Systematic Review and Meta-Analysis

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Biceps tenotomy versus tenodesis for lesions of the long head of the biceps tendon

A systematic review and meta-analysis of randomized controlled trials

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Abstract

Background: Biceps tenotomy and biceps tenodesis are 2 most common surgical procedures for long head of the biceps tendon (LHBT) pathology, but debate still exists regarding the choice of treatment. This meta-analysis was conducted to compare clinical results between tenotomy and tenodesis for the treatment of lesions of LHBT. It was hypothesized that there is no difference in outcomes of tenotomy and tenodesis for lesions of LHBT.

Methods: A comprehensive search of literature published between 1980 and April 2020 was performed using MEDLINE, EMBASE, Web of Science, and the Cochrane Library databases. Randomized controlled trials (RCTs) comparing tenotomy and tenodesis for LHBT lesions were included. The primary outcomes were Constant score and Popeye deformity. The secondary outcomes included the American Shoulder and Elbow Surgeons (ASES) score, visual analog scale (VAS) for pain, muscle strength, cramping pain, and operative time. For primary outcomes, trial sequential analysis (TSA) was conducted to reduce the risk of random errors and the GRADE (grading of recommendations, assessment, development, and evaluations) approach was used to assess the quality of the body of evidence.

Results: A total of 9 RCTs were included. In pooled analysis, statistical significance was observed in the Constant score (mean difference [MD], 1.59; 95% confidence interval [CI] 0.04–3.14; $P=.04$), Popeye deformity (risk ratio [RR], 0.33; 95% CI, 0.22–0.49; $P<.00001$) and operative time (MD, 9.94; 95% CI 8.39–11.50; $P<.00001$). However, there were no significant differences between the tenodesis and tenotomy in ASES score ($P=.71$), VAS for pain ($P=.79$), cumulative elbow flexion strength ($P=.85$), cumulative elbow supination strength ($P=.23$), and cramping pain ($P=.61$) TSA revealed that the results for Constant score was inconclusive.

Conclusion: For the treatment of LHBT lesions, with the exception of constant score, there was no significant benefit of tenodesis over tenotomy. Although tenotomy is affected by a higher risk of Popeye sign, it is more timesaving.

Abbreviations: ASES = American Shoulder and Elbow Surgeons score, LHBT = long head of the biceps tendon, MD = mean difference, RCTs = randomized controlled trials, RR = risk ratio, RRR = relative risk reduction, SMD = standardized mean difference, TSAs = sensitivity and trial sequential analyses, VAS = visual analogue scale.

Keywords: bicep, meta-analysis, tenodesis, tenotomy

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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1. Introduction

Shoulder pain is a highly prevalent musculoskeletal disorder in the general population and negatively influence the quality of life of patients.[1,2] Shoulder pain has a variety of potential causes. Lesions of long head of the biceps tendon (LHBT), one of the major contributors of chronic shoulder pain, may occurs as isolated, but more closely associated with other complex shoulder disorders, such as rotator cuff disorders.[3–6] The treatment of lesions of the LHBT is aimed at alleviating pain and improving shoulder function. Biceps tenotomy and biceps tenodesis are 2 most common surgical procedures for patients failing conservative management.[7] However, despite that both methods have been shown to produce favorable and effective results, considerable debate remains within the literature regarding the surgical treatment of choice.[8,9] Advocates of biceps tenotomy suggest that, compared with biceps tenodesis, tenotomy is technically simpler, more cost-effective, and easier to plan for postoperative rehabilitation.[10–12] However, tendon retraction may occur after tendon dissection. Therefore, some authors advocate biceps tenodesis, as it is better to maintain length and tension of the proximal LHBT, potentially resulting in decreased risk of Popeye deformity of upper arm and less strength loss.[8,12]

Several systematic reviews and meta-analyses[13–15] have conducted to compare the clinical outcomes of these 2 techniques. However, in considering such meta-analyses, it is important to note that the level of evidence included studies in such meta-analyses are not strong, such as retrospective studies or cohort studies, and only few are randomized controlled trials (RCTs). These non-RCTs usually have more potential sources of bias and confounding, as majority of surgeons prefer tenotomy for the elderly and tenodesis for younger patients, workers and athletes with higher levels of activity.[16,17] Therefore, findings came from these reviews were compromised by the limited availability of high-quality trials. To date, there is a lack of high-quality evidence, entirely from RCTs, to compare tenotomy and tenodesis for the treatment of LHBT lesions. So, with several RCTs newly published in recent years, it is necessary to update the literature and conduct a meta-analysis with a higher-quality evidence grade to determine the superior technique for treatment of LHBT lesions.

2. Methods

A systematic review was performed according to the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[18]

2.1. Data sources and search strategy

A comprehensive search of literature published between 1980 and April 2020 was performed using MEDLINE, EMBASE, Web Of Science, and the Cochrane Library databases. Two independent reviewers (PZ and JL) searched each database using the following Key words biceps and (tenotomy or tenodesis); in addition; reference lists cited in these articles were reviewed to ensure that no eligible literature was omitted. Discrepancies were resolved by a third reviewer (ZL).

2.2. Study selection

Literature was included if it met all of the following criteria: RCTs comparing tenotomy and tenodesis for LHBT lesions with or without concomitant reparable rotator cuff tears; published in English language; articles reported clinical outcomes data.

The exclusion criteria were non-RCTs (e.g., prospective cohort studies, retrospective studies, observational studies, case series, and reviews); animal or cadaver studies; comparisons that were not between tenodesis, and tenotomy method in LHB lesions; laboratory studies. However, references of these excluded studies were cross-checked to find potential eligible studies not found by the initial search.

2.3. Data extraction

Two reviewers (PZ and JL) independently extracted relevant data from each included study using the predefined form. Any discrepancies between the extracted data were resolved by discussion between the review authors or by consultation with another author (ZL). Where required, the corresponding authors were contacted for additional data. Extracted data included as following: study characteristics (first author, publication date, study design, levels of evidence [defined by the Oxford Centre for Evidence-Based Medicine[19]]), sample sizes, number of depletions (withdrawn/drop out/loss of follow-up), length of follow-up, patient details (sex, age, rotator cuff tears ratio), clinical outcomes. All reported endpoint outcomes data of these trials were summarized. The primary outcome measure was Constant score and Popeye deformity. Secondary outcome measure was measured with reliable and valid patient-reported outcome measures, such as the American Shoulder and Elbow Surgeons score (ASES), visual analogue scale (VAS), flexion strength and supination strength, cramping pain, and operative time.

