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Radiographic appearance of the distal clavicle in relation to the acromion after acromioclavicular joint reconstruction using a braided polyester mesh

Sven A.F. Tulner [a, b, *], Andy Fowler [b], Kimberley L. Edwards [c], Vinod Kumar [d], Paul Manning [b], John M. Geoghegan [b], William A. Wallace [b c]

[a] OrthoDirect, Weteringschans 72, 1017 XR, Amsterdam, The Netherlands
[b] Nottingham Shoulder & Elbow Unit, Nottingham City Hospital Campus, Nottingham University Hospitals, Nottingham, NG5 1PB, United Kingdom
[c] Academic Orthopaedics, Trauma and Sports Medicine, School of Medicine, University of Nottingham, Queens Medical Centre, Nottingham, NG7 2UH, United Kingdom
[d] NMC Royal Hospital, Abu Dhabi, United Arab Emirates

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ABSTRACT

ACJ stabilization using a braided polyester mesh has become popular in ACJ injuries. However, concerns have been raised about excessive anterior clavicle displacement. The purpose of this study was to report radiographic position of the distal clavicle in relation to the acromion after ACJ reconstruction using this device immediately postoperative and after 6 months follow-up compared with a healthy control group.

Thirty-eight patients with ACJ instability treated with a braided polyester mesh were compared within group (pre-/postoperatively) and between groups (with age/sex matched controls). Biplane radiographic measurements by 2 observers were made preoperatively, immediate postoperatively and at 6 months follow-up. Inter-observer reliability was assessed and clinical outcome scores were recorded.

ACJ stabilization significantly reduced vertical displacement immediately postoperatively (13.8 ± 4.2 to 3.5 ± 5.5 mm; $p < 0.0001$) towards controls (1.7 ± 2.3 mm,$p < 0.0873$). Slight further superior displacement (4.4 mm) occurred at 6 months follow-up compared to immediately postoperative ($p = 0.0029$) and 6.2 mm more than mean controls ($p < 0.0001$). In the axial plane, significant early reduction of posterior displacement was achieved (10.3 ± 8.0 to 1.1 ± 5.1 mm,$p = 0.0240$) and the clavicle settled back to a more posterior position at 4.5 ± 6.7 mm at 6 months post-surgery ($p = 0.3062$). At both time points, posterior displacement was comparable with the controls (3.4 ± 3.0 mm,$p = 0.4371$ postoperative, $p = 0.563$ at 6 months follow-up). Excessive anterior displacement has been observed in 2 of the 5 available axial radiographs early postoperative and in 4 of 14 available axial radiographs at 6 months. Constant, Oxford Shoulder and Nottingham Clavicle scores significantly improved (25 ± 12 to 43 ± 7:$p < 0.0001$, 46 ± 27 to 80 ± 19:$p = 0.0038$, 53 ± 14 to 80 ± 17:$p < 0.0001$). ACJ stabilization using a braided polyester device in ACJ instability is effective at reducing both superior and posterior clavicle displacement with excellent clinical outcome. Overcorrection in the axial plane seems to occur, however this is of no clinical and radiographic significance. Posterior displacement is significantly reduced towards control values at 6 months follow-up.

1. Introduction

Acromioclavicular (ACJ) dislocations are common injuries, with a specific high prevalence in those participating contact sports.[1] Patients complain of pain, deformity, instability and loss of shoulder function. The decision to carry out surgical stabilization depends on the severity of displacement usually assessed by Rockwood's classification.[2,3] There is evidence that more anatomical coracoclavicular reconstructions may have better outcomes than non-anatomical reconstructions suggesting that this is due to better restoration of horizontal and vertical stability of the joint.[4,5]

In 1995, the Nottingham Shoulder Unit with Surgicraft™ developed a braided polyester mesh originally called the "Surgilig" but now known as "LockDown".[6] This device corrects the deformity

* Corresponding author.
E-mail address: info@orthodirect.nl (S.A.F. Tulner).

