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Prospective outcome analysis following tenodesis of the long head of the biceps tendon along with locking plate osteosynthesis for proximal humerus fractures

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ABSTRACT

Background: Fractures of the proximal humerus are often associated with lesions of the long head of the biceps (LHB) tendon. This often leads to prolonged shoulder pain. Hence, many surgeons decide to perform a tenodesis of the LHB tendon simultaneous to ORIF. The purpose of this study was to evaluate the postoperative outcome after interlocking plate fixation and biceps tenodesis for treating proximal humerus fractures.

Methods: 56 patients (38 females, 18 male) suffering from proximal humerus fractures who underwent surgery were retrospectively included. 26 of these 56 patients (19% Neer II, 38% Neer III, 43% Neer IV) were treated with simultaneous tenodesis of the LHB tendon when ORIF using interlocking plate fixation was performed. 30 patients (17% Neer II, 40% Neer III, 43% Neer IV) served as control group receiving only interlocking plate fixation. The patients were asked to complete the Munich Shoulder Questionnaire (MSQ) for evaluation of postoperative shoulder function. Results of the Disabilities of the Arm, Shoulder and Hand (DASH) Score and Shoulder Pain and Disability Index (SPADI) were calculated from the MSQ. Patients were clinically evaluated for a positive O'Brien test and Popeye sign.

Results: The tenodesis group demonstrated significant superior outcome regarding the MSQ (mean 90.47 points vs. 79.41 points, $p = 0.006$), DASH Score (mean 4.2 points vs. 16.81 points, $p = 0.017$) and SPADI (mean 94.59 points vs. 83.56, $p = 0.045$). Flexion, external rotation and the capability of throwing a soft ball were significantly improved in the tenodesis group compared to the control group. The O'Brien test as indicator for lesions of the LHB was positive in fewer patients of the tenodesis group (2/26, vs. 21/30, $p = 0.001$). There was no significant difference of a positive Popeye Sign.

Conclusion: Our results show evidence of an improved shoulder function when a simultaneous tenodesis of the LHB tendon is performed during treatment of proximal humerus fractures using interlocking plate fixation.

Introduction

Postoperative shoulder pain and limited range of motion are frequently observed after surgical treatment of proximal humeral fractures. Several studies describe extensive fracture-related soft tissue lesions of the shoulder joint including the long head of the biceps (LHB) tendon [1–4]. Especially due to its vestigial intra-articular portion in the glenohumeral joint and the poor blood supply within this area, pathologies of the LHB tendon are very common and were identified as reasons for prolonged shoulder pain associated with restricted forward flexion [5–10]. To limit these effects, many surgeons adopted to this problem by performing either simultaneous tenotomy or tenodesis of the LHB tendon alongside locking plate osteosynthesis. Several studies showed significant pain relief after performance of this rather simple procedure [8,11]. Regarding global shoulder function, there is no difference reported between tenodesis and tenotomy. However, the incidence of cosmetic deformity of the arm is higher in tenotomy patients [9,12]. Up to now, there is limited information regarding the role of LHB tendon treatment in proximal humerus fractures. It was shown that patients who suffered from complex

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four-part fractures benefit from a tenodesis when hemiarthroplasty was performed [13]. In a preselected study population Kerschbaum et al. [14] achieved good clinical results when patients received simultaneous biceps tendon treatment during plate osteosynthesis. The outcome was independent of the kind of intervention (tenotomy vs. tenodesis). However, neither general recommendations whether or not to perform surgery of the LHB tendon during proximal humerus fracture treatment nor long-term results of interlocking plate fixation and simultaneous tenodesis of the LHB tendon exist in the current literature. Therefore, the purpose of this study was to evaluate the postoperative outcome after interlocking plate fixation and biceps tenodesis for treating proximal humerus fractures.

The study protocol was approved by the local board of ethics (Ethics Committee of the medical faculty, Klinikum rechts der Isar, Technical University of Munich, Germany; study number 71/15 S).

Patients and methods

For this retrospective cohort study the in-house fracture register of the years 2014 and 2015 was searched for patients who underwent interlocking plate osteosynthesis for proximal humerus fractures. Patients' records were scanned whether a tenodesis of the LHB tendon was performed. Before patients were enrolled written informed consent was obtained. Exclusion criteria were dementia, psychiatric diseases or other cognitive diseases.