2.4. Quality assessment and risk of bias assessment

Two reviewers independently assessed the risk of bias of each included study by using the Cochrane Collaboration risk-of-bias tool.[20] Methods included in the bias assessment were random sequence generation, allocation sequence concealment, blinding of participants and outcome assessors, incomplete outcome data, reporting bias, and other bias. Subsequently, each item was scored as “low risk of bias,” “unclear risk of bias,” or “high risk of bias.” The reasons for each judgment were presented in this manuscript. A third researcher (ZL) was consulted in any disagreement in the risk of bias assessment. We used the GRADE system to assess the quality of the evidence for each outcome.[21] The results of the GRADE analysis are presented in Supplemental Figure 1, http://links.lww.com/MD/F510.

2.5. Statistical analysis

Statistical analysis was performed using Review Manager Version 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration). Continuous variables were entered as means and standard deviations, and dichotomous outcomes as the number of events. The mean difference (MD) was used to perform continuous variables, and the dichotomous variables were reflected risk ratio (RR). When outcomes were assessed by distinct measures, standardized mean difference (SMD) with 95% confidence intervals (CIs) were utilized to standardize the results of studies to a uniform scale. Both were reported with 95% CI, and the significance level was set at $P=.05$. The heterogeneity was quantitatively detected by I-square tests. I-square values of 0% to 24.9%, 25% to 49.9%, 50% to 74%,

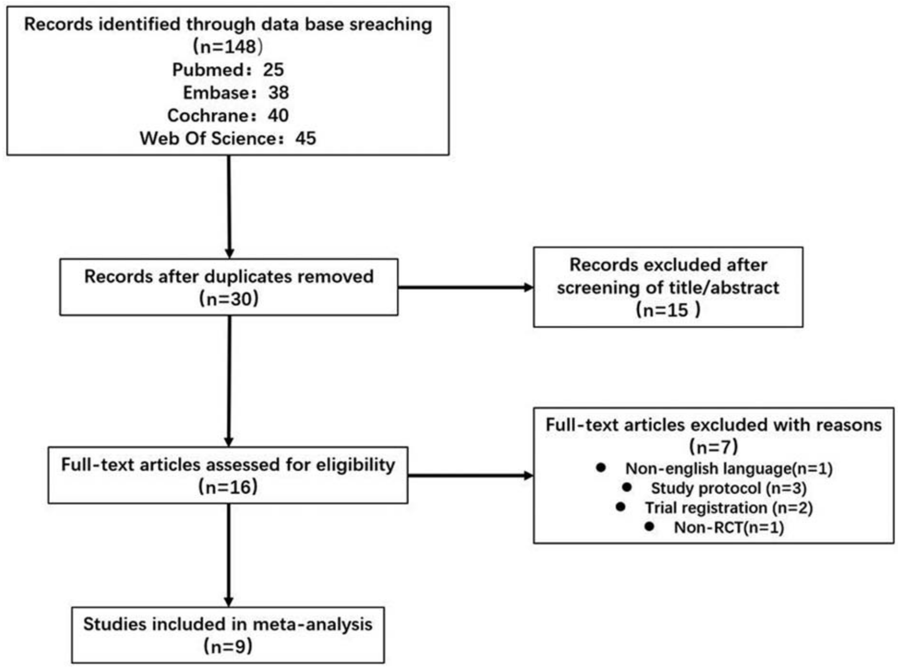

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram. RCTs = randomized controlled trials.

and 75% to 100% were considered none, low, moderate, and high heterogeneity, respectively.[22] Random-effects or fixed-effects models were used depending on heterogeneity of the study. The fixed effect model was utilized for I^2 values $\leq 25\%$.[23] If heterogeneity was significant ($I^2 > 50\%$), a sensitivity analysis was conducted by omitting each individual trial at a time to reveal the potential source of heterogeneity. The study by Belay et al[11] only separately reported the standard deviation of VAS pain scores and ASES scores of subgroup at the last follow-up, so the subgroup data were combined for the pooled analyses. In addition, we did not perform a publication bias due to the limited literature.

For primary outcomes, sensitivity and trial sequential analyses (TSAs) were conducted to avoid an early false-positive conclusion drawn by traditional meta-analysis techniques. The risk of type I error was set at 5% with a power of 80%. For dichotomous outcomes, we calculated required information size (RIS) to detect a 20% relative risk reduction (RRR). For continuous outcomes, we calculated RIS based on empirical estimation from TSA software. TSA was conducted with the TSA viewer version 0.9.5.10 Beta (www.ctu.dk/tsa).

3. Results

3.1. Search results and characteristics of the included studies

A total of 148 records were identified by the initial search. After selection, 9 RCTs[4,5,8,11,16,17,24–26] that met our inclusion criteria were included in this meta-analysis. The PRISMA flow diagram for the screening process in presented in Fig. 1.

Five of these 9 studies included only patients with concomitant reparable rotator cuff tears,[5,16,17,25,26] 1 of these 9 only included patients with isolated LHB lesions,[24] and the remaining 2 included patients with both concomitant rotator cuff tears and isolated LHB lesions.[4,12] There were 770 patients in total, initially. However, 97 patients were withdrawed, leaving 608 patients for analysis. Of these 673 patients, 340 in tenodesis group and 333 in tenotomy group. Details of these studies are summarized in Table 1.

