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ARTHROSCOPY AND SPORTS MEDICINE

Assessments of activities of daily living after arthroscopic SLAP repair with knot-tying versus knotless suture anchors

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Abstract

Purpose The clinical influence of knot-tying or knotless anchor systems for the arthroscopic repair of SLAP lesions (superior labrum lesion from anterior to posterior) remain unclear.

Materials and methods In a retrospective cohort analysis, 61 of 78 (78.2%) patients with isolated symptomatic SLAP II lesions were examined with a minimum of 24 months after arthroscopic SLAP repair compared to a control group: 28 patients with knot-tying anchors (group I, G1; 28.95 ± 9.48 years, 23 male/5 female), 33 with knotless anchors (group II, G2; 31 ± 10.09 years, 26 male/7 female) and 140 healthy volunteers (group III, G3; 30.9 ± 8.9 years, 109 male/31 female). The clinical assessment included an examination and estimated parameters of ADL (activities of daily living), the CS (Constant score), ASES (American Shoulder and Elbow score), DASH (disability of arm-shoulder hand) and the RS (Rowe score).

Results The ROM analysis recorded no significant differences for the external rotation in 0° abduction (G1 63.75° ± 15.55° versus = vs G2 65.30° ± 18.15°; $p_{\mathrm{ERG1\ vs\ G2}} = 0.72$). The clinical outcomes revealed significantly decreased pain status in G1 for the O'brien test and in G2 for the Palm-up test, whereas Yergason test showed similar pain levels ($p_{\mathrm{O'brien}} = 0.03$; $p_{\mathrm{palm\ up}} = 0.02$; $p_{\mathrm{yergason}} > 0.5$). The pulley associated rotator cuff tests revealed a significantly inferior force status in G2 compared to G1 ($p_{\mathrm{lift\text{-}off}} = 0.005$, $p_{\mathrm{Jobe}} = 0.02$) whereas the further rotator cuff assessments were equal. In general, the intervention group showed increased pain level and functional deficits compared to the G3. The score analysis detected no significant differences with $P_{\mathrm{CSG1\ vs\ G2}}$, $P_{\mathrm{ASESG1\ vs\ G2}}$, $P_{\mathrm{DASHG1\ vs\ G2}}$ and $P_{\mathrm{RSG1\ vs\ G2}}$ all > 0.05 and significant impairments compared to G3 in all scores $p_{\mathrm{G1/G2\ vs\ G3}} < 0.05$ ($CS_{G1} = 88.28 \pm 14.42$, $CS_{G2} = 92.73 \pm 9.24$, $CS_{G3} = 96.2 \pm 4.96$; $ASES_{G1} = 81.10 \pm 21.69$, $ASES_{G2} = 85.35 \pm 17.12$, $ASES_{G3} = 94.95 \pm 10.39$,; $DASH_{G1} = 35.75 \pm 13.44$, $DASH_{G2} = 36.03 \pm 17.55$, $DASH_{G3} = 27.13 \pm 6.52$; $RS_{G1} = 90.71 \pm 9.88$, $RS_{G2} = 88.33 \pm 11.22$, $RS_{G3} = 92.96 \pm 11.27$).

Conclusions The clinical assessment revealed for both anchor systems similar outcomes but showed general underestimated impairments after the SLAP repair surgery compared to the healthy control. The clinical status only marginally differed between both techniques, wherefore the present assessment of ADL allowed no recommendation of one of these two specific surgery technique for SLAP repair.

Keywords SLAP lesion · Arthroscopic SLAP-repair · Suture anchor horizontal knot · Knotless

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Introduction

Andrews et al. [1] and Snyder et al. [2] initially described the pull-off injury of biceps origin from the cranial glenoid, respectively, the consecutive cranial labrum pathology. Snyder coined the term "SLAP lesion" in 1990 for injuries of the _superior labrum from anterior to posterior position and proposed a descriptive classification [3]. Regarding the Snyder classification of SLAP lesions, the SLAP II subtype correlates to lesion described by Andrews ("Andrews" lesion), and encompasses 50–55% of all SLAP injuries [4–6].