The identified patients were divided as follows: group I underwent ORIF of the proximal humerus using interlocking plate fixation including tenodesis of the LHB tendon and group II which was treated equally without tenodesis. Patients of both groups were operated by two senior shoulder trauma experts. All fractures were classified according to the Neer classification [15]. After surgery the enrolled patients underwent routine follow-up examinations at our outpatient clinic for an average of 1.5 years. The focus was set on the anatomic profile of the upper arm and its possible deformity (Popeye sign) as well as on the incidence of a positive O'Brien test as indicator for potential impairment of the biceps tendon. For the O'Brien test, the patients were asked to extend the elbow and flex the affected arm 90° with additional 10° to 15° adduction. Initially, the patients had to pronate the arm with the thumb pointing downwards. Then a moderate downward force was applied with simultaneous resistance of the patient. The examination was repeated in the same manner with the arm in supination and the thumb pointing upwards. The test was considered positive when the patients mentioned a pain relief during supination in comparison to pronation. The pain is thought to originate from lesions in the biceps complex origin [10,16].

In addition, the patients were asked to complete the Munich Shoulder Questionnaire (MSQ) for self-assessment of shoulder function. The MSQ has been validated and its effectiveness for follow-up assessment was demonstrated thoroughly. It furthermore allows for a quantitative assessment of the Shoulder Pain and Disability Index (SPADI) and the Disability of the Arm, Shoulder and Hand (DASH) score [17–20]. The results of both groups were compared using the mann whitney rank sum test.

Statistical analysis was performed using Sigma Stat 3.5 software (Systat Inc, Chicago, IL, USA). The level of significance was set at $p < 0.05$.

Surgical technique

Surgery was performed with the patients laying in a beach chair position. An anterior approach along the deltopectoral interval was used. The incision was 10–15 cm long in line of the deltopectoral groove. While the cephalic vein was retracted, the preparation onto the clavipectoral fascia in the deltopectoral grove was performed. The fascia was then opened for exposure of the humeral head with special attention paid to the axillary nerve. After identifying the LHB tendon in the bicipital grove, tenotomy at the supraglenoidal tubercle was performed. After fracture reduction and fixation using an interlocking plate osteosynthesis, subpectoral soft tissue tenodesis with absorbable transtendinous sutures at the junction of the biceps tendon was performed. After surgery the shoulder was placed in a sling for four weeks. Abduction was limited to 90° for two weeks. From the third postoperative week on patients were allowed to move the shoulder without any restrictions.

Results

In total 56 patients were enrolled whereas 26 patients were allocated to the tenodesis group (18 females, 8 males) and 30 patients to the control group (20 women, 10 men). The gender ratio was 0.44 in group I versus 0.5 in group II ($p = 0.36$). In the tenodesis group the mean age was 60 years (range 19–90 years) compared to the control group of 65 years (range 18–87 years). Fig. 1 depicts the age distribution in both groups. Mean follow-up was 19 ± 6 months. Regarding the fracture patterns 5 patients in each group (19% vs. 17%) were classified as Neer II-fractures. 10 patients (38%)

