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Superior suspensory complex of the shoulder reconstruction for acute and chronic acromioclavicular joint dislocations: the Queensland Unit for Advanced Shoulder Research 3-tunnel technique

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Background: Management of acromioclavicular joint (ACJ) injuries have wide variety of classification systems, surgical indications and operative techniques. Our study describes the Queensland Unit for Advanced Shoulder Research (QUASR) 3-Tunnel Technique with Ligament Augmentation and Reconstruction System (LARS; Surgical Implants and Devices, Arc sur Tille, France) artificial ligament to reconstruct the superior shoulder suspensory complex in acute, chronic, and revision ACJ dislocations and lateral clavicle fractures.

Methods: Our prospective cohort series of patients undergoing the QUASR 3-Tunnel Technique using LARS artificial ligament. This technique reconstructs the superior shoulder suspensory complex using 2 4-mm clavicle tunnels, 1 acromion tunnel, and is arthroscopically assisted to pass the artificial ligament under the coracoid. The ligament is secured with braided composite sutures and no interference screw is used. Preoperative and postoperative functional outcome scores were compared in patients with minimum 12-months follow-up.

Results: Of 26 patients in this series, 7 (27%) were operated within 4 weeks of injury, 2 (8%) were revision cases, and 6 (23%) were lateral clavicle fractures. Mean time to surgery was 14 weeks (2-650). Mean postoperative scores with associated 95% confidence interval were Specific Acromioclavicular Score 87.38 (confidence interval 75.38-99.37), American Shoulder and Elbow Surgeons score 94.60 (87.85-101.35), Constant 79.47 (71.87-87.07), simple shoulder test 85.44 (72.34-98.54) and visual analog score 0.50 (−0.15 to 1.15). There were 2 infections and 1 atraumatic loss of reduction; however, there were no tunnel fractures.

Conclusion: The QUASR 3-Tunnel Technique with LARS artificial ligament is a safe and efficient technique for both acute and chronic ACJ reconstruction, lateral clavicle fractures with coracoclavicular ligament disruption and complex revision cases with favorable outcomes at the mid-term follow-up.

Management of acromioclavicular joint (ACJ) injuries is controversial, with a wide variety of classification systems, surgical indications, and operative techniques. There is little evidence suggesting superiority of one described anatomic technique over another. Injury incidence among the young athletic population is reported as 9.2 per 1000 person-years,[8] increasing the demand for a robust anatomic reconstruction that allows early return to sport and avoids the consequences of tendon autograft harvest. Although

The Ramsay Health Care QLD Human Research Ethics Committee approved this study—Protocol 19/11.

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each case should be individually assessed, the consensus among shoulder surgeons suggests that surgery should be considered for cases of complete coracoclavicular (CC) ligament disruptions, and some cases of partial disruptions with combined vertical and horizontal instability.[4,14,20,23,26,32]

The ACJ contributes to the superior shoulder suspensory complex (SSSC), a complex ring structure divided into 3 parts; (i) the clavicular–CC ligamentous–coracoid link, (ii) the clavicular–ACJ–acromial (Acr) strut, and (iii) the scapular body junction. High-grade ACJ injuries occur within parts (i) and (ii) causing vertical and horizontal instability, respectively. It should therefore be a principle of surgical management to anatomically reconstruct these 2 deficient complexes.[7,22]

Despite this principal, nonanatomic reconstruction is widely utilized, aiming to restore vertical instability by reconstructing the CC ligaments. Satisfactory results have been reported; however, failing to address horizontal instability may lead to residual instability symptoms, failure of ACJ reconstruction and subsequent poor clinical outcomes.[1,22,25] Hook plates restore both vertical and horizontal instability and are still used by many. They have, however, fallen out of general use as newer techniques negate the risk of cuff impingement, Acr fracture, and the need for implant removal which could delay a return to work or sport.[3,26] In reconstruction cases, elongation of tendon grafts can occur and may cause loss of reduction.[2,17]

The Ligament Augmentation and Reconstruction System (LARS; Surgical Implants and Devices, Arc sur Tille, France) is a synthetic ligament that has been used previously to nonanatomically reconstruct the CC ligament complex with favorable outcomes.[12,23] The traditional LARS technique involved the use of 2 interference screws in bony clavicular tunnels.[19] This has been associated with clavicular fractures through the tunnels, due to the high tensile stresses through the construct and stress risers at the screw interface.[16] In our new Queensland Unit for Advanced Shoulder Research (QUASR) 3-Tunnel Technique with LARS artificial ligament, we reconstruct part (i) and (ii) of the SSSC without the use of transtunnel interference screws and address both horizontal and vertical instability. This technique is versatile and can be used for reconstruction of acute and chronic cases of ACJ dislocation, lateral clavicle fractures and complex revision scenarios. In this prospective cohort study, the surgical technique is described with clinical, radiological, and functional outcomes in patients who have had injured parts (i) and (ii) of the SSSC.

Materials and methods

From July 2016 to October 2022, consecutive patients with injuries to (i) the clavicular–CC ligamentous–coracoid link and (ii) the clavicular–ACJ–Acr strut, of the SSSC who underwent the QUASR 3-Tunnel Technique with LARS artificial ligament were enrolled prospectively. The specific injuries include acute (within 4 weeks), chronic (greater than 4 weeks) ACJ dislocations, lateral clavicular fractures with associated CC ligament disruption, and revision cases following failed reconstruction. The local institutional board (Greenslopes Research and Ethics Committee, Protocol 19/11) approved the prospective cohort study and appropriate patient consent was obtained. Patients were assessed and graded on preoperative radiographs and cross-sectional imaging. All procedures were performed by a single subspecialist shoulder surgeon (AG). Patient-reported outcomes were evaluated using 6 validated scores: American Shoulder and Elbow Surgeons score, Constant Score, University of California Los Angles Shoulder score, visual analog score—pain, simple shoulder test (SST) and Specific Acromioclavicular Score preoperatively, at 6 and 12 months, 2 years, 3 years, 4 years, and 5 years. Bilateral strength testing was performed using a digital dynamometer (Commander Echo MMT; J Tech, Chester Springs, PA, USA) and involved the mean strength (kg) of lateral elevation. Patients were assessed radiologically with a routine anterior-posterior radiograph of the clavicle postoperatively in which CC distance were measured.

