Surgical treatment of lesions of the long head of the biceps brachii tendon with rotator cuff tear: a prospective randomized clinical trial comparing the clinical results of tenotomy and tenodesis

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**Background:** Tenotomy and tenodesis are common treatments for lesions in the long head of biceps tendon (LHBT); however, which treatment is superior is still controversial. This study compared the outcomes of tenotomy with outcomes of tenodesis for treatment of LHBT lesions with rotator cuff tears.

**Methods:** The study enrolled 128 patients with LHBT lesions and small- to medium-sized rotator cuff tear. Arthroscopic LHBT tenotomy was done in 56 patients (group I), and LHBT tenodesis was done for 72 patients (group II) with rotator cuff repair. American Shoulder and Elbow Surgeons Score, simple shoulder test, pain visual analog scale, range of motion, and cosmetic changes were assessed initially, at 3, 6, and 12 months postoperatively, and the last visit. The elbow motor power and magnetic resonance imaging were evaluated at 12 months.

**Results:** Both groups showed improvement in functional scores after treatments, but no significant difference was found between the 2 groups at each assessment. The rate of Popeye deformity was 3 times higher in group I ($P = .04$). Group II showed greater forearm supination power than group I ($P = .02$). On magnetic resonance imaging, 45 patients (80.4\%) in group I showed maintenance of the LHBT cut end within the bicipital groove, whereas 65 patients (90.3\%) in group II showed maintenance of fixed LHBT.

**Conclusion:** For the treatment of LHBT lesions with rotator cuff tear, patients with tenotomy and tenodesis both showed significant improvements in functional scores. The incidence of Popeye deformity was about 3-times higher in tenotomy group. No significant differences in elbow motor power were observed except greater forearm supination power in the tenodesis group.

**Level of evidence:** Level I; Randomized Controlled Trial; Treatment Study

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**Keywords:** Biceps long head; tenotomy; tenodesis; clinical outcomes; elbow power; Popeye deformity
Lesions of the long head of the biceps brachii tendon (LHBT) are a common source of shoulder pain; however, its function in shoulder biomechanics is not clearly understood.\textsuperscript{10,11,13,26,31} Rather than single isolated tendinitis or partial tear, most LHBT lesions are frequently combined with rotator cuff lesions, labral lesions, or instability.\textsuperscript{5,8,20-22} Owing to its anatomic complexity with unclear functional contribution and common involvement of other lesions, diagnosis of LHBT lesion is often laborious, and several factors complicate optimal treatment. For patients who are not responsive to nonoperative treatments, including medication, injection, or physical therapy, surgical treatments are recommended.

Débridement has been tried for the treatment of LHBT lesions. However, the treatment had the limitation of having a narrow and unclear indication, which was only applicable to partial tears of less than 25% of the tendon or lesions of reversibility.\textsuperscript{1,2,28} In recent years, tenotomy or tenodesis has become more common to control persistent pain postoperatively than the past efforts of preservation.\textsuperscript{2,3,5,27} Although favorable clinical outcomes have been reported for both procedures, no clear indications for these 2 have been established.\textsuperscript{3,7,16,17,19}

In addition, the superiority of either treatment in outcome is still controversial. Some authors have claimed the superiority of tenotomy for easier execution and fewer restrictions after the operation, with an earlier return to activity.\textsuperscript{1,9} Meanwhile, some have advocated tenodesis for having fewer cosmetic problems, such as Popeye deformity,\textsuperscript{1,9} and have claimed that maintenance of the LHBT by tenodesis was associated with higher load to failure compared with patients treated with LHBT tenotomy.\textsuperscript{9} Most previous studies have had methodologic problems, including retrospective design, lack of randomization, and inadequate sample sizes. A recently published level I study showed tenotomy and tenodesis both had favorable results, with differences in surgical time and time to onset of pain relief.\textsuperscript{32}

The purpose of this study was to prospectively compare the clinical outcomes of tenotomy with those of tenodesis for the treatment of LHBT lesions in patients with reparable rotator cuff tears. Through this study, we comprehensively compared clinical outcomes of both treatments, including range of motion (ROM), functional scores, elbow strength, and cosmetic changes. Furthermore, postoperative magnetic resonance imaging (MRI) was performed to evaluate the result of treated LHBT. We hypothesized that the type of treatment for LHBT lesion (1) would not influence overall shoulder function after rotator cuff repair but (2) would influence elbow function and cosmetic aspect.