3.2. Quality assessment and risk of bias

The results of the assessment for the risk of bias in the included studies were summarized in Fig. 2. In studies by Mardani-Kivi et al,[17] participants were not blinded to their treatment allocation; thus, this study was rated as having high risk of performance bias. In studies by Belay et al[11] and Mardani-Kivi et al,[17] the outcomes were not bling to assessment; thus, these 2 studies were rated as having a high risk of detection bias. The attrition bias was rated as high for 3 studies, the reason as following: Belay et al[11] did not reported the incidence of cramping pain in each group; Oh et al[25] lost >20% of enrolled patients to the last follow-up; Lee et al[5] did not report full structured values, including the standard deviation of VAS pain score and standard deviation of Constant score at the last follow-up. The study by MacDonald et al[8] did not reported the range of motion that was pre-specified in their study protocol; thus, this study was rated as having a high risk of bias of reporting bias. The quality of evidence was assessed using The Grading of Recommendations Assessment.[21] The results of the GRADE analysis are presented in Supplemental Figure 1, http://links.lww.com/MD/F510.

3.3. Primary outcome

3.3.1. Constant score. The Constant scores at the final follow-up were described in 5 RCTs[4,16,17,24,26] including a total of 353 patients (n = 175, tenodesis; n = 178, tenotomy). There was a

Table 1

Overview of studies included.

Study (year)	Study design/LOE	Number of patients/depletions, n		Male, %		Age, yrs		Cuff tears, %		Follow -up, mo		Biceps tenodesis methods
		Td	Tt	Td	Tt	Td	Tt	Td	Tt	Td	Tt	
Belay et al (2019)	RCT,II	15/1	20/0	85.7	95	52.9	57.7	35.7	70	24	24	ISC
Castricini et al (2017)	RCT,I	69/14	29.2	45.2	57.1	59.9	100	100	24	24	ISC	
Hufeland et al(2019)	RCT,I	11/2	11/0	77.8	36.4	51.5	52.8	0	0	12	12	ISC
Lee et al (2016)	RCT,I	77/5	60/4	25	19.6	62.9	62.8	100	100	19.7	25.1	ISC
MacDonald et al (2020)	RCT,I	57/9	57/5	82.5	78.9	58.7	56.3	79	73	24	24	ISC or button
Mardani-Kivi et al (2019)	RCT,II	44/11	44/15	66.7	69.0	55.5	54.5	100	100	24	24	ISC
Oh et al (2016)	RCT,II	40/9	40/13	67.7	33.3	56.6	61.0	100	100	21.5	22.0	Suture anchor
Zhang et al (2015)	RCT,I	80/6	80/3	47.3	46.8	61	61	100	100	25	25	Suture anchor
De Carli et al (2012)	RCT,II	35/0	30/0	NA	NA	56.3	59.6	100	100	25	23	Suture

ISC = interference screw, LOE = levels of evidence, RCT = randomized controlled trial, Td = tenodesis, Tt = tenotomy.

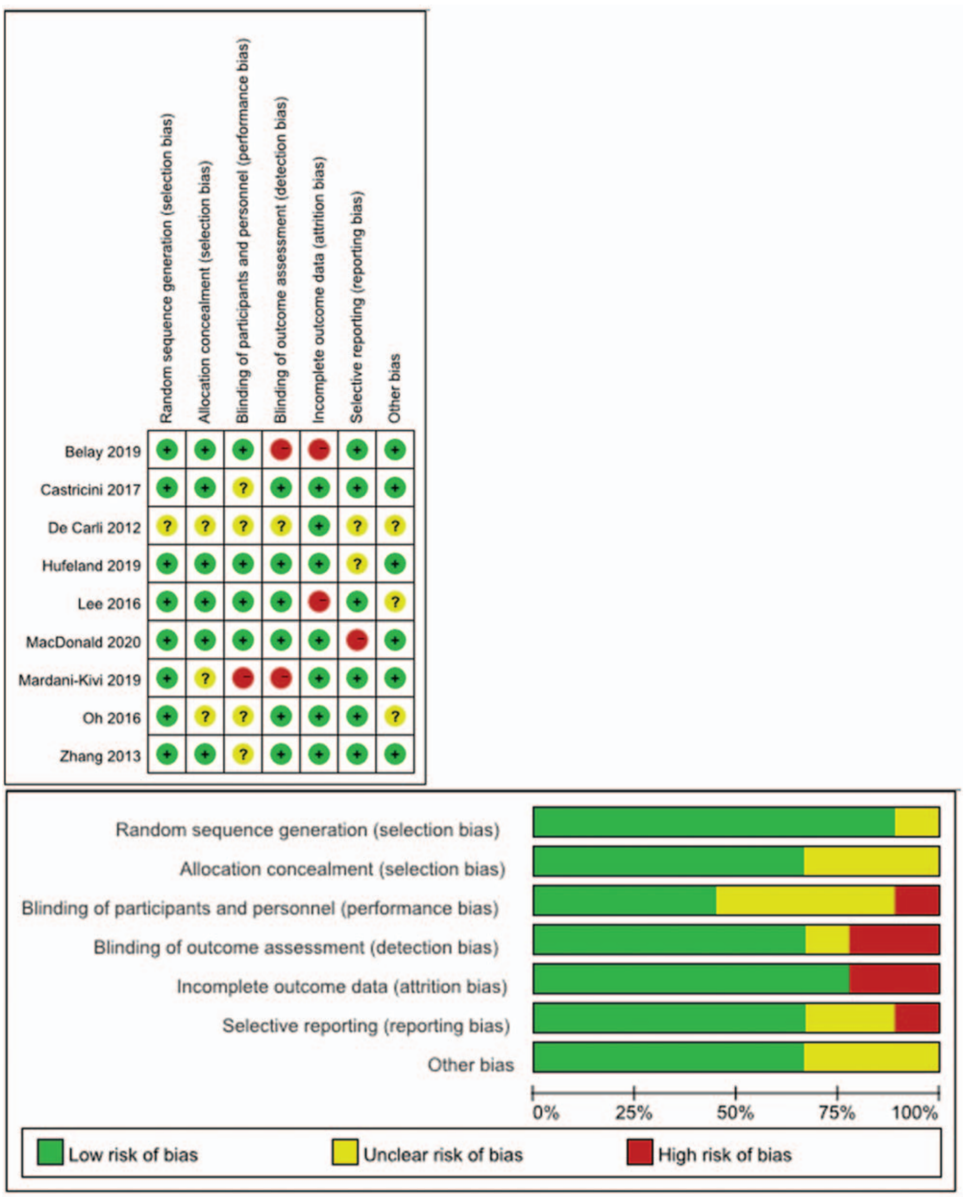

Figure 2. Summary of the risk-of-bias assessment for included studies.