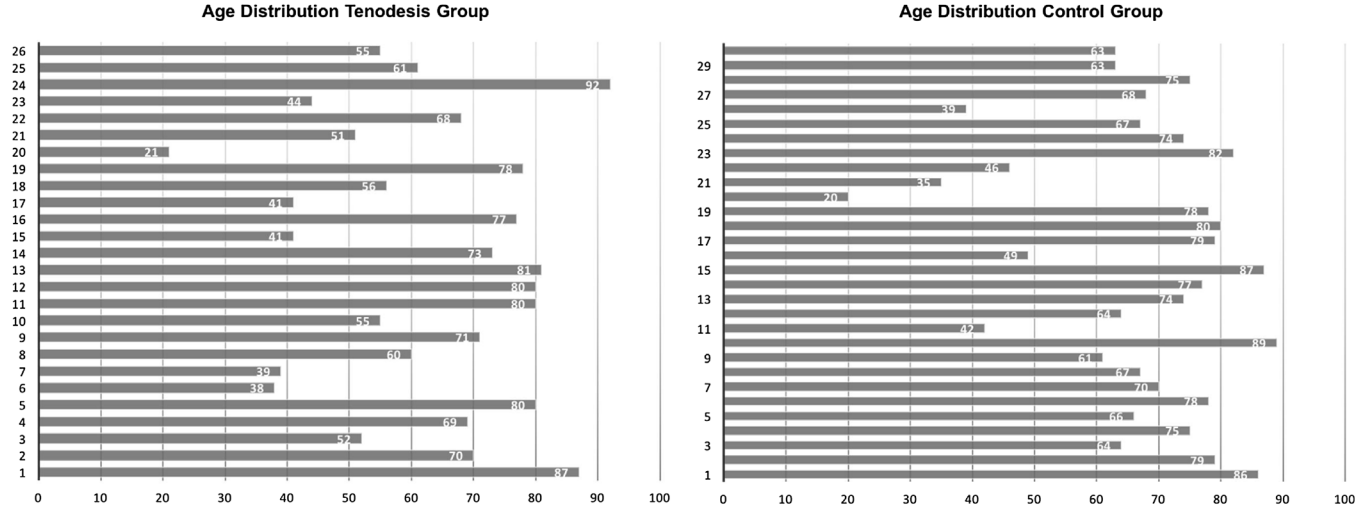

Fig. 1. Age distribution: Tenodesis group, n = 26 (left); Control group, n = 30 (right).

presented with a two-part fracture of the surgical neck (Neer III) compared to 12 patients (40%) in the control group. 11 group I-patients (42%) and 13 group-II-patients (43%) suffered from complex three- and four-part fractures (Neer IV) (more details see Table 1).

Regarding the MSQ the tenodesis group showed superior results compared to the control group (MSQ mean 90.47 ± 4.69 vs. mean 79.41 ± 16.13, p = 0.006; SPADI mean 94.59 ± 5.74 vs. mean 83.56 ± 18.61, p = 0.045; DASH score mean 4.2 ± 4.78 vs. mean 16.81 ± 20.1, p = 0.017).

Analyzing the subscales of the MSQ, group-I-patients presented with a significantly higher degree of flexion (mean 9.61 ± 1.27 points vs. mean 9.61 ± 1.27 points, p = 0.012) and external rotation (mean 7.92 ± 039 vs. 7.07 ± 2.52 points) compared to the control group. Especially in the performance of overhead movements, patients of the tenodesis group showed a greater range of motion in throwing movements than patients in the control group (mean 9.5 ± 0.91 points vs. mean 8.167 ± 2.52 points, p = 0.029). The incidence of a positive O'Brien test was significantly lower in patients with additional tenodesis (2/20, vs. 21/30, p = 0.001). There was no significant difference regarding anatomic deformity including the Popeye sign (3/26 vs. 2/30, p = 0.538) (for more details, see Fig. 2).

Discussion

In the presented study our results show a superior outcome after proximal humerus fractures when the treatment involved a locking plate osteosynthesis along with a tenodesis of the LHB tendon.

Fractures of the proximal humerus are often associated with injury of intraarticular structures of the glenohumeral joint such as the tendons of the rotator cuff or biceps tendon. The standard diagnostic work-up includes radiographs in two orthogonal planes but not mandatorily MRI scans, so that such intraarticular lesions are often missed leading to prolonged pain after surgical fracture treatment only. The widespread use of arthroscopy has uncovered collateral damage accompanying shoulder injuries. Schai et al. [3] investigated 80 patients suffering from proximal humerus fractures with additional arthroscopy. Among fracture-associated injuries such as glenoid labral tears, cartilage damage or rotator cuff injuries, 35% had an affected LHB tendon. Other studies presented similar results [21–23]. Due to the intraarticular course of the LHB tendon within the glenohumeral joint, even mild injuries such as contusion to the shoulder joint can cause LHB tendon lesions [22]. In order to identify histological features which might correlate with evolution of pain, Tosounidis et al. [2] conducted a histologic and immunohistochemical analysis of harvested LHB tendons after complex proximal humerus fractures. The authors detected increased neural differentiation under influence of neoangiogenic stimulation in the study group compared to harvested LHB tendons from human cadavers with no history of shoulder pathologies. The results implicate that the LHB tendon is considered as potential source of pain after proximal humerus fractures on a histological level. These findings highlight the vulnerability of the biceps tendon and stress the importance of adequate treatment to prevent patients from prolonged shoulder pain, which could have been treated easily.

In reviewing the current literature studies on the outcome after simultaneous treatment of the LHB tendon in patients suffering from proximal humerus fractures are quite rare. Soliman et al. [13] analyzed the outcome of patients with complex proximal humerus fracture patterns who underwent hemiarthroplasty along with tenodesis of the LHB tendon. Their findings indicate superior results of the Constant score when tenodesis was performed. Kerschbaum et al. [14] investigated the influence of tenodesis and tenotomy in a collective of 27 patients treated with interlocking plate osteosynthesis. In patients with high cosmetic and functional shoulder demands, tenodesis was the preferred technique. However, there was no evidence for a potential advantage of tenodesis or tenotomy respectively regarding the postoperative outcome. These results are in line with a meta-analysis of Hsu et al. [12] who demonstrated the same outcome regarding global shoulder function but a higher incidence of cosmetic deformity with an associated lower load to tendon failure in patients treated with tenotomy compared to tenodesis-treated patients.

