



REVIEW ARTICLES

## Biceps tenotomy versus tenodesis: a review of clinical outcomes and biomechanical results

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**Hypothesis:** There are significant differences in incidence of cosmetic deformity and load to tendon failure between biceps tenotomy versus tenodesis for the treatment of long head of the biceps brachii (LHB) tendon lesions which are supported by the evidence-based strengths and weaknesses of each procedure in the literature.

**Materials and methods:** PubMed, Embase, and Cochrane databases were searched for eligible clinical and biomechanical articles relating to biceps tenotomy or tenodesis from 1966 to 2010. Keywords were *biceps tenotomy*, *biceps tenodesis*, *long head of the biceps brachii*, and *Popeye sign*. All relevant studies were included based on study objectives, and excluded studies consisted of abstracts, case reports, letters to the editor, and articles without outcome measures.

**Results:** All articles reviewed were of level IV evidence. Combined results from reviewed papers on the differences between LHB tenotomy vs tenodesis demonstrated a higher incidence of cosmetic deformity in patients treated with biceps tenotomy. Complications were similar for each treatment, with a higher likelihood of bicipital pain associated with tenodesis. Lack of high levels of evidence from prospective randomized trials limits our ability to recommend one technique over another.

**Discussion:** This review demonstrated a higher incidence of cosmetic deformity in patients treated with biceps tenotomy compared with tenodesis, with an associated lower load to tendon failure. However, there was no consensus in the literature regarding the use of tenotomy vs. tenodesis for LHB tendon lesions due to variable results and methodology of published studies. Individual patient factors and needs should guide surgeons on whether to use tenotomy or tenodesis.

**Conclusions:** There is a great need for future studies with high levels of evidence, control, randomization, and power, with well-defined study variables, to compare biceps tenotomy and tenodesis for the treatment of LHB tendon lesions.

**Level of evidence:** Review Article, with Supplementary Biomechanical Study.

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**Keywords:** Biceps brachii; tenotomy; tenodesis; tendinitis; load to failure

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Lesions of the long head of the biceps brachii (LHB) tendon are common and frequently share the clinical presentation of anterior shoulder pain with associated loss of forward flexion.<sup>17,21</sup> One of the primary objectives during conservative management (eg, nonsteroidal anti-inflammatory drugs, physical therapy, steroid injection) of suspected LHB tendon pathology is to rule out concurrent rotator cuff or labral injuries.<sup>2,3,20</sup> Surgical exploration and potential treatment is warranted if pathology is identified or if symptoms persist for longer than 3 months without a clear diagnosis.<sup>3</sup>

Debate continues regarding the use of the 2 most common surgical treatments for LHB tendon lesions, namely, the biceps tenotomy and biceps tenodesis. There is no consensus in the literature about tenotomy vs tenodesis because most studies lack high levels of evidence.<sup>3,6,8,9,14,16,19,21</sup> Some studies promote biceps tenotomy as the preferred treatment method, arguing that it is quick, well-tolerated, and requires less postoperative rehabilitation with a faster return to activity.<sup>11-13</sup> However, although technically simpler to perform, tenotomy may result in a cosmetic defect, possible cramping and fatigue pain, and biomechanical changes of the humeral head that may carry unknown functional deficits in the long-term.<sup>4</sup> Studies advocating tenodesis note a better ability to return to physical activity and that a closer approximation of normal anatomy should be the primary goal for patients with LHB tendon injuries despite longer rehabilitation times and a technically more difficult procedure.<sup>4,6</sup>

Current literature lacks quality evidence to promote one technique over another, and studies have found widely variable differences in the clinical outcomes of tenotomy compared with tenodesis. No reports or analyses have clearly demonstrated that one treatment is better than the other because most studies lack power, randomization, and control. The purpose of this review was to analyze tenotomy vs tenodesis in incidence of cosmetic deformity and load to tendon failure for each technique. This review also aimed to summarize the relevant available literature, incorporate biomechanical findings with clinical outcomes, and clarify the evidence-based strengths and weaknesses of each procedure to provide general guidelines for when to use each treatment.