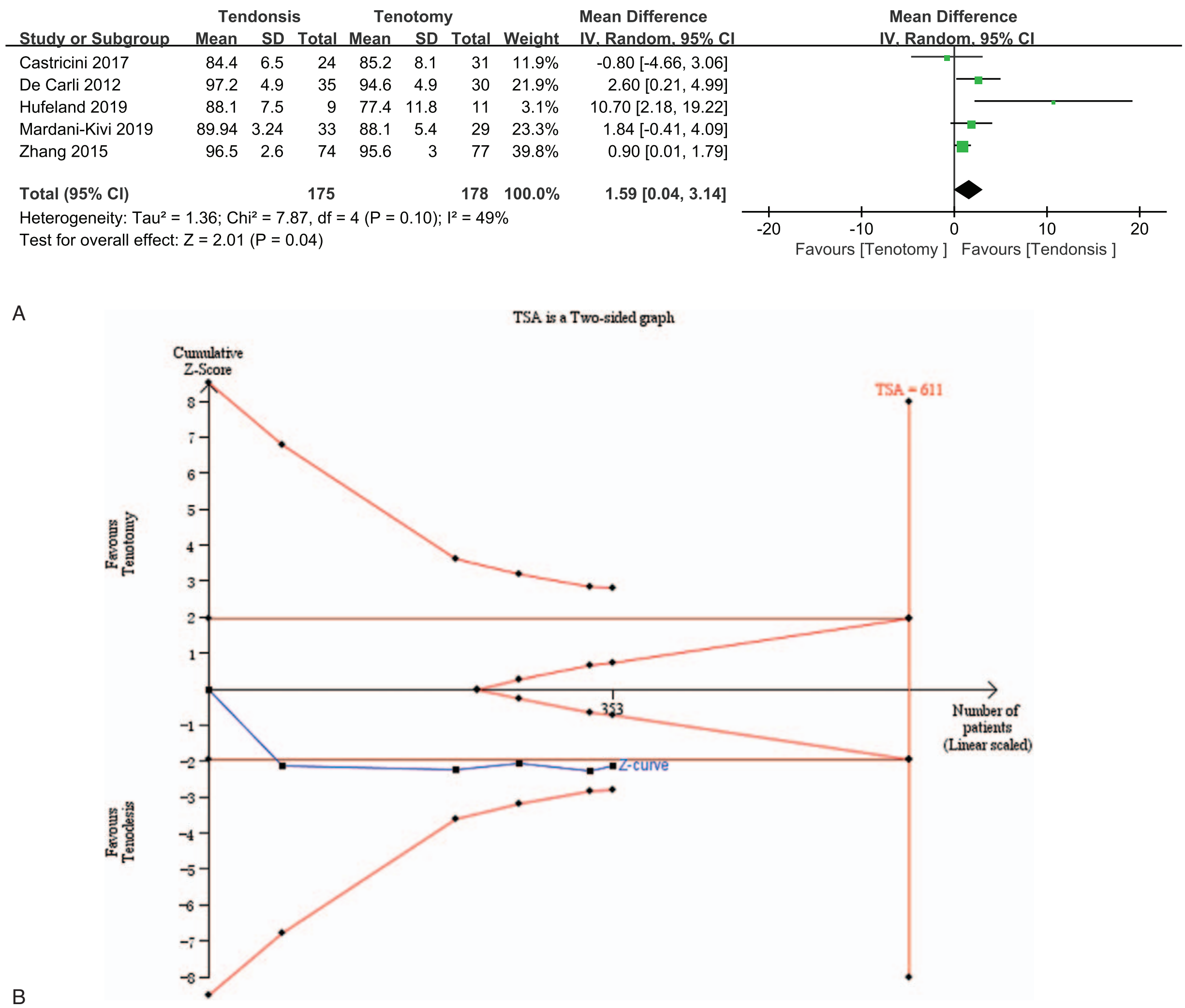

Figure 3. A, Forest plots of mean difference with 95% confidence intervals in Constant scores between biceps tenodesis and tenotomy technique. Random effect models were used. B, Trial sequential analysis of Constant scores.

statistically significant difference in favor of the tenodesis group in Constant scores at the last follow-up. (MD, 1.59; 95% CI 0.04–3.14; $P=.04$), with moderate heterogeneity ($I^2=49\%$) (Fig. 3A).

After sensitivity analysis, there was also a statistically significant difference in favor of the tenodesis group (MD, 1.13; 95% CI 0.33–1.92; $P=.005$, $I^2=2\%$), as shown in Table 2.

TSA showed that the Z curve crossed the conventional boundary, but failed to cross futility boundaries and trial sequential monitoring boundaries, indicating that the meta-analysis may obtained false-positive conclusion and need more trials to confirm the result (Fig. 3B).

3.3.2. Popeye deformity. Nine RCTs[4,5,8,11,16,17,24–26] including a total of 719 patients (369 tenodesis, 350 tenotomy) reported data regarding the rate of Popeye deformity (7.8% tenodesis, 25% tenotomy). The analysis showed the risk ratio for Popeye deformity was 0.33 in favor of tenodesis (95% CI, 0.22–0.49; $P<.00001$, $I^2=0\%$) (Fig. 4A).

Table 2

Sensitivity analysis.

Outcome	Number of RCTs	Number of patients	MD or RR	95% CI	*P*-value	I^2	Model
Constant score	4	333	1.13	0.33–1.92	.005	2%	Fixed
ASES score	4	192	−0.54	−4.78–3.71	.80	13%	Fixed
Supination strength index	2	186	0.18	0.15–0.21	<.00001	0%	Fixed
Cramping pain	4	284	0.79	0.25–2.50	.69	19%	Fixed

ASES = American Shoulder and Elbow Surgeons, CI = confidence interval, I^2 = statistical heterogeneity, MD = mean difference, RCTs = randomized controlled trials, RR = relative risk.