Surgical technique

All patients undergo a standardized surgical technique that includes an awake interscalene block, general anesthetic, and beach chair positioning. Surgical technique is performed in a stepwise manner with portals defined by Lafosse (Fig. 1 *A* and *B*).[27]

Step 1—arthroscopic coracoid dissection

Diagnostic arthroscopy is performed from the posterior 'A' viewing portal to screen for intra-articular pathology and the rotator interval is opened using the E working portal. Intra-articular pathology ie, superior labrum anterior and posterior tears, cuff tears and labral injuries are addressed. The coracoid is then visualized over its lateral aspect and dissected laterally and superiorly working from the D portal. Using a percutaneous needle, the I portal is then created 3-cm inferior to the coracoid. The camera is switched to the D viewing portal and the I portal is used as the working portal to clear the medial coracoid soft tissue. The coracoid can now be viewed in its entirety over the lateral, superior, and its medial surface. The M portal is made 5-cm inferior to the clavicle in line with the anteroposterior axis of the glenoid while looking lateral to the pec minor ensuring a safe distance from the plexus and axillary artery. Partial release of the pec minor from this portal may be needed to safely pass the graft and ensure the brachial plexus is protected. Lastly, the H portal is created superiorly and adjacent to the anterior border of the clavicle and marked with a needle. The portal is opened with blunt artery forceps to avoid injury to the superficial tributaries of the cephalic vein. Care is taken to identify the brachial plexus which is in very close proximity to the medial border of the coracoid. Medial 1 cm of the pectoralis minor insertion is released for safe passage of the graft and to avoid injury to the plexus.

Step 2—pass LARS ligament under coracoid

Using a combination of suture graspers and retrievers, the LARS ligament is passed under the coracoid. Firstly, one end is introduced through the H portal on the under surface of the lateral coracoid anterior to the subscapularis and posterior to the conjoint tendon. Secondly, from the M portal, the ligament is guided under the coracoid and placed proximal to the pec minor tendon. Care is taken to protect the brachial plexus. Lastly, from the H portal the ligament is retrieved and pulled out of the portal to form a loop of ligament around the coracoid (Fig. 2). Arthroscopic instruments are now removed, and an open approach is performed.

Step 3—preparation of the ACJ and excision

Following the central axis of the clavicle a transverse incision is made 5-cm medial to the ACJ extending to the anterolateral edge of the acromion (Fig. 3*A*). Deep dissection is continued down to the clavicle across the ACJ and to the lateral edge of the acromion elevating in a single layer full thickness flaps of the deltoid and trapezius muscles. The dislocated ACJ can now be visualized, noting that the clavicle rests superior and posterior to the acromion. The articular disc and 5-mm of lateral clavicle are excised to complete the exposure.

Step 4—divergent clavicular tunnels

A Cobbs elevator is placed 4 cm from lateral to medial through the ACJ under the clavicle to protect underlying structures while

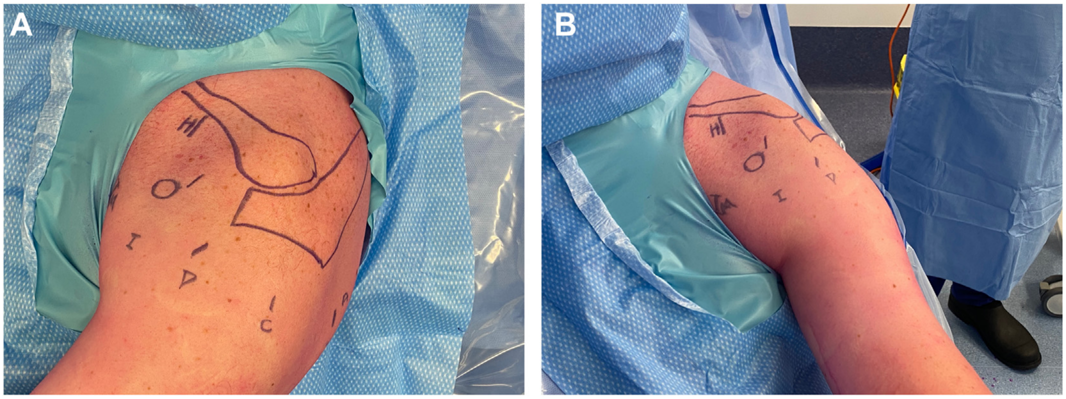

Figure 1 (**a**) and (**b**): Portals used for arthroscopic passage of LARS around coracoid. A: Posterior; C: Lateral; D: Anterior-Lateral; I: Inferior; H: Superior; M: Medial. *LARS*, Ligament Augmentation and Reconstruction System.

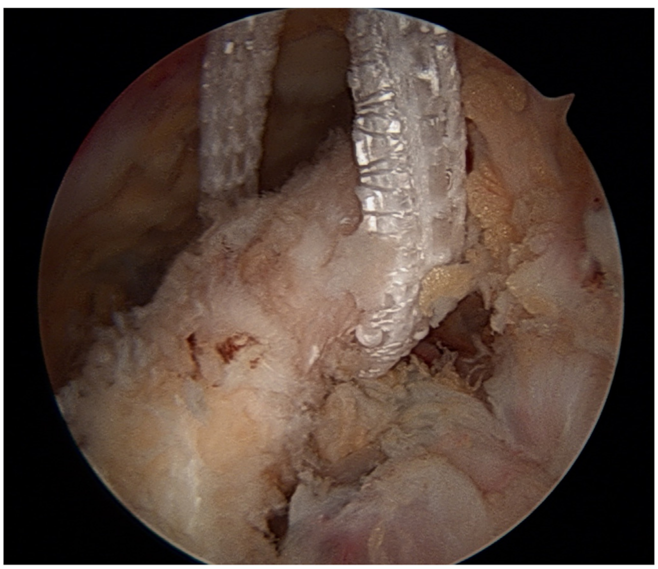

Figure 2 Arthroscopic view depicting position of LARS around coracoid. *LARS*, Ligament Augmentation and Reconstruction System.

drilling the clavicular tunnels. Four-mm medial and lateral clavicular tunnels (CMed and CLat) are drilled in a divergent fashion from the superior clavicle surface to reconstruct the isometric points of the CC ligaments and prevent stress risers within the clavicle (Fig. 3*B*). The CMed entry point is posterior on the clavicle 4 cm from the lateral border with the tunnel directed anterior and lateral. The CLat entry point is anterior on the clavicle 2 cm from the lateral border and the tunnel directed posterior and medial. Using a nitinol wire suture passer, the LARS ligament is shuttled through the under surface of the clavicle ensuring that the graft is crisscrossed over the coracoid (Fig. 3*C*). Thus, the medial limb of the graft is brought laterally through the CLat tunnel and the lateral limb of the graft is brought medially through the CMed tunnel.

