Archives of Orthopaedic and Trauma Surgery (2019) 139:961–970
https://doi.org/10.1007/s00402-019-03136-4

ARTHROSCOPY AND SPORTS MEDICINE

Biceps tenodesis versus tenotomy in isolated LHB lesions: a prospective randomized clinical trial

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Received: 7 August 2018 / Published online: 6 February 2019

Abstract

Introduction Currently there exists no clear evidence concerning the surgical treatment of LHB lesions with either tenotomy or tenodesis. The aim of the study is therefore to evaluate elbow flexion and forearm supination force as well as the biceps muscle distalization according to both techniques in isolated LHB lesions.

Methods Consecutive patients aged 40–70 years with shoulder arthroscopies for isolated SLAP or biceps pulley lesions were prospectively randomized to arthroscopic suprapectoral intraosseous LHB tenodesis or tenotomy. Pre-, 6 and 12 months postoperatively, the SST, ASES, Constant–Murley and LHB scores were recorded. The elbow flexion force was measured in 10°/90° flexion, the supination force in neutral/pronation position. In addition, the maximum upper-arm circumference and its position relative to the radial epicondyle of the humerus were evaluated preoperatively and in follow-up.

Results 20/22 patients (mean age 52.0 ± 8.5; range 36–63 years, 11 male) completed the follow-up. 9/20 were treated with LHB tenodesis (mean age 51.5 ± 9.5; range 37–63 years, 7 male) and 11/20 with tenotomy (mean age 52.8 ± 8.0; range 36–62 years, 4 male). The force measurements and scores showed no significant difference after 12 months. Tenodesis achieved a significant increase in force 6 months postoperatively compared to preoperatively. One tenodesis patient and three tenotomy patients showed a postoperative popeye-sign deformity.

Conclusion This prospective randomized study comparing LHB tenodesis and tenotomy in isolated LHB lesions has shown no significant difference in elbow flexion and forearm supination force and clinical scores after 12 months. After LHB tenotomy, there was a non-significant trend for a higher rate of popeye-sign deformities of the upper arm and biceps muscle cramps.

Keywords Biceps · SLAP lesion · Biceps pulley lesion · Tenodesis · Tenotomy · Thrower shoulder

Introduction

Tears of the proximal long head of biceps tendon (LHB) as SLAP lesions at its origin or biceps pulley lesions more distally resulting in LHB instability in the glenohumeral joint are common causes of persistent shoulder pain.

If conservative treatment is not successful, surgical therapy is indicated. In particular, the focus is on pain reduction and functional improvement. In young patients, a repair of the SLAP complex is indicated, whereas in patients over 35 years tenodesis tends to show better results [5]. Concerning the options for tenodesis, both open and arthroscopic techniques as well as a proximal or distal suprapectoral and a subpectoral position have been established [4, 14, 24]. Here, intraosseous tendon fixation using interference screws results in the highest primary stability [11, 21]. In our own research group, a technique of arthroscopic proximal suprapectoral tenodesis with lasso-loop stitch tendon securing and intraosseous single-limb LHB interference screw fixation was developed, biomechanically tested and clinically evaluated [20, 33].

LHB tenodesis and tenotomy have shown comparable results in regard to pain reduction and functional

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improvement [2, 7]. Simple tenotomy also shows good clinical long-term results without evidence of fatty infiltration or atrophy of the biceps muscle [29]. It is unquestioned that distal biceps tendon rupture results in a significant loss of elbow flexion and supination force [27, 30] but in regard to LHB tenotomy, varying results are reported [25, 31]. After tenotomy, a visible distalization of the muscle belly (popeye-sign deformity of the upper arm) and cramps in the area of the ventral upper arm are more common [10, 26].

Frost et al. showed in their comparative review that the incidence of a postoperative popeye-sign deformity is higher after tenotomy and patients < 60 years of age may perceive a reduced elbow flexion force. The authors also concluded that currently no higher-level evidence exists comparing both therapeutic surgical options and furthermore, that several techniques for biceps tenodesis do not result in sufficient primary or even secondary stability, making it difficult to compare tenotomy with a sufficient tenodesis [8]. To date, there is a lack of evidence and a prospective randomized trial comparing LHB tenotomy and tenodesis for the treatment of isolated LHB lesions has not been published yet. Therefore, the main goal of this study is the prospective randomized evaluation of elbow-flexion and supination force, specific objectification of a popeye-sign deformity and established clinical scores after sufficient primary stable biceps tenodesis or tenotomy for the treatment of isolated LHB lesions without concomitant rotator cuff pathologies. It has been hypothesized that a primary stable LHB tenodesis using an interference screw is significantly superior to tenotomy both in terms of the clinical scores and restoration of elbow flexion and supination force. It was further hypothesized that a popeye-sign deformity and upper arm cramps are more common after tenotomy.

Patients and methods

Study population

Defined as inclusion criteria were isolated SLAP lesion type II–IV according to Snyder and Maffet [18] in patients 40–70 years of age. Exclusion criteria included full thickness rotator cuff tears, osteoarthritis higher than grade II according to Samilson and Prieto [22] in the standard preoperative radiograph, postoperative trauma affecting the operated shoulder, as well as malignant disease and joint infection.