Although Kerschbaum et al. investigated the potential benefit of LHB tendon treatment along with simultaneous ORIF, there was no control group included in the study protocol. To the best of our knowledge, the presented study is the first in the literature analyzing the outcome after LHB tendon treatment compared to a control group in a patient collective of proximal humerus fractures treated with ORIF. Due to slight advantages regarding cosmetic aspects tenodesis was chosen over tenotomy as the preferred therapy. Since group I (tenodesis group) and group II (controls) contained similar patients regarding fracture pattern, age and gender any potential bias can be excluded in our study regarding the complexity of the fractures, the individuals' age or gender. In this study we demonstrated significantly superior MSQ results (mean 90.47 points vs. 79.41 points, p = 0.006) in the tenodesis group compared to the control group. The calculated results of the SPADI (mean 94.59 points vs. 83.56, p = 0.045) and DASH score

Table 1
Results comparing the tenodesis- with the control group. Statistical analysis was performed using the mann whitney rank sum test (p < 0.05).

Results overview:			
	Tenodesis group: n=26	**Control group: n=30**	**Significance:**
Gender:	8 men, 18 women	10 men, 20 women	
Age:	Mean 60 (19-90) years	Mean 65 (18-87) years	
Neer II:	5 (19%)	5 (17%)	
Neer III:	10 (38%)	12 (40%)	
Neer IV:	11 (43%)	13 (43%)	
MSQ:	Mean 90,47 (±4,69)	Mean 79,41 (±16,13)	p=0,006**
SPADI:	Mean 94,59 (±5,74)	Mean 83,56 (±18,61)	p=0,045*
DASH:	Mean 4,2 (±4,78)	Mean 16,81 (±20,1)	p=0,017*
O'Brien test positive:	2/26	21/30	p=0,001***
Popeye sign positive:	3/26	2/30	p=0,538
Flexion:	Mean 9,61 (±1,267)	Mean 9,61 (±1,267)	p=0,012*
Throwing soft ball:	Mean 9,5 (±0,906)	Mean 8,167 (± 2,52)	p=0,029*
External rotation:	Mean 7,92/10 (±0,39)	Mean 7,07/10 (±1,87)	p=0,02*
Age:	Mean 60 (19-90)	Mean 65 (18-87)	p=0,36