Demographic data analysis revealed, that patients with SLAP injuries are generally dividable into "young" patients with micro- and macrotraumatic lesions (< 30 years) and "old" patients with degenerative pathologies (40 to 49-years) [7]. These cohorts have to be analyzed separately because the pathologies and concomitant lesions differ between both cohorts. According to the classification of Synder [2], arthroscopic stabilization of the SLAP complex using suture anchor systems is regarded as one method of choice for types II in the young cohort and older patients with tenodesis or tenotomy [8–10]. The arthroscopic SLAP repair of type II lesions with bioabsorbable suture anchors provides a significant improvement in functional capacity and pain relief [11], but there exist only rare comparative studies investigating the clinical outcome after usage of knotless versus knot tying anchor systems. In conclusion of the current cohort studies, knot tying anchor are hypothesized to generate irritations at the musculotendinous integrity of the rotator cuff [12] with cranial knot associated impingement situations [13] and secondary limitations of the rotational glenohumeral capacity [14], but the current literature lacks regarding scientifically proved recommendations for knotless or knot tying suture anchor usage for the anatomic SLAP repair.

The present study, "young" patients after isolated arthroscopic anatomic SLAP repair with knot-tying versus knotless suture anchors were assessed regarding of activities of daily living in a multi- score system with shoulder instability and SLAP specific questionnaires. Primary, we hypothesized that the anatomic SLAP repair with both anchor systems would enable equally superior ADL score outcomes on an equal status for young active patients compared to an healthy and active cohort. We also hypothesized that the knot tying anchor application would generate increased rates of knot associated irritations and impingement situations with secondary functional limitations.

Materials and methods

The local institutional Ethics Committee approved all data collection and randomization procedures, and all the subjects provided their informed consent to their participation in the study (clinical trial registry number: FF 49/2010) (Table 1).

All consecutive patients treated between 2006 and 2014 with isolated anatomic SLAP repair were retrospectively analyzed according the inclusion criteria (Table 2a). The anatomic SLAP repair with knot tying anchors was standardized performed between 2006 and 2009 (group I; GI). After the institutional change to the knotless anchor system, all patients between 2009 and 2014 were stabilized by the arthroscopic SLAP repair with the knotless anchor system (group II; G2). To recruit the healthy control group (group III, G3), 140 volunteers were contacted and selected according to the inclusion criteria (Table 2b). To create a valid control group, the sport activity level of the volunteers had to be analogue to the preoperative sport activity status in the inclusion criteria for the patients (injury > 1 ×/week, Table 2a). The loss of patients (10 patients of G1 and 7 of G2) based on: unavailability, noncompliance, or lack of interest in the study.

Table 1 The table provides the demographic data of the intervention and control groups

	G1	G2	G3	p
Operation period	2006–2009	2009–2014		
Total number/included number	28/38 (73.68%)	33/40 (82.5%)	140	$p_{G1\ vs\ G2} = 0.5$
Male/female	23/5	26/7	109/31	$p_{G1\ vs\ G2} = 0.9$ $p_{G1\ vs\ G3} = 0.8$ $p_{G2\ vs\ G3} = 1$
Age (years) (average ± standard deviation)	28.95 ± 9.48 at surgery	31 ± 10.09 at surgery	30.97 ± 8.90 at examination	$p_{G1\ vs\ G2} = 0.3$ $p_{G1\ vs\ G3} = 0.2$ $p_{G2\ vs\ G3} = 0.8$
Time to surgery (m) (average ± standard deviation)	13.6 ± 19.6	10.7 ± 12.1		$p_{G1\ vs\ G2} = 0.6$
Follow up (m) (average ± standard deviation)	40.45 ± 23.01	29.82 ± 7.30		$p_{G1\ vs\ G2} = 0.06$
Macrotrauma/microtrauma	18 (67%)/9 (33%)	28 (85%)/5 (15%)		$p_{G1\ vs\ G2} = 0.2$
Injury of dominant side/non-dominant side	18/10	17/16		$p_{G1\ vs\ G2} = 0.4$

Table 2 The table provides the inclusion criteria for the interventions groups (2a) and the control group (2b).