Clinical scores and force measurements were assessed preoperatively, 6 and 12 months postoperatively. Complications were documented. Study enrolment and the first data collection took place the day before surgery. Randomization was conducted using 22 blinded sealed envelopes including a note inside with "TD" ($n = 11$) or "TN" ($n = 11$), respectively. The envelope was opened directly at the beginning of each operation after having confirmed indication for LHB treatment and after having checked the inclusion and exclusion criteria.

Surgical technique

The operative therapy of tenodesis (Fig. 1) was conducted by the senior author in all included patients in a modification of the technique already published and evaluated [13, 33]. The operation is performed in standard beach chair position. The elbow is placed in 90° flexion, the forearm in neutral position in an arm holder. After establishing the standard portals, the tendon is secured intraarticularly via the anterior rotator interval portal with a modified lasso-loop-stitch directly at the entrance of the bicipital groove. The tendon is hereby secured and its anatomical position at the entrance of the groove is marked before tenotomy 20 mm proximally using a 45° angled punch. The LHB is then pulled out above skin level through the anterior portal. Here, the proximal 20 mm of the tendon are armed with a non-interlocking Krackow stitch using a no. 2 Orthocord suture (DePuy Mitek, Raynham, MA, USA). The suture limbs are inserted into the eyelet of a 7.0-mm BC SwiveLock™ (Arthrex, Naples, FL, USA) interference screw. The remaining tendon remnant is resected adjacent to the SLAP complex. In 45° glenohumeral flexion, a 20-mm-deep osseous canal in 135° angulation to the humeral shaft axis is now established with a hand-operated drill (Arthrex, Naples, FL, USA). Depending on the diameter of the biceps tendon, a 6.5-mm drill is used especially in female patients and a 7.0-mm drill in male patients.

Now the tendon is directed into the glenohumeral joint again and pushed 20 mm deep into the bone tunnel guided by the tip of the SwiveLock™. Hereby the suture marked position of the tendon directly at the entrance of the bicipital groove is kept exactly to preserve anatomical tension of the biceps muscle. Now the 19.5-mm-long SwiveLock™ is completely screwed in, herewith compressing and fixating the single tendon limb in the tunnel. At the end the screw ends up flush to the cortex with the tendon securely reinserted.

LHB tenotomy was performed in all patients by the senior author by transecting the tendon directly at the SLAP complex with an angulated punch.

In all patients, the subacromial space was inspected and a subacromial bursectomy and subacromial decompression were performed if indicated. Depending on the preoperative clinical and radiological findings, arthroscopic resection of the acromioclavicular joint was conducted.