Materials and methods

This prospective randomized study compared the clinical outcomes of LHBT tenotomy and tenodesis for the treatment of LHBT lesions in patients with rotator cuff tears. From June 2006 to December 2010, 171 consecutive patients with partial tear of the LHBT with concomitant small- to medium-sized rotator cuff tears were enrolled.

Inclusion and exclusion criteria

Patients were included if they had symptomatic LHBT partial tear and small- to medium-sized rotator cuff tears that required surgical repair at the time of their visit. Before surgery, patients showed no improvements after at least 1 month of preoperative conservative treatments such as medication or corticosteroid injections.

All lesions were confirmed by using MRI preoperatively and during the arthroscopic procedure. The study excluded patients who had large or massive rotator cuff tears, a history of shoulder surgery or trauma, or concomitant shoulder lesions, such as arthritis in the glenohumeral joint, or labral lesions. Among the 171 patients who were assessed for the eligibility, 28 patients who did not meet the inclusion criteria and 6 who had self-selected the treatment were excluded. Finally, 137 patients were selected for the study.

Treatment groups

Patients were allocated to 2 groups. Group I underwent LHBT tenotomy, and group II underwent LHBT tenodesis. Both groups received rotator cuff repair. Assignment of patients to each group was achieved through computer-generated block randomization. After confirmation that the patients met the inclusion criteria, the treatment method for LHBT lesions was determined by a random number taken from a sealed envelope at the time of surgery. Patients, who were blinded at the time of allocation, were informed about the advantages and disadvantages of both treatments before allocation. Because 9 patients dropped out during the study, 128 patients were analyzed (Fig. 1), 56 in group I and 72 in group II.

Operative techniques

All surgical procedures were conducted by 1 senior shoulder specialist. The patients were positioned in lateral decubitus, and all arthroscopic surgical procedures were performed under general anesthesia. For small (<1 cm) rotator cuff tears, single-row repair was performed. For medium (1-3 cm) tears, transosseous equivalent repair (suture-bridge technique) was performed.

Standard posterior and anterior portals were placed in the glenohumeral joint for exploration. After a routine diagnostic maneuver, the LHBT was evaluated for any pathologic condition such as partial tear, subluxation, or tendinitis. A probe was used to pull the LHBT into the glenohumeral joint space to scrutinize the portion hidden within the bicipital groove.

In group I, funnel-shaped tenotomy was performed by dividing the LHBT at its proximal origin of the labrum, as suggested by Cho et al.\textsuperscript{4} In group II, tenodesis was performed inside the glenohumeral joint. After the tenotomy, a No. 1 polydioxanone (PDS) suture was passed through the tenotomized tendon for tagging. The PDS suture was retrieved to the outside through the anterior portal. With gentle traction of the PDS suture, the tenotomized biceps tendon was pulled out for débridement. Bilateral side-running sutures (Krackow whip-stitch) with FiberWire sutures (Arthrex, Naples, FL, USA) were made on the tenotomized biceps tendon (Fig. 2). Then, the suture was tightly tied to the distal hole of a 7.0-mm...
BioComposite SwiveLock interference screw (Arthrex). A drill hole was made in the intertubercular groove just lateral to the insertion of subscapularis tendon, and the interference screw with the tenotomized cut end was inserted (Fig. 3).