(a) Inclusion criteria for patients of G1 and G2
Preoperative:
Age at surgery between 18 and 45 years
Isolated, unilateral symptomatic SLAP II lesion without accompanying injuries
Sport activity before injury > 1 ×/week
No rotator cuff or labrum repair
No prior ipsi- and contralateral shoulder macrotraumatic injury or surgery
No preexisting disadvantages, neurological deficiency, glenohumeral hyperlaxity, GIRD (glenohumeral internal rotation deficit) omarthrosis, no rotator cuff or pulley lesion at both shoulders, no fatty degeneration and tissue lost of the labrum
Postoperative:
No macro ipsi- and contralateral reinjury
No postoperative resurgery
(b) Inclusion criteria for volunteers of G3
Age at examination between 18 and 45 years
Sport activity > 1 ×/week
No prior ipsi- and contralateral shoulder macrotraumatic injury or surgery
No preexisting disadvantages, neurological deficiency, glenohumeral hyperlaxity, GIRD (glenohumeral internal rotation deficit) omarthrosis, no rotator cuff or pulley lesion at both shoulders, no fatty degeneration and tissue lost of the labrum

All surgeries were treated by all together six surgeons, all of them were at least senior physicians.

Surgical techniques

Group I (knot-tying anchor)

All patients were treated with a previously described three-portal technique in the lateral position, using the standard posterior viewing portal and anteroinferior (with a working twist-in cannula, 6.0 mm in diameter 7.0 cm in length) and suprabicipital working portals [15]. After mobilization of the superior labrum–biceps tendon complex, the cranial glenoid footprint was prepared through the anteroinferior portal. The anchor (3.0 mm Bio-Fastak, Arthrex Naples, FL, USA) was implanted via the suprabicipital portal after drill hole placement. According to the "anchor first principle" of the knot-tying anchor system, the sutures were placed through the cranial labrum with a curved suture-passing instrument after the anchor placement. The SLAP repairs were standardly performed with two anchors, which were set ventral and dorsal to the biceps anchor approximately 1 and 11 o'clock and according to the biceps insertions type of Vangsness [16]. After anchor application, the sutures were placed in vertical stitching technique and with the usage of the SutureLasso™ (Arthrex Naples, FL, USA) [17]. The knots were tied through the suprabicipital portal, at first for the anterior and then for the posterior anchor.

Group II (knotless anchor)

According to the "suture first principle", at first the sutures were placed after footprint preparation through the cranial labrum with a curved suture-passing instrument (SutureLasso™; Arthrex Naples, FL, USA [17]). After shuttling the sutures through the suprabicipital portal, the drill hole was placed and the first the anterior anchor and then the posterior anchor were set (3.5 mm Bio-PushLock, Arthrex Naples, FL, USA). Analogue to G1, the SLAP repairs were performed with two anchors ventral and dorsal to the biceps anchor approximately 1 and 11 o'clock and according to the biceps insertions type of Vangsness [16].

Group II (knotless anchor)

According to the "suture first principle", at first the sutures were placed after footprint preparation through rehabilitation directly after surgery, the abduction orthosis (mediSAS® 15; medi GmbH & Co. KG Bayreuth, Germany) was placed in gentile external rotation of 10°–15° degrees of external rotation and 10° abduction for 4 weeks day and night and in week 5 and 6 only at night. The passive abduction and anteversion were allowed to 60° with inflected elbow and without external rotation for week 1–4 after surgery. In weeks 5 and 6, active assisted exercise was permitted, with 90° abduction/anteversion and 20° external rotation. Any tension exposure of the biceps was restricted for 6 weeks Active biceps stress was restricted for 12 weeks.

Physical examination and score assessments

Both shoulders were standardized examined including inspection and palpation to be sure the patient had no further trauma and infection and included ROM in external rotation at the side (0° abduction) and specific tests [18]. For the stability assessments following specific tests were applied: anterior apprehension and posterior apprehension test, front and reer drawer test as well as the relocation test [6, 19, 20], The capsular sufficiency was measured by the sulcus sign assessment [21, 22]. As impingement test the specific tests were measured: anterior (ASI; Hawkins test) and posterior (PSI) impingement test [23–26]. The long biceps tendon (LBT) was tested using the Palm-up test [24], O'Brien test [27] and Yergason test [28, 29].