## Materials and methods

Investigational Review Board approval was not required for this article.

Four independent researchers reviewed the Medline, Embase, and Cochrane databases for eligible clinical and biomechanical articles relating to biceps tenotomy or tenodesis between January 1966 and January 2010. Keywords used included *biceps tenotomy*, *biceps tenodesis*, *long head of the biceps brachii*, and *Popeye sign*. All relevant studies were included based on study objectives, and excluded studies consisted of abstracts, case reports, and letters to the editor. Primary factors analyzed for this review were (1) cosmetic deformity, defined as an abnormality of the biceps belly,

and (2) biomechanical load to pull tenotomized or tenodesed tendons free from fixation. Cosmetic deformity was defined broadly as biceps deformity by examination. Secondary outcomes included patient-reported outcomes, concomitant injuries and treatments, complications, and superior migration of the humeral head.

Outcomes reported from each study were combined in table format (Tables I-V) to provide a broad comparison across studies of tenotomy and tenodesis. Statistical analyses using analysis of variance, odds ratios (OR), and relative risk (RR) comparing clinical outcome measures and loads to tendon failure with significance set to  $P \leq .05$  were performed using SPSS software (SPSS Inc, Chicago, IL).

## Results

### Demographics

A total population of 517 patients included 416 treated with tenotomy<sup>5,12,13,21</sup> and 117 treated with tenodesis<sup>4,7,10</sup> (Table I; some patients underwent surgery in both shoulders, so one patient counted for 2 shoulders). Gender distribution was 251 women (51%) and 239 men (49%), with an age range of 16 to 83 years. Identified age group for tenotomy was the same as the entire population (range, 16-83 years), whereas tenodesis patients were aged 25 to 81 years (the precise breakdown of number of women and men was not included in the paper by Boileau et al). The dominant arm was affected in 379 of 533 cases (71%).<sup>4,5,7,10,21</sup>

### Operative data

Isolated biceps pathology was reported in 4 studies and found in 36 of 128 patients (28%; Table II).<sup>4,6,12-13</sup> When separated by treatment group, there were 28 cases of isolated biceps pathology in 70 tenotomy cases (40%) and 8 cases in 58 tenodesis cases (14%). In a subgroup of 6 studies treating 488 patients, the LHB was subluxed in 179 (37%), ruptured in 60 (12%), and dislocated in 75 (15%).<sup>5-7,10,12,21</sup> The LHB tendon in 9 patients (2%) was completely ruptured at the time of surgery. Procedures performed concomitantly with tenotomy included 310 rotator cuff repairs (89%), 118 acromioplasties (31%), 3 distal clavicle excisions, and 2 debridements of irreparable repairs.<sup>6,13,21</sup> In patients treated with tenodesis, there were 65 dominant rotator cuff repairs (77%), 10 acromioplasties (10%), and 7 superior labral anterior and posterior (SLAP) repairs (7%).<sup>4-7</sup>

### Clinical outcomes

The weighted-mean average follow-up for patients treated with tenotomy was 51.3 months (range, 12-168 months) compared with 37.0 months (range, 12-158 months) for those who underwent tenodesis. All reviewed tenodesis fixations were within the biceps groove. Postoperative bicipital pain

**Table I** Demographics

First author	Technique	Pts	Shoulders	Dominant shoulder	Males	Females	Age groups, y
		No.	No. (%)	No. (%)	No. (%)	No. (%)	Mean (range) or SD
Overall	Tenotomy/ Tenodesis	517	416 (78) 117 (22)	275 (66) 104 (89)	197 (47) 42 (57)	219 (53) 32 (43)	62.8 (16-83)* 62.2 (25-81)*
Berlemann <sup>4</sup>	Tenodesis	15	15	11 (73)	9 (60)	6 (40)	44.6 (29-67)
Boileau <sup>6</sup>	Tenodesis	43	43	43 (100)	NR	NR	63 (25-78)
Boileau <sup>5</sup>	Tenotomy/ Tenodesis	72	39 33	36 (92) 27 (82)	9 (23) 19 (58)	30 (77) 14 (42)	73.1 ± 6.2 69.8 ± 6.4
Checchia <sup>7</sup>	Tenodesis	15	15	15 (100)	9 (60)	6 (40)	62 (41-81)
Franceschi <sup>10</sup>	Tenodesis	11	11	8 (73)	5 (45)	6 (55)	58.1 (40-81)
Gill <sup>12</sup>	Tenotomy	30	30	NR	27 (90)	3 (10)	50 (16-75)
Kelly <sup>13</sup>	Tenotomy	40	40	NR	29 (73)	11 (27)	48 (18-83)
Walch <sup>21</sup>	Tenotomy	291	307	239 (78)	132 (43)	175 (57)	64.3 (39-81)