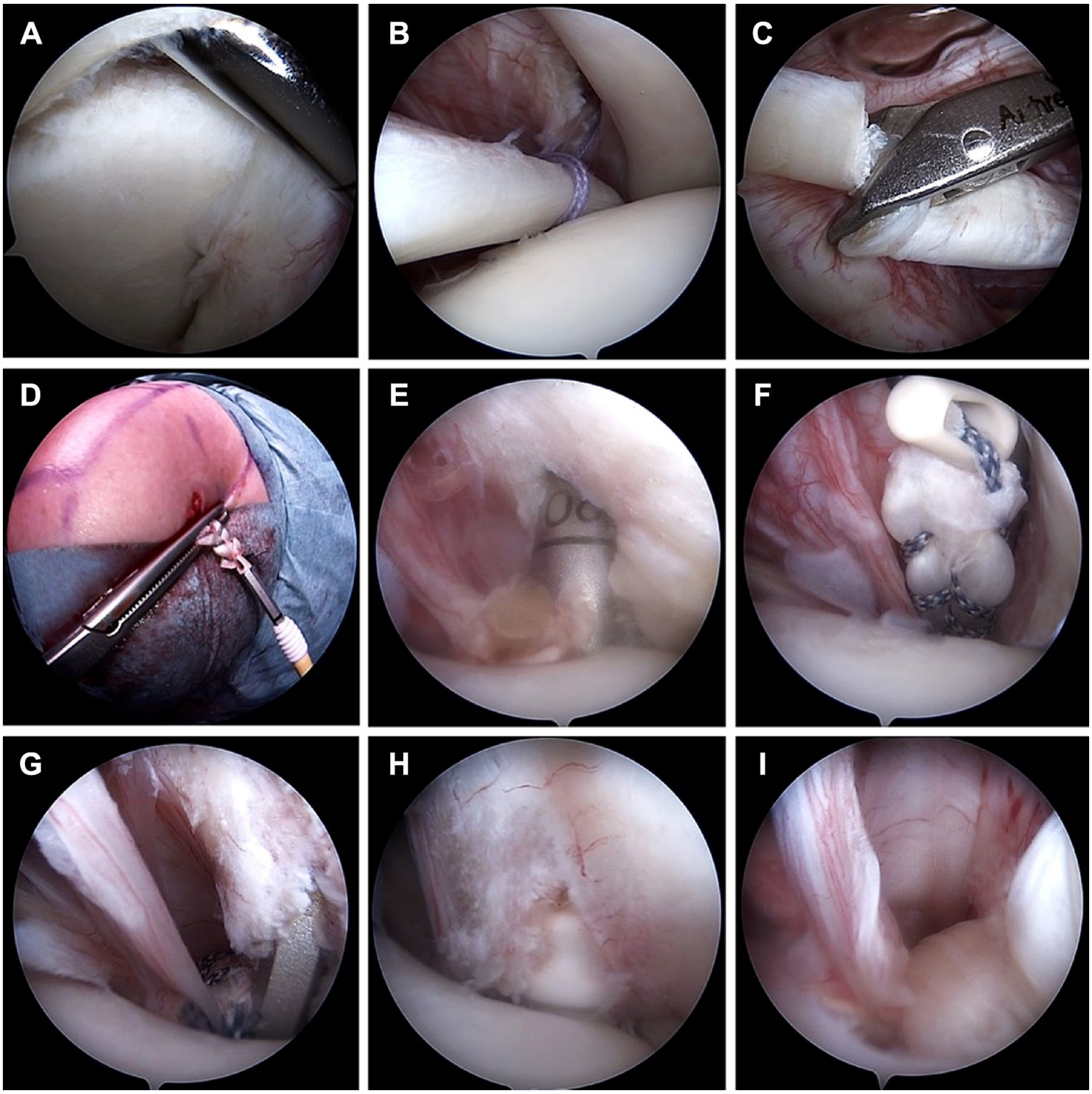

Fig. 1 Surgical technique of the tenodesis. Shoulder arthroscopy in a 45-year-old woman, right shoulder, beach chair positioning of the patient, view from the posterior standard portal. **a** SLAP-IIC lesion; **b** intraarticular securing of the LHB directly at the entrance to the bicipital groove with a modified lasso-loop stitch using a BirdBeak™ via the anterior rotator interval portal; **c** tenotomy of the LHB at the origin after securing; **d** the LHB is pulled above skin level, reinforced proximally to a length of 20 mm with a non-interlocking Krackow stich and then placed at the eyelet of a 7.0 × 20 mm BC SwiveLock™ interference screw anchor; **e** manual drilling of a 6.5 × 20 mm osseous canal directly at the entrance of the bicipital groove; **f** guiding the tendon with the eyelet of the suture anchor into the osseous canal; **g** screwing in of the SwiveLock™; **i** the LHB lies flush between SSC and SSP tendon without impingement or soft tissue irritation. With intraosseous interference screw fixation, a high primary stability of the tenodesis is achieved

Rehabilitation protocol

Early functional physiotherapy with active and passive free glenohumeral motion without immobilization was allowed from the first day postoperatively. Elbow flexion was limited to less than 1 kg for 12 weeks postoperatively.

Objective outcome measurements

All measurements were conducted by the second author who was blinded for the type of surgical therapy. Preoperatively and at each follow-up appointment, the elbow flexion force was measured using the IsoforceControl microprocessor-controlled device (Medical Device Solutions AG, Oberburg, Switzerland). The flexion force was recorded continuously over 5 s with determination of the maximum and average in Newton (N) in 90° of elbow flexion with the patient sitting and in 10° of elbow flexion with the patient standing (Fig. 2). Preoperatively, the measurements were additionally performed on the contralateral side.

For the measurement of the supination force, a T-handle attached to a digital torque measurement adapter with 0.1 mm accuracy (Digital Torque Adapter 412 V1760, Hebesberger Messtechnik, Neuhofen, Austria) was fixed to the tabletop in a standard vise. The measurements were conducted with the shoulder in neutral position, the elbow flexed 90° and the patient sitting (Fig. 2). Three repeated measurements of the maximum force in Newton (N) were recorded in neutral position and in 90° pronation of the forearm with subsequent calculation of the mean value. Preoperatively, the measurements were additionally performed on the contralateral side.

Popeye-sign deformity

Preoperatively, the maximum biceps circumference of both upper arms in forearm supination and maximum contraction was measured and its distance to the lateral epicondyle in centimetre was documented (Fig. 3). At the follow-up examinations this distance was measured again on the operated side. An objective popeye-sign deformity was defined when a distalization of the maximum circumference by more than 20% compared to the preoperative status was present.

Standardized patient-based scores

As standardized scores the Simple Shoulder Test, the ASES [1], the age- and sex-specific Constant–Murley [3] and a modified LHB score [23] were included. In addition to information on elbow function and strength, the LHB score evaluates the occurrence of nocturnal biceps cramps and the external appearance of the upper arm contour an herewith subjective assessment of the popeye-sign deformity.

Statistical analysis

The statistical analysis was carried out using IBM SPSS Statistics (Armonk, New York, USA) in the latest version and in collaboration with the Coordination Centre for Clinical Trials (KKS) of the local University Hospital. Normal distribution was verified using the Kolmogorov–Smirnov test. As a parametric test method for analysing the mean values, the *t* test for dependent samples was carried out. To analyse the influence of the surgical therapy (tenotomy or tenodesis) on the force measurements and the clinical scores, bivariate regression analysis was conducted.