The musculotendinous integrity was assessed in comparison to the uninjured shoulder and graded into the strengths 0 to 5 according to the British Medical Research Council [30]. The subscapularis unit was measured by the belly-press [31], bear hug [32, 33] and lift-off test [20]. The supraspinatus unit was examined by the Starter test and the Jobe test in elevation at 90° of scapular elevation and + 45° of humeral rotation in "full can position" [24, 33–37]. The infraspinatus and teres minor unit were assessed by the lower external rotation testing at the side (lER) and the high external rotation testing at 90° degree (hER) [38] as well as by the hornblowers sign test (HST) [33, 35, 38, 39].

In addition to the specific musculotendinous tests, the shoulder function was evaluated by the Constant score (CS) [40], the American Shoulder and Elbow score (ASES) [41] score, the disability of arm-shoulder hand questionnaire (DASH) [42, 43] and the Rowe score (RS) [44]. The RS is recommended to assess patient satisfaction separately by a self-reported question with response possibilities of poor, fair, good and excellent. All the participants were examined by the same orthopedic specialist, who had not operated on the included patients.

Statistic analysis

When the data were not normally distributed, we used nonparametric tests. Statistical analyses were performed with the Chi-square, Wilcoxon–Mann–Whitney, Kruskal–Wallis, Friedmann, Wilcoxon matched pair and Fisher–Freeman–Halton's exact contingency panel tests, in the statistical program BIAS (Biometric Analysis of Samples, version 8.4.2 for Microsoft). $p < 0.05$ was considered significant.

The power analysis was performed for the accurate measurement of the primary hypothesis, comparing the previously published functional outcome parameter of the ASES (PMID: 24388713 and PMID: 28675978) with regards to the own healthy control group. The power analysis for the outcome scores, using GPower 3.1.9.2, two groups t test revealed for a sample size of 20 accepted alpha error of 0.05 with a power of 0.95.

Results

After arthroscopic SLAP-repair, 61 of 78 initially included patients (78.21%) were followed with a minimal postoperative interval of 24 months. The demographic data and the inclusion criteria are shown in Tables 1 and 2, there were no significant differences between both groups (all $p > 0.05$).

The clinical examination of the external rotation 0° showed, that there were no significant differences detectable for the intervention groups G1 + G2 (Table 3). The stability and impingement specific assessments revealed benefits for G2 in all parameters, but there were no significant

Table 4 Results of positive instability G1 versus G2 and G3 in percent

	G1 (%)	G2 (%)	G3 (%)	p value
Anterior apprehension	3.75	3.03	9.29	$p_{G1\ vs\ G2} = 0.45$ $p_{G1 + G2\ vs\ G3} = 0.24$
Posterior apprehension	3.75	0	0.71	$p_{G1\ vs\ G2} = 0.29$ $p_{G1 + G2\ vs\ G3} = 0.5$
Front drawer	0	0	1.43	$p_{G1\ vs\ G2} = 1$ $p_{G1 + G2\ vs\ G3} = 1$
Rear drawer	0	0	0	$p_{G1\ vs\ G2} = 1$ $p_{G1 + G2\ vs\ G3} = 1$
Relocation	3.57	0	0	$p_{G1\ vs\ G2} = 0.14$ $p_{G1 + G2\ vs\ G3} = 0.3$
Sulcus sign	10.71	3.03	5	$p_{G1\ vs\ G2} = 0.4$ $p_{G1 + G2\ vs\ G3} = 0.7$

Table 3 Results for external rotation in G1 and G2 at 0° abduction in degree (average ± standard deviation)

