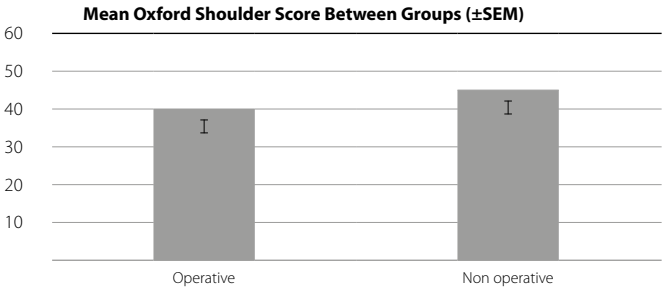

Fig. 1. Mean Oxford Shoulder Score Between Groups (±SEM)

Results

Rockwood grade III patient cohort

We found that 47% of all acromioclavicular joint dislocations presenting to our institution over a 5-year period were Rockwood grade III injuries (54/116). Of this group of 54 patients, 46% (25/54) were treated operatively and 54% (29/54) were treated non-operatively. The sample under study, however, was 25 patients with 15 patients in the operated and 10 in the non-operated groups. The patients in the non-operated group were treated identically with a broad arm sling and a programme of range of movement and strengthening exercises under the supervision of the physiotherapists. In the operated group, 73% (11/15) had an acromioclavicular joint reconstruction with SurgiLig™, 20% (3/15) had a modified Weaver-Dunn procedure and 7% (1/15) had an acromioclavicular joint reconstruction with the TightRope™ technique.

Of the 25 patients who successfully completed the follow-up, 93% (14/15) of the operated group were male and 100% (10/10) of the non-operated group were male. The mean age of the operated group was 38.5 years (16-67) and that of the non-operated group was 36.8 years (18-62). The mean follow up in the operated group was 3.56 years and in the non-operated group this was 3.29 years (see Tab. 1).

The OSS system relies on the patient's subjective assessment of pain and impairment and illustrates improvement post-operatively. The mean OSS in the operated group was 39.8 (26-48), whereas the mean OSS in the non-operated group was 45.9 (43-48) (see Fig. 1). This difference was found to be statistically significant with the unpaired t test, with a p value of 0.01. This simple tool was used to assess pain post-operatively. The mean pain score in the operated group was 2.2 (0-8) and in the non-operated group it was 1.6 (0-7). This was measured on a scale of 1-10. The mean satisfaction score in the operated group was 8.2 (2-10) and that in the non-operated group was 7.8 (0-10). Neither of these differences was statistically significant (Tab. 2).

We then went on to stratify our results into age at injury and time to surgery. This was to establish if increased age at injury or a delay in treatment resulted in inferior Oxford Shoulder, Pain or Satisfaction scores for patients with grade III injuries whether treated operatively or non-operatively. We found that age at injury and the time to surgery did not have any statistically significant impact on the eventual result of treatment. The overall age distribution of the two groups is shown in Table 3.

In the cohort of operatively treated patients, 2 patients treated with the SurgiLig™ had to have the screw removed due to discomfort and irritation of the overlying skin. The first of these had complete resolution of symptoms following removal of the screw and was discharged. The second had co-existing osteolysis of the posterior clavicle and complained of persistent pain and clicking, despite the screw being removed. One patient in the Weaver-Dunn group was revised to a SurgiLig for ongoing pain and residual deformity and a second patient in the Weaver-Dunn group had a residual deformity but did not want further surgery.

Surgilig™ treatment cohort

In total, Twenty-two patients underwent reconstruction of the acromioclavicular joint with Surgilig™. The mean follow up was 2.7 years and the average time from injury to surgery was 327 days (7-2160). This was skewed, by 2 patients who had surgery at 2160 days, and 1800 days post-injury. Table 4 demonstrates the Oxford Shoulder Score (OSS), pain score and satisfaction score for the cohort under study.

Oxford Shoulder Score

The mean OSS score was 39.6 (CI 35.8-43.4). The scores ranged from 18 to 48. We found that 16/ 22 patients (73%) scored 40 or above, indicating satisfactory function post-operatively. We stratified the cohort into groups based on Rockwood grade and age. This was to establish if either of these factors impacted on the eventual OSS. We found that there was no statistical significance in terms of age (p = 0.91), or Rockwood grade (p = 0.30).

Pain

The mean pain score was 2.5, (CI 1.2-3.8). 5/22 patients (23%) scored 0/10, indicating they were in no pain after the procedure. Furthermore, 68% of patients (15/22) scored 2 or less. When the pain scores were stratified for age (p = 0.79) and Rockwood grade (p = 0.72), we found no statistically significant difference.

Satisfaction

The mean satisfaction score was 8.4, (CI 7.6-9.2). We found that 23% (5/22) were extremely satisfied, scoring 10/10, and 86% (19/22) scored 8 or above. When the satisfaction scores were stratified for age (p=0.63) and Rockwood grade (p =0.51), we found no statistically significant difference.

Complications

We found that 17/22 (77%) patients were very happy with their outcome, and were asymptomatic with a full range of movement on discharge.

One patient developed subacromial impingement post-operatively and required a subacromial decompression to treat this. Two patients required removal of screws; the reason for this is highlighted above. We found that two patients in all developed osteolysis at the posterior end of the clavicle, where the Surgilig™ crosses over it. One was asymptomatic and, therefore, discharged. In the second we believe the persistent clicking is related to the Surgilig™ flicking in and out of the osteolysis trough. This patient remains under review.

Tab. 2 Mean outcome measures in the operated and non-operated groups for patients with grade 3 dislocations

	Operated Group	**Non-operated Group**	**p Value**
Mean OSS (Range)	39.8 (26-48)	45.9 (43-48)	0.01
Mean Pain score (Range)	2.2 (0-8)	1.6 (0-7)	0.57
Mean Satisfaction score (Range)	8.2 (2-10)	7.8 (0-10)	0.74

Tab. 3 Distribution of patients treated for grade 3 dislocation by age

Age	**Non-opertive (Number of Patients)**	**Operative (Number of Patients)**
16-20	1	2
21-30	1	3
31-40	6	4
41-50	1	4

Tab. 4 Patient demographics in the Surgilig™ treatment group

Patient Demographics		
	Number/Mean	**Range**
Number of Patients	22	–
Male : Female	19.3	–
Mean age of patient at time of injury (years of age)	41.4	16-62
Mean follow-up period (months)	32.6	6-56
Post-Operative OSS	39.6	18-48
Post-Operative Pain Score	2.5	0-9
Post-Operative Satisfaction	8.4	2-10

Discussion

The principal findings of this work showed that non-operative treatment had superior Oxford Shoulder Scores that were statistically significant, compared to operative treatment for grade III acromioclavicular joint dislocations. We did not find any difference in Pain or Satisfaction scores between the two groups. Additionally, our results show the use of the Surgilig™ implant appears to be effective in treating acute acromioclavicular joint dislocations of Rock-Wood grades 3-5.

Management of Rockwood grade III patients

The evidence in the literature does in general agree with the findings of this work regarding the management of grade III acromioclavicular joint dislocations. However, there remains a degree of controversy around the subgroups of patients that could benefit from surgery.

Several comparative studies have recommended non-operative treatment for the majority of grade III acromioclavicular joint dislocations based on a failure to demonstrate a difference in clinical outcomes with operative treatment both in the short and long term [16-21]. A meta-analysis by Smith et al, suggested that, although surgical treatment is more likely to maintain anatomical reduction, there is no evidence to suggest that this is clinically advantageous. Nonoperative treatment has, however, been shown to produce more prominent, unstable and radiographically wider ACJs, but clinical results were good at up to 20-year follow-up [22].