Results

A total of 22 patients were included and prospectively randomized for tenodesis or tenotomy. Two patients in the tenodesis group did not appear for the appointment 12 months postoperatively. 20 patients (mean age 52.0 ± 8.5; range

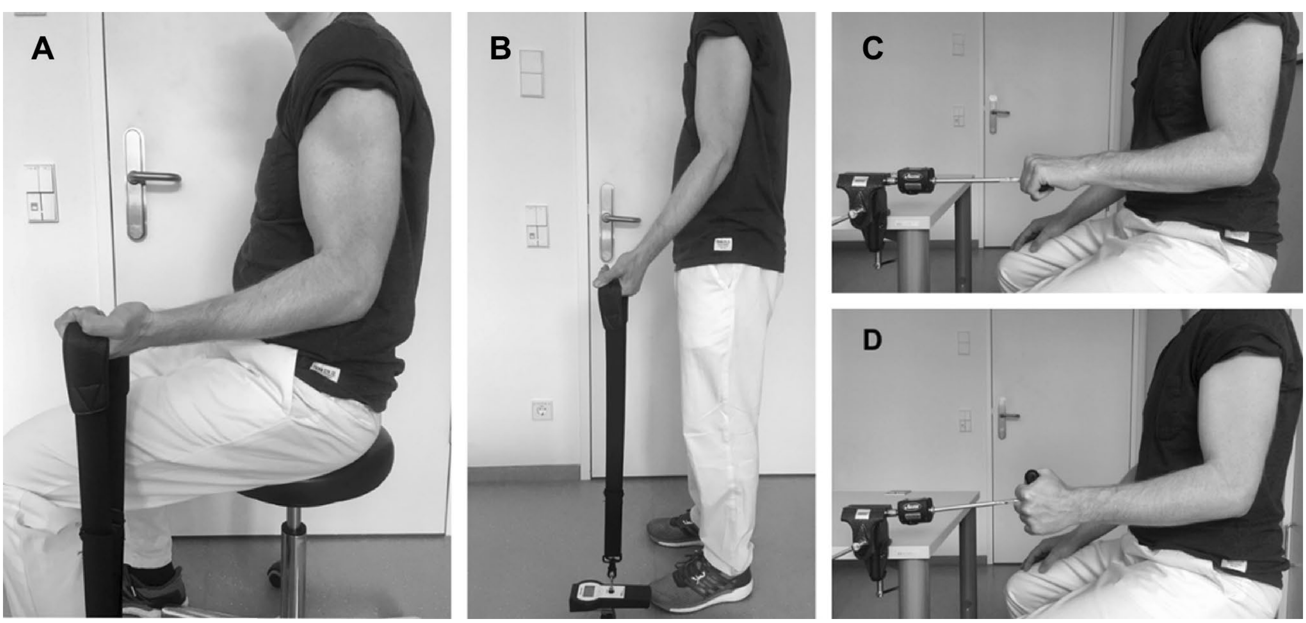

Fig. 2 Force measurements. **a** Measurement in 90° of elbow flexion; **b** measurement in 10° of elbow flexion. **c** Supination force with the forearm pronated; **d** supination force with the forearm in neutral position