	G1	G2	G3	p value
ER	63.75° ± 15.55°	65.30° ± 18.15°	62.04° ± 16.93°	$p_{G1\ vs\ G2} = 0.72$ $p_{G1 + G2\ vs\ G3} > 0.05$
ER opposite	68.21° ± 16.84°	71.06° ± 17.40°	62.61° ± 16.05°	$p_{G1\ vs\ G2} = 0.56$ $p_{G1 + G2\ vs\ G3} = \mathbf{0.015}$

Bold values indicate significance level < 0.05

Table 5 Results of positive impingement G1 versus G2 and G3 in percent

	G1 (%)	G2 (%)	G3 (%)	*p* value
ASI/Hawkins	3.57	3.03	9.29	$p_{G1\ vs\ G2}=0.45$ $p_{G1+G2\ vs\ G3}=0.24$
PSI	3.57	0	0.71	$p_{G1\ vs\ G2}=0.29$ $p_{G1+G2\ vs\ G3}=0.5$

Table 6 Results of positive tests of the LBT in G1 versus G2 in percent

	G1 (%)	G2 (%)	G3 (%)	*p* value
Palm up	25	15.2	7.9	$p_{G1\ vs\ G2}=\mathbf{0.02}$ $p_{G1/G2\ vs\ G3}=\mathbf{0.03}$
O'brien	14.3	27.3	10	$p_{G1\ vs\ G2}=\mathbf{0.03}$ $p_{G1/G2\ vs\ G3}=\mathbf{0.03}$
Yergason	3.6	3	2.1	$p_{G1\ vs\ G2}=0.6$ $p_{G1/G2\ vs\ G3}=0.6$
All tests negative	21 (75)	25 (76)	129 (92)	$p_{G1\ vs\ G2}>0.05$ $p_{G1/G2\ vs\ G3}=\mathbf{0.02}$

Bold values indicate significance level < 0.05

differences neither between both intervention groups nor compared to the control group (Tables 4, 5).

The assessment of the long biceps tendon (LBT) showed poor results for both groups, only 75% in group 1 and 76% and 92% in G3 had no symptoms at all. Whereas the G1 showed significantly higher rates of persisting pain in the Palm-up test, the G2 had significantly increased pain level for the O'Brien test (Table 6). In summary, the intervention groups had significantly increased pain level compared to the control group G3 except the Yergason test.

The assessment of the subscapularis unit revealed for the knotless anchor group (G2) significant impairments. Whereas G1 showed no limitations at all, G2 had in all subscapularis tests significantly increased motoric deficits compared to G1 (belly press test $p_{G1\ vs\ G2} < 0.01$, bear hug test $p_{G1\ vs\ G2} < 0.01$, lift-off $p_{G1\ vs\ G2} = 0.005$). Compared to the control cohort, only the Lift-off test revealed significant deficits for the intervention groups (lift-off $p_{G1/G2\ vs\ G3} = 0.04$).

The supraspinatus unit revealed for the Starter and Jobe test only marginal differences between both groups. The Starter test and the Jobe test showed significant more cases of force reduction in G2 compared to G1 (Starter $p_{G1\ vs\ G2} < 0.05$; Jobe $p_{G1\ vs\ G2} = 0.02$). The Starter test revealed similar outcomes between intervention and control groups, but the Jobe test showed significantly increased pain level for the intervention groups G1 + 2 compared to G3 ($p_{G1/G2\ vs\ G3} = 0.04$).

The assessment of the musculotendinous unit of the infraspinatus and the teres minor for the Hornblower sign test ($p_{G1\ vs\ G2} > 0.05$) and the lower ER at the side (lER $p_{G1/G2}$ >0.5) similar outcome parameter without significant differences, whereas the high ER test in 90° abduction detected significant more cases of force reduction in G2 (hER $p_{G1\ vs\ G2} = 0.02$).

Scores

The score analysis showed, that only the CS detected significant differences between both intervention groups (Table 10a). The analysis of the ASES, DASH and RS (Rowe Score) score systems revealed similar outcome data after both surgical procedures. The comparison of the healthy control group reflected, that after arthroscopic SLAP repair remain in all applied score systems significant impairments for stability, function and pain.