NR, not reported; SD, standard deviation.

\* Weighted-mean age with the cumulative reported age range.

**Table II** Operative data and concomitant injuries

First author	Technique	Biceps tendon condition			Simultaneous procedures			
		Subluxated	Dislocated	Preruptured	RCR	Acromioplasty	DCE	SLAP
Overall		179	75	60	377	138	3	7
Berlemann <sup>4</sup>	Tenodesis	NR	NR	2	2	0	0	0
Boileau <sup>6</sup>	Tenodesis	11	13	15	37	0	0	6
Boileau <sup>5</sup>	Tenotomy/tenodesis	45	19	34	0	0	NR	NR
Checchia <sup>7</sup>	Tenodesis	2	6	7	15	10	NR	1
Franceschi <sup>10</sup>	Tenodesis	4	3	0	11	NR	NR	NR
Gill <sup>12</sup>	Tenotomy	3	0	2	NR	NR	NR	NR
Kelly <sup>13</sup>	Tenotomy	NR	NR	NR	5	8	NR	NR
Walch <sup>21</sup>	Tenotomy	114	34	NR	307	110	3	0

DCE, distal clavicle excisions; NR, not reported; RCR, rotator cuff repair; SLAP, superior labral anterior and posterior.

was found in 19 of 109 cases (17%) of tenotomy<sup>6,12,13</sup> and in 18 of 74 cases (24%) of tenodesis.<sup>4-5,7,10</sup> Corresponding OR and RR for bicipital pain was larger for tenodesis patients (OR, 1.5; RR, 1.4). Two studies exclusively reporting tenotomy outcomes documented patient satisfaction,<sup>13,21</sup> with were 291 good to excellent (84%), 37 fair (11%), and 19 poor (5%) outcomes reported. Patient satisfaction outcomes for tenodesis were only reported in a combined study of tenotomy and tenodesis.<sup>5</sup> Of 77 total patients, 33 were very satisfied, 23 were satisfied, 11 were disappointed, and 5 were dissatisfied.

Two validated surveys, the Constant score<sup>5,6,21</sup> and University of California-Los Angeles (UCLA) rating scale,<sup>7,13</sup> were used for the 2 treatment groups. The weighted-mean average Constant scores for tenotomy and tenodesis groups were 66.9 and 76.1, respectively (Table III). One study for each procedure used the UCLA scores. The weighted-mean average UCLA score was 33 (range, 21-35) for tenotomy and 28 (range, 10-35) for tenodesis. One study measured tenodesis outcomes with the modified UCLA rating scale and reported a mean score of 33 (range, 29-35).<sup>10</sup>

Additional examination scales were used, but not mutually, for comparison between treatment groups.

Acromiohumeral distance was measured in 3 studies but gave limited comparison between the 2 treatment groups. The first study reported a mean acromiohumeral interval of 5.3 mm (range not given) in 307 tenotomy cases.<sup>21</sup> In the second study, the mean subacromial height was 7.5 mm (range, 4-10 mm) in 15 cases of tenodesis.<sup>4</sup> The third study reported an unclassified mean height of 4.5 mm (range, 1-10 mm) in 39 tenotomy and 33 tenodesis cases.<sup>5</sup>

### Cosmetic deformity

Cosmetic deformity of tenotomy and tenodesis was defined as an obvious deformity of the biceps belly (Popeye sign). At follow-up of 376 tenotomy cases, 156 patients (41%) reported deformity of the biceps muscle.<sup>5,12,21</sup> In the tenodesis group, 29 of 117 individuals (25%) had deformity.<sup>4-7</sup> The corresponding OR and RR for cosmetic deformity was larger for tenotomy than for tenodesis (OR, 2.15; R.R, 1.7).