Despite seeing satisfactory results in patients treated non-operatively, Schlegel et al, did find that bench press strength on the injured side was on average 17% weaker [21]. Rawes and Dias also demonstrated good results with non-operative treatment but found some patients reported discomfort from the injured extremity with increased intensity of activity [20]. This may not necessarily be a problem for most people, but those engaged in high level sports or manual work may not tolerate this. Korsten et al. also agree with this conclusion, with their systematic review concluding that physically active young adults seem to have a slight outcome benefit when treated operatively [23]. This implies that there is certainly a group in whom surgical treatment has a role.

A cautionary note however, is that many of the older studies on the subject did not use validated outcome measures, there was no separate statistical analysis of manual labourers and athletes and some included selection bias. Additionally, the multitude of surgical procedures and non-operative regimes used in these papers makes extrapolation of data difficult. These are shortcomings outlined by Spencer in his systematic review of grade III acromioclavicular joint dislocations [4,12,23]. Some studies have demonstrated superior outcome scores in the operated group but they are limited in number [24,25].

Furthermore, any intervention where surgery is undertaken does carry the risk of surgical complication and the need for implant failure or removal. This is something that was seen in our data, and other implants also face this problem. Based on the current literature, there is an improved cosmetic and radiological result with surgery but increased sick leave with no difference in pain, strength or throwing ability [12, 26 27].

The second area of uncertainty in the treatment of grade III injuries is the time to surgery. Some authors have suggested that early surgery may yield better results for grade III-V dislocations in terms of superior constant scores, acromioclavicular joint reduction, complications and patient satisfaction [7]. We, however, did not see this to be the case in this study.

The fact alone that there are as many non-operative treatment methods as operative techniques in the treatment of grade III acromioclavicular joint dislocations is evidence that this is a problem for which we are yet to find the ideal treatment algorithm. It is, however, apparent that the treatment of this group of patients must be individualised. We believe that, based on the current literature, there is a strong case for giving virtually every patient a period of non-operative treatment. We feel that the approach of an interval of non-operative treatment followed by a clinical review is the ideal way forward in the management of this difficult injury [2,27].

Treatment of AC Joint dislocations using the Surgilig™ implant

Although there are several small case series published regarding the use of Surgilig™ in treating chronic acromioclavicular joint dislocations, there is only one study that has shown the effectiveness of this implant in treating acute dislocation [28].

The purpose of this study was to retrospectively review the use of Surgilig™ in both acute and chronic acromioclavicular joint dislocations over a 5-year period. Our results show the use of the Surgilig™ ligament appears to be safe and effective in treating acromioclavicular joint dislocations regardless of age [14,28,29].

Bhattacharya et al, demonstrated their results of treatment with the Surgilig™ in chronic acromioclavicular joint dislocations. They looked at 11 patients with a mean time from injury to operation of 21 months [14]. All patients were grade III and above. Nine out of the 11 patients were satisfied with the overall procedure. Four had screw prominence with latency around the screw but only 1 was symptomatic and declined removal of screw. One patient needed reoperation from rupture of the central portion of the ligament. He was revised with a clavicular hook plate [14].

The Nottingham group presented the results of 11 patients for chronic injuries. Three had previous failed Weaver-Dunn procedures. The average age was 39 and patients were followed up for an average of 55 months. Ten patients out of the 11 had excellent results with average constant scores of 92. One did poorly due to fracture of the coracoid. Two required further surgery, one for screw removal and lateral end of clavicle excision and one had a subacromial decompression. The Nottingham group also published a larger series which demonstrated that the Surgilig™ synthetic ligament achieved better outcome scores and earlier return to work and sports compared with the modified Weaver-Dunn procedure [30]. Similarly, A study into military personnel where the Surgilig™ was used in conjunction with a coracoacromial ligament transfer looked at 11 patients with follow-up for 6 months. The results demonstrated a return to full military duties post-operatively [15].

Limitations

We acknowledge that there are some limitations in this study. The first of these is that the numbers are small and this was largely due to difficulties in tracking a large number of patients. We searched the hospital records for contact details and then called patients repeatedly. If this proved unsuccessful, we followed this up with written correspondence to the address on file. It was only after consistently failing to contact a patient that we abandoned any further attempts. Another apparent limitation is the potential selection bias introduced into the operated group, where patients performing poorly at 6 weeks were included. There is an argument that this group may include patients who are less likely to do well with either treatment modality and their accumulation in one group was likely to generate inferior results. Randomising the patients into treatment groups may have avoided this but there is a risk with such an approach of potentially subjecting patients to an operation unnecessarily, as we have already established that many people will do well without surgery. One further potential weakness may be that the operated group was a heterogenous group. Additionally, we did not routinely collect data from patients with regard to occupation and functional limitations related specifically to occupational tasks.

Conclusions

1. Non-operative treatment is not inferior to operative treatment for grade III acromioclavicular joint dislocations. The data from this study demonstrated that the non-operated group had superior Oxford Shoulder Scores that were statistically significant.

2. Additionally, the use of the Surgilig™ ligament appears to be effective in treating both chronic and acute acromioclavicular joint dislocations.

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Anatomic reconstruction of acromioclavicular joint dislocations using allograft and synthetic ligament

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Background

Acromioclavicular (AC) separations are commonly seen shoulder injuries. Numerous surgical reconstruction techniques have been described. In this study, we present a series of patients who underwent an anatomic reconstruction using a synthetic ligament and allograft construct.

Methods

We performed a retrospective review of patients with type IV or V AC separations who underwent primary or revision AC reconstruction with a luggage-tag synthetic ligament and a semitendinosus allograft placed through the anatomic insertion sites of the coracoclavicular ligaments. Patient-reported outcomes, as well as complication rates, were recorded at a minimum 2-year follow-up.

Results

Ten patients with a mean age of 44.2 ± 14.9 years were included in the study. The mean Disabilities of the Arm, Shoulder and Hand score was 15.5 ± 15.4; mean Single Assessment Numeric Evaluation score, 81.8 ± 12.1; mean Simple Shoulder Test score, 11.4 ± 1.1; mean American Shoulder and Elbow Surgeons score, 84.6 ± 15.7; mean Constant score, 82.5 ± 11.6; and mean visual analog scale score, 2 ± 2.6.

Conclusion

The technique using a luggage-tag synthetic ligament along with an anatomic allograft coracoclavicular ligament reconstruction is a safe, effective alternative to other techniques described in the literature.

Acromioclavicular (AC) joint dislocations are common injuries in active individuals. The mechanism of injury is typically a direct blow to the top of the shoulder and is classified as types I-VI depending on the degree of soft-tissue injury and displacement.[29] Type I is a sprain of the AC ligament with no displacement. Type II is a rupture of the AC ligament and sprain of the coracoclavicular (CC) ligaments, with a slight increase in the CC distance compared with the contralateral side. In type III-VI injuries, both the AC and CC ligaments are ruptured. In type III injuries, there is 25%-100% vertical displacement of the clavicle but the joint is reducible, as the deltotrapezial fascia has not been violated. Type IV injuries have posterior displacement of the clavicle through the trapezial fascia, whereas type V injuries show 100%-300% vertical displacement. Type VI injuries are exceedingly rare and are characterized by inferior displacement and entrapment of the distal clavicle under the conjoint tendon. The treatment of type I and II injuries is conservative, whereas types IV-VI are generally treated operatively.[4,7,8,16] The treatment of type III injuries is controversial, with patient-specific factors playing a larger role in decision making.[4]

Many AC joint reconstruction techniques have been developed over the years. Weaver and Dunn[35] were the first authors to publish a case series of coracoacromial (CA) ligament transfers to the distal clavicle. In the Weaver-Dunn technique, the distal clavicle is excised, the CA ligament is passed into the intramedullary canal of the clavicle, and the sutures are tied over a bone bridge.