Discussion

The most interesting findings of the present study are that arthroscopic SLAP repair with anchor systems at the young patients showed equally underestimated impairments of the shoulder regarding function and pain in activities of daily livings compared to a healthy cohort. These findings refute the primary hypothesis. Interestingly, the knotless anchor fixation technique showed significantly increased positives signs for persisting LBT-instability and Pulley-associated deficits compared to the knot tying intervention group and the healthy control groups in the O'brien test. These findings also refute the secondary hypothesis.

Previous biomechanical investigations hypothesized, that the placement of the anchors anterior and posterior to the SLAP anchor complex could theoretically normalize the tension the anterior capsulolabral structures via the superior and middle glenohumeral ligaments to the superior labrum [45]. With these regards, knotless and knot tying anchor configurations had equal initial fixation strength and enable arthroscopic repairs of type II SLAP lesions with restoration of the glenohumeral rotation without over-constraining the SLAP anchor complex [46, 47]. The authors assumed, that the knot configuration on the SLAP anchor complex could generate soft tissue irritations at the undersurface of the supraspinatus with clinically relevant impairments. Dines et al. reported 2008 an irritation caused by the knot because of the reduced space between glenoid and acromion what causes gliding of the supraspinatus tendon in the area of the superior labrum where the knot comes to rest [12]. Rhee et al. valued this 2006 as an knot-impingement which results in glenoid erosion [48]. Previous studies revealed that the ROM is reduced after SLAP repair. Boesmueller et al. found reduced active ROM in 28.6% of the patients and reduced external rotation in 9.5% [49]. Katz et al. reported pain and decreased ROM in 75% [50]. A reduced ROM was seen as the result of reduced dynamic movement of the labrum because of a too rigid secure by the knot-tying technique caused by fixating the entire superior labrum by Kartus et al. [13].

The finding of the present physical investigation let assume, that the knotless anchor group (G2) seemed to result in increased rates for persisting incomplete healings of the SLAP complex with consecutive SLAP-instability associated repair. The O'Brien-test was conducted to detect labral instabilities for the cranial labrum and the SLAP complex [27]. For these pathologies, the sensitivity of the O'Brien test varied in the current literature between 54 and 100% and the specificity between 47 and 99% [27, 51]. Chronic instabilities of the SLAP complex are able to generate secondary lesions of the pulley system [52]. With these regards, Braun et al. were able to show, that instabilities of the superior labral anterior posterior lesions were significantly associated with anteromedial and posterolateral pulley tears. The present data show for knotless anchor group (G2) both, increased levels of pathologic O'Brien tests and pathologic tests for the rotator cuff associated to anteromedial and posterolateral pulley structures but no increased levels of pathologic Yergason and palm-up test. So there are no homogeneous results for significant differences between the intervention groups detectable. The clinic differentiation between tenosynovialitis of the LBT and structural lesions of the pulley-associated rotator cuff remain difficult lager [53]. The Bear-hug test optimizes the chance of detecting a tear of the upper part of the subscapularis tendon, which is an important stabilization of the anteromedial pulley system. The Bear-hug test showed the sensitivity in the current literature of 60% and the specificity of 92% [32]. In the present study, the posterolateral pulley including the anterior supraspinatus was examined by the Jobe test in "full can position" [36]. The applied version of the Jobe test has a sensitivity in the current literature of 77% and the specificity of 74% to detect structural lesions of the supraspinatus tendon [36]. Principally, current data show for the 3-T MR unit, that indirect MR arthrography (iMRA) and direct MR arthrography (dMRA) enable similar sensitivity and specificity for superior labral tears (100/100% and 100/100%), for SSC tears (100/86% and 100/100%), and for SSP tears (78/90% and 89/100%) (PMID: 19225775). Regarding the radiologic assessment of the healing of SLAP repair procedures, the dMRA showed only 54% as healed SLAP repairs while 46% of MRAs were interpreted as having a re-torn SLAP repair. While the intraobserver reliability ranged from 0.71 to 0.81, the interobserver reliability between different radiologist ranged from 0.13 to 0.44 which let conclude, that the postoperative MRA assessment of the SLAP repair remain difficult [54]. The present clinical tests for the with cranial subscapularis inserting into the anteromedial pulley and the anterior supraspinatus inserting into the posterolateral pulley were increased in the all applied tests for the knot tying anchor group G2 compared the intervention group 1 and the healthy control group G3 (Tables 7, 8, 9). These present data seem to confirm the current findings, that chronic SLAP complex instability rates show increased rates of pulley associated pathologies [52]. For the present intervention groups G1 and G2 chad been recorded, that the intraoperative assessment excluded pathologies at the pulley structure and the rotator cuff unit. In conclusion, the presented clinical impairments of the SLAP complex and the rotator cuff unit have to be considered as new, which can be considered to base on incomplete healings of the SLAP complex.