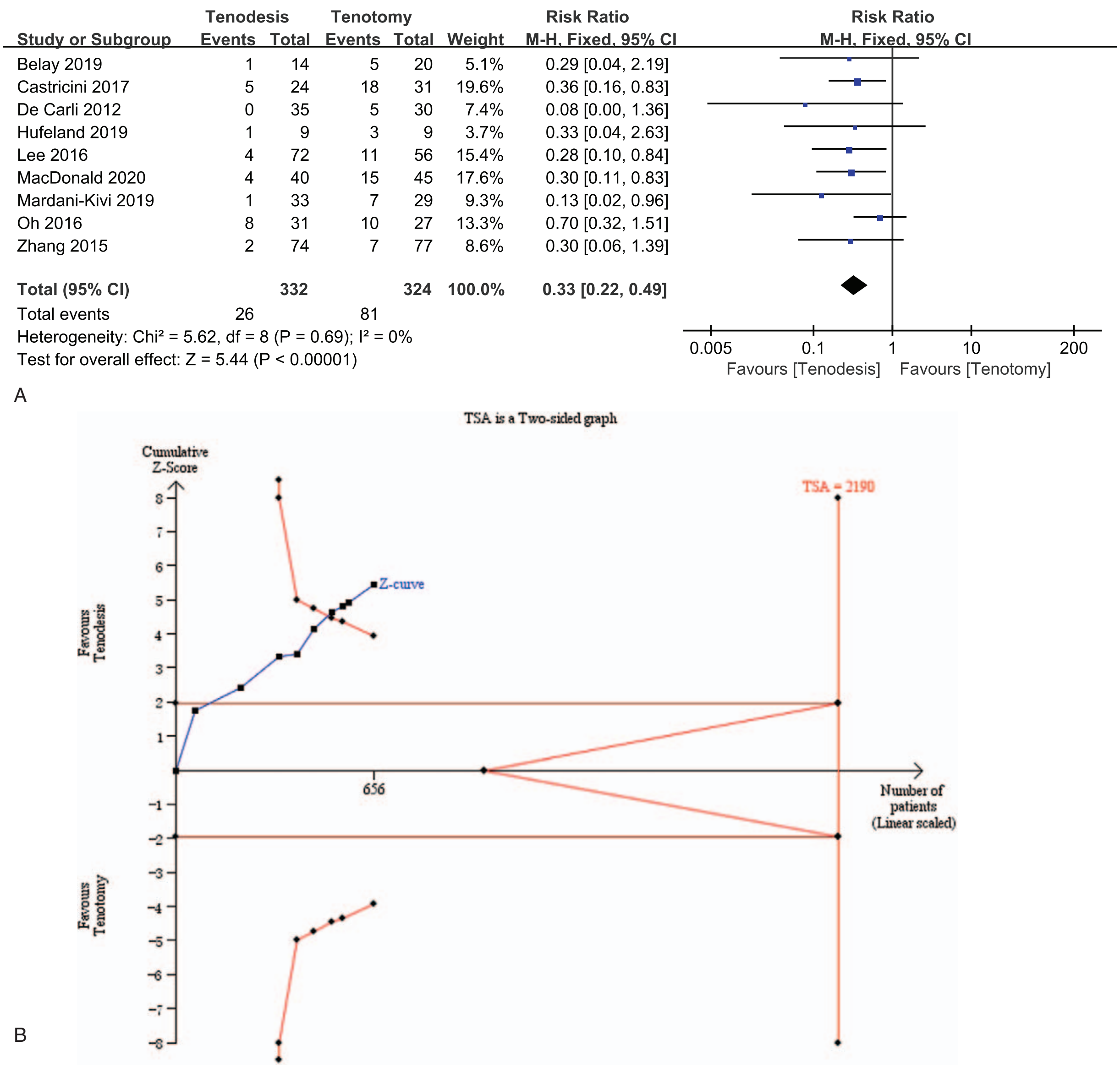

Figure 4. A, Forest plots of mean difference with 95% confidence intervals in Popeye deformity between biceps tenodesis and tenotomy technique. Fixed effect models were used. B, Trial sequential analysis of Popeye deformity.

TSA showed that the cumulative Z-curve crossed the trial sequential monitoring boundary, indicating that the current evidence was sufficient to reach a firm conclusion (Fig. 4B).

3.4. Secondary outcome

3.4.1. ASES score. Four RCTs[8,11,24,25] including a total of 212 patients (n=102, tenodesis; n=110, tenotomy) reported the ASES scores at the last follow-up. Although the study by Lee et al[5] reported the ASES scores, this study was excluded from analysis as it did not report the standard deviation of ASES score. There was no statistically significant difference between 2 groups in ASES scores at the last follow-up (MD, 1.43; 95% CI –6.15–9.01; P=.71), with moderate heterogeneity (I^2=65%) (Fig. 5).

Sensitivity analysis did not change the result for ASES scores between 2 groups (MD, –0.54; 95% CI –4.78–3.71; P=.80, I^2= 13%), as shown in Table 2.

3.4.2. VAS for pain. The VAS for pain at the final follow-up was described in 6 RCTs[4,8,11,16,17,25] including a total of 460 patients (n=224, tenodesis; n=236, tenotomy). There was no statistically significant difference between 2 groups in VAS for pain at the last follow-up. (MD, 0.04; 95% CI –0.22–0.29; P=.79), and no heterogeneity (I^2=0%) (Fig. 6).

3.4.3. Muscle strength. Five RCTs[5,16,25] reported the outcomes of muscle strength measurements. However, 2 of these 5 studies were performed with strength index (defined as the strength of the affected arm divided by the strength of the contralateral arm), while the remaining studies were performed with absolute value of the muscle strength. Thus, we analyzed the 2 different forms of flexion muscle strength separately.