Since the original technique was described, numerous variants of the Weaver-Dunn procedure have been developed.[1,2,9,11,13-15,18-23,25-27,33,34] Many of these variants incorporated either AC or CC transfixation methods to protect the reconstruction during healing. Indeed, biomechanical studies have shown that isolated CA ligament transfers are significantly weaker than the native CC ligaments, and augmentation techniques can help restore time-zero strength to the native state.[12,36] This has not proved clinically significant, however, as the recurrent instability rates between CA ligament transfer techniques with and without supplemental fixation are similar (15%-29%).[31]

The high rate of recurrent instability and poor restoration of biomechanics in the axial plane with CA ligament transfer procedures prompted the development of anatomic reconstruction techniques using tendon grafts. Mazzocca et al[24] described a technique in which a doubled-over semitendinosus allograft was docked into a 7-mm bone socket at the base of the coracoid and secured with an interference

screw. The free ends of the graft were then passed through 6-mm tunnels in the clavicle corresponding to the anatomic insertion sites of the conoid and trapezoid ligaments. Biomechanically, this construct was more stable to cyclic loading than the modified Weaver-Dunn technique in the anterior-posterior direction. However, drilling a 7-mm socket at the coracoid base theoretically raised the risk of fracture.

To mitigate the fracture risk of the original anatomic reconstruction technique, a new method was described by Baldwin et al.[3] Instead of the use of a coracoid bone tunnel, a loop of graft was passed under the coracoid tip. The free ends were then passed through the loop in a luggage-tag configuration, after which they were passed through the clavicle and secured as previously described. At 4.5 years' follow-up, the authors reported redisplacement in 5% and pain resolution in 94% of the patients in their series.

Luggage-tag CC fixation using a synthetic ligament was also recently described, and favorable results with its use have been reported.[19,37] A braided polyester graft is strong and has the potential for tissue ingrowth.[17] In addition, it provides secure but nonrigid fixation of the AC joint, allowing normal clavicular rotation with shoulder motion. It is a nonanatomic, single-bundle technique, however, and requires appropriate placement between the native insertion sites to allow accurate joint reduction.[32]

In this study, we introduce a technical variation that combines luggage-tag synthetic ligament reconstruction and anatomic allograft reconstruction of the CC ligaments. During healing, the potential stress shielding of the allograft by the synthetic graft would theoretically minimize progressive tendon creep and elongation with cyclic loading. This study details the surgical technique and presents the clinical and radiographic results of a series of patients who underwent the procedure.

Methods

Study design

We performed a retrospective review of consecutive patients who underwent primary or revision anatomic AC joint reconstruction using both semitendinosus tendon allograft and the LockDown Shoulder Stabilization System (LSSS) (LockDown Surgical, Chanhassen, MN, USA) between May 2014 and May 2018. The exclusion criteria included clinical follow-up < 2 years and the presence of concomitant fractures about the shoulder girdle. All surgical procedures were performed by a single surgeon (J.I.).

Data collected included initial diagnosis and indication for surgery; duration of clinical and radiographic follow-up; Disabilities of the Arm, Shoulder and Hand score; Single Assessment Numeric Evaluation score; visual analog scale score for pain; Simple Shoulder Test score; American Shoulder and Elbow Surgeons score; Constant score; and complications. Preoperative, initial postoperative, and most recent follow-up radiographs were reviewed and assessed for loss of reduction over time.

Surgical technique

All patients were positioned in the supine position with a small bump under the ipsilateral scapula. Prior to skin incision, the semitendinosus allograft was prepared with either FiberLink sutures (Arthrex, Naples, FL, USA) or the Speedtrap graft preparation device (DePuy Mitek, Raynham, MA, USA) and pre-tensioned at 9 kg (20 lb) for ≥20 minutes. A horizontal skin incision was made, and full-thickness skin flaps were elevated. The deltotrapezial fascia was incised, and portions of the pectoralis major and anterior deltoid muscles were elevated in a subperiosteal fashion to expose the AC joint, distal clavicle, and coracoid process.

By use of a radiopaque ruler, the length of the entire clavicle was measured under intraoperative fluoroscopy. Anatomic drill hole positions were then calculated using the ratios described by Rios et al[28] and marked on the clavicle with electrocautery. Five millimeters of distal clavicle was resected to assist with reduction and decrease the risk of postoperative AC joint arthrosis.

To allow room for graft and LSSS passage around the coracoid, the coracohumeral ligament was released from the coracoid, and a large Satinsky vascular clamp was passed from medial to lateral to avoid injury to the underlying neurovascular structures. With the AC joint held reduced, a NiceLoop (Wright Medical, Memphis, TN, USA) was then passed through these holes and tied for provisional fixation and prevention of anteroposterior translation of the distal clavicle. This step is very important as it achieves and maintains AC joint alignment in the axial plane. A FiberTape (Arthrex) was then passed around the base of the coracoid in a luggage-tag fashion. While the joint was being held reduced as confirmed by fluoroscopic imaging, the LSSS measuring tape was used to determine the correct final device size.

Two 2.5mm drill holes were made, one in the acromion and one in the distal clavicle. With the AC joint held reduced, a NiceLoop was then passed through these holes and tied for provisional fixation and prevention of anteroposterior translation of the distal clavicle.

Two 3.5mm drill holes were made at the predetermined positions on the clavicle: The lateral hole was drilled superior to inferior and the medial hole was drilled obliquely posterior to anterior to recreate the anatomic trajectories of the trapezoid and conoid ligaments, respectively. A small curette was used to ensure the holes were patent for graft passage.

The 2 limbs of the graft were passed under the coracoid with a Satinsky clamp, and the graft was then secured using the luggage-tag technique.[3] The 2 limbs of the graft were brought up through the holes, and while tension was held on each limb with the AC joint reduced, 3.5mm polyetheretherketone screws (Arthrex) were placed in each hole. The graft limbs were then tied together over the top of the clavicle.

The LSSS device was shuttled under the coracoid using the previously placed measuring tape, and the loop end was brought over the clavicle and tied to the previously passed FiberTape luggage-tag suture. To avoid placement of an additional stress riser

in the clavicle and to minimize the risk of fracture, the optional LSSS anteroposterior clavicular screw was not used in any case. Final fluoroscopic imaging was then used to confirm reduction.

The deltotrapezial fascia was repaired in interrupted fashion with heavy nonabsorbable braided suture, with care taken to bring the underside of the pectoralis major and anterior deltoid up to provide additional soft tissue over the reconstruction. The subcutaneous tissues and skin were closed over a drain. Patients were placed in a shoulder immobilizer for 6 weeks, at which time they began formal physical therapy.

Results

A total of 10 eligible patients were identified and successfully contacted by phone for follow-up (Table I). All patients had either type IV or V AC injuries. The mean age at the time of surgery was 44.2 years (range, 21-61 years). There were 7 men and 3 women. Of the cases, 8 were primary reconstructions whereas 2 were revisions. Two patients underwent surgery <4 weeks after injury, whereas the other 8 had chronic injuries.