**Table III** Physical examination rating scales

First author	Technique	Rating scale	Outcomes	
			Mean (range) or $\pm$ SD	
Berlemann <sup>4</sup>	Tenodesis	Post and Benca	8 Excellent, % 1 Good, % 4 Fair, % 2 Failures, %	???
Boileau <sup>6</sup>	Tenodesis	Constant Score, ROM	Mean: 79 (59-87)	43 Full ROM 0 Compromised
Boileau <sup>5</sup>	Tenotomy Tenodesis	Final Constant Score Pain Score Activity Score	Tenotomy 61.2 $\pm$ 18 10 $\pm$ 3.8 13.9 $\pm$ 4.5	Tenodesis 72.8 $\pm$ 12 11.3 $\pm$ 3.3 17.2 $\pm$ 4.4
Checchia <sup>7</sup>	Tenodesis	UCLA, ROM	11 Excellent 3 Good 1 Fair 0 Failures	4 Full ROM 11 Compromised
Franceschi <sup>10</sup>	Tenodesis	Modified UCLA	8 Excellent 3 Good 0 Poor	
Gill <sup>12</sup> Kelly <sup>13</sup>	Tenotomy Tenotomy	ASES L'Insalata ASES UCLA	Mean: 82 (35-100) Mean: 76 (29.1-100) Mean: 78 (13.3-100) Mean: 28 (10-35)	
Walch <sup>21</sup>	Tenotomy	Constant	157 Excellent 63 Good 45 Fair 42 Poor	

ASES, American Shoulder and Elbow Surgeons; ROM, range of motion; SD, standard deviation; UCLA, University of California-Los Angeles.

## Complications

Primary reported complications of tenotomy and tenodesis included reflex sympathetic dystrophy<sup>5,6,21</sup> and infection (Table IV).<sup>7,21</sup> Two manipulations were reported for loss of range of motion in patients treated with tenotomy,<sup>13</sup> and 4 manipulations were reported in tenodesis patients.<sup>4</sup> Additional reported complications are outlined in Table IV.

## Biomechanical results

Four studies reporting biomechanical outcomes were analyzed,<sup>1,15,18,22</sup> with 1 of the 4 directly comparing biceps tenotomy and tenodesis (Table V).<sup>22</sup> These studies together investigated 54 cadaveric tendons, in which 13 samples were used to study tenotomy and 41 for tenodesis. At the time of death, the donors were a weighted-mean average age of 51 years for tenotomy and 64 years for tenodesis. In cyclic loading, there was a 40% rate of failure in the tenotomy group and no failure of 30 samples in the tenodesis group. The weighted-mean average load to tendon failure was 81.6 N for tenotomy compared with 233.5 N for tenodesis.

One study investigated the anatomic factors influencing the force required to pull diseased and healthy biceps tendons through the bicipital groove beneath the transverse

humeral ligament.<sup>1</sup> The mean peak load of 7 healthy tendons (21.6 N,  $\sim$ 1 lb) was significantly less than that of diseased tendons (33.0 N,  $\sim$ 1.5 lb;  $P = .02$ ). These findings were attributed to an increased mean cross-sectional area of diseased tendons (diseased, 54.5 mm<sup>2</sup>; healthy, 39.5 mm<sup>2</sup>,  $P = .07$ ) and relative stenosis of the bicipital groove in shoulders with diseased tendons (diseased, 18.8 mm<sup>2</sup>; healthy, 19.4 mm<sup>2</sup>;  $P = .8$ ).