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not only in the vertical plane but also in the axial plane. While this technique has been effective at correcting superior translation, there have been concerns regarding overcorrecting the distal clavicle into an excessively anterior position relative to the acromion.[8]

The purpose of this study was to report the radiological appearance of the distal clavicle in relation to the acromion after ACJ reconstruction using this device immediate postoperative and after 6 months follow-up compared with a healthy control group.

2. Methods

2.1. Patient identification/selection

Patients with chronic ACJ dislocation across three hospitals in Nottingham, UK, were retrospectively recruited into this study between January 2008 and February 2014. Patients who underwent a revision ACJ reconstruction or had a previous history of shoulder surgery on the affected side and patients with absence of radiographic data were excluded. In each patient, the severity of the ACJ dislocation was assessed by one of the senior authors using the Rockwood classification. The patients were operated on by one of the senior authors.

2.2. Radiographic evaluation

Radiographic measurements were performed before, immediately post-surgery, and 6 months after surgery from standardised routine erect trans-thoracic anterior-posterior (AP) and axial radiographic views of the shoulder. For both radiographic views there is an agreed standard positioning of the patient, this ensured that the magnification is roughly the same each time an X-ray is taken for the same patient. All radiographic measurements were made using digital rulers on the hospital radiographic database (IMPAX 6.5.2.657 Philips Medical Systems - Picture Archiving and Communications Systems) and were performed independently by the first and second author. The mean measurement of both was used for final analysis. Fig. 1 illustrates an example of the chosen specific measurement method on the both views. On the AP view for superior-inferior displacement lines were drawn parallel at the undersurface of the lateral end clavicle and at the undersurface of the medial acromion (Fig. 1a). On the axial view lines were drawn parallel at the anterior surface of the lateral end of the clavicle and at the most anterior prominence of the acromion and the distance between these lines was defined as anterior-posterior displacement (Fig. 1b). The same method was used in the control group. For each patient who underwent ACJ stabilization, a control with the same age and gender was randomly selected from the radiological database. All these patients had shoulder complaints for which they underwent biplane X-ray examination but with normal findings.

2.3. Clinical outcome scores

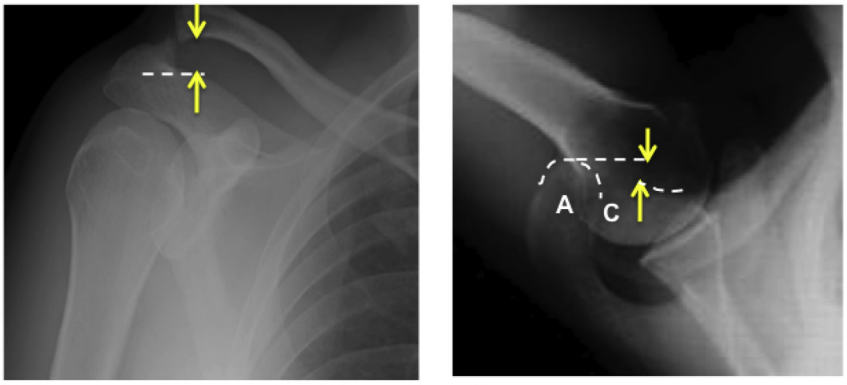
Clinical data regarding pain and shoulder function were collected before, and 6 months postoperative using three clinical outcome scoring systems, namely the Constant score,[9] the Oxford Shoulder score[10] and the Nottingham Clavicle score (Fig. 2).[11]

2.4. Surgical technique

A para-sagittal skin incision was made from the superior margin of the clavicle just medial to the ACJ. The deltoid was split in line with its fibres and the deltotrapezial interval opened. Approximately 5 mm of distal clavicle was excised. After reduction of the clavicle, the appropriate size was determined by using a measuring length gauge. The braided polyester mesh (Lockdown) was passed around the coracoid process and threaded through its soft loop to afford secure attachment at the coracoid process. The free-end was then passed from inferiorly around the posterior aspect of the clavicle, at the level of the conoid tuberosity, and finally tensioned before it was fixed onto the anterior surface of the clavicle with one 3.5 mm bi-cortical screw through the free-end “hard” loop (Fig. 3). The screw was placed in line with the conoid tuberosity.