3.4.4. Elbow flexion strength. The elbow flexion strength index at the final follow-up were described in 3 RCTs[5,16,25]

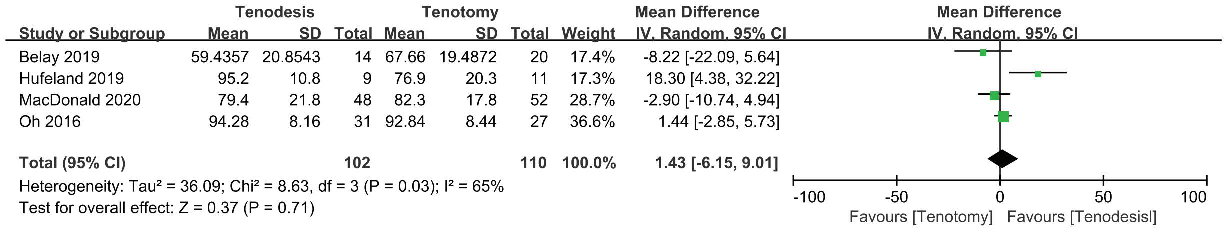

Figure 5. Forest plots of mean difference with 95% confidence intervals in ASES score between biceps tenodesis and tenotomy technique. Random effect models were used. ASES=American Shoulder and Elbow Surgeons score.

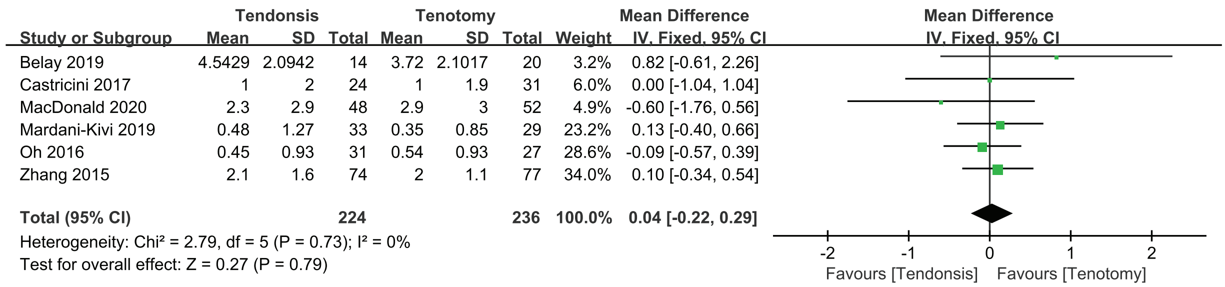

Figure 6. Forest plots of mean difference with 95% confidence intervals in VAS for pain between biceps tenodesis and tenotomy technique. Fixed effect models were used. VAS=visual analogue scale.

including 337 patients (n=177, tenodesis; n=160, tenotomy). There was no statistically significant difference between 2 groups in elbow flexion strength index at the final follow-up (MD, –0.01; 95% CI –0.03–0.01; $P=.42$), with no heterogeneity ($I^2=0\%$).

The elbow flexion strength change at the final follow-up were described in 2 RCTs[8,24] including 120 patients (n=57, tenodesis; n=63, tenotomy). There was no statistically significant difference between the 2 groups in elbow flexion strength changes at the final follow-up, (MD, 0.38; 95% CI –2.28–3.03; $P=.78$), with no heterogeneity ($I^2=0\%$).

3.4.5. Cumulative assessment of elbow flexion strength.

The combined result indicated that there was no statistically significant difference between 2 groups (SMD, –0.02; 95% CI, –0.20–0.17; $P=.85$). The corresponding I^2 value (0%) indicated no heterogeneity (Fig. 7).

3.4.6. Elbow supination strength.

The elbow supination strength index at the final follow-up were described in 3 studies[5,16,25] including 337 patients (n=177, tenodesis; n=160, tenotomy). There was statistically significant difference between 2 groups in elbow supination strength index at the final follow-up

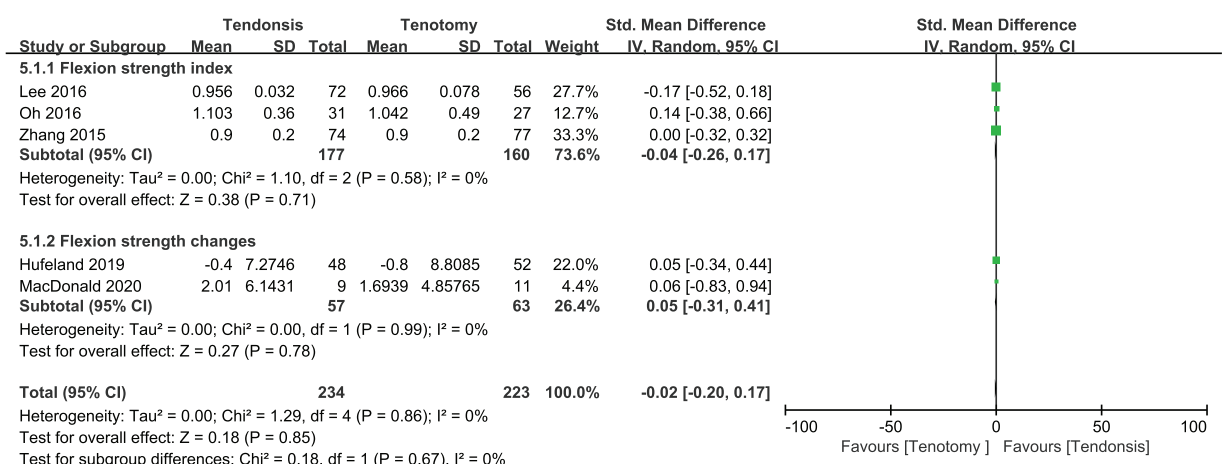

Figure 7. Forest plots of mean difference with 95% confidence intervals in cumulative assessment of elbow flexion strength between biceps tenodesis and tenotomy technique. Fixed effect models were used.