## Discussion

Lesions of the LHB tendon are a frequent cause of shoulder pain and disability, yet few if any well-controlled, randomized studies have investigated the optimal treatment for these injuries. The purpose of this review was to attempt to clarify the strengths and weaknesses of biceps tenotomy vs tenodesis as reported in the existing literature. Of the studies included in this review, the incidence of cosmetic deformity was 41% in tenotomy and 25% in tenodesis patients, with an OR of 2.15 for tenotomy. Biceps cosmetic deformity was a well-reported and consistent outcome measure across the studies reviewed. Gill et al<sup>12</sup> and Kelly et al<sup>13</sup> compared biceps tenotomy and tenodesis directly and found no differences between treatments, with the exception of the Popeye sign being present in 3%

**Table IV** Operative and Postoperative complications

First author	Tenotomy complications	No.	Tenodesis complications	No.
Berlemann <sup>4</sup>	Not applicable		Pulmonary embolism	1
Boileau <sup>6</sup>	Not applicable		Temporary reflex sympathetic dystrophy	4
Boileau <sup>5</sup>	Pseudoparalysis	1		
	Reflex sympathetic dystrophy	1		
	Arthroscopic irrigation	1		
	Shoulder arthroplasty	2		
Checchia <sup>7</sup>	Not applicable		None stated	
Franceschi <sup>10</sup>	Not applicable		None stated	
Gill <sup>12</sup>	None stated		Not applicable	
Kelly <sup>13</sup>	None stated		Not applicable	
Walch <sup>21</sup>	Debridement of irreparable rotator cuff tears	2	Not applicable	
	Trauma	4		
	Shoulder arthroplasty	6		
	Wound infection	1		
	Reflex sympathetic dystrophy	4		

**Table V** Sample demographics and biomechanical results

First author	Technique	Sample size	Mean age, y	Load to tendon failure
		No.	(Range or SD)	(N)
Wolf <sup>22</sup>	Tenotomy	6	49 (41-57)	110.7
	Tenodesis	10		310.8
Ahmad <sup>1</sup>	Tenotomy	7	63.6	33.0
Mazzocca <sup>14</sup>	Tenodesis AIS	5	78 (18)	237.6
	Tenodesis ASA	5		164.8
	Tenodesis SIS	5		252.4
	Tenodesis SBT	5		242.4
Richards <sup>18</sup>	Tenodesis AIS	5	52 (44-57)	233.5
	Tenodesis ASA	6		135.5

AIS, arthroscopic interference screw; ASA, arthroscopic suture anchor; SIS, subpectoral interference screw; SBT, subpectoral bone tunnel; SD, standard deviation.

to 70% of patients undergoing tenotomy. Boileau et al<sup>5</sup> reported that the Popeye sign was not a significant clinical outcome of tenotomy in patient satisfaction. Patient complaints regarding cosmetic deformity varied, with sporadic reports of related cramping and fatigue that were not examined or further discussed. Overall, it was unknown what the long-term effects were of the cosmetic defect.

Analysis of available biomechanical studies showed a lower load to tendon failure in tenotomy compared with tenodesis groups (81.6 vs 233.5 N). Although these results tend to support the use of tenodesis over tenotomy, it is important to note that all studies showed improvement in outcome measures for LHB tendon injuries, regardless of which technique was used, and that tenodesis was associated with a higher likelihood of bicipital pain (OR, 1.5; RR, 1.4). In addition, Franceschi et al<sup>10</sup> reported that patients undergoing tenotomy rather than tenodesis had significantly better results in shoulder function and higher satisfaction levels.

The findings of the present review, although notable, are limited because many of the reviewed studies were

constrained by methodologic deficiencies, low power, and lack of randomization and a control group. Therefore, we note that although there are interesting differences between the tenotomy and tenodesis data, it is still uncertain whether there are any definitive outcome differences between the techniques. Similar limitations in analyzing outcome data for biceps tenotomy and tenodesis were reported by Frost et al,<sup>11</sup> who found little difference in outcome measures, partly due to low Coleman Methodology Scores of the available studies reviewed.