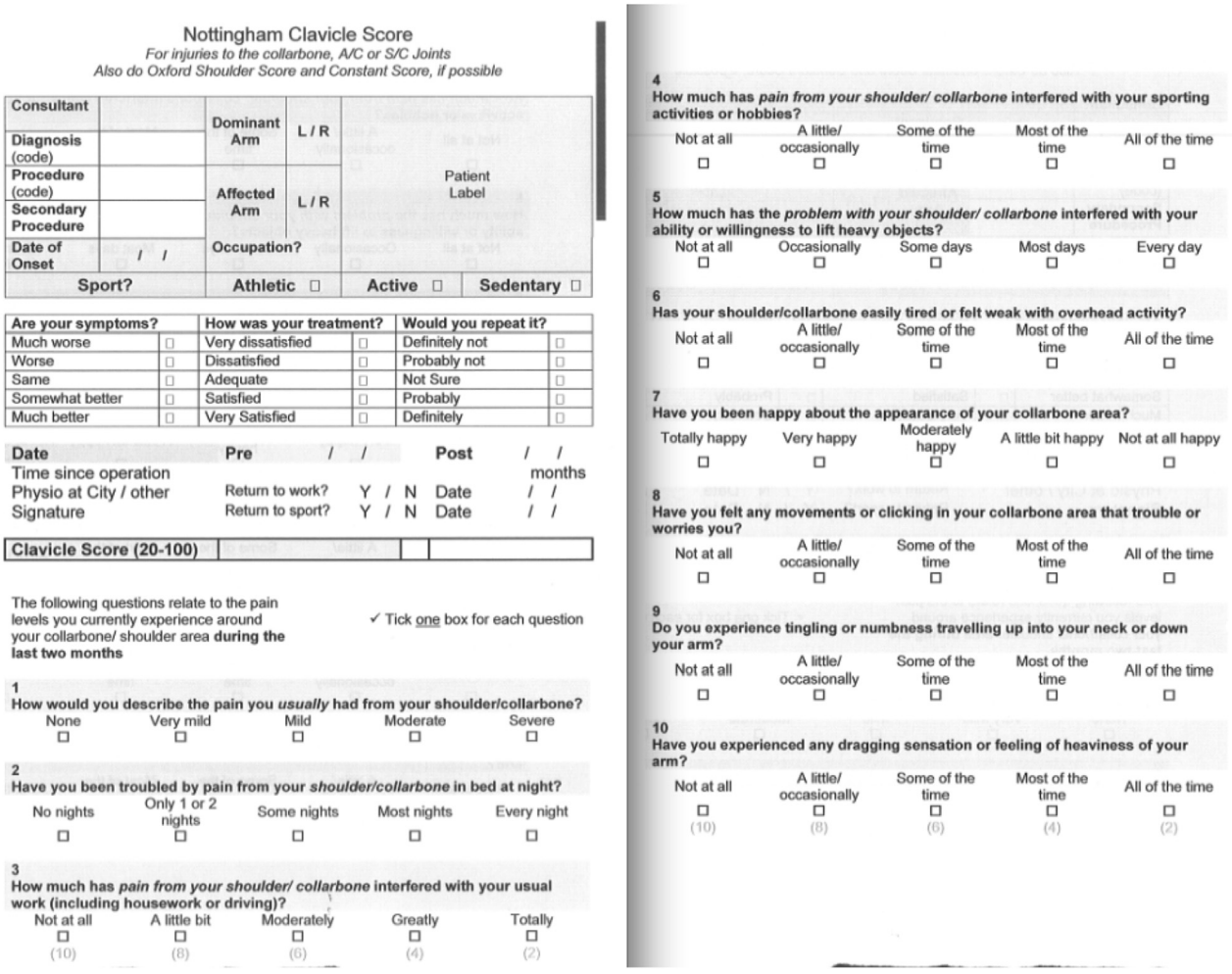
2.5. Postoperative management and rehabilitation protocol

Postoperatively the affected arm was placed in a sling for comfort for two weeks. One day after surgery, biplane radiographs were performed and patients were taught active range of motion by the physiotherapist. After two weeks they were permitted to mobilise as freely, but were advised to avoid heavy lifting up to 6 weeks postoperatively. After evaluation with the surgeon at six weeks, complete strengthening, scapular stability, rotator cuff and motor movement control work was initiated with full active range of motion as symptoms allowed. After three months patients were allowed to return to contact sports. At six months follow-up, patients had a clinical and radiographic evaluation. All the operations were carried out across three hospitals but within the same upper limb unit.