Table I: Averages of outcome measures (N=10)

	Average
Age, yr	44.2 ± 14.9
F/U, mo	40.4 ± 11.1
Radiographic F/U, mo	10.3 ± 11.1
DASH score	15.5 ± 15.4
SANE score	81.8 ± 12.1
VAS pain score	2 ± 2.6
SST score	11.4 ± 1.1
ASES score	84.6 ± 17.3
Constant score	82.5 ± 11.6

F/U, follow-up; *DASH,* Disabilities of the Arm, Shoulder and Hand; *SANE,* Single Assessment Numeric Evaluation; *VAS,* visual analog scale; *SST,* Simple Shoulder Test; *ASES,* American Shoulder and Elbow Surgeons.

The average follow-up period was 40.4 months (range, 24-54 months), at which point the mean outcome scores were as follows: Disabilities of the Arm, Shoulder and Hand score, 15.5 ± 15.4; Single Assessment Numeric Evaluation score, 81.8 ± 12.1; Simple Shoulder Test score, 11.4 ± 1.1; American Shoulder and Elbow Surgeons score, 84.6 ± 15.7; Constant score, 82.5 ± 11.6; and visual analog scale score for pain, 2 ± 2.6. Table II provides a summary of the data and stratifies outcomes by primary vs. revision cases.

The average length of radiographic follow-up was 10.3 months (range, 0-36 months). Of the 10 patients, 2 (20%) did not undergo the radiographic evaluation. In 9 of 10 patients (90%), postoperative reduction was maintained. There were no cases of infection, hardware complications, or recurrent instability requiring reoperation.

Discussion

The technique combining synthetic ligament reconstruction and anatomic allograft reconstruction of the CC ligaments attempts to address the potential drawbacks of previously described methods.[31] The results of this study suggest that combining the LockDown device with anatomic CC ligament reconstruction using allograft is a viable surgical treatment option for AC dislocations. There was an 8% rate of recurrent dislocation, which is lower than the 15%-29% reported in the literature. In addition, there were no hardware complications or reoperations.

Initial efforts at AC reconstructions were nonanatomic procedures. In the modified Weaver-Dunn technique, the distal clavicle is excised, after which the acromial end of the CA ligament is passed through the intramedullary canal and tied over a bone bridge. Isolated CA ligament transfers have historically shown a 90% rate of good to excellent results, with a recurrent instability rate of 16%.[27,30,34,35] Furthermore, the addition of trans-articular stabilization has not decreased the incidence of recurrent dislocation but rather introduced a significant rate of fixation-related complications.[28]

Table II: Averages of primary vs. revision outcome measures

	Primary (n=8)	Revision (n=2)
Age, yr	41.9 ± 15.5	**53.5 ± 10.6**
F/U, mo	41.5 ± 11.3	**36 ± 12.7**
Radiographic F/U, mo	11.6 ± 12.1	**5 ± 4.2**
DASH score	12.3 ± 15.6	**28.3 ± 1.2**
SANE score	82.9 ± 13.4	**77.5 ± 3.5**
VAS pain score	2.1 ± 2.9	**1.5 ± 0.7**
SST score	11.5 ± 1.1	**11 ± 1.4**
ASES score	83.7 ± 19.5	**87.8 ± 3.1**
Constant score	85.2 ± 10.5	**71.5 ± 12**

F/U, follow-up; *DASH,* Disabilities of the Arm, Shoulder and Hand; *SANE,* Single Assessment Numeric Evaluation; *VAS,* visual analog scale; *SST,* Simple Shoulder Test; *ASES,* American Shoulder and Elbow Surgeons.

Attempts to improve on these results led to the development of an anatomic CC ligament reconstruction procedure by Mazzocca et al.[24] This involved securing a doubled-over soft-tissue graft into a 7mm tunnel at the coracoid base, with the free ends passing through clavicular tunnels at the native trapezoid and conoid ligament insertion sites. This technique was shown to be superior to the modified Weaver-Dunn procedure in restoring anteroposterior stability of the AC joint.[24] Its use of a large bone tunnel at the base of the coracoid, however, theoretically increases the risk of fracture. Fractures after AC reconstructions involving transcoracoid drilling have been reported in the literature.[6,10]

An alternative anatomic CC ligament reconstruction technique was presented by Baldwin et al.[3] In their method, the soft-tissue graft was secured to the coracoid with a luggage-tag loop, obviating the use of a coracoid tunnel. The authors reported a 5% rate of re-displacement and 94% rate of pain resolution in their series. The current technique reinforces the soft-tissue reconstruction

described by Baldwin et al with a synthetic graft. This theoretically reduces the potential for loss of reduction via soft-tissue creep. However, the small number of patients in this retrospective study makes it difficult to directly compare rates of re-displacement with other studies.

A potential problem with relying solely on soft-tissue grafts to maintain AC joint reduction is creep. Even with preconditioning, tendons can elongate under chronic loads. The technique presented in this study supplements allograft fixation with the LockDown synthetic ligament. The LockDown device is a robust, braided polyester graft that is stronger than No. 2 FiberWire (Arthrex) and less rigid than a screw, making it less likely to break or cut out with cyclic loading.[5]

Clinical results with synthetic ligament reconstructions have been encouraging. Although the LockDown device was originally designed for revision AC reconstructions after failed Weaver-Dunn procedures, it soon came to be used in primary settings. Wood et al[37] reported good outcomes with no radiographic failure in a group of military recruits who underwent a CA ligament transfer augmented with a synthetic CC ligament reconstruction. In addition, Kumar et al[19] found that patients treated with the LockDown device had significantly better postoperative outcomes and a quicker return to work than those treated with a modified Weaver-Dunn procedure. Our article describes an alternative technique that can be used by surgeons who perform AC reconstructions. Although it does not suggest that the described technique is superior, it does add technical points that surgeons can decide to use in their practice.

This study has a number of limitations. First, our sample size was fairly small, making it difficult to compare our complication rate with the complication rates in the overall literature. We also did not have any preoperative data to assess the degree of improvement postoperatively. In addition, we did not have long-term follow-up for most patients. Finally, the surgical procedures were performed by a single high-volume surgeon, which improves the internal validity of the study but makes it difficult to generalize the results to the rest of the community.

Conclusion

According to the results of this study, the presented technique is an effective surgical treatment for AC dislocations. It provides strong, nonrigid fixation and anatomic ligament reconstruction while minimizing the risk of iatrogenic fracture and graft elongation..

Disclaimer

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New possibilities: the LockDown device for distal clavicle fractures

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Keywords

Distal clavicle fracture
LockDown device
distal clavicle resection
AC joint
AC dislocation
CC ligament

Regarding ethical committee approval, a non-research complying with the Dutch law on medical research in humans was given to this study by the Medical Ethics Review Committee of VU University Medical Center (study no. 2019.203).

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Level of evidence:
Level IV; Case Series; Treatment Study

Background and hypothesis

The majority of distal clavicle fractures are displaced fractures and constitute a treatment challenge because they have a 30% chance of delayed union or nonunion. Although several options for surgical reconstruction have been described, in patients with a comminuted and/or small distal fragment, these reconstructive options have proved to be prone to failure. Moreover, secondary surgery for removal is necessary in most cases. We hypothesized that the LockDown device, a braided synthetic ligament device, combined with resection of the distal fracture fragment is a suitable alternative in specified patients with distal clavicle fractures.