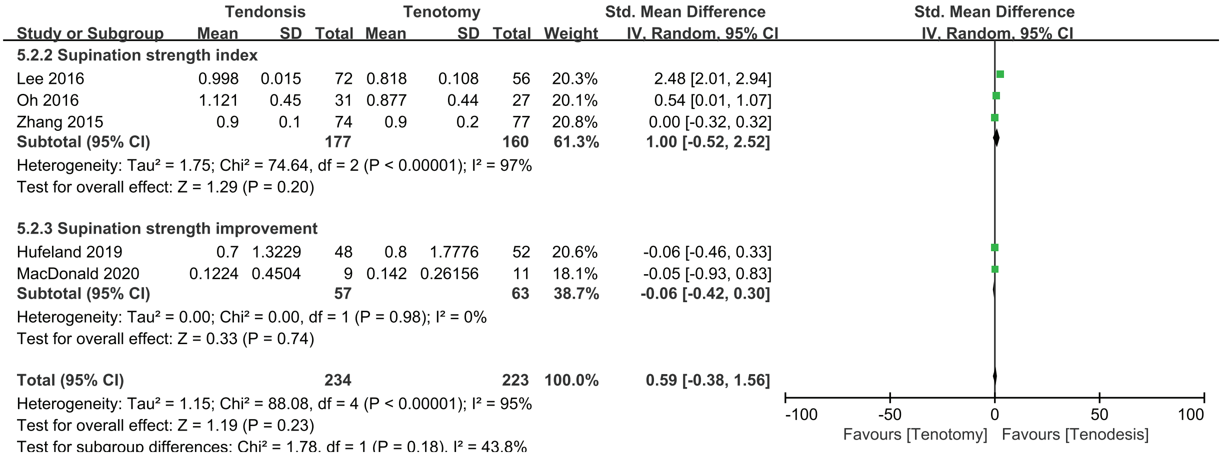

Figure 8. Forest plots of mean difference with 95% confidence intervals in cumulative assessment of elbow supination strength between biceps tenodesis and tenotomy technique. Random effect models were used.

(MD, 0.14; 95% CI 0.11–0.16; $P < .00001$), with high heterogeneity ($I^2 = 95\%$). After sensitivity analysis, there was also a statistically significant difference in favor of the tenodesis group (MD, 0.18; 95% CI 0.15–0.21; $P < .00001$, $I^2 = 0\%$), as shown in Table 2.

The elbow supination strength changes at the final follow-up were described in 2 studies[8,24] including 120 patients (n=57, tenodesis; n=63, tenotomy). There was no statistically significant difference between the 2 groups in elbow supination strength changes at the final follow-up (MD, –0.04; 95% CI –0.33–0.25; $P = .80$), and no heterogeneity ($I^2 = 0\%$).

3.4.7. Cumulative assessment of elbow supination strength.

The combined result indicated that there was no statistically significant difference between 2 groups (SMD, 0.59; 95% CI, –0.38–1.56; $P = .23$). The corresponding I^2 value (95%) indicated significant heterogeneity (Fig. 8).

3.4.8. Cramping pain.

Five RCTs[4,16,17,24,25] including a total of 346 patients (171 tenodesis, 175 tenotomy) reported the rate of cramping pain. There was no statistically significant difference between the 2 groups (RR, 1.50; 95% CI 0.31–7.25; $P = .61$), with moderate heterogeneity ($I^2 = 56\%$).

Sensitivity analysis did not change the result for the rate of cramping pain (RR=0.79, 95% CI, 0.25–2.50, $P = .69$, $I^2 = 19\%$) (Fig. 9).

3.4.9. Operative time.

Two RCTs[8,16] including a total of 274 patients (137 tenodesis, 137 tenotomy) reported data regarding the operative time. There was a statistically significant difference in favor of the tenotomy group (MD, 9.94; 95% CI 8.39–11.50; $P < .00001$, $I^2 = 0\%$) (Fig. 10).

3.5. Evidence quality assessment according to GRADE

According to GRADE guidelines, the quality of evidence is evaluated from 5 aspects: risk of bias, inconsistency, indirectness, imprecision, publication bias. For the comparison between the tenodesis and tenotomy, there is moderate evidence in Popeye deformity and VAS, low evidence in flexion strength and surgical time, very low evidence in constant score, ASES score, Supination strength, and Cramps pain. Detailed information was shown in Supplementary figure.1, http://links.lww.com/MD/F510.

4. Discussion

The main findings observed in this meta-analysis were that biceps tenodesis resulted in higher Constant score, lower risk of Popeye sign, and greater time cost, but there was no significant difference between the 2 groups in terms of ASES score, VAS for pain, Elbow flexion strength, and cramping pain. Several systematic reviews and meta-analyses[13–15,27] have performed to compare

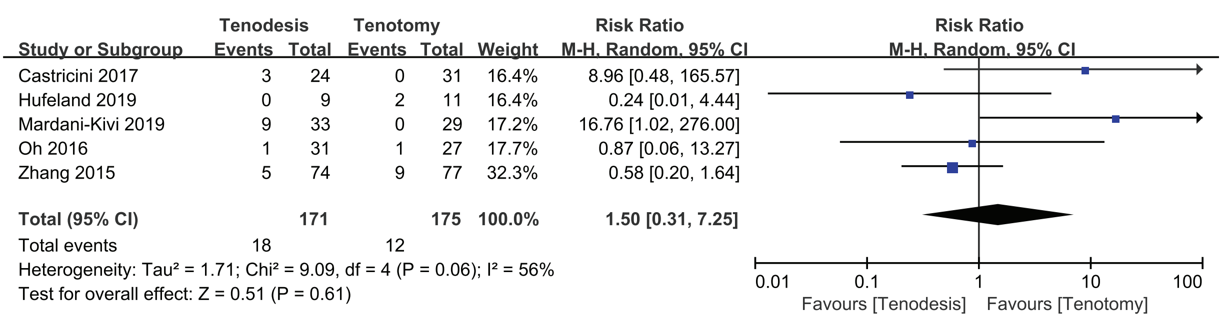

Figure 9. Forest plots of mean difference with 95% confidence intervals in cramping pain between biceps tenodesis and tenotomy technique. Random effect models were used.