1a 1b

Fig. 1. a. (left-hand side) The superior-inferior displacement recorded was measured on the AP view - undersurface of lateral end clavicle to undersurface medial acromion (Superior defined as positive). b. (right-hand side) The anterior-posterior displacement was measured on the axial view - anterior surface lateral end of clavicle to most anterior prominence of acromion (Posterior defined as positive).



Nottingham Clavicle Score

For injuries to the collarbone, A/C or S/C Joints
Also do Oxford Shoulder Score and Constant Score, if possible

Consultant		Dominant Arm	L / R	Patient Label
Diagnosis (code)				
Procedure (code)		Affected Arm	L / R	
Secondary Procedure				
Date of Onset	/ /	Occupation?		
Sport?		Athletic ☐	Active ☐	Sedentary ☐

Are your symptoms?		How was your treatment?		Would you repeat it?	
Much worse	☐	Very dissatisfied	☐	Definitely not	☐
Worse	☐	Dissatisfied	☐	Probably not	☐
Same	☐	Adequate	☐	Not Sure	☐
Somewhat better	☐	Satisfied	☐	Probably	☐
Much better	☐	Very Satisfied	☐	Definitely	☐

Date	Pre / /			Post	/ /
Time since operation					months
Physio at City / other	Return to work?	Y	/ N	Date	/ /
Signature	Return to sport?	Y	/ N	Date	/ /
Clavicle Score (20-100)					

The following questions relate to the pain levels you currently experience around your collarbone/ shoulder area **during the last two months**

✓ Tick one box for each question

1 **How would you describe the pain you *usually* had from your shoulder/collarbone?**
None ☐ | Very mild ☐ | Mild ☐ | Moderate ☐ | Severe ☐

2 **Have you been troubled by pain from your *shoulder/collarbone* in bed at night?**
No nights ☐ | Only 1 or 2 nights ☐ | Some nights ☐ | Most nights ☐ | Every night ☐

3 **How much has *pain from your shoulder/ collarbone* interfered with your usual work (including housework or driving)?**
Not at all ☐ (10) | A little bit ☐ (8) | Moderately ☐ (6) | Greatly ☐ (4) | Totally ☐ (2)

4 **How much has *pain from your shoulder/ collarbone* interfered with your sporting activities or hobbies?**
Not at all ☐ | A little/ occasionally ☐ | Some of the time ☐ | Most of the time ☐ | All of the time ☐

5 **How much has the *problem with your shoulder/ collarbone* interfered with your ability or willingness to lift heavy objects?**
Not at all ☐ | Occasionally ☐ | Some days ☐ | Most days ☐ | Every day ☐

6 **Has your shoulder/collarbone easily tired or felt weak with overhead activity?**
Not at all ☐ | A little/ occasionally ☐ | Some of the time ☐ | Most of the time ☐ | All of the time ☐

7 **Have you been happy about the appearance of your collarbone area?**
Totally happy ☐ | Very happy ☐ | Moderately happy ☐ | A little bit happy ☐ | Not at all happy ☐

8 **Have you felt any movements or clicking in your collarbone area that trouble or worries you?**
Not at all ☐ | A little/ occasionally ☐ | Some of the time ☐ | Most of the time ☐ | All of the time ☐

9 **Do you experience tingling or numbness travelling up into your neck or down your arm?**
Not at all ☐ | A little/ occasionally ☐ | Some of the time ☐ | Most of the time ☐ | All of the time ☐

10 **Have you experienced any dragging sensation or feeling of heaviness of your arm?**
Not at all ☐ (10) | A little/ occasionally ☐ (8) | Some of the time ☐ (6) | Most of the time ☐ (4) | All of the time ☐ (2)

Fig. 2. Nottingham clavicle score.