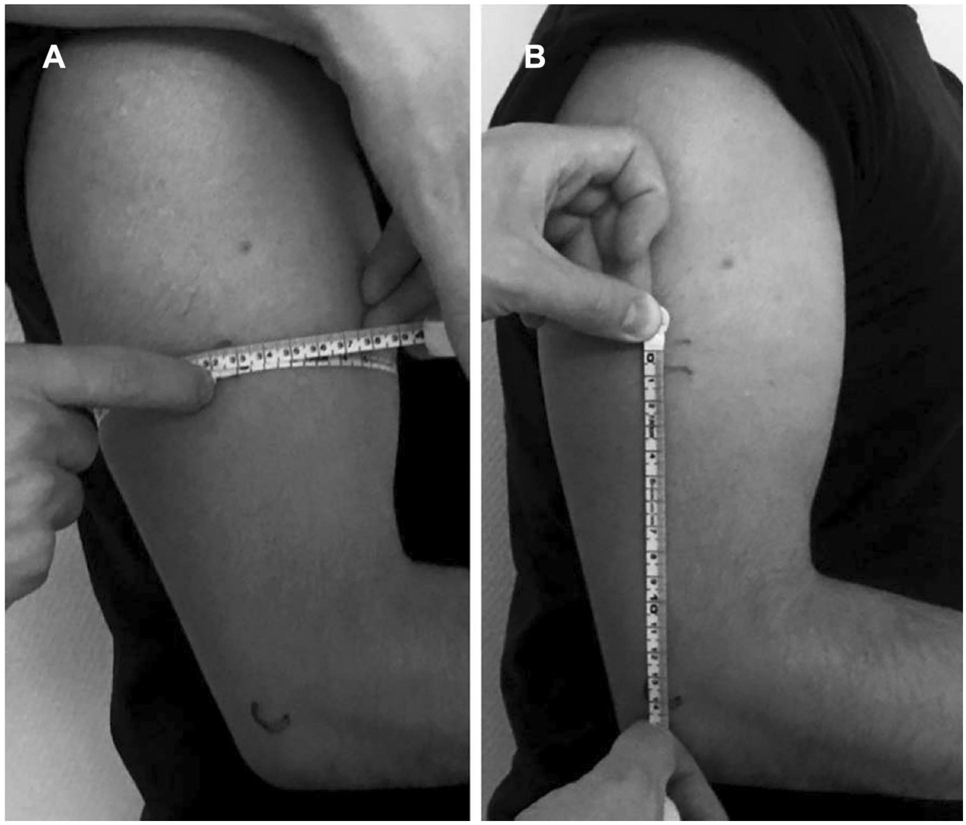

Fig. 3 Popeye-sign measurements. The maximum biceps circumference of both upper arms in forearm supination is measured in maximum contraction (**a**) and its distance to the lateral epicondyle in centimetre is documented (**b**). An objective popeye-sign deformity was defined when a distalization of the maximum circumference by more than 20% compared to the preoperative status was present at follow-up

Table 1 Patient details

Demographics	
Mean age ± SD (range)	52.0 ± 8.5 (36–63)
Gender, male:female	11:9
Type of LHB lesion	*n*
SLAP type II	15
SLAP type III	1
SLAP type IV	2
LHB tendinitis	2
Associated pathologies	*n*
Simultaneous acromioclavicular joint resection and/or subacromial decompression	17

36–63 years, 11 male) completed all follow-up examinations (Table 1). Tenodesis was conducted in 9/20 patients (mean age 51.5 ± 9.5; range 37–63 years, 7 male), tenotomy in 11/20 (mean age 52.8 ± 8.0; range 36–62 years, 4 male). In regard to age ($p = 0.45$) and gender ($p = 0.37$) no significant difference between the groups was seen.

Strength measurements

Tenodesis resulted in a significant increase in 10° and 90° elbow flexion force after 6 and 12 months in comparison to the preoperative values. After tenotomy no significant difference in 10° and 90° elbow flexion force was seen at 6 months postoperatively but 12 months postoperatively, a significant increase in 10° and 90° elbow flexion force was observed in comparison to the preoperative values (Table 2). For the supination force in the neutral and pronated position of the forearm no significant increase after 6 and 12 months in comparison to the preoperative values could be seen. In the direct comparison between tenodesis and tenotomy by bivariate regression analysis, the improvement of the flexion and supination force was not significant at 6 and 12 months postoperative (Fig. 4). The improvement in the flexion force in 10° flexion was greater in the tenodesis group than in the tenotomy group in all postoperative measurements ($p = 0.09$).

Patient-based clinical scores

In the clinical scores, apart from the force measurement in the CMS, a significant improvement for both tenodesis and tenotomy could be seen at 6 and 12 months (Table 3). The force measurement in the CMS was increased significantly in both groups at the 12 months follow-up. In the direct comparison by bivariate regression analysis there was no significant difference in the scores obtained between tenodesis and tenotomy (Fig. 5). The postoperative LHB score for the

Table 2 Force measurements

	Preoperative	6 months	12 months	Contralateral
Tenodesis				
90° elbow flexion	152.3 ± 59.9	166.8 ± 63.1*	172.0 ± 60.5*	180.9 ± 82.8
10° elbow flexion	154.3 ± 63.1	199.3 ± 63.3*	213.3 ± 54.0*	173.7 ± 68.6
Supination pronated	8.4 ± 4.4	9.2 ± 3.7	9.8 ± 3.6	9.2 ± 4.6
Supination neutral	9.5 ± 4.6	10.1 ± 4.1	10.7 ± 4.2	10.8 ± 4.7
Tenotomy				
90° elbow flexion	80.8 ± 43.9	91.1 ± 52.2	97.4 ± 50.6*	113.2 ± 43.9
10° elbow flexion	94.3 ± 38.2	103.3 ± 52.2	117.3 ± 52.2*	126.5 ± 49.4
Supination pronated	4.9 ± 2.7	5.2 ± 2.7	5.8 ± 2.8	6.2 ± 2.6
Supination neutral	5.3 ± 2.4	5.8 ± 2.6	6.7 ± 2.7	6.1 ± 2.1