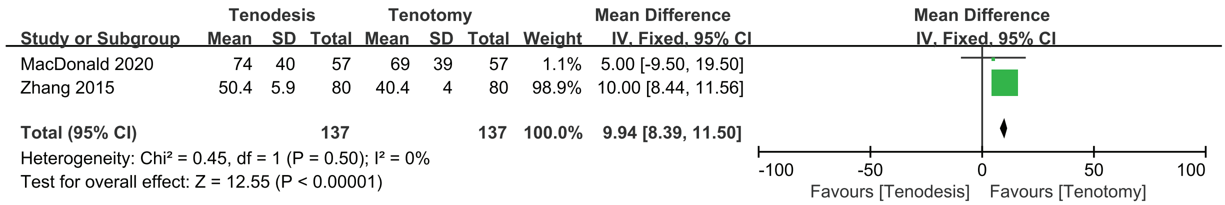

Figure 10. Forest plots of mean difference with 95% confidence intervals in operative time between biceps tenodesis and tenotomy technique. Fixed effect models were used.

the clinical outcomes of these 2 techniques. However, no consensus has been reached regarding the most effective treatment. Many finds in these meta-analyses were derived from lower-level studies, such as retrospective studies[28,29] or cohort studies.[30–32] In comparison with this review, our current review utilized a systematic and comprehensive search strategy to combine the maximum available data, which contained 9 RCTs involving 673 participants in total. Moreover, in terms of inclusion criteria, studies of LHBT lesions with or without concomitant reparable rotator cuff tears were included. Na et al[14] and Shang et al[13] only focused on patients who have LHBT lesions with concomitant rotator cuff tears. Thus, their results cannot be extrapolated to all patients with LHBT lesions. Although LHBT lesions are more commonly associated with rotator cuff tears than isolated LHBT pathology, we believe that inclusion of patients with isolated LHBT lesions make the comparison between tenotomy and tenodesis for LHBT lesions more generalizable.

The Constant score is one of the most commonly applied tools for the assessment of the shoulder joint, which comprehensively evaluates the patient's subjective and objective outcomes from the following aspects: pain, daily living activities, range of motion, and strength.[33] Recently published meta-analyses resulted in inconsistent conclusions concerning Constant score.[13–15] Some studies[13,14,27] found that biceps tenodesis for LHBT lesions with concomitant reparable rotator cuff tears results in significantly improved Constant score compared with biceps tenotomy. However, Gurnani et al[15] observed no significantly different between 2 groups in Constant score. In addition, recent clinical studies also yield opposite results in terms of constant score.[24,34] In the current study, the pooled Constant scores are consistent with the studies by Na et al[14] and Shang et al.[13] However, even though the result for Constant score was statistically reliable after sensitivity analysis, the TSA indicated that the meta-analysis may obtained false-positive conclusion. As shown in Fig. 3, the required information size was 611 participants, the cumulative Z-curve (blue line) did not cross the trial sequential monitoring boundaries for benefit or harm (red inward sloping lines). And that the cumulative Z-curve did not cross the inner-wedge futility line (red outward sloping lines nor the diversity-adjusted required information size). So, the result of TSA showed that we had enough information to reject tenodesis compared with tenotomy that we did not have enough information to confirm or reject that tenodesis versus tenotomy improved the Constant score. Thus, the results concerning Constant score should be interpreted cautiously. In regard to Popeye sign deformity, it was one of most important reasons for not choosing tenotomy.[16] Although some recent clinical studies reported that there was non-significant difference rate of postoperative Popeye sign deformity between 2 groups,[24,35] according to our data, if the biceps tendon is cut, Popeye sign deformity is more likely to occur. The present meta-analysis and TSA strengthened the evidence of previous studies.[13–15] The Popeye deformity occurred in 25% of patients undergoing biceps tenotomy, which is in keeping with the findings of Frost et al[10] study showing incidence of Popeye deformity after biceps tenotomy varied from 3% to 70%. The occurrence of the Popeye deformity in the tenodesis group was 7.8%, which are probably due to failure of the tenodesis or too much slack tension of the biceps tendon with successful tenodesis.[8,25]

For the secondary outcomes. These pooled results were mostly consistent with previous studies, except for the cramping pain. The analysis showed the risk ratio for cramping pain was 1.50 in favor of tenotomy, but it was no statistically significant. This is in contrast to results from Gurnani et al,[15] but is similar to the Na et al[14] and Anil et al.[27] Furthermore, most studies describe cramping as a temporary complication, recovering within a few months.[4,16,24] Secondly, the pooled result found that biceps tenodesis resulted in a higher elbow supination strength index compared with biceps tenotomy, inconsistent with previous studies.[13–15] However, significant heterogeneity ($I^2=95\%$) was found between studies. This may be due to the position of the arm when the force was measured, which was not explicitly mentioned in several studies. Furthermore, we found that there was no significant difference between the 2 groups in terms of cumulative assessment of elbow supination strength. Therefore, this result should be intreated cautiously. Additionally, no differences in elbow flexion strength were found after biceps tenotomy versus tenodesis. However, some studies indicated that elbow flexion strength and supination strength probably do not truly assess the role of the long head of the biceps and are not often clinically significant.[8,11]

4.1. Limitations

The limitations of this study should also be noted. First, only 9 RCTs involving 673 participants were included in the present review, and the limited sample sizes weakened the strength of the meta-analysis. Besides, some of the results of this review have significant study heterogeneity, which is due to differences in age, techniques and fixation methods, type of LHBT lesions and concomitant disorders in addition to the previously mentioned reasons for strength measurement. Subgroup analysis could not be conduct as limited number of studies. Furthermore, studies not published in English were excluded, thereby potentially leading to language bias.

4.2. Future directions

There was insufficient evidence to identify which of the 2 methods was significantly better for LHBT lesions considering the limitations of this study. Thus, more high-quality RCTs are still needed in order to adopt a worldwide-accepted treatment method. In addition, cost effectiveness analysis of biceps tenodesis and tenotomy should be carried out in the future, which may contribute to the clinical decision-making.

5. Conclusion

Based on the results above, with the exception of constant score, there was no significant benefit of tenodesis over tenotomy. Given its shorter surgical time and lower cost than tenodesis, tenotomy may also be a more commonly used clinical method for LHB lesion, but we must inform all patients in our daily practice of the surgical options of tenotomy and the high prevalence of tenotomy in Popeye deformity.

Author contributions

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