Postoperative rehabilitation

All patients followed the rehabilitation procedures after rotator cuff repair. The patients were fitted with an abduction brace immediately after the operation. The abduction brace was worn for 4 weeks postoperatively, and the same standardized rehabilitation protocols were prescribed in both groups. After the patients were weaned from using the brace, pulley exercises were prescribed to increase their range of flexion. The patients were asked to undergo home-based active assisted shoulder exercises 3 times daily, with each session lasting for at least 20 minutes. TheraBand (Hygenic Corp, Akron, OH, USA) exercises, strengthening exercises for the muscles stabilizing the scapula, were initiated 2 months after the operation. All sports activities were permitted after 6 months. During the time of home-based exercise, the patients were asked to visit the clinic every month for regular checkups.

Outcome measurements

Each patient was assessed before surgery; at 3, 6, and 12 months after surgery; and at the last follow-up based on the American Shoulder and Elbow Surgeons (ASES)\textsuperscript{21} and the simple shoulder test scores. A visual analog scale (VAS) for pain (0, no pain; 10, the most severe pain) was given to all patients at each visit. A goniometer was used to measure ROM, including forward flexion, external rotation at side, external rotation at 90° of abduction, and internal rotation of the treated shoulder. Internal rotation, measured with the patient sitting, was evaluated by the

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**Figure 1** Flow chart shows the conduct of the study according to the Consolidated Standards of Reporting Trials criteria.

**Figure 2** Tenotomized long head of the biceps tendon taken outside the joint.

**Figure 3** Cut end of the tendon inserted to the humeral head.
tip of the thumb reaching the vertebral level. For the analysis, the vertebral level was numbered serially as follows: 0 for any level below the sacral region and 1 point added for each level above the sacrum. Evaluation for presence of Popeye deformity was performed at each visit.

Forearm supination and pronation and elbow flexion motor power test were evaluated at the last visit by using a digital force gauge transducer (CFG+200 N; Mecmesin Ltd, Slinfold, West Sussex, UK) with comparison with those of the contralateral unaffected arm. The compact force gauge transducer used in this study has been certified by “Force and torque measurement application engineering, Mecmesin Ltd, UK, to conform operational accuracy of ±0.5% for any measurement within working range.”

Strength index, defined as the strength of the affected arm divided by the strength of the contralateral arm, was used to compare the nondominant arm with the dominant arm instead of using the absolute value of the muscle. Because normal muscle strength for the individual is different from that of others, a comparison of the absolute values is not objective. The muscle strength of the affected elbow was divided by the strength of the contralateral side.

The assessment data were prospectively collected by a clinical researcher who was blinded to the study design. The patients were also blinded during the assessment. The postoperative cuff tendon integrity was assessed at 12 months after the operation by using MRI. The images were blindly interpreted by one of the authors.

### Statistical methods

The ASES score has been validated and widely used for the evaluation of outcomes of arthroscopic shoulder surgery. A sample size of 37 patients in each group was required for a statistical power of 80% at a type I error level of 0.05. A follow-up loss of 20% was expected. Statistical analysis was performed with SPSS 12.0 software (IBM Corp, Armonk, NY, USA). The Student t test was used to compare the differences between the outcomes of the 2 groups. A paired t test was used to compare the differences in functional evaluation scores before and after surgery for each group. P < .05 was considered significant.

### Results

Preoperative demographic data, including age, sex, mean follow-up, size of the rotator cuff tear, and initial clinical score in both groups, showed no significant differences between the groups (P > .05, Table I). The mean follow-up period was 25.1 months for the tenotomy group (group I) and 19.7 months for the tenodesis group (group II). Group I consisted of 11 men and 45 women, with a mean age of 62.8 years (range, 55-77 years). Group II consisted of 18 men and 54 women, with a mean age of 62.9 years (range, 50-75 years).