In considering when to choose tenotomy vs tenodesis for the treatment of biceps lesions, we have included guidelines from the literature as well as our own experiences that are summarized in Table VI. In general, we recommend biceps tenotomy for older patients with sedentary baseline physical activity, low demands for future physical activity, fat-obese arms, and who are not concerned about cosmesis or pursuing workers compensation. We recommend biceps tenodesis for younger patients (<40 years) with high levels of physical activity, high demands for future activity,

**Table VI** General guidelines for choosing tenotomy versus tenodesis

Factor	Tenotomy	Tenodesis
Age	Old	Young (<40 years)
Physical activity level	Sedentary	Active (athletes, laborers)
Physical demand needs	Low	High
Arm size	Fat, obese	Thin, normal
Cosmesis Concern	No	Yes
Workers Compensation	No	Yes

thin-normal arms, and who have greater concern for cosmesis or are involved in workers compensation claims. It is important to note that we have treated patients with biceps ruptures from autotenotomies as well as those who have undergone tenotomy and were referred due to cosmetic deformity, cramping pain, or fatigue. In our own series (unpublished data), we found that younger, more active patients who underwent biceps tenotomy experienced significant cramping and fatigue in their biceps after several hours of physical activity. The possibility of cramping pain and fatigue, along with cosmetic deformity, are the primary reasons why we recommend tenodesis over tenotomy in a younger active patient population.

This review presents a broad clinical picture of patients and their outcomes, but it is important to note that not all relevant variables were reported in every study. To address this limitation, we included the collected data in its raw form to demonstrate the heterogeneity among studies. As an example, studies investigating tenodesis alone varied among fixation with an interference screw, suture anchor, soft tissue suturing, and keyhole tenodesis. Although reviews are inherently limited by included studies with low levels of evidence, the mitigating benefit of this review was to compile an expanded population so that clinical outcomes and biomechanical results could be compared between tenotomy and tenodesis treatment groups.

To improve future studies investigating biceps tenotomy vs tenodesis, we recommend that in addition to greater control, randomization, and power, that study variables include patient demographics, baseline and future physical activity levels, arm circumference with fat percentage, condition of biceps tendon, concomitant injuries, simultaneous surgical procedures, Constant, Pain, and Activity Scores, detailed information regarding operative and postoperative complications, specific examination of clinical outcomes after surgery (time to fatigue, time to return to physical activity, cramping, etc), and load to tendon fatigue and failure. We believe that these variables will help standardize the data on tenotomy and tenodesis and enhance the surgeon's ability to choose between each treatment.

Overall, this review provides evidence to suggest that patients treated with biceps tenodesis will tend to experience more postoperative residual bicipital pain and less

cosmetic deformity than individuals treated with tenotomy. This increased probability of cosmetic deformity is supported by complimentary findings in existing biomechanical studies. However, these results are limited by interstudy differences and varying methodology. Both treatment groups were found to have the same span of operative and postoperative complications, and both groups showed overall improved outcome measures after surgery.

With the differences between treatment techniques remaining unclear, tenotomy has the apparent advantages of being simple, quick, and with less associated rehabilitation time. Tenodesis has a longer and more rigid rehabilitation regimen but can better restore normal anatomy, which may theoretically improve long-term function. In our experiences, we have found that overall treatment success of tenotomy or tenodesis largely depends on individual patient factors, such as age, physical activity status, and occupational or recreational activity needs. No definitive treatment recommendations can be made after reviewing the current literature, but we recommend that each patient be treated on an individual case basis in accordance with the patient's activity expectations, importance of cosmetic result, compliance, and associated pathologic entities.

## Conclusions

The results of this review on the differences between LHB tenotomy vs tenodesis demonstrated a higher incidence of cosmetic deformity in patients treated with biceps tenotomy, with an associated lower load to failure compared with patients treated with biceps tenodesis. Complications were similar for each treatment, with a higher likelihood of bicipital pain associated with tenodesis. Individual patient factors and needs should guide surgeons on whether to use tenotomy or tenodesis. There is a great need for future studies with high levels of evidence, control, randomization, and power, with well-defined study variables to compare biceps tenotomy and tenodesis for the treatment of LHB tendon lesions. In addition, basic science and biomechanical studies are needed to clarify the underlying mechanisms

of LHB tendon lesions to help guide future treatment options.

## Disclaimer

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, or US Government.

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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