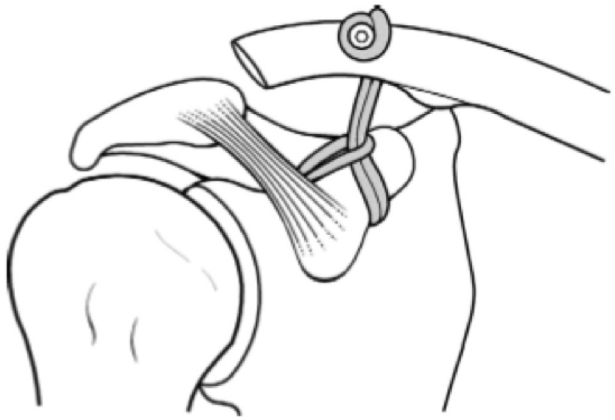


Fig. 3. ACJ stabilization using a braided polyester mesh around the corocoid process and clavicle fixed with a screw from anterior to posterior through the clavicle.

2.6. Statistical analysis

Statistical differences between time points and groups were assessed using t-tests. The threshold for statistical significance was $P = 0.05$. Inter-observer reliability was evaluated by calculating the Pearson's Correlation coefficient of the AP and axial measurements between the two raters, and Bland Altman plots.

3. Results

3.1. Patient data

Thirty-eight patients (30 males; 8 females; mean age 46 ± 16 years) with ACJ injuries, who underwent ACJ stabilization and 38 age and gender matched control subjects were included. Ten injuries were classified as Rockwood III, 8 as Rockwood IV and 19 as Rockwood V injuries. In one patient who underwent ACJ stabilization the baseline radiographic data were absent, thus this patient was excluded. In a further 21 patients axial baseline measurements were not available, resulting in 37 AP and 16 axial surgical group baseline measurements. The surgical procedure failed for one patient. An intention to treat analyses was used (i.e. we have included this failed patient in the analysis).

3.2. Radiographic outcome

Table 1 summarizes the mean AP and axial measurements at all three time points compared with the baseline measurements of the control group.

Pre and postoperative radiographic data. ACJ stabilization significantly reduced the initial superior displacement immediately postoperatively compared to the patients baseline position. However, there was significant widening in the space between immediately postoperatively and 6 months postoperatively

Table 1
Mean (standard deviation) of AP and axial measurements of the clavicle alignment showing comparison between the ACJ instability patients treated the braided polyester device (Lockdown) and the control group for all three time-points, including changes seen in reduction after surgery.

	N	Mean mm (SD)	Pre- compared with Post-op	Post-op/6 m follow up	Pre- compared with 6 m follow up	LockDown compared with controls
AP view			P-values			
Pre-op mean (SD)	37	13.8 (4.2)				<0.0001
Post-op mean (SD)	33	3.5 (5.5)	<0.0001			0.0873
6 months mean (SD)	24	7.9 (4.9)		0.0029	<0.0001	<0.0001
Controls	38	1.7 (2.3)				
Axial view						
Pre-op mean (SD)	16	10.3 (8.0)				0.0038
Post-op mean (SD)	5	1.1 (5.1)	0.0240			0.4371
6 months mean (SD)	14	4.5 (6.7)		0.3062	0.0404	0.5363
Controls	38	3.4 (3.0)				

(4.4 mm,$p = 0.0029$), however there remains a significant reduction of displacement at 6 months when compared with the preoperative values. In the axial plane, ACJ stabilization significantly reduced the mean posterior displacement immediately postoperatively, although this did recede slightly by 6 months, it was still a significant improvement compared with the preoperative starting point. Between immediately postoperatively and 6 months follow-up no significant change in posterior displacement has been reported in the axial plane. Overcorrection anteriorly of the clavicle immediately postoperatively was seen in 2 of the 5 available axial measurements (−3.3 mm and −3.4 mm) and in 4 of the 14 available axial measurements at 6 months follow-up (−4.6 mm, −0.4 mm, -4.6 mm and −3.1 mm). The mean axial values of the total group remained positive at both postoperative time points.