Mean force in Newton ± SD

*$p < 0.05$

**$p < 0.01$

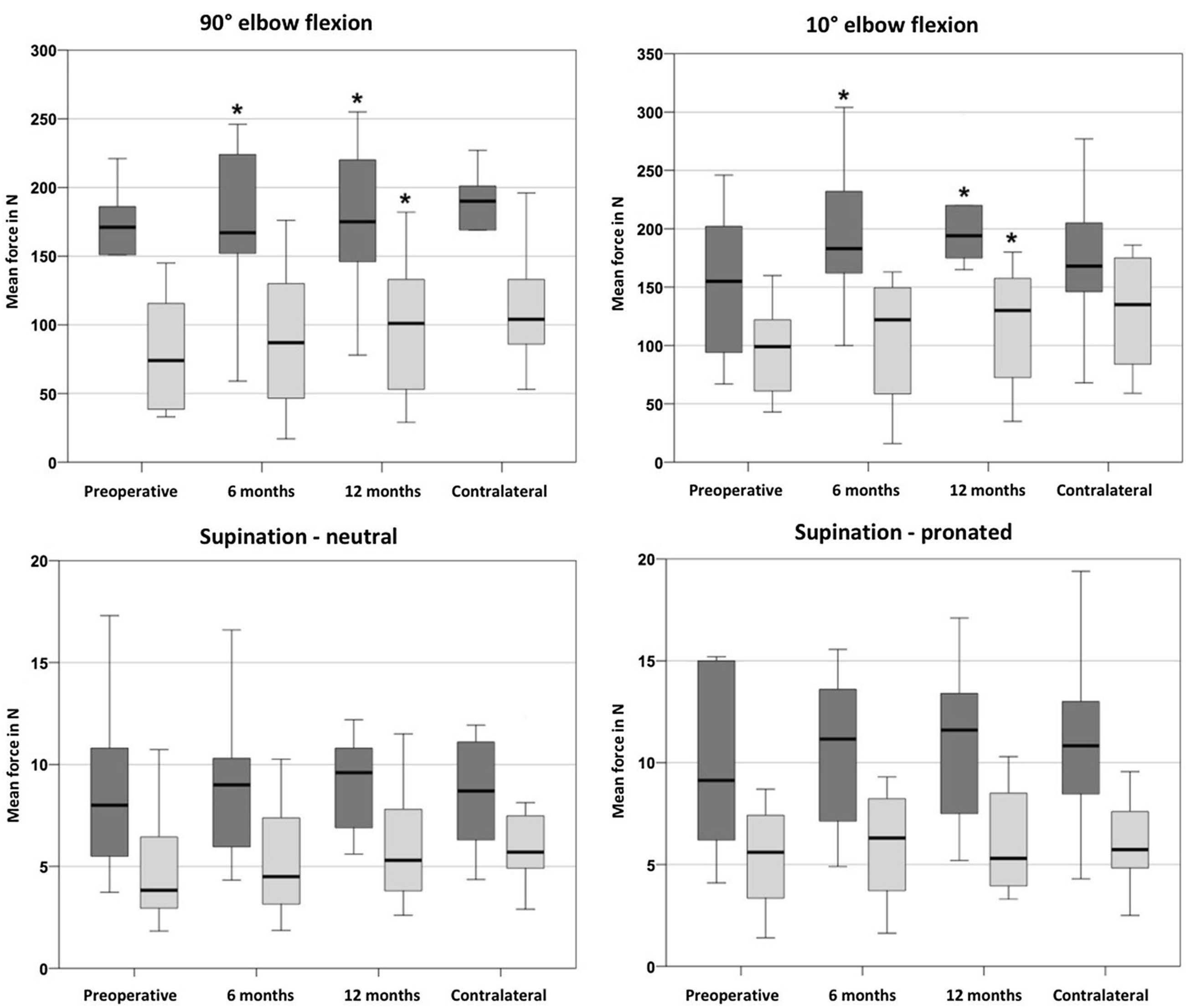

Fig. 4 Boxplot analysis of the flexion and supination force measurements. Dark grey box: tenodesis; light grey box: tenotomy, horizontal line = median. *$p < 0.05$ in comparison to preoperative

Table 3 Clinical scores outcome overview

	Preoperative	6 months	12 months
Tenodesis			
SST	6.1 ± 2.6	10.3 ± 2.1**	11.4 ± 1.1**
ASES	48.7 ± 14.8	85.9 ± 15.5**	95.2 ± 10.8**
CMS			
Pain	8.2 ± 2.4	12.1 ± 3.6*	14.56 ± 0.9**
ADL	10.9 ± 2.8	16.4 ± 3.6**	18.7 ± 2.0**
Mobility	29.3 ± 6.7	35.8 ± 3.4*	39.1 ± 1.4**
Strength	11.7 ± 4.5	13.9 ± 4.9	15.9 ± 4.9**
Total	60.1 ± 8.5	77.7 ± 10.2**	88.1 ± 7.5**
Tenotomy			
SST	5.0 ± 2.7	7.6 ± 3.3**	10.2 ± 2.2**
ASES	45.9 ± 20.7	68.5 ± 22.5**	76.9 ± 20.3**
CMS			
Pain	8.4 ± 3.4	12.1 ± 3.3*	12.6 ± 4.2*
ADL	7.9 ± 3.2	13.5 ± 4.3**	15.9 ± 3.5**
Mobility	26.2 ± 5.7	33.6 ± 4.8**	37.8 ± 3.4**
Strength	8.7 ± 5.8	9.2 ± 4.5	11.0 ± 5.2*
Total	50.9 ± 8.5	68.5 ± 14.0**	77.4 ± 11.8**

Mean ± SD
*$p < 0.05$
**$p < 0.01$

tenotomy group was 15.3 ± 2.2 after 6 months and 17.2 ± 0.6 points at 12 months. In the tenodesis group the score was 16.6 ± 1.6 after 6 months and 17.3 ± 1.1 at 12 months without significant difference in comparison.