Functional scores evaluated after 12 months showed significant improvement in both groups compared with those of the initial preoperative period (Fig. 4 and Table II). However, no significant differences were found in ROM, pain, and functional scores between the 2 groups at each assessment (P > .05, Figs. 4 and 5). The incidence rate of Popeye deformity was about 3-times higher in group I than in group II (19.6% vs. 5.6%, P = .04). Furthermore, men (4 of 11 [36.4%]) showed a higher rate of Popeye deformity than women (7 of 45 [15.6%]) in group I. We could not evaluate the sex discrepancy on the incidence of Popeye deformity in group II because only 4 patients showed positive sign.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group I</th>
<th>Group II</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (range), year</td>
<td>62.8 (55-77)</td>
<td>62.9 (50-75)</td>
<td>.15</td>
</tr>
<tr>
<td>Sex, No.</td>
<td>11</td>
<td>18</td>
<td>.77</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>45</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>Average follow-up period, months</td>
<td>25.1</td>
<td>19.7</td>
<td>.13</td>
</tr>
<tr>
<td>Biceps tendon condition, No.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Partial tear</td>
<td>37</td>
<td>47</td>
<td>.22</td>
</tr>
<tr>
<td>Subluxated</td>
<td>13</td>
<td>17</td>
<td>.39</td>
</tr>
<tr>
<td>Dislocated</td>
<td>6</td>
<td>8</td>
<td>.48</td>
</tr>
<tr>
<td>Average tear size of rotator cuff in medial to lateral dimension, cm</td>
<td>1.3</td>
<td>1.2</td>
<td>.35</td>
</tr>
<tr>
<td>Initial ROM, °</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Forward flexion</td>
<td>144 ± 12.19</td>
<td>140 ± 10.44</td>
<td>.58</td>
</tr>
<tr>
<td>External rotation at 90° abduction</td>
<td>89 ± 8.21</td>
<td>86 ± 8.84</td>
<td>.54</td>
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<tr>
<td>External rotation at side</td>
<td>86 ± 7.51</td>
<td>84 ± 7.54</td>
<td>.75</td>
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<tr>
<td>Internal rotation</td>
<td>10 ± 1.19</td>
<td>10 ± 2.11</td>
<td>.32</td>
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<tr>
<td>Initial clinical score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAS for pain</td>
<td>7.1 ± 1.41</td>
<td>6.8 ± 1.27</td>
<td>.09</td>
</tr>
<tr>
<td>ASES score</td>
<td>44.2 ± 4.74</td>
<td>50.1 ± 6.04</td>
<td>.24</td>
</tr>
<tr>
<td>Constant score</td>
<td>69.9 ± 7.47</td>
<td>69.9 ± 7.19</td>
<td>.98</td>
</tr>
</tbody>
</table>

ASES, American Shoulder and Elbow Surgeons; VAS, visual analog scale.
No significant differences in elbow flexion power and forearm pronation power ($P > .05$) were observed at the last visit. However, group II showed greater forearm supination power ($0.818 \pm 0.108$) than group I ($0.998 \pm 0.015$, $P = .02$).

The retear rate after rotator cuff repair was 16.1% (9 of 56 patients) in group I and 15.3% (11 of 72 patients) in group II, as determined by postoperative follow-up MRI studies ($P > .05$, Table III).

In group I, the cut end of the LHBT was found within the bicipital groove in 45 of 56 patients (80.4%). In the rest of the patients, the LHBT was not found within the bicipital groove or was found below the bicipital groove. Among the group II patients, 7 showed no tenodesed LHBT within the intertubercular groove where it was fixed. The overall success rate of LHBT tenodesis according to the maintenance of the fixed tendon was 90.3%.

### Table II

Comparison of functional scores between preoperative and postoperative treatment

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Preoperative score</th>
<th>Score at last F/U</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAS pain score</td>
<td>7.1</td>
<td>2.0</td>
<td>.02</td>
</tr>
<tr>
<td>ASES score</td>
<td>44.2</td>
<td>82.8</td>
<td>.01</td>
</tr>
<tr>
<td>Constant score</td>
<td>69.9</td>
<td>88.3</td>
<td>.03</td>
</tr>
<tr>
<td>Group II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAS pain score</td>
<td>5.9</td>
<td>1.8</td>
<td>.03</td>
</tr>
<tr>
<td>ASES score</td>
<td>51.5</td>
<td>77.6</td>
<td>.02</td>
</tr>
<tr>
<td>Constant score</td>
<td>69.9</td>
<td>86.5</td>
<td>.02</td>
</tr>
</tbody>
</table>

ASES, American Shoulder and Elbow Surgeons; F/U, follow-up; VAS, visual analog scale.