Patients compared to control. At the initial preoperative stage in comparison to the control group the clavicle was shown to be significantly superiorly displaced by an average of 12.1 mm ($p < 0.00001$) and posteriorly displaced by an average of 6.9 mm ($p = 0.0038$). There is no statistical difference in AP measurements seen immediately post surgery, again demonstrating correction with the device, but at 6 months there is statistical difference, indicating recurrence in superior displacement. The axial measurements show statistically significant differences between the injured and the control group preoperatively, but this improves postoperatively such that the differences between the treated group and the control group were no longer statistically significant at either time point.

Statistical results. The Pearson correlation coefficient between the radiographic measurements of the two raters taken on both AP and axial views showed good inter-observer correlation, $r = 0.920$ and 0.894 respectively. This was also assessed using the Bland Altman plots, which further verify the high correlation between the values of the two raters (Fig. 4). Whilst all patients meeting the inclusion criteria were included in this study, in view of the small numbers, a post-hoc comparison of means unpaired sample size calculation was undertaken using the variance in the control group data. This showed that with the standard assumptions of 80% power and $\alpha = 0.05$ that the study had sufficient power to detect a change in AP measurements of 1.5 mm and 2.0 mm in the axial measurements to 6 month follow up.

Thus, this study was sufficiently powered.

3.3. Clinical outcome

Clinical outcome scores are summarized in Table 2. Important to note is that not all patients were clinically scored preoperative and at 6 months follow-up. The mean postoperative clinical follow-up was 20 months with a range from 3 to 66 months. For the patients, who were clinically assessed, statistically significant improvements at 6 months are seen for all three clinical outcome scores. On closer examination of the 4 patients found to have overcorrection at 6 months follow-up, 2 patients lacked any clinical data and the other 2 patients had almost complete scores showing excellent improvement following surgery.

3.4. Data excluding patient with failed surgery

Separate analysis of the patient whose surgical procedure failed showed that the 14 mm of displacement superiorly was only corrected by 1.4 mm to the 12.9 mm seen immediately postoperative. This worsened further by the 6 months stage to 15.2 mm. This failure was associated with poor Constant and Nottingham Clavicle scores of 35 and 38 respectively. When this patient's results are excluded for analysis minor variations has been reported in the means and there is no meaningful difference in p values (Appendix 1).

4. Discussion

The results of our study have been shown that ACJ stabilization in ACJ injuries using this braided polyester device significantly corrects ACJ displacement in the AP and axial plane. However, at 6 months follow-up this correction remains in the axial plane whereas recurrence of slight superior displacement occurs in the AP plane.

The limited early postoperative axial radiographic data available from this study demonstrated two patients with overcorrection anteriorly immediately postoperatively. It would be reasonable to assume that if more axial view data were available immediately postoperatively more patients with initial overcorrection may have been reported. At 6 months follow-up, the axial data shows that four patients still had overcorrection anteriorly but this seems to be not clinically relevant as two of them had improved clinical outcome scores. For the whole group, the mean posterior displacement of the clavicle at 6 months compared to the healthy controls was not significantly different. Thus, our results suggest that ACJ stabilization using this braided polyester device may lead to overcorrection in the axial plane immediately postoperatively, but that this is of no clinical and radiographic significance at 6 months follow-up.

The superior displacement of the clavicle was corrected initially, however there was a slight increase again by the late postoperative stage of 4.4 mm on average but the final position remained statistically different to the preoperative position. Several previous studies also showed slight recurrence of superior displacement after ACJ stabilization using the same braided polyester device.[7,12,13] Carlos et al. found that 29% of patients treated with this device experienced migration superiorly between the immediate postoperative period and late postoperative at a mean follow-up of 26 months.[7] This is relatively consistent with our results showing