Methods

Eleven patients with distal clavicle fractures were treated with distal fracture resection and the LockDown procedure. All patients underwent regular follow-up with data collection; additionally, 7 were assessed at 1-year follow-up according to the study protocol. On the basis of radiography, these patients had a clear coracoclavicular ligament disruption and subsequent cranial dislocation of the medial fragment. Regular follow-up was performed at 6 weeks, 3 months, and 6 months. Control radiographs were taken at 3 and 6 months. Furthermore, the 7 enrolled patients were assessed at 1 year, when the Disabilities of the Arm, Shoulder and Hand score, Constant shoulder score, Nottingham Clavicle Score, and range of motion were recorded. Residual pain was ascertained by a visual analog scale score.

Results

In total, 11 patients were treated with distal clavicle resection and the LockDown procedure. Eight patients underwent surgery within 3 weeks after presentation at the emergency department. The other 3 patients were operated on after a trial of conservative treatment (due to persisting pain and delayed union). None of the patients had postoperative complications. At 3 months, 9 of the 11 patients had made a full recovery.

Discussion

All 11 patients had good short-term clinical outcomes. None showed acromioclavicular instability. Furthermore, secondary surgery was avoided, and hardware complications did not occur. In low-demand patients or patients with a high risk of nonunion, this technique may be a favorable alternative to other known techniques.

Distal clavicle fractures account for 17%-30% of all clavicle fractures.[7,9,14] Of these, 51%-55% are significantly displaced fractures indicative of coracoclavicular (CC) ligament rupture.[7,9,14] Furthermore, there is a 30% chance of delayed union or nonunion.[14,15,18] Clavicular fractures have a bimodal age distribution. The first peak occurs in young active adult men, and the second peak occurs in elderly women with osteoporosis. Distal-end fractures occur more commonly in the latter age group.[17] The acromioclavicular (AC) joint articulation anchors the clavicle to the scapula.

Horizontal and vertical stability of the AC joint is required. Static restraints include the AC, CC, and coracoacromial ligaments (Fig. 1). The AC ligaments and joint capsule provide horizontal translation. The CC ligament is divided into 2 portions: the posteromedial conoid and the anterolateral trapezoid. The conoid prevents vertical translation of the distal clavicle, and the trapezoid confers axial stability. More dynamic restraints of the AC joint include the deltoid, trapezius, and serratus anterior musculature. Movement in the AC joint includes rotation (5°-8° with forward elevation and abduction of the arm) and translation in the anteroposterior and superoinferior directions. Additionally, the AC joint serves as the pivot point for scapular (acromial) protraction and retraction.[20]

Distal clavicular fractures are classified according to Neer[12] (Fig. 2). In elderly patients, as well as smokers and patients with comorbidities such as diabetes, the likelihood of nonunion and consequent chronic pain and disability is more pronounced in unstable distal clavicle fractures (eg, fractures in which the medial fragment is not stabilized by the CC ligament).[6,10] When conservative treatment fails and a painful nonunion remains or if surgery is indicated because of severe dislocation of fragments caused by disruption of the CC ligament, there are several options for reconstruction.

The most common procedure is open reduction and internal fixation of the fracture with a combination small- and mini-fragment distal clavicle plate containing multiple locking mini-fragment options on the lateral aspect of the implant.

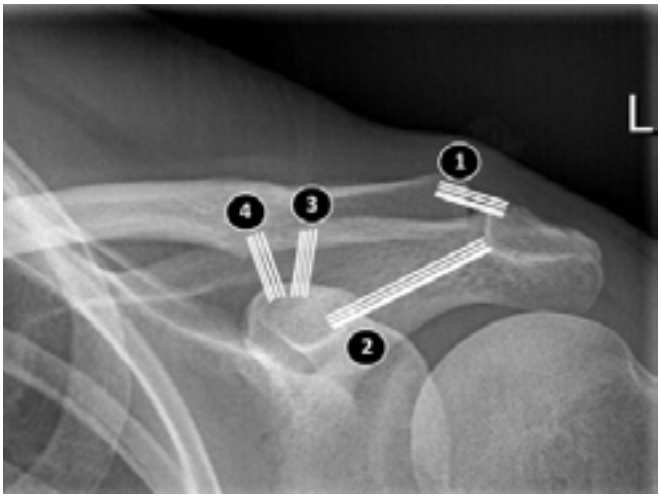

Fig. 1 Schema of ligaments: acromioclavicular ligament (1), coracoacromial ligament (2), and coracoclavicular ligament with trapezoid (3) and conoid (4) parts. L, left.

Nevertheless, in patients with a comminuted distal fragment or with a fragment < 2cm, especially when bone stock is poor, fixation might not be stable enough. Implant failure or nonunion may occur. Furthermore, in a biomechanical study, the distal clavicle plate showed less construct strength compared with cortical button fixation.[23] The hook plate is a well-known option for comminuted or small distal clavicle fragments; however, it has been reported to be painful until the mandatory removal of hardware.[10] In addition, the hook passes through the AC joint, making it prone to cause damage to the cartilage with a subsequent risk of symptomatic arthritis. Moreover, abduction is allowed to only 90˚, owing to the possibility of cuff injury or wear of the acromion due to friction of the subacromial hook. Secondary surgery for removal is necessary in most cases because of hook migration into the acromion and pain.[11] The hook plate has been associated with high failure rates such as implant failure, reoperation, and redislocation after removal.[19]

We hypothesized that the LockDown device (LockDown Surgical, Chanhassen, MN, USA), a braided synthetic ligament device, combined with resection of the distal fracture fragment would be a suitable alternative in older patients with distal clavicle fractures with CC ligament disruption, Neer type 2 (Fig. 3), and in patients with a painful nonunion of fractures of all Neer types (Fig. 4). We report on 11 cases in which this procedure was performed.

Materials and methods

Since 2016, 11 patients have been treated with distal fracture fragment resection and the LockDown procedure. The indication for this treatment was based on the fracture configuration on radiographs (Neer classification). Patients with CC ligament disruption and considerable cranial dislocation of the distal fragment were selected. When the size or amount of comminution

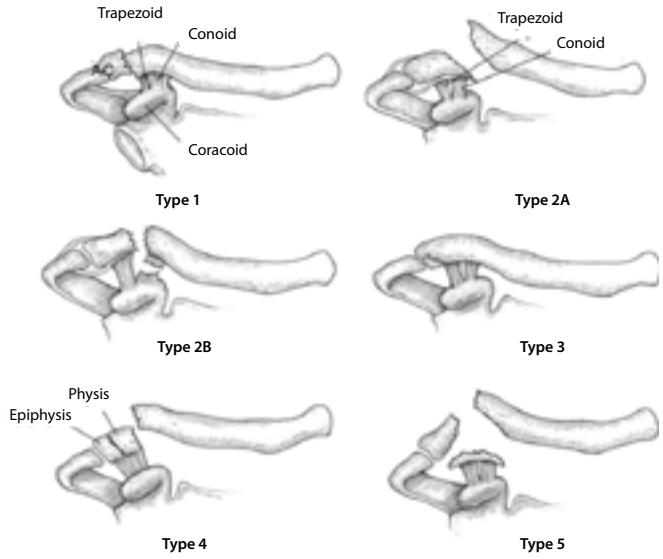

Fig. 2 Neer classification. Type 1 is a fracture lateral to the coracoclavicular ligament, in which the conoid and trapezoid remain intact, with minimal displacement. Type 2A is a fracture medial to the coracoclavicular ligament, in which the conoid and trapezoid remain intact, with medial clavicle displacement. Type 2B is a fracture that occurs between or lateral to the coracoclavicular ligaments, in which the conoid is torn and the trapezoid may be intact, with medial clavicle displacement. Type 3 is an intra-articular fracture, in which the conoid and trapezoid remain intact, with minimal displacement. Type 4 is a physeal fracture in an immature skeleton, in which the conoid and trapezoid remain intact, with lateral clavicle displacement. Type 5 is a comminuted fracture, in which the conoid and trapezoid remain intact, with medial clavicle displacement.[1] AC, acromioclavicular.