Figure 4  Range of motion measured as forward flexion, external rotation at abduction and at side, and internal rotation. No significant differences were found between the 2 groups at each assessment. $m$, months.

No significant differences in elbow flexion power and forearm pronation power ($P > .05$) were observed at the last visit. However, group II showed greater forearm supination power ($0.818 \pm 0.108$) than group I ($0.998 \pm 0.015$, $P = .02$). The retear rate after rotator cuff repair was 16.1% (9 of 56 patients) in group I and 15.3% (11 of 72 patients) in group II, as determined by postoperative follow-up MRI studies ($P > .05$, Table III).

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Figure 5  Functional scores, assessed as pain visual analog scale (VAS), American Shoulder and Elbow Surgeons score (ASES), and Constant Shoulder Score (CSS) improved after surgery in both groups. No significant differences were observed between the 2 groups at each assessment.


Discussion

In this study, tenotomy and tenodesis for the treatment of LHBT lesions both yielded favorable results in functional scores, without significant differences between the 2 groups. However, the tenodesis group showed a significantly lower incidence of Popeye deformity and allowed smaller loss of supination power than the tenotomy group.

LHBT lesions are commonly accompanied with rotator cuff tear, and the treatment for the rotator cuff tear is obvious. However, for the treatment of LHBT lesions, it has been controversial. For patients who are not responsive to nonoperative treatments, such as medication, injection, or physical therapy and who have accompanying rotator cuff tear that needs to be repaired surgically, surgical treatments of LHBT are often recommended. Tenotomy and tenodesis are 2 classic representative treatments with well-described results.

Besides functional problems, because the LHBT lesion itself is a well-known source of shoulder pain, both modalities have been shown to be effective in removing the pain source. Furthermore, many techniques have been introduced to improve outcomes. However, the optimal surgical treatment of LHBT lesions remains controversial. Few well-controlled, prospective randomized clinical trials have been conducted to definitively determine which between tenotomy and tenodesis is superior.

The cosmetic problem caused by Popeye deformity is a concern in the treatment of LHBT lesions, especially with tenotomy. Similar results have been reported by Gill et al,6,9 and Kelly et al.,12 showing no clinical differences between tenotomy and tenodesis, except that a tenodesis group showed a lower incidence of Popeye deformity. Moreover, according to the systematic review of level IV studies that compared the results of LHBT tenotomy and tenodesis, a higher incidence of cosmetic deformity was observed in patients treated with tenotomy.6,9,29

However, tenotomy does not always result in Popeye deformity. A recently published level I study showed no significant differences in clinical results, including Popeye deformity, between LHBT tenotomy and tenodesis.32 Even if cosmetic deformity is present, it rarely causes problems and is often not even noticed by patients themselves.3 If the cut end of the LHBT remains in the bicipital groove, the overall biceps muscle length may be left unchanged, showing no Popeye deformity by the autotenodesis effect.23 In fact, the overall incidence of cosmetic deformity can be lowered by performing funnel tenotomy based on LHBT.4

The incidence of Popeye deformity in our study was about 3.5-times higher in the tenotomy group (19.6% vs. 5.6%). Even though the rate was higher in the tenotomy group, 80% of the patients in the tenotomy group did not have the deformity. That is probably because the LHBT was resected at the base as close as possible to the superior labrum, which leads to the autotenodesis effect. Among the 45 patients who showed the existence of a tenodesed LHBT within the bicipital groove, 43 patients showed no apparent Popeye deformity. In group II, the rate of Popeye deformity (5.6%) was lower than the fixation loss rate of tenodesed tendon (9.7%). We can explain that despite the fixation loss, there is a greater chance of existence of LHBT within the bicipital groove that can lead to autotenodesis effect and avoid distal migration of the LHBT.