Step 5—acromioclavicular tunnel

To reconstruct the AC ligament, 1 3.5-mm Acr tunnel is drilled from an entry point on the anterolateral tip of the acromion directed to the posteromedial border of the ACJ. The thickness of the acromion is on average 12 to 14 mm; therefore, care is taken to only perform one pass of the drill to prevent fracture. The anterolateral limb of the LARS ligament from the CLat tunnel is shuttled from posterior to anterior through the Acr tunnel using the nitinol wire (Fig. 3*C*).

Step 6—reduction of the AC joint

The ACJ is reduced by axially pushing the arm up and applying a superiorly and anteriorly directed force with Cobb's elevator. A 2-mm K-wire is inserted lateral to medial transfixating the ACJ in its reduced position (Fig. 3*D*).

Step 7—secure the graft

The ligament ends are crisscrossed over the top of the clavicle under tension and repaired with a 2-0 FiberWire (Arthrex, Naples, FL, USA) nonabsorbable composite braided suture (Fig. 3*E*). The acromial limb end is sutured to the CMed ligament and the CMed ligament end it sutured to the CLat ligament. Additionally, the 2 limbs of the ligament are reattached in a side-to-side repair under maximal tension with locked sutures. This creates a fixation which is spanned across the whole construct to prevent any focal areas of excessive strain.

Step 8—closure

At the end of the procedure, the K-wire is removed and the maintenance of ACJ reduction is visually checked. The ACJ is inspected to ensure rotation and translation is possible at the joint to avoid postoperative pain and restore normal ACJ kinematics. Care is taken not to over-reduce the clavicle (often employed in biologic fixation) as the LARS construct has no elasticity and over-reduction may result in reduced forward elevation postoperatively.

The delto-trapezial fascia is tightened and double-breasted to compensate for the capsule redundancy which is created by the injury. This is a critical step in the technique and care should be employed to ensure a tight repair is achieved using nonabsorbable sutures. This further reinforces the SSSC reconstruction (Fig. 3 *F* and *G*). Subcuticular skin closure is performed with 3.0 Monocryl (Ethicon, Raritan, NJ, USA) absorbable poliglecaprone-25 suture.

Postoperative protocol

The patient is immobilized in a standard shoulder sling with abduction pillow for 6 weeks. Active internal and external rotation exercises and standard passive and active-assisted elevation are commenced on day 1. The patient must refrain from driving and avoid loading of the shoulder joint for 6 weeks. Open chain exercises are commenced at week 6; however, patients are counseled