Popeye-sign deformity

One patient (11%) after tenodesis and 3 patients (27%) after tenotomy showed an objective postoperative popeye-sign deformity ($p = 0.52$). In the LHB score, the same patient after tenodesis and the same three patients after tenotomy reported a visible difference in the upper arm contour representing a subjective popeye-sign deformity. In the LHB score, two patients in the tenotomy group reported cramps in the biceps at the 6-months follow-up. At the 12 months follow-up no patient reported any biceps cramps.

Discussion

The present clinical trial is the first prospective randomized evaluation of biceps tenodesis compared to biceps tenotomy in patients with isolated LHB pathologies including the evaluation of elbow flexion and forearm supination force, objective and subjective assessment of a popeye-sign deformity and established clinical scores.

The most important finding of this study was that neither the force measurements for elbow flexion and forearm supination nor the clinical scores revealed a significant difference between LHB tenodesis and tenotomy for the treatment of isolated biceps pathologies. In addition to these findings a not significant trend to a higher rate of popeye-sign deformities (27%) after biceps tenotomy compared with tenodesis (11%) and a higher rate of postoperative biceps muscle cramps following tenotomy were found.

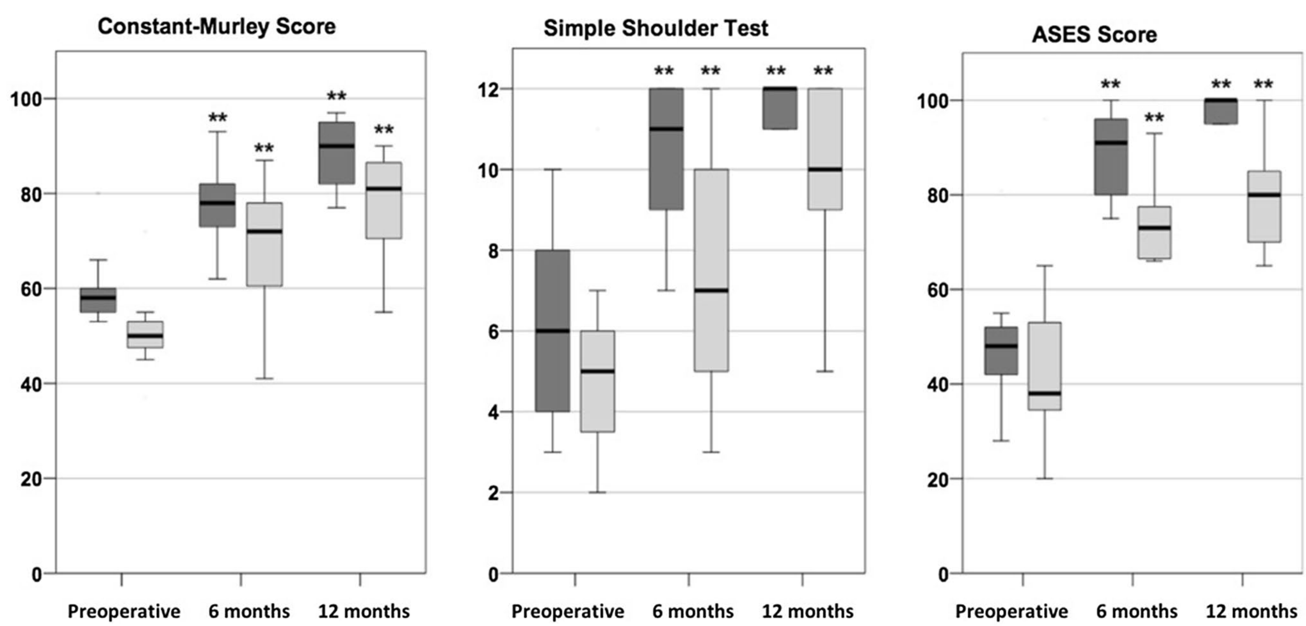

Fig. 5 Boxplot analysis of the clinical scores. Dark grey box: tenodesis; light grey box: tenotomy, horizontal line = median *$p < 0.05$ in comparison to preoperative; **$p < 0.01$ in comparison to preoperative

After both surgical options, LHB tenotomy and tenodesis, a significant increase in the elbow flexion force of the operated side compared to preoperatively without significant difference to the unimpaired contralateral side could be seen 12 months after surgery. Shank et al. also found no significant loss of force for both flexion and supination after tenodesis or tenotomy [25]. Zhang et al. randomized the treatment of the LHB in 151 patients with concomitant rotator cuff repair and found no difference in flexion or supination force as well.

In contrast, Kerschbaum et al. have reported in a retrospective study of preselected patients according to the decision criteria described by Hsu [12], a significantly higher flexion force in patients after knot-free epiosseous proximal suprapectoral tenodesis compared to tenotomy but without comparison to the preoperative status [16]. However, 6% of the tenodesis patients developed a subjective and 69% an objective popeye-sign deformity [17] which may be explained by the biomechanically proven lower primary stability (mean load to failure: 111 N) of epiosseous tenodesis compared to intraosseous tenodesis using an interference screw (mean load to failure: 218 N) [21].