Table 7 Results for force grades in belly press test, bear hug test, lift-off test (absolute values)

	G1	G2	G3	*p* value
Belly press test				
1–3/5	0	0	0	
4/5	0	2	1	
5/5 full	28	31	139	$p_{G1\ vs\ G2} > 0.05$; $p_{G1\ vs\ G3} > 0.05$; $p_{G2\ vs\ G3} = \mathbf{0.03}$
Bear hug test				
1–3/5	0	0	0	
4/5	0	2	1	
5/5 full	28	31	139	$p_{G1\ vs\ G2} > 0.05$; $p_{G1\ vs\ G3} > 0.05$; $p_{G2\ vs\ G3} = \mathbf{0.03}$
Lift-off test				
1–3/5	0	0	0	
4/5	0	4	1	
5/5 full	28	29	139	$p_{G1\ vs\ G2} > 0.05$; $p_{G1\ vs\ G3} > 0.05$; $p_{G2\ vs\ G3} < \mathbf{0.001}$

Bold values indicate significance level < 0.05

Table 8 Results for force grades in starter test and jobe test (absolute values)

	G1	G2	G3	*p* value
Starter test				
1–3/5	0	0	0	
4/5	1	2	2	
5/5 full	27	31	138	$p_{G1\ vs\ G2} > 0.05$; $p_{G1\ vs\ G3} > 0.05$; $p_{G2\ vs\ G3} > 0.05$
Jobe test				
1 and 3/5	0	0	0	
2/5	0	1	0	
4/5	1	2	1	
5/5 full	27	30	139	$p_{G1\ vs\ G2} > 0.05$; $p_{G1\ vs\ G3} > 0.05$; $p_{G2\ vs\ G3} < \mathbf{0.01}$

Bold values indicate significance level < 0.05

Table 9 Results for force grade in lER at the side, hER at abduction and hornblowers sign test (absolute values)

	G1	G2	G3	*p* value
lER at the side				
1–3/5	0	0	0	
4/5	0	2	2	
5/5 full	28	31	138	$p_{G1\ vs\ G2} > 0.05$; $p_{G1\ vs\ G3} > 0.05$; $p_{G2\ vs\ G3} > 0.05$
hER 90°				
1–3/5	0	0	0	
4/5	1	3	5	
5/5 full	27	30	135	$p_{G1\ vs\ G2} > 0.05$; $p_{G1\ vs\ G3} > 0.05$; $p_{G2\ vs\ G3} > 0.05$
HST				
1–3/5	0	0	0	
4/5	1	0	0	
5/5 full	27	33	140	$p_{G1\ vs\ G2} > 0.05$; $p_{G1\ vs\ G3} = \mathbf{0.02}$; $p_{G2\ vs\ G3} > 0.05$