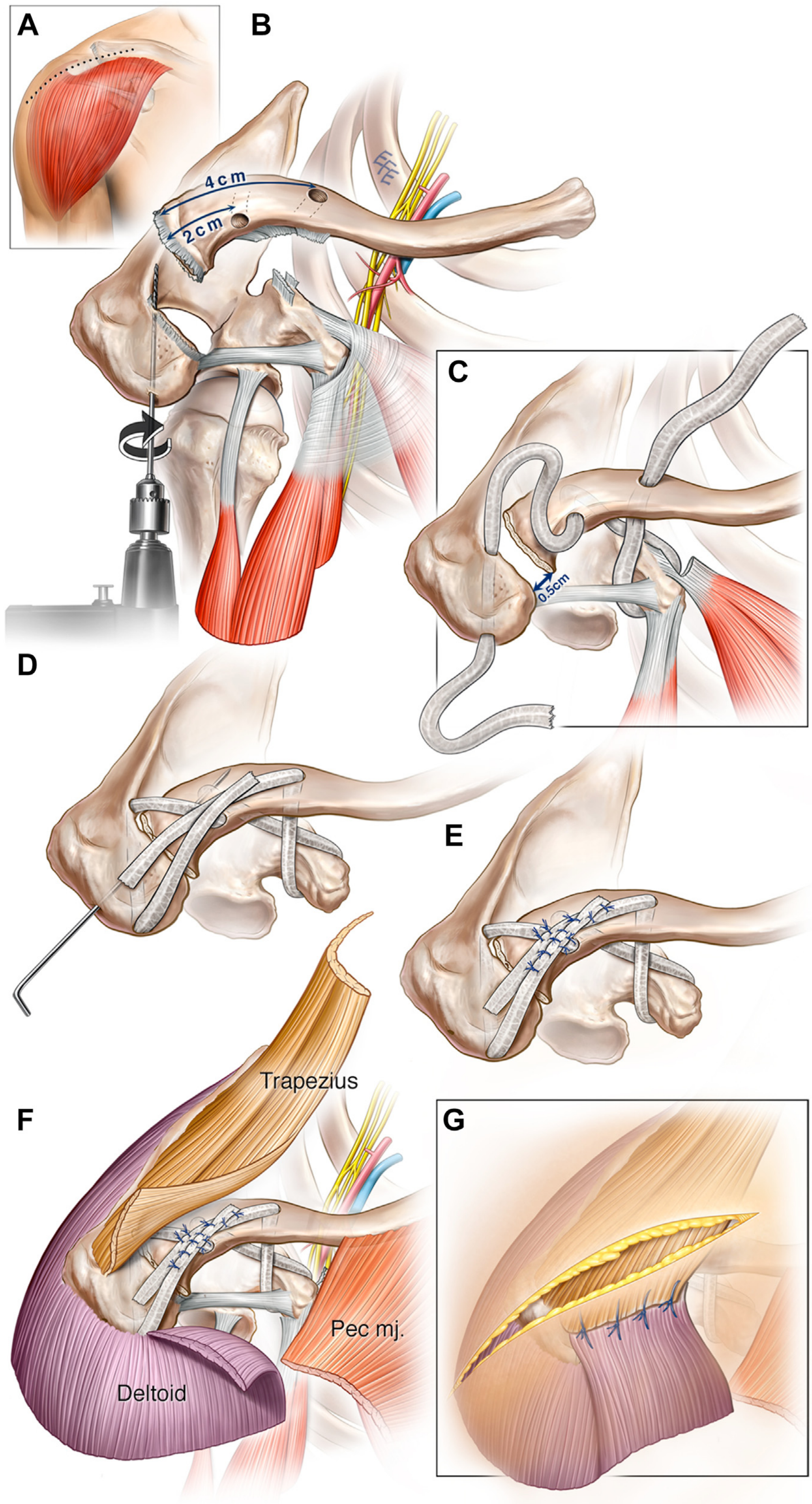

Figure 3 Schematic diagram depicting steps of 3-tunnel technique. (**A**) Five-cm incision made centered over ACJ; (**B**) tunnel position 4 cm from ACJ and drilling of the clavicle tunnels; (**C**) passage of LARS ligament through tunnels; (**D**) reduced ACJ with preliminary K-wire fixation; (**E**) interrupted Fiberwire sutures; (**F**) delto-trapezial fascia double-breasted repair and G-Skin closure. *LARS*, Ligament Augmentation and Reconstruction System; *ACJ*, acromioclavicular joint.

Table I
Demographic characteristics of the study cohort.

Age at time of surgery, median; range (yrs)	45; 15-69
Gender	
Male, N (%)	23 (88%)
Female, N (%)	3 (12%)
Dominant side affected	
Yes, N (%)	15 (58%)
No, N (%)	11 (42%)
Injury type	
Rockwood type III, N (%)	7 (27%)
Rockwood type IV, N (%)	3 (12%)
Rockwood type V, N (%)	10 (38%)
Clavicle fracture with CC disruption	6 (23%)
Duration from injury to surgery in d median; (range);	102; (2-4553);
mean ± standard deviation	656 ± 1247
Acute within 4 wk, N (%)	7 (27%)
Chronic after 4 wk, N (%)	19 (73%)
Mode of injury	
Cycling, N (%)	8 (31%)
Contact sport, N (%)	7 (27%)
Motor vehicle accident, N (%)	5 (19%)
Fall, N (%)	4 (15%)
Surfing/Snowboarding, N (%)	2 (8%)

against strenuous shoulder activity such as weightlifting for a period of 4 months. The aim of reducing force over the construct is to allow satisfactory scar tissue to form within the complex.

Statistical analysis

Demographic data for all patients are reported and patients with 12 month or more follow-up are included in an analysis of postoperative outcomes. Continuous variables are presented as a mean ± standard deviation and 95% confidence interval, and categorical variables are presented as frequencies and percentages. Data are presented as box plots comparing preoperative, postoperative and contralateral normal shoulder for patient reported outcome scores, range of motion and lateral elevation strength. Statistical tests were performed using SPSS version 26 (IBM Corp., Armonk, NY, USA).

Results

The QUASR 3-Tunnel Technique with LARS ligament was utilized in 26 consecutive patients. Patient and injury characteristics are presented in Table I. Seven (27%) of patients were operated acutely within 4 weeks of injury. The remaining presented following trial of conservative management and several patients were more than 10 years post injury who had good function until presenting with recent symptoms. All patients were active and were either participating in sporting and recreational activities that put demands on their shoulder or were manual laborers before injury. The LARS artificial ligament was used in several complex and revision cases that are presented in Table II.

The average follow-up of patients in this cohort was 23 months (range 6-65). Four patients were lost to follow-up after 6 weeks, 6 patients have not reached 12 months follow-up, and 16 patients who had 12 months or more follow-up were included in the statistical analysis. All functional outcome scores and range of motion improved at the final follow-up and were similar to the normal uninjured contralateral shoulder (Table III, Figs. 4 and 5). Physical examination at the latest follow-up revealed vertical and horizontal stability during full range of passive and active shoulder range of movement.

Average postoperative CC distance at last radiographic follow-up was on average 10.9 mm (range 4.8 mm-15.8 mm) in 13 patients. The other 3 patients had standard shoulder X-ray examination which did not show evidence of loss of reduction; however, accurate CC distance could not be measured. No tunnel widening, osteolysis, or additional fracture was identified at the last radiological follow-up.

Sixteen patients had associated intra-articular pathology identified on arthroscopic examination during primary surgery including labral tears (n = 7), partial cuff tears (n = 3), full cuff tears (n = 3), synovitis with capsular contraction (n = 7), and biceps pathology (n = 3). Of these patients, 1 had a sub pec tenodesis for chronic biceps rupture and a capsular release, a second had a full thickness supraspinatus repair and biceps tenodesis, a third patient had a subscapularis repair. The fourth had postsurgical arthrolysis in addition to their revision from failed dog bone suspensory fixation to LARS ligament. The fifth patient had a concurrent labral repair, supraspinatus, and infraspinatus cuff repair plus biceps tenodesis, paraglenoid cyst decompression and suprascapular nerve decompression.

Six complications were noted in the cohort of 26 patients, these are detailed in Tables II and IV.

Discussion

The LARS ligament is designed to be stronger and stiffer than the native ligament, resulting in a high resistance to flexion, traction, torsion and stretching. On a microstructural level, the polyethylene terephthalate woven mesh has *in vivo* cellular and connective tissue ingrowth properties acting as a scaffold for fibroblastic activity.[28,31] Using synthetic graft has other advantages including the avoidance of donor side morbidity in autologous tendon harvest and the possible biocompatibility issues associated with allograft.[14,20]

The QUASR 3-Tunnel Technique with LARS ligament is an anatomic technique which restores the entire SSSC. Anatomic reconstruction of ACJ has demonstrated superior outcomes than other nonanatomic techniques in several studies conferring that horizontal stability is important and should be addressed as part of any reconstruction.[1,5,11] Failures of nonanatomic LARS ligament reconstructions have been unacceptably high in some series secondary to coracoid fractures, intrasubstance tear at the level of the coracoid, and interference screw failures.[19,23,24,30] The QUASR 3-Tunnel Technique with LARS artificial ligament has the following advantages: (i) the technique negates the use of interference screws and coracoid drilling, which are a potential point of weakness in the construct leading to fracture. The avoidance of screw fixation devices in any of the tunnels avoids the fixation-related fractures and implant-related complications including screw pull out, repeat surgery for removal of implants, and implant migration and failure.[5,11,14,15,21] (ii) The drilling of small 4-mm diameter divergent clavicular tunnels positioned 20-mm apart is thought to reduce the risk of fracture.[15] Huang et al suggests that tunnels of 5 mm or less and at least 20-mm apart reduce the risk of fracture, supporting this theory.[15] There were no clavicular, acromial, or coracoid fractures associated with the drill holes in our cohort. (iii) Securing the LARS ligament to itself and additionally in a side-to-side to fashion shares the load within the construct. Failure of the whole construct would require failure at multiple fixation points, creating some allowance for suture failure without loss of reduction. (iv) The LARS ligament is stiff, therefore loss of reduction by creep relaxation is unlikely.[9,18] (v) Arthroscopic assisted reconstruction provides better visibility of the passage and positioning of the LARS ligament around the coracoid, ensuring the surrounding neurovascular structures are visualized and protected. Arthroscopic assessment also allows intra-articular pathologies that are present in 20%-25% of cases to be addressed concurrently.[32] (vi) The technique can be used in both

Table II
Complex cases.