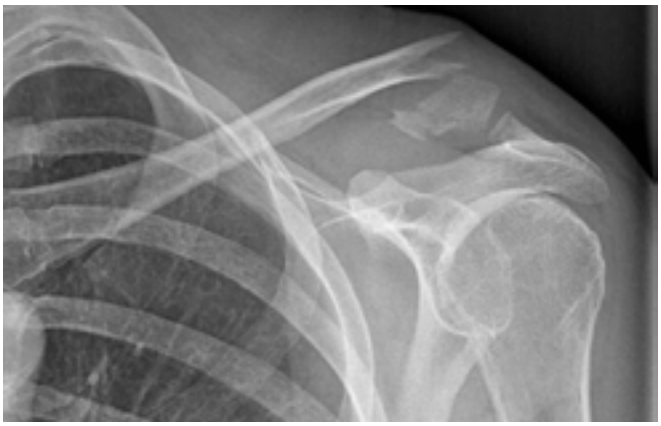

Fig. 3 Radiograph of patient with Neer type 2 fracture.

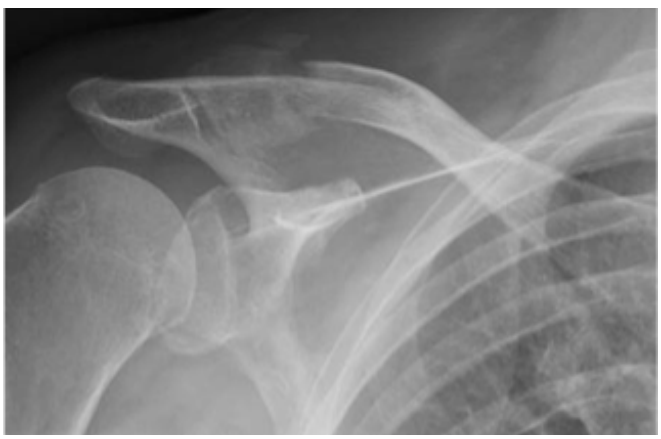

Fig. 4 Radiograph of patient with painful nonunion.

of the distal fragment was unclear, a computed tomography scan was performed. In cases deemed unstable (Neer types 2, 4, and 5), when the distal fragment was <3 cm in size and osteoporotic, or when the fragment was severely comminuted (Fig. 5), this technique was considered suitable. Furthermore, delayed union or persistent pain after conservative treatment was also considered an indication for resection and LockDown fixation. In 8 patients, semi-elective surgery (within 3 weeks of injury) was planned, whereas 3 patients were treated after failed conservative treatment.

In 2019, we approached all 11 patients with distal clavicle fractures treated with the LockDown device to obtain final measurements. Of these, 7 patients agreed to participate and signed the informed consent form (Fig. 6). Of the other 4 patients, 2 were lost to follow-up and 2 were undergoing treatment for newly diagnosed malignancies and were not able to participate because of their treatment schedule. The 7 aforementioned patients answered 3 questionnaires in an interview style: Disabilities of the Arm, Shoulder and Hand score; Constant shoulder score; and Nottingham Clavicle Score. Furthermore, the visual analog scale (VAS) score was assessed, and range of motion was measured with a protractor. Other patient characteristics recorded were age, smoking status and/or physical performance level, and comorbidity.

Statistical analyses were executed by descriptive statistics. IBM SPSS software (version 26; IBM, Armonk, NY, USA) was used.

Surgical procedure

The LockDown device is a braided polyester augmentation device originally used to treat AC joint dislocations.[8,21] All patients received general anesthesia; 6 of the 11 patients received a complementary plexus block. All patients were placed in the beach-chair position. After disinfection and sterile draping, a longitudinal incision was made from the distal clavicle to the coracoid proess. The anterior portion of the deltoid muscle was carefully dissected off the distal clavicle and fringed for later reattachment. The distal fracture part was removed and the coracoid base identified. The measurement device was used in the typical manner, after which the appropriate-sized polyester ligament was passed through. A 2.5mm hole was drilled in the clavicle from anterolateral to posteromedial, after which the ligament was attached with a 3.5mm none self-tapping screw of measured length (+4mm considering the caliber of the ligament and washer). Reduction of the clavicle in relation to the acromion was checked using fluoroscopy (Fig. 7). The anterior segment of the deltoid muscle was reattached, covering the screw head, to diminish postoperative pain from the implant and screw. Both the subcuticular tissue and the skin were closed with absorbable sutures. A compressive dressing was applied for 2 days.

Postoperative management

The arm was rested in a sling for 1-2 weeks for wound healing, allowing rotational shoulder exercises. Subsequently, a 4-week period of passive and active non-weight-bearing motion in the horizontal plane was allowed, preferably guided by a shoulder physical therapist. At 6 weeks, patients returned to the outpatient clinic. Routine radiography was performed to evaluate congruency of the AC joint and to ensure there was no implant failure (Fig. 8). At 6 weeks, full range-of-motion exercises were allowed. At 3 months, return to normal activities was permitted. At 6 months, final follow-up was performed.

Results

The patient characteristics of all patients treated with distal clavicle resection and the LockDown procedure are shown in Table I. The age of the patients ranged between 24 and 76 years, with a median age of 62 years.

One patient with diabetes was included in our population. Three patients used anticoagulants, and 2 were heavy smokers.

Eight patients were scheduled for surgery at presentation in the emergency department. They had clear disruption of the AC capsule and CC ligament, with superior displacement of the medial clavicle, and therefore a high likelihood of nonunion if left unstabilized. In 3 patients, surgery was performed after failed conservative treatment; due to persisting pain and delayed union, resection of the distal clavicle fragment was planned. The fragment size ranged from 13 to 30 mm. As the size of the fragment in all cases exceeded 10 mm, the clavicle was stabilized with the LockDown implant. No postoperative complications occurred. At 6 weeks, all patients complained of slight discomfort and limitation in active abduction and anteflexion. At 3 months, 9 of the 11 patients were complaint free. Two reported slight anterior discomfort at the level of the screw, and 1 patient still complained of pain. We could not relate this to the procedure. This patient had a good postoperative outcome, but after a second fall on the same shoulder, brachial plexopathy was diagnosed after consultation with a neurologist. At 6 months' follow-up, there was no change or increase in complaints in all 11 patients. The 7 patients included in the case series were assessed after 1-year follow-up (Table II). These patients had excellent Constant shoulder scores; Disabilities of the Arm, Shoulder and Hand scores; and Nottingham Clavicle Scores. The range-of-motion assessment showed very small to no differences compared with the uninjured arm.