There is a concern that tenotomy of the LHBT leads to functional deterioration of the biceps brachii. The biceps works as a chief forearm supinator and a secondary elbow flexor. In a level III study by Wittstein et al.,30 the tenodesis group showed significantly higher peak supination torque than the tenotomy group. No significant differences in peak flexion torque and flexion/supination endurance were observed. In our study, similar results were obtained. Supination power was significantly greater in the tenodesis group, whereas no significant differences were observed in flexion and pronation. Despite the difference in supination power, no significant difference was observed in the clinical scores. Considering the age distribution of the enrolled patients and gender proportion (77% female), the lack of supination power in the tenotomy group might have little effect on the quality of life of the patients.

According to the postoperative MRI, 90% of the tenodesed LHBT remained within the fixation point. The strength of this study is in the postoperative MRI evaluation. We not only observed the outcome of repaired rotator cuff but also kept track of the tenodesed LHBT. The high maintenance rate of tenodesis can explain the functional and cosmetic superiority of LHBT tenodesis over tenotomy. Even though the failure rate of tenodesis was approximately 10%, the incidence of a Popeye

<table>
<thead>
<tr>
<th>Table III</th>
<th>Comparison of clinical results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group I</td>
</tr>
<tr>
<td>Result</td>
<td>(n = 56)</td>
</tr>
<tr>
<td>Popeye deformity, No. (%)</td>
<td>11 (19.6)</td>
</tr>
<tr>
<td>Retear rate of repaired rotator cuff, No. (%)</td>
<td>9 (16.1)</td>
</tr>
<tr>
<td>Elbow motor power, mean ± SD</td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>0.966 ± 0.078</td>
</tr>
<tr>
<td>Supination</td>
<td>0.818 ± 0.108</td>
</tr>
<tr>
<td>Pronation</td>
<td>0.872 ± 0.134</td>
</tr>
</tbody>
</table>

SD, standard deviation.
deformity was only 5.6%. The possibility of the spontaneous tenodesis effect is high despite the fixation failure of the tendon. Also on postoperative MRI, we confirmed the usefulness of a funnel-shaped tenotomy with a low incidence of Popeye deformity by showing that the tendon often remained within the groove.

We can conclude that tenotomy and tenodesis of the LHBT with rotator cuff repair are both effective for resolving symptoms of LHBT lesions with rotator cuff tear. Compared with tenotomy, tenodesis has more advantages in maintaining supination power and shows a lower incidence rate of Popeye deformity. However, we should be aware that tenodesis is far more technically demanding than tenotomy and that results may vary, depending on the skill or familiarity of the procedure. Meanwhile, despite the disadvantage of the cosmetic problem, tenotomy is preferred in some cases for its relative simplicity and consistent outcomes. Treatment should be individualized and performed by considering the surgeon’s preference and patient’s condition.

This study has some limitations. First, the sample size was relatively small. However, the number of enrolled patients satisfied the minimum condition calculated in the preceding power analysis and proportional numbers of patients were allocated to each group. In fact, this is one of the largest studies among the prospective studies that have compared the outcome of LHBT tenotomy and tenodesis.

Second, no control group was included to prove the effect of each treatment.

Third, assessment of motor power was limited to a one-time event. Assessing fatigue with repetition to further clarify functional deficit would have been useful.

Fourth, we could not guarantee the normal condition of the contralateral elbows, which were used for the calculation of the strength index. If the contralateral side had unknown condition affecting elbow power, the ipsilateral side might have had relatively higher strength.

Fifth, the imbalance in gender proportion meant we were not able to acquire significant results regarding the influence of gender. Also, patients were not divided into subgroups by age, which might have affected the treatment results.

Lastly, we did not evaluate local symptoms of the LHBT lesions. Evaluation of tenderness on the biceps groove or postoperative muscle cramp/pain would have been more helpful in supporting the results.

**Conclusion**

For the treatment of LHBT lesions with rotator cuff tear, tenotomy and tenodesis both showed significant improvements in functional scores evaluated after 12 months. The incidence of Popeye deformity was about 3-times higher in tenotomy group. No significant differences in elbow flexion power and forearm pronation power were observed at the last visit, the tenodesis group had greater forearm supination power.

**Disclaimer**

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**References**