Injury	Previous surgery	Surgery	Complication
Segmental clavicle fracture and chronic ACJ dislocation		Open reduction internal fixation plus LARS ligament reconstruction	
ACJ dislocation	1. Dog bone 2. Hamstring autograft	LARS ligament reconstruction	
Lateral clavicle fracture nonunion and instability	1. Dog bone 2. Lateral clavicle resection	LARS ligament reconstruction, transacromial plate fixation, sub pec tenodesis and arthrolysis	Postsurgical stiffness requiring arthrolysis
ACJ dislocation with irreparable cuff tear		LARS ligament reconstruction and reverse shoulder arthroplasty	
Lateral clavicle fracture nonunion and instability		LARS ligament reconstruction with bone graft	Asymptomatic clavicle nonunion instability resolved

ACJ, acromioclavicular joint; *LARS*, Ligament Augmentation and Reconstruction System.

Table III
Comparison between preoperative and postoperative outcome scores.

	Preoperative			Postoperative		
	n	Mean (SD)	95% CI	n	Mean (SD)	95% CI
VAS	11	2.73 (0.76)	1.03-4.43	16	0.50 (0.30)	−0.15 to 1.15
Constant	8	53.00 (7.36)	35.59-70.41	15	79.47 (3.34)	71.87-87.07
SST	11	25.09 (6.25)	11.17-39.01	16	85.44 (6.15)	72.34-98.54
ASES	10	50.30 (6.99)	34.48-66.12	15	94.60 (3.15)	87.85-101.35
UCLA	6	19.38 (2.63)	13.17-25.58	16	26.44 (0.53)	25.30-27.57
SACS	7	27.07 (4.63)	15.75-38.39	12	87.38 (5.45)	75.38-99.37
Range of motion						
FF	9	114.44 (17.96)	73.03-155.86	16	171.56 (4.99)	160.92-182.21
LE	8	121.25 (15.29)	85.10-157.40	16	168.44 (6.08)	155.47-181.41
ER1	10	47.00 (8.03)	28.82-65.18	16	65.63 (4.76)	55.47-75.78
IR2	10	52.00 (8.27)	33.28-70.72	16	69.06 (2.89)	62.89-75.23
LE strength	9	4.43 (0.96)	2.21-6.65	16	5.07 (0.40)	4.22-5.92

VAS, visual analog score; *SST*, simple shoulder test; *ASES*, American Shoulder and Elbow Surgeons score; *SACS*, Specific Acromioclavicular Score; *UCLA*, University of California Los Angles Shoulder score; *ER1*, external rotation position 1; *IR2*, internal rotation position 2; *CI*, confidence interval; *FF*, forward flexion; *LE*, lateral elevation.