Duff et al. have conducted flexion force measurements on 103 patients following tenotomy and found no significant decrease [6]. However, Wittstein et al. showed a significant reduction of the supination, but not of the flexion force in comparison to the contralateral side and to the treatment by tenodesis [31]. At a median follow-up of nearly 7 years after tenotomy, The et al. found a significant loss of flexion and supination force in their patient collective compared to the opposite side [28]. In the same study population, no muscle degeneration or fatty infiltration could be seen [29]. In the present study, tenotomy resulted in a subjective and objective popeye-sign deformity in 27% of the patients, which is comparable to other studies [6]. Here, the vinculum of the LHB may partially limit further distalization of the tendon below the bicipital sulcus [9]. If the proximal end of the LHB including a part of the SLAP is prominent enough, a certain *“autotenodesis effect”* is possible and the force needed to further distalize the tendon is significantly greater than if the tendon is severed in the distal intra-articular portion.

The allowance of free functional rehabilitation in the present study is based on biomechanical measurements that have shown a primary stability of > 218 N for the intraosseous LHB tenodesis with interference screw fixation [21]. For a comparable operative technique, Wolf et al. have reported a load to failure of 310 N. In the same study used as the basis for the ISAKOS recommendation in favour of LHB tenodesis the authors analysed 10 LHB tenotomies in a cadaveric biomechanical setting, of which 40% failed after a cyclic load of 50 N, the other 60% failed at a load of 110 N [32]. Nordin et al. were able to show that with 1 kg of load in the hand in elbow flexion a load of 112 N results at the proximal LHB [19]. Thus, for an early functional therapy after LHB tenotomy, a load of 1 kg in the hand would already be higher than the load to failure. Frost et al. have concluded in their comparative review that restrictive physiotherapy with immobilization following tenodesis may possibly reduce some benefits compared to tenotomy [8].

After tenodesis a greater increase especially in 10° flexion force, albeit not significant, compared to tenotomy could be seen in the present study. This may be explained by an improved pretensioning of the biceps muscle after tenodesis. The low incidence of popeye-sign deformities after LHB tenodesis in this study with consecutively less biceps cramps despite early functional rehabilitation without limitation of the shoulder activity is most likely based primarily on the high primary stability (> 218 N) of the intraosseous tendon fixation [21]. In the present study, using the absorbable 7.0-mm biocomposite interference screw for tenodesis, 11% of the patients showed a subjective and objective popeye-sign deformity at 12 months compared to 18% in our study population in which the absorbable 6.25 mm PLLA screw was used [13, 33] with the same size of the drilled bone tunnel (6.5 in female or 7.0 mm in male patients) which may indicate a further increase in primary stability by using the larger screw.

Limitations

No power calculations were conducted prior to the beginning of the study and the number of patients is low for a prospective randomized study design. The low number of included patients is mainly based on the restrictive inclusion criteria with isolated LHB pathologies. Two patients in the tenodesis group did not appear at the 12 months follow-up appointment.

Although established and used in most LHB studies with flexion force measurements, the comparison with the healthy contralateral side can be seen critically. Kerschbaum et al. showed in healthy volunteers that there are significant differences in elbow flexion and supination strength between the dominant and non-dominant arms, and therefore, do not recommend to use the non-operated side as a reference [15].

Strengths

The study presented follows a prospective randomized study design including only isolated LHB lesions. Surgical therapy was performed standardized by a single surgeon (senior author). The operative technique for tenodesis was developed on the basis of biomechanical studies and has already been successfully evaluated after 12 and 24 months [13, 33]. Standardized and internationally validated patient-based scores were used. All force measurements were performed standardized by a single investigator (second author) who was blinded for the patients' surgical treatment option.

Although there was no significant benefit of tenodesis over tenotomy in terms of strength restoration and clinical scores in the present and most available studies, a recent survey among members of the American Shoulder and Elbow Society showed that 94% of the specialized shoulder surgeons ($n = 142$) would prefer an LHB tenodesis in a 45-year-old patient with an isolated LHB lesion. In a 50-year-old patient with a concomitant rotator cuff tear, 60% of the surgeons would still choose a tenodesis [4]. Hsu postulated that especially young and slender patients with high functional and cosmetic demands benefit from tenodesis [12]. This certainly remains in our opinion valid for further practice even if, as confirmed by the present work, the objective parameters do not provide any justification.

Conclusion

This prospective randomized study comparing a primary stable biceps tenodesis and biceps tenotomy in isolated LHB lesions revealed no significant differences in flexion and supination strength as well as in the clinical scores after 12 months. Following LHB tenotomy, there was a trend to a higher rate of cosmetic deficits in the form of a popeye-sign deformity of the upper arm with distalization of the biceps muscle and a higher rate of temporary biceps muscle cramps.

Compliance with ethical standards

Conflict of interest All authors declare that they have no competing interests. The senior author receives royalties by Arthrex, (Freiham, Germany), Smith & Nephew (Hamburg, Germany) and Lima (Hamburg, Germany) which have no influences on this study.

Research involving human and animal participants All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The local ethics committee approved this study (Registration Number 4647R).

Informed consent Written consent was given by all participants.

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