Discussion

Eleven patients with Neer type 2 distal clavicle fractures or painful delayed union of distal clavicle fractures (2 Neer type 1 and 1 Neer type 2) were treated with distal fragment resection and LockDown stabilization. They have shown good short-term clinical outcomes. Secondary surgery following either discomfort due to the device or hardware complications has not been necessary thus far (median follow-up period, 27.3 months), in contrast to the frequent necessity for secondary surgery after distal plating and hook plate procedures.[11,19] Furthermore, because of the distal clavicle resection, necrosis of the cartilage and an incongruent articulation between the acromion and clavicle are averted; thereby, osteoarthritis is prevented. Intra-articular (especially incongruent) distal clavicle fractures and/or distal clavicle fractures treated with a hook plate are prone to osteoarthritis. Nonunion, owing to, for example, smoking and diabetes, is prevented. Although the largest fragment excised in our study was 28mm, none of the patients had signs

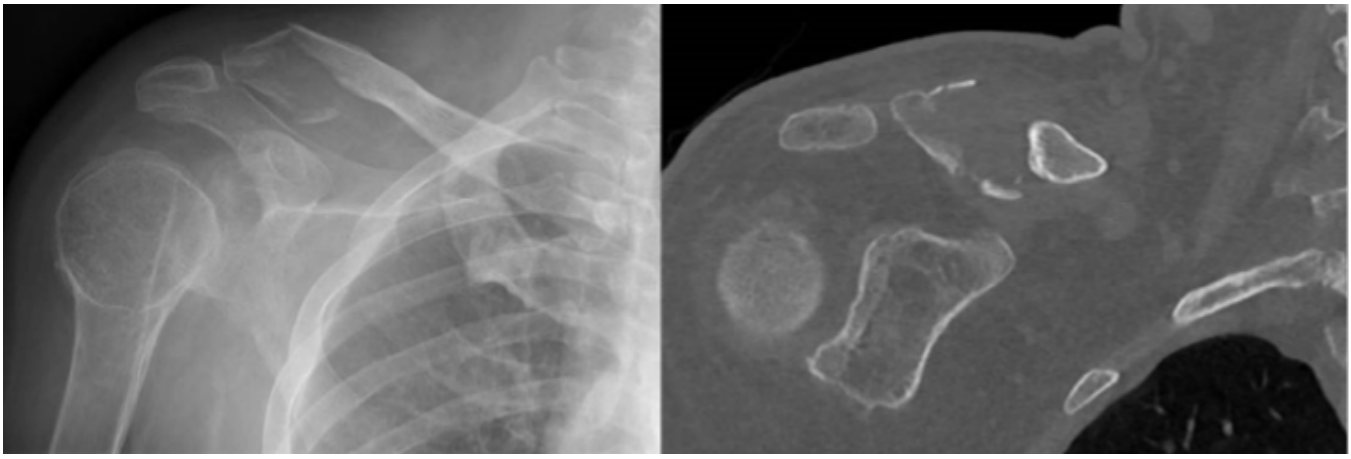

Fig. 5 Imaging of comminuted distal clavicle fragment in case 1.

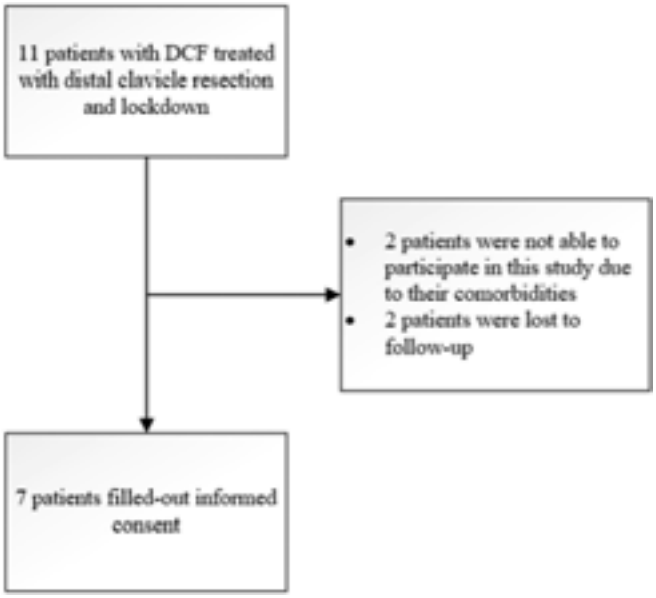

Figure 6 Inclusion of patients. At the time of inclusion, 2 patients were not able to participate in the study because they were undergoing treatment for malignancies. DCF, distal clavicle fracture.

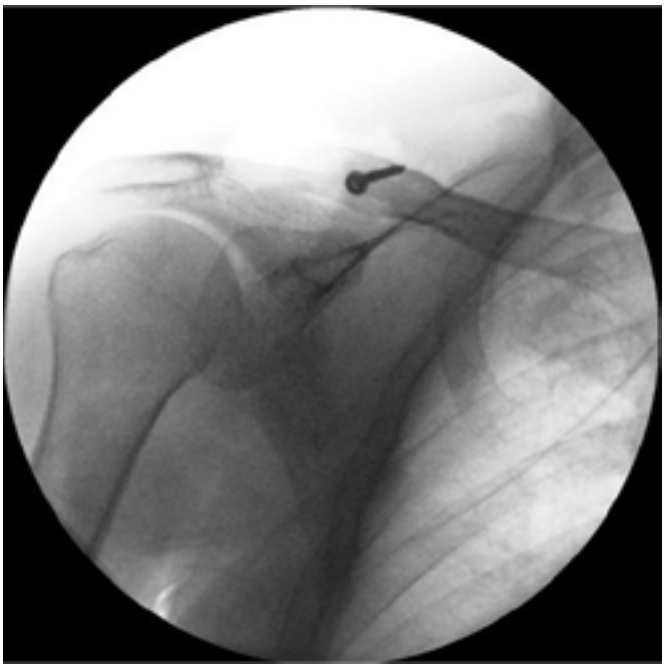

Fig. 7 Fluoroscopic image after placement of LockDown device.

of postoperative AC instability, whereas over-resection has been described in distal clavicle resection for AC osteoarthritis.

Although the AC capsule provides horizontal stability, Mazzocca et al[10] stated that anatomic reconstruction procedures involving both the conoid and trapezoid ligaments appear to have the ability to control anteroposterior translation without the need to reconstruct the AC capsular ligaments. This gave us reason to believe that resection of the distal clavicle, even with segments slightly larger than 8mm, would be permitted because trapezoid and conoid function would be taken over by the synthetic ligament.

However, Gokkus et al[6] and Boehm et al[4] stated that in cases of a resection of >5-10mm, AC joint instability can occur. This assertion was supported by Pandhi et al,[13] who found that the anteroposterior load to clinical failure of the AC joint after 5mm of resection from the distal clavicle (and medial acromion) is significantly greater than that with 10mm of resection of the distal clavicle alone. Moreover, Eskola et al[5] found that patients with resection of >10 mm, with osteoarthritis or traumatic separation of the AC joint, experienced more pain. When a more limited resection of 5mm is performed and the inferior capsule is preserved, Gokkus et al found that cutting the AC ligament did not cause symptomatic instability. In their anatomic study of 36 shoulders, Boehm et al found that resection of 10 mm of the distal clavicle detaches an average of 8% of the trapezoid ligament; moreover, with 20mm, this increased to 60%. Therefore, they hypothesized that resection of >10 mm may lead