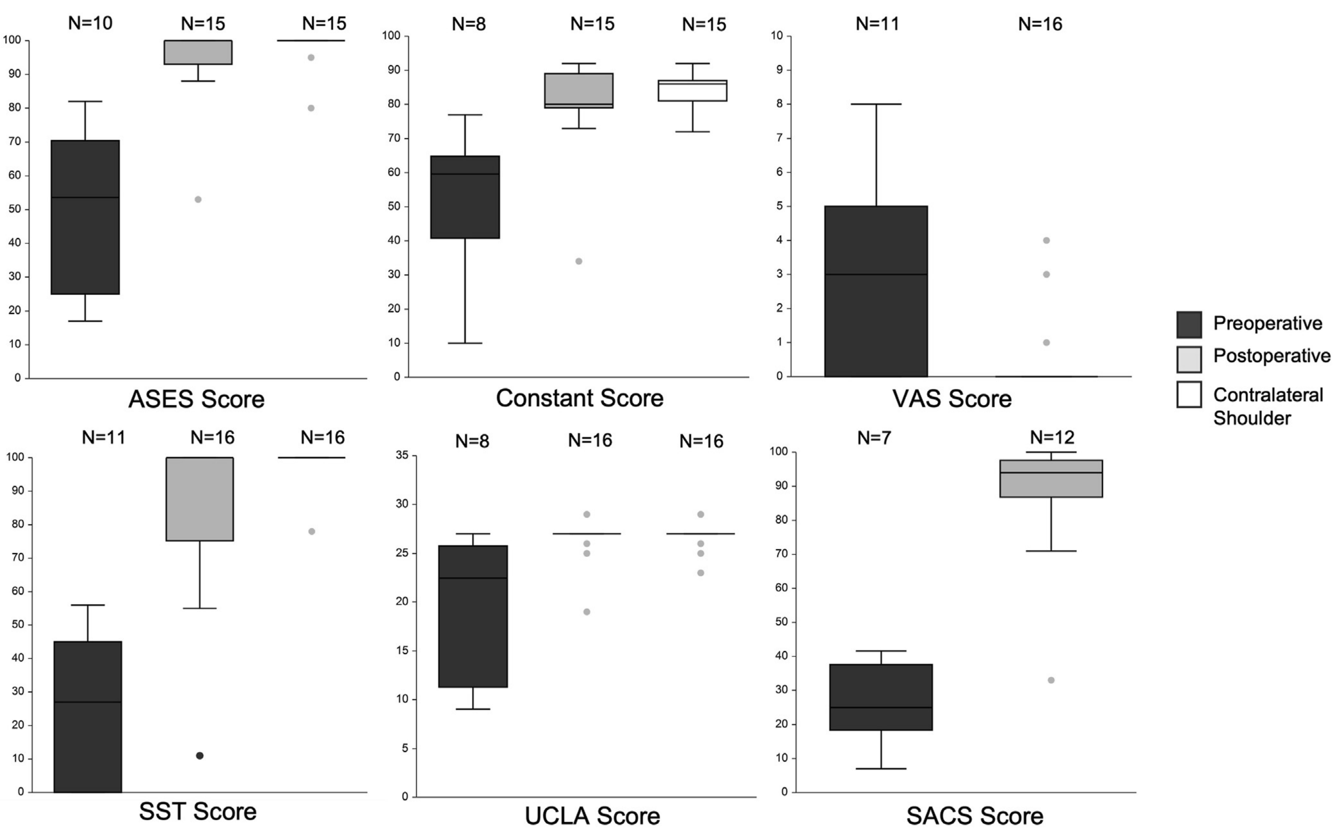

Figure 4 Preoperative, postoperative, and contralateral clinical outcome scores. *ASES*, American Shoulder and Elbow Surgeons score; *VAS*, visual analog score; *SST*, simple shoulder test; *UCLA*, University of California Los Angles Score; *SACS*, Specific Acromioclavicular score.

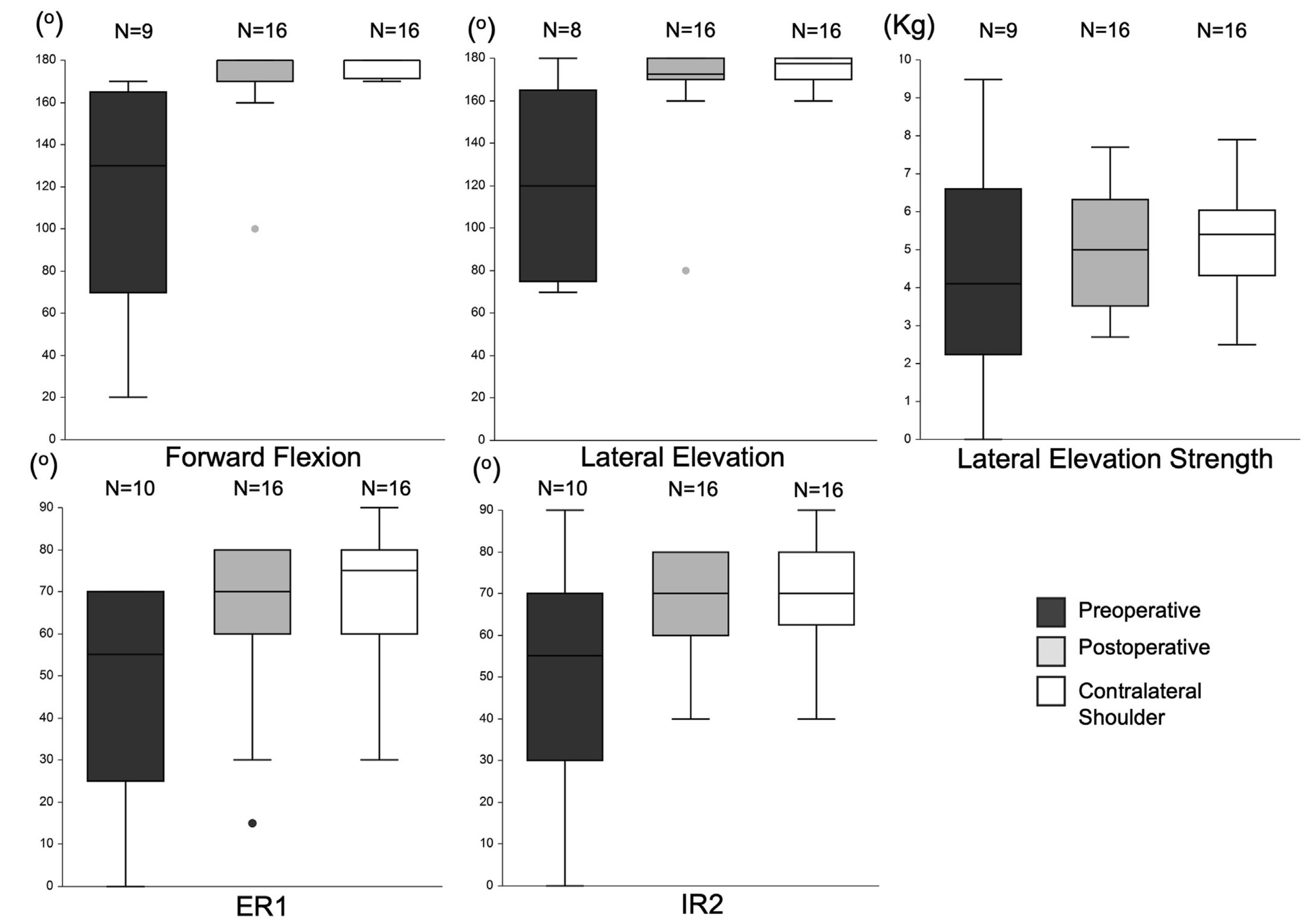

Figure 5 Preoperative, postoperative, and contralateral range of movement. *ER1*, external rotation position 1; *IR2*, internal rotation position 2.

acute and chronic cases, in lateral clavicle fractures, and in revision cases, requiring no additional collective learning curve for surgeon or scrub team necessitating an alternative procedure based on injury chronicity.

Our study had a mean postsurgical follow-up of 23 months. At the final follow-up, there was improvement in all outcome measures, range of motion and lateral elevation strength compared to the presurgery level and the contralateral limb in both acute and chronic cases. It is recognized that some of our reported outcome measures may not pick up the nuisances of ACJ pathology as they are directed to the specifics of the glenohumeral joint. Indeed, the Specific Acromioclavicular score did show improvement. While our results are comparable with other techniques, due to the complexities of case series reporting, it is difficult to make direct comparisons. The need for a core outcome set for ACJ and lateral clavicle fractures has already been highlighted.[29]

Whether synthetic grafts should be used in chronic cases is a matter of debate with no conclusive proof from evidence to date. Many studies have shown favorable results with the use of LARS ligament for both acute and chronic cases. Giannotti et al[13] in their study on 17 patients that included 80% acute and 20% chronic cases, reported excellent outcomes assessed by the Constant Score and SST with all patients returning to preinjury level activities. Motta et al[21] also report excellent outcomes with the use of LARS ligament irrespective of chronicity of the dislocation. At a median follow-up of 5 years (range 2-9 years), they report a mean Constant Score of 97 and 91, and SST score of 11 and 10 for acute and chronic cases respectively. Recently a study by Ochen et al,[23] reported good functional outcome for both acute and chronic dislocations using LARS ligament at a median follow-up of 23 months. They did not find any significant difference in outcome measures based on chronicity of dislocation.