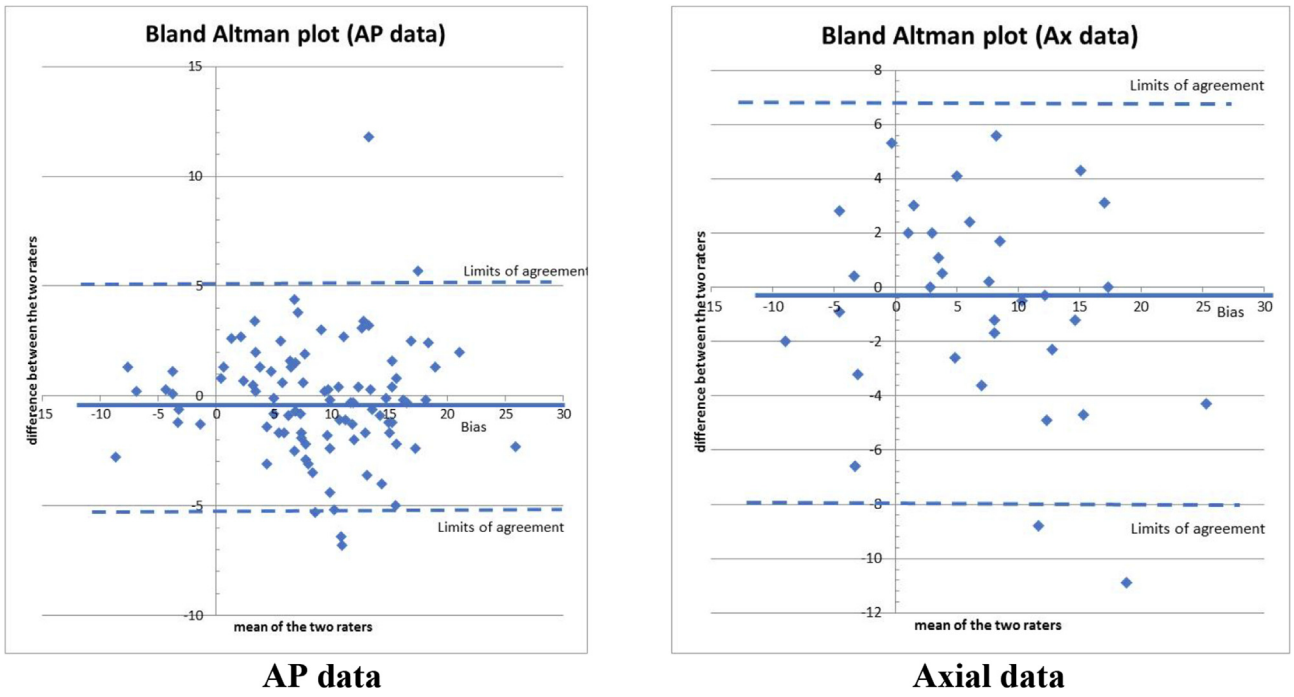


Fig. 4. Bland Altman plots comparing the two observers for the AP and axial data.

Table 2
Mean (standard deviation) of clinical outcome scores pre- and post-operative.

	N	Pre –op mean (SD)	N	Post-op mean (SD)	P-value
Oxford Shoulder Score	27	25.6 (12.4)	25	42.6 (7.3)	<0.0001
Constant Score	12	46.4 (27.1)	9	79.8 (19.2)	0.0038
Nottingham Clavicle Score	22	52.8 (14.2)	23	79.4 (16.7)	<0.0001

further migration in over 50% of cases after 6 months follow-up. However, the mean Oxford Shoulder score in the study of Carlos et al. and ours was 45 and 43 respectively, which implies that this slight recurrence of superior displacement has no significant clinical consequences. Jeon et al. studied eleven patients treated with the same device, which included three revision cases after a previous Weaver-Dunn procedure.[13] They reported that the majority of patients experienced minor subluxation of the ACJ following surgery of between 2 and 4 mm at an average follow-up of 55 months. However, in their study there was no comparison with preoperative values as reported in our study. Wood et al. published results suggesting no subluxation was seen postoperatively at 6 months but the methodology for the measurements is not described.[14] Overall, from the published data, there are mixed reports concerning migration of the clavicle in terms of superior-inferior displacement, however the methodology and reliability behind these measurements are not well documented.[7,12–14] This is the first study to evaluate the radiographic outcomes on biplane x-rays following ACJ stabilization with the use of a matched control group with a low inter-observer bias.