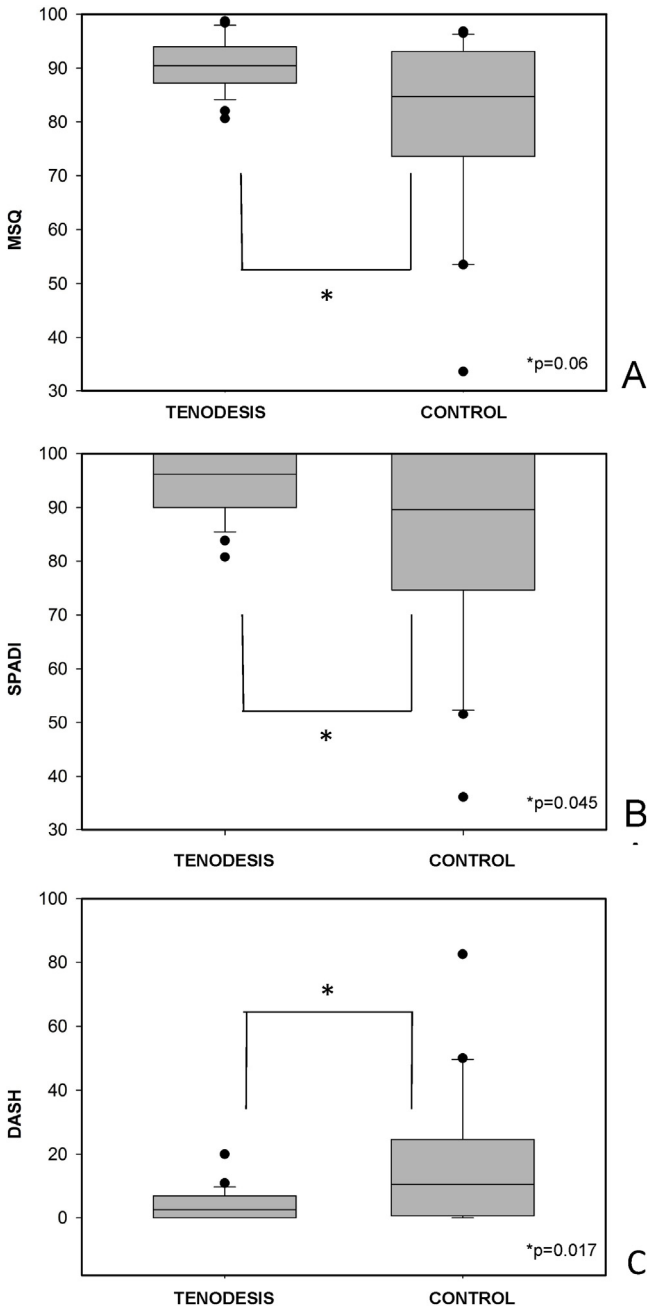

Fig. 2. Results of the MSQ (A), SPADI (B) and DASH score (C). The results of the tenodesis (n = 26) group were compared to the results of the control group (n = 30). Functional Shoulder Scores.

(mean 4.2 points vs. 16.81 points, p = 0.017) and the lower incidence of a positive O'Brien test (2/20, vs. 21/30, p = 0.001) also indicate a better outcome after tenodesis was performed. Focusing on the subscales of the MSQ a significant higher range of motion regarding flexion, external rotation and performing throwing movements resulted for the tenodesis group compared to the control group indicating that tenodesis and simultaneous ORIF does not lead to an impaired shoulder function.

It is difficult to explain the results on a physiological level, since the overall function of the LHB tendon in the shoulder joint is still not completely solved. Sometimes the LHB tendon is described as "appendix of the shoulder" without considering any important function for shoulder movements. With the arm in external rotation the LHB tendon slightly contributes to abduction with a maximum 10% of power [24,25]. Its role as a depressor of the humeral head is still controversial. Biomechanical cadaver studies and radiological data support this thesis because the loss of the LHB tendon result in a superior translation of the humeral head [26,27]. However, by analyzing the activity of the LHB tendon physiologically in normal shoulders and after rotator cuff tears, Yamaguchi et al. [28] detected no activity of the LHB tendon in all ranges of active motion. In 307 patients who underwent arthroscopic LHB tenotomy when suffering from rotator cuff tears, no immediate superior migration of the humeral head was observed [29]. In summary the major known function of the LHB is supination and flexion in the elbow joints.

According to Ahrens et al. [30] we advocate that the function of the LHB on glenohumeral stability and depression of the humeral head is limited and a retaining, abnormal tendon has more negative functional consequences than the loss of the tendon itself. We therefore hypothesize that the observed superior outcome after tenodesis in patients with proximal humerus fractures result from eliminating a potential long-term pain source.

Limitations

For the presented study the data was primarily taken from an in-house fracture register containing preselected patient data. In addition, data analysis was performed retrospectively. However, 56 patients met the inclusion criteria and present a rather high number of cases to minimize a potential bias.

The enrolled individuals suffered from heterogeneous fracture patterns. Mostly presenting with three- (39%) and four-part (43%) fractures. However, the tenodesis and control group had similar portions of two-, three- and four-part fractures according to the Neer classification. Therefore, we consider this effect to be minor. Nevertheless, there might be more undetected individual factors which affect the ability to compare the tenodesis and control group. To overcome this limitation, more patients with less severe fractures should be included in future prospective randomized trials considered as the gold standard with the lowest risk of potential bias. In a next step, future studies could furthermore include the procedure of a tenotomy as additional surgical procedure and postoperative arthroscopies could deliver an in vivo result of LHB tendon treatment.

Conclusion

We were able to present benefits of tenodesis in a collective of patients treated with ORIF when suffering from proximal humerus fractures. Apparently, this rather simple procedure has a positive influence on outcome and range of motion of the glenohumeral joint.

Based on our results and taking into account, that the physiological meaning of the LHB tendon has been proven to be inferior for normal shoulder function, we regard tenodesis as a promising adjunct to ORIF of proximal humerus fractures.

Conflict of interests

Greve, Kirchhoff, Zyskowski, Beirer, Crönlein, Müller, Pesch, Felix, Biberthaler and Buchholz disclose any financial and personal relationships with other people or organisations that could inappropriately influence or bias their work.

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