In our series, 3 patients had resubluxation; 1 secondary to infection and removal of ligament, 1 secondary to early high-energy trauma, and 1 due to atraumatic LARS ligament rupture at 6 months The explanations for this are manifold and it cannot be solely attributed to our technique; however, transfixation of the ACJ with a 2-mm k wire may have penetrated the graft thereby weakening it. We have modified our technique by cycling the ligament following k wire fixation to ensure that it is not transfixed. Only 1 of our patients had an atraumatic rupture which is the commonest mode of failure in cases of LARS ligament reconstruction described by Ramsingh et al, Fauci et al and Geraci et al[10,12,24] The patients with complications that returned for follow-up continued to do well and reported acceptable outcomes at the final follow-up.

Two infections noted in our cohort were both initially treated for postoperative stiffness, as there were no overt signs of infection. In the 1 patient who continued follow-up at our institution, 2 samples were positive for Cutibacterium. Synthetic grafts are recognized to cause foreign body reactions and the braided nature of such ligaments increases the risk of potential infection.[6] These 2 cases

Table IV
Complications.

Complication	History	Treatment	Outcome
Infection and LARS Ligament rupture	High alcohol intake and 40 cigarettes per d	Washout removal of LARS ligament. Antibiotic treatment	Did not require revision stabilization
Loss of reduction, wound dehiscence	Fall downstairs 2 d post operatively, sustained lateral clavicle fracture outwith the bone tunnels.	LARS ligament intact but Fiberwire sutures were ruptured. Re-tensioned and resutured plus supplemental fixation with all suture anchor across ACJ	Uncomplicated clinical course following revision surgery
Loss of reduction with LARS ligament rupture	Atraumatic rupture at 6 months	All clavicle tunnels intact. LARS ligament replaced and re-tensioned	Uncomplicated clinical course following revision surgery
Infection and loss of reduction	Unknown	Revised to Dogbone but not within our institution	No further information on the clinical course of this patient

LARS, Ligament Augmentation and Reconstruction System; *ACJ*, acromioclavicular joint.

occurred early in the series; since the routine introduction of Vancomycin powder placed in the wound before closure, no further infections have been noted.

Limitations

A limitation to our study is the small size of our cohort with more than 12 months follow-up. Follow-up was attempted in all patients up to 5 years; however, due to the transitory nature of the young and working population, with few ongoing issues requiring a review after the early postoperative period, and the COVID pandemic, face-to-face clinical follow-up was challenging. Standardized preoperative and postoperative X-rays and contralateral imaging was inconsistent as X-rays were taken by multiple radiology providers, reducing the numbers of patients eligible to measure and compare CC distance. Due to small sample sizes statistical comparisons could not be performed.

Conclusion

The QUASR 3-Tunnel Technique with LARS artificial ligament is a safe and efficient technique for both acute and chronic ACJ reconstructions, lateral clavicle fractures with CC disruption and complex revision cases, with favorable outcomes at the mid-term follow-up.

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References

1. Aliberti GM, Kraeutler MJ, Trojan JD, Mulcahey MK. Horizontal instability of the acromioclavicular joint: a Systematic review. Am J Sports Med 2020;48:504-10. https://doi.org/10.1177/0363546519831013.
2. Baran S, Belisle JG, Granger EK, Tashjian RZ. Functional and radiographic outcomes after allograft anatomic coracoclavicular ligament reconstruction. J Orthop Trauma 2018;32:204-10. https://doi.org/10.1097/BOT.0000000000001079.
3. Beitzel K, Cote MP, Apostolakos J, Solovyova O, Judson CH, Ziegler CG, et al. Current concepts in the treatment of acromioclavicular joint dislocations. Arthroscopy 2013;29:387-97. https://doi.org/10.1016/j.arthro.2012.11.023.
4. Beitzel K, Mazzocca AD, Bak K, Itoi E, Kibler WB, Mirzayan R, et al. ISAKOS upper extremity committee consensus statement on the need for diversification of the Rockwood classification for acromioclavicular joint injuries. Arthroscopy 2014;30:271-8. https://doi.org/10.1016/j.arthro.2013.11.005.
5. Boffano M, Mortera S, Wafa H, Piana R. The surgical treatment of acromioclavicular joint injuries. EFORT Open Rev 2017;2:432-7. https://doi.org/10.1302/2058-5241.2.160085.
6. Çaykara T, Sande MG, Azoia N, Rodrigues LR, Silva CJ. Exploring the potential of polyethylene terephthalate in the design of antibacterial surfaces. Med Microbiol Immunol 2020;209:363-72. https://doi.org/10.1007/s00430-020-00660-8.
7. Dawson PA, Adamson GJ, Pink MM, Kornswiet M, Lin S, Shankwiler JA, et al. Relative contribution of acromioclavicular joint capsule and coracoclavicular ligaments to acromioclavicular stability. J Shoulder Elbow Surg 2009;18:237-44. https://doi.org/10.1016/j.jse.2008.08.003.
8. Enger M, Skjaker SA, Melhuus K, Nordsletten L, Pripp AH, Moosmayer S, et al. Shoulder injuries from birth to old age: a 1-year prospective study of 3031 shoulder injuries in an urban population. Injury 2018;49:1324-9. https://doi.org/10.1016/j.injury.2018.05.013.
9. Falconer TM, Tusak L, Breidahl WH, Annear PT. The Lars Augmented 4-tunnel hamstring “Hybrid” ACLR graft construction allows Accelerated Rehabilitation without Knee Laxity — case series of 111 patients after 2 Years. J Muscoskel Res 2015;18;1550020. https://doi.org/10.1142/s0218957715500207.
10. Fauci F, Merolla G, Paladini P, Campi F, Porcellini G. Surgical treatment of chronic acromioclavicular dislocation with biologic graft vs synthetic ligament: a prospective randomized comparative study. J Orthop Traumatol 2013;14:283-90. https://doi.org/10.1007/s10195-013-0242-2.
11. Frank RM, Cotter EJ, Leroux TS, Romeo AA. Acromioclavicular joint injuries: evidence-based treatment. J Am Acad Orthop Surg 2019;27:e775-88. https://doi.org/10.5435/jaaos-d-17-00105.
12. Geraci A, Riccardi A, Monia Montagner I, Pilla D, Camarda L, D'Arienzo A, et al. Acromion clavicular joint reconstruction with LARS ligament in acute dislocation. Arch Bone Jt Surg 2019;7:143-50.
13. Giannotti S, Dell'osso G, Bugelli G, Cazzella N, Guido G. Surgical treatment of acromioclavicular dislocation with LARS artificial ligament. Eur J Orthop Surg Traumatol 2013;23:873-6. https://doi.org/10.1007/s00590-012-1113-x.
14. Gowd AK, Liu JN, Cabarcas BC, Cvetanovich GL, Garcia GH, Manderle BJ, et al. Current concepts in the operative management of acromioclavicular dislocations: a Systematic review and Meta-analysis of operative techniques. Am J Sports Med 2019;47:2745-58. https://doi.org/10.1177/0363546518795147.
15. Huang FT, Lin KC, Lin CY, Chang WN. Concomitant acromioclavicular and coracoclavicular ligament reconstruction with a Duo-Figure-8 Autogenic graft Wrapping technique for treating chronic acromioclavicular separation. Clin Orthop Surg 2021;13:366-75. https://doi.org/10.4055/cios20194.
16. Hunter TJ, Abdus-Samee M, Balasubramanian S, Grocott N, McClelland D. Medium- to long-term results of acromioclavicular joint stabilisation using the Ligament Augmentation Reconstruction System (LARS) ligament. Shoulder Elbow 2020;12:163-9. https://doi.org/10.1177/1758573219833697.
17. LaPrade RF, Hilger B. Coracoclavicular ligament reconstruction using a semitendinosus graft for failed acromioclavicular separation surgery. Arthrosc J Arthrosc Relat Surg 2005;21:1277. https://doi.org/10.1016/j.arthro.2005.07.020.
18. Liu ZT, Zhang XL, Jiang Y, Zeng BF. Four-strand hamstring tendon autograft versus LARS artificial ligament for anterior cruciate ligament reconstruction. Int Orthop 2010;34:45-9. https://doi.org/10.1007/s00264-009-0768-3.