Several reasons for the recurrence of superior displacement occurring at 6 months can be put forward. Koscis et al. recently reported the biological response to this device and stated that the device acts as a scaffold for connective tissue, which forms an investing fibrous pseudo-ligament.[15] Based on these findings, one likely explanation of the recurrence in displacement between early and 6 months postoperative values is that the connective tissue scaffold was not yet fully matured and the polyester ligament stretched. Settling of soft tissue interposition between the synthetic device and bony structures may also play a role.

The clinical outcome scores after ACJ stabilization with this device are very good and consistent when compared with previous studies.[13,14] However, these studies do not compare pre and post-operative scores as we have reported. Recently, Kumar et al. showed that chronic ACJ reconstruction using this device achieved better Oxford Shoulder scores and Nottingham Clavicle scores and earlier return to work and sports, compared with the modified Weaver-Dunn procedure.[16] Our results support current evidence, suggesting that anatomical ligament reconstruction have better outcomes than non-anatomical transfers due to better restoration of horizontal and vertical stability of the joint[4] and that it has superior biomechanical properties compared with the modified Weaver-Dunn, nonanatomic allograft, anatomic suture, and Graft Rope techniques.[17]

4.1. Limitations of the study

The limitations of this study are related to the limited number of axial radiographic measurements due to postoperative x-rays taken in this plane which could not be reliably measured; true axial x-rays would be uncomfortable to perform early postoperatively. Furthermore, clinical and radiographic follow-up at 6 months was poor due to the general subject population being young and active. Also there was a large difference in the timing of the late post-operative clinical measurements (from 3 to 66 months). Retrospective collection of the Oxford Shoulder score has been validated and it is possible to use these recollected scores to assess the impact of an intervention.[18] However, retrospective evaluation of the Nottingham Clavicle score has not yet been validated.

4.2. Conclusions

ACJ stabilization using a braided polyester device in patients with ACJ instability is effective at reducing both superior and posterior displacement of the clavicle improving clinical symptoms. Radiographic measurements performed in this study were reliable with a low inter-observer bias. Immediately after operation, this device may lead to overcorrection anteriorly, but this is of no clinical and radiographic significance at 6 months follow-up. A slight recurrence of superior displacement of the clavicle occurs at 6 months assumed to be due to stress relaxation or stretching of the polyester ligament, but this did not impact clinical outcomes.

Appendix 1. Data excluding patient with failed surgery

Table 1
Mean (standard deviation) of AP and axial measurements of the clavicle alignment showing comparison between the ACJ instability patients treated the braided polyester device (Lockdown) and the control group for all three time-points, including changes seen in reduction after surgery (n = 36).

	N	Mean mm (SD)	Pre- compared with Post-op	Post-op/6 m follow up	Pre compared with 6 m follow up	LockDown compared with controls
AP view			P-values			
Pre-op mean (SD)	36	13.8 (4.2)				<0.0001
Post-op mean (SD)	32	3.3 (5.3)	<0.0001			0.1440
6 months mean (SD)	23	7.5 (4.7)		0.0028	<0.0001	<0.0001
Controls	38	1.7 (2.3)				
Axial view						
Pre-op mean (SD)	16	10.3 (8.0)				0.0038
Post-op mean (SD)	5	1.1 (5.1)	0.0240			0.4371
6 months mean (SD)	13	4.2 (6.8)		0.3540	0.0367	0.6649
Controls	38	3.4 (3.0)				

Table 2
Mean (standard deviation) of clinical outcome scores pre and post-operative (n = 36).

	N	Pre −op mean (SD)	N	Post-op mean (SD)	P-value
Oxford Shoulder Score	27	25.6 (12.4)	24	43.1 (7.0)	<0.0001
Constant Score	12	46.4 (27.1)	8	85.4 (10.0)	0.0004
Nottingham Clavicle Score	22	52.8 (14.2)	22	81.3 (14.4)	<0.0001

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