Bold values indicate significance level < 0.05

Regarding the clinical score outcome, there were only significant differences detectable between the intervention groups compared to healthy control with similar outcomes between the two intervention groups (Table 10). The current literature analysis confirms the present data, that both anchor systems generate similar outcomes in scores for ADL. Yang et al. described similar ASES and CS outcomes after SLAP repair with 21 patients with knot-tying and 20 patients with knotless anchors [55]. The present meta-analysis of Gorantla et al. revealed in fort the ASES score, that the SLAP repair reached in the average generally good values of 84–97 points [56]. In the present assessments, the scores of ADL showed generally impairments compared to the healthy control, regardless the functional muscle testings. The underlying reasons may be the insufficient SLAP repair healing [54] with consecutive secondary pathologies at the pulley structure [52]. Furthermore, the literature analysis detected inhomogeneous patients cohorts regarding the age and concomitant lesions. SLAP injuries can be separated into "young cohort" (20–29 years) and "old cohort" (40–49-years) injuries [7]. These cohorts have to be analyzed separately because the pathologies of micro- and macrotraumatic lesions differ in the young cohort, but occur as degenerative lesions in the old cohort. Therefore, younger patients are primarily stabilized with SLAP repair and older patients with tenodesis or tenotomy [8–10, 57, 58]. With these regards, the current treatment options including tenotomy and tenodesis of the biceps as well as the conservative treatment have to be analyzed regarding structural healing and clinical outcome. Comparative clinical trials have shown no broad agreement in advantages conferred by these procedures [57, 58], and Schrøeder et al. even questioned the benefits of SLAP repair and tenodesis relative to the outcomes of sham surgery [59]. We included patients until an age of 45 years. The decision to include patients older than 29 years was made intraoperatively depending of the condition of the joint. If no fatty degeneration and tissue lost of the labrum as well as no omarthrosis was found the patient was included corresponding to our including criteria.

This present study had several limitations. First, the assessment of the structural healing and secondary pathologies had been performed only by clinical assessments. Regarding the current literature, only the second look arthroscopy seems be the appropriate procedure to sufficiently assess healing of the SLAP complex and an additional standardized direct follow-up MR arthrography would enable the assessments of the glenoidal healing of the SLAP repair which was restricted by the local ethics committee. Second, the surgical procedures of both groups were done consecutively and not performed during the same time period. Therefore, the results might be influenced by the learning curve and the experience of the surgeon. To avoid a differential bias in terms of surgical expertise between study groups, all surgeons were at least senior physicians.

Third, the retrospective study design generally limits the quality of the findings, but the low incidence of isolated SLAP lesions in the young patient's cohort and the applied strict inclusion criteria make a prospective assessment in a single-center study difficult. This also caused the different follow-up periods between 40.45 ± 23.01 months in G1 and 29.82 ± 7.30 in G2. The minimum follow-up was 24 months

Table 10 Results for instability- and functional specific scores G1/G2 versus G3 (average ± standard deviation)

	G1	G2	G3	*p* value
CS	88.28 ± 14.42	92.73 ± 9.24	96.2 ± 4.96	$p_{G1\ vs\ G2} = 0.06$ $p_{G1/G2\ vs\ G3} < \mathbf{0.0001}$
ASES	81.10 ± 21.69	85.35 ± 17.12	94.95 ± 10.39	$p_{G1\ vs\ G2} = 0.58$ $p_{G1/G2\ vs\ G3} < \mathbf{0.01}$
DASH	35.75 ± 13.44	36.03 ± 17.55	27.13 ± 6.52	$p_{G1\ vs\ G2} = 0.51$ $p_{G1/G2\ vs\ G3} < \mathbf{0.00001}$
RS	90.71 ± 9.88	88.33 ± 11.22	92.96 ± 11.27	$p_{G1\ vs\ G2} = 0.53$ $p_{G1/G2\ vs\ G3} < \mathbf{0.001}$

Bold values indicate significance level < 0.05

to avoid to early post-repair testing, a maximum follow-up was not defined. The possibility of a bias based on attrition cannot be excluded but currently there's no study with worsened results of a cured SLAP lesion over time. Fourth, Six surgeons performed the operations which can cause a bias but all of them were at least senior physicians to reduce the risk of a training curve bias. Fifth, we wanted to exclude an "older" cohort with natural attrition in the glenohumeral joint.

Conclusion

The clinical assessment revealed for both anchor systems similar outcomes but showed general underestimated impairments after the SLAP repair surgery compared to the healthy control. The clinical status only marginally differed between both techniques, wherefore the present assessment of ADL allowed no recommendation of one of these two specific surgery technique for SLAP repair.

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