19. Marcheggiani Muccioli GM, Manning C, Wright P, Grassi A, Zaffagnini S, Funk L. Acromioclavicular joint reconstruction with the LARS ligament in professional versus non-professional athletes. Knee Surg Sports Traumatol Arthrosc 2016;24:1961-7. https://doi.org/10.1007/s00167-014-3231-y.
20. Mazzocca AD, Arciero RA, Bicos J. Evaluation and treatment of acromioclavicular joint injuries. Am J Sports Med 2007;35:316-29. https://doi.org/10.1177/0363546506298022.
21. Motta P, Bruno L, Maderni A, Tosco P, Mariotti U. Acromioclavicular motion after surgical reconstruction. Knee Surg Sports Traumatol Arthrosc 2012;20:1012-8. https://doi.org/10.1007/s00167-011-1627-5.
22. Nolte PC, Ruzbarsky JJ, Midtgaard KS, Tanghe KK, Elrick BP, Douglass BW, et al. Quantitative and Qualitative surgical anatomy of the acromioclavicular joint capsule and ligament: a Cadaveric study. Am J Sports Med 2021;49:1183-91. https://doi.org/10.1177/0363546521995504.
23. Ochen Y, Beks RB, Emmink BL, Wittich P, van der Velde D, Houwert RM, et al. Surgical treatment of acute and chronic AC joint dislocations: five-year experience with conventional and modified LARS fixation by a single surgeon. J Orthop 2020;17:73-7. https://doi.org/10.1016/j.jor.2019.08.030.
24. Ramsingh V, Yewlett AD, Pullen HC. Three intrasubstance failures of a LARS™ ligament used for ligament reconstruction. Ann R Coll Surg Engl 2019;101:e79-83. https://doi.org/10.1308/rcsann.2018.0212.
25. Rios CG, Mazzocca AD. Acromioclavicular joint problems in athletes and new methods of management. Clin Sports Med 2008;27:763-88. https://doi.org/10.1016/j.csm.2008.06.006.
26. Rosso C, Martetschläger F, Saccomanno MF, Voss A, Lacheta L, Beitzel K, et al. High degree of consensus achieved regarding diagnosis and treatment of acromioclavicular joint instability among ESA-ESSKA members. Knee Surg Sports Traumatol Arthrosc 2021;29:2325-32. https://doi.org/10.1007/s00167-020-06286-w.
27. Ryu R, Angelo R, Abrams J, editors. The shoulder : AANA Advanced arthroscopic surgical techniques. 1st edition. CRC Press; 2015. https://doi.org/10.1201/9781003526407.
28. Smith RD, Carr A, Dakin SG, Snelling SJ, Yapp C, Hakimi O. The response of tenocytes to commercial scaffolds used for rotator cuff repair. Eur Cell Mater 2016;31:107-18. https://doi.org/10.22203/ecm.v031a08.
29. The Collaborative Orthopaedic Research Network (CORNET) Study Group. A prospective multi-centre observational cohort study to evaluate frequency, management and outcomes of acute severe (grade III–VI) acromioclavicular joint injuries in the United Kingdom. Shoulder Elbow 2022;15:381-9. https://doi.org/10.1177/17585732221088553.
30. Tiefenboeck TM, Boesmueller S, Popp D, Payr S, Joestl J, Binder H, et al. The use of the LARS system in the treatment of AC joint instability – long-term results after a mean of 7.4 years. J Orthop Traumatol Surg Res 2018;104:749-54. https://doi.org/10.1016/j.otsr.2018.02.010.
31. Trieb K, Blahovec H, Brand G, Sabeti M, Dominkus M, Kotz R. In vivo and in vitro cellular ingrowth into a new generation of artificial ligaments. Eur Surg Res 2004;36:148-51. https://doi.org/10.1159/000077256.
32. van Bergen CJA, van Bemmel AF, Alta TDW, van Noort A. New insights in the treatment of acromioclavicular separation. World J Orthop 2017;8:861-73. https://doi.org/10.5312/wjo.v8.i12.861.