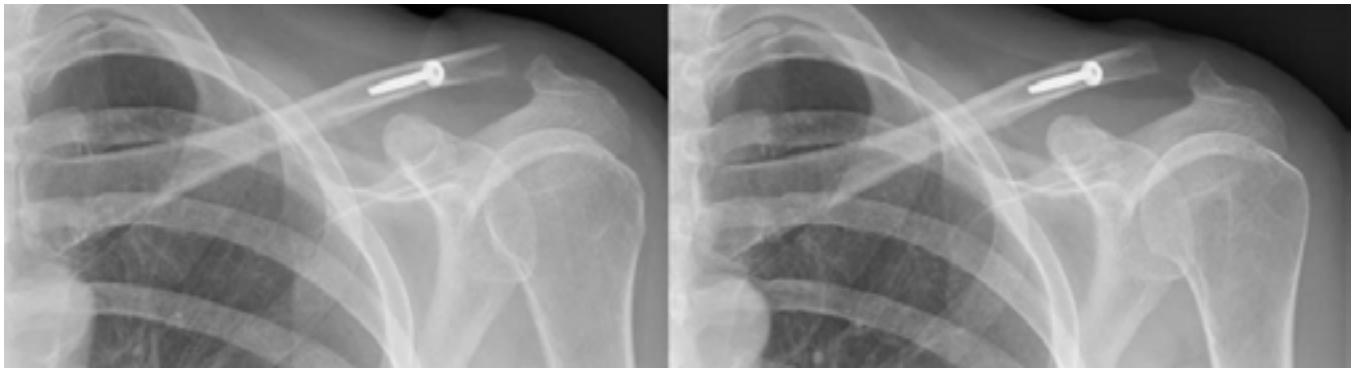

Fig. 8 Radiographs at 6 weeks (left) and 3 months (right).

Table I: Patient characteristics

	Sex	Age, Yr	Comorbidity	ASA Class	Acute (≤3 weeks) or delayed (>3 weeks)	Fragment size (mm)	Neer Classification
Case 1*	M	62	Paresis ipsilateral	2	Acute (1 week)	28	2b
Case 2*	F	61	-	1	Acute (1 week)	16	2b
Case 3*	F	76	Hypertension, angina pectoris	2	Delayed (6 weeks)	13	2b
Case 4*	M	60	Heavy smoker	2	Delayed (13 weeks)	30	1
Case 5	F	67	Hypothyroidism	2	Acute (2 weeks)	22	2b
Case 6	F	65	Heavy smoker, COPD	2	Delayed (13 weeks)	27	1
Case 7*	M	32	-	1	Acute (2 weeks)	17	2b
Case 8*	M	74	-	1	Acute (2 weeks)	18	2b
Case 9*	V	75	Hypertension, angina pectoris, hypothyroidism, DVT	3	Acute (1 week)	19	2a
Case 10	M	58	Hemophilia A, type 2 diabetes mellitus, liver transplantation	3	Acute (3 weeks)	13	2b
Case 11	M	24	-	1	Acute (3 weeks)	22	2b

*ASA, American Society of Anesthesiologists; M, male; F, female; COPD, chronic obstructive pulmonary disease; DVT, deep venous thrombosis. * Included in case series.*

to AC joint instability. According to Blazar et al,[3] the amount of AC instability was directly correlated to the VAS pain score but did not correlate to the apparent joint space seen on radiographs after surgery.

When instability occurs after over-resection, there are a variety of surgical options with modifications to Weaver-Dunn reconstruction, including the addition of CC stabilization with a screw, suture, or graft.[20] However, in our procedure, possible over-resection causing CC instability in grade Neer 1, 2a, or 3 nonunions is directly prevented by using the LockDown device as a stabilizing device. In type 2b fractures, the CC ligaments are already disrupted. They are surgically stabilized by the LockDown device, and the distal fragment is resected, with a good outcome and a low VAS score of 1-4.[16]

With resection of the distal clavicle and use of the LockDown device, the biomechanical function of the AC joint is not restored. This may hypothetically cause a 5˚-8˚ reduction of forward elevation and abduction of the arm as compared with the other side. This is supported by the results of our case study. The minimal functional loss is, in our opinion, acceptable in a lower-demand patient group, but it should be taken into consideration in younger patients and athletes. If dyskinesis of the scapula was at all present, it was not evident during the regular follow-up of the outlined patients. However, we did not specifically test scapular function, and it is possible that subtle dyskinesis was missed. As suggested in the literature addressing this issue, physiotherapy is usually sufficient in compensating for subtle scapular dyskinesis. Because all patients received physiotherapy after surgical treatment, patients learned how to use and train the slightly altered mobility in case of subtle dyskinesis to obtain a normal functional outcome.[16]

In an earlier study in which the surgical procedure was similar, although performed in 2 steps and in patients with chronic instability, Baxter et al[2] provided supporting evidence. In their case series on 13 patients with AC joint stabilization for instability following distal clavicle excision with a synthetic ligament, good results were obtained. Full resolution of symptoms was not reached, hypothetically owing to the chronicity of the patients' symptoms and multiple previous procedures.

Although our study focuses on distal clavicle fracture segment resection and stabilization by the LockDown device in patients with distal clavicle fractures, other studies have shown the effectiveness of the LockDown device in patients with AC dislocation.[22] Wright et al[22] reported outcomes in 21 patients undergoing AC stabilization with the braided polyester prosthetic ligament for Rockwood type 3 dislocations.

Table II Results after 1 year of follow-up

	No. of patients or median (interquartile range)
Patients	7
Sex: female	3
Fracture side: right	4
Age, yr	62 (61-75)
No. of planning procedures	2 (1-6)
Fragment size, mm	18.6 (16-28)
VAS score	1 (0-4)
CSS	9.5 (1.5-14.5)
DASH score	3.40 (1.7-22.4)
NCS	92 (76.0-100)
Anteflexion, °	
- Fractured side	156.5 (139-180)
- Non-fractured side	156.5 (151.8-180)
Abduction, °	
- Fractured side	160 (139-177)
- Non-fractured side	171 (146.5-178.5)
External rotation, °	
- Fractured side	48.5 (33-56.5)
- Non-fractured side	50 (45.25-70.5)

VAS, visual analog scale; CSS, Constant shoulder score; DASH, Disabilities of the Arm, Shoulder and Hand; NCS, Nottingham Clavicle Score.

The outcomes were good at a mean follow-up of 30 months, but the mean abduction power on the operated side was 82% (range, 31%-97%) of that on the normal side.

Some surgeons are reluctant to use the ligament as it does not provide exact anatomic reconstruction. Careful dissection is of major importance. The dissection and LockDown device should leave the coracoacromial ligament intact by tunneling the device posterior to this ligament. Placing the LockDown device too medially across the clavicle will leave a craniocaudal dislocation, although it will still stabilize the joint. Placing the LockDown device too distally will result in forward translation of the clavicle. Pulling the clavicle too far caudally (over-tightening) may cause screw cutout. Meticulous technique is mandatory. Furthermore, early postoperative mobilization may reduce stiffness and the chance of early adhesive capsulitis.

To our knowledge, no studies have described the use of the LockDown device for an indication other than pure AC joint disruption. In low-demand patients with a high risk of nonunion and persisting pain and in patients with comminuted or osteoporotic distal fragments, distal clavicle fragment resection with LockDown device stabilization may be a suitable alternative to osteosynthesis or hook plate fixation. Obviously, a prospective comparative study with a longer follow-up would be necessary to confirm the superiority of this treatment.

Conclusion

In low-demand patients or patients with a high risk of nonunion, removal of the outer fracture segment in distal clavicle fractures, followed by placement of the LockDown device, appears to be a suitable treatment option for distal clavicle fractures.

Disclaimer

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