■ SYSTEMATIC REVIEW

Effect of scapular notching on clinical outcomes after reverse total shoulder arthroplasty

A META-ANALYSIS

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Aims

Scapular notching is thought to have an adverse effect on the outcome of reverse total shoulder arthroplasty (RTSA). However, the matter is still controversial. The aim of this study was to determine the clinical impact of scapular notching on outcomes after RTSA.

Methods

Three electronic databases (PubMed, Cochrane Database, and EMBASE) were searched for studies which evaluated the influence of scapular notching on clinical outcome after RTSA. The quality of each study was assessed. Functional outcome scores (the Constant-Murley scores (CMS), and the American Shoulder and Elbow Surgeons (ASES) scores), and post-operative range of movement (forward flexion (FF), abduction, and external rotation (ER)) were extracted and subjected to meta-analysis. Effect sizes were expressed as weighted mean differences (WMD).

Results

In all, 11 studies (two level III and nine level IV) were included in the meta-analysis. All analyzed variables indicated that scapular notching has a negative effect on the outcome of RTSA . Statistical significance was found for the CMS (WMD –3.11; 95% confidence interval (CI) –4.98 to –1.23), the ASES score (WMD –6.50; 95% CI –10.80 to –2.19), FF (WMD –6.3°; 95% CI –9.9° to –2.6°), and abduction (WMD –9.4°; 95% CI –17.8° to –1.0°), but not for ER (WMD –0.6°; 95% CI –3.7° to 2.5°).

Conclusion

The current literature suggests that patients with scapular notching after RTSA have significantly worse results when evaluated by the CMS, ASES score, and range of movement in flexion and abduction.

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Introduction

Reverse total shoulder arthroplasty (RTSA) is one of the most effective ways of managing patients with an irreparable rotator cuff tear, a cuff tear arthropathy, or a fracture of the proximal humerus,[1-4] as a a conventional shoulder arthroplasty cannot guarantee a reliable outcome. This is mainly because a conventional shoulder arthroplasty is compromised by a non-functioning rotator cuff.[5] Since Grammont[6] introduced the RTSA and its several subsequent modifications,[5] it is now gaining in popularity[7] and many mid-term follow-up studies have shown its effectiveness.[8-17] Although its non-anatomical features make it both original and unique, these attributes are also associated with complications and limitations.

Scapular notching, in particular, is a unique phenomenon of RTSA, and is caused by mechanical impingement between the humeral component and the neck of the glenoid. This can cause wear of the polyethylene humeral component and consequent osteolysis of the surrounding bone.[18,19] Many have predicted that scapular notching can also cause instability of the glenoid component;[20,21] others have expressed concern that scapular notching may have a negative effect on clinical outcome.[14,22–30] The incidence of scapular notching after RTSA ranges from 10% to 96%.[18,25,31] Due to its rising popularity and the alarmingly high

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reported incidence of scapular notching in some reports, it is important to have a better understanding of its complications.[5] For this reason, many researchers have compared the clinical outcome of patients with scapular notching after RTSA to those of patients without scapular notching.[8,14,16,22–30,32–44] However, the issue remains controversial.

Most studies on the topic have been underpowered[25,29] because of the relatively small number of patients enrolled and an imbalance between the number of patients in notched and non-notched groups.[25,29] Furthermore, the rate of scapular notching after RTSA is dependent on the implant design and its orientation.[5,45,46] Consequently, we considered that a comprehensive review was needed which weighted the statistical powers of previous studies. Meta-analysis is the best available option for improving the level of evidence and provides a means of addressing the issue of underpowering. However, to the best of our knowledge, no meta-analysis has been previously been undertaken on the effect of scapular notching on patient outcome after RTSA.

The purpose of this meta-analysis was to compare the clinical variables of patients with and without scapular notching. Our hypothesis was that patients with scapular notching would have a worse clinical outcome in terms of functional score and range of movement.

Methods

Inclusion and exclusion criteria. A systematic review of the literature was carried out following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) protocol. Search criteria and review objectives were defined before the literature search was conducted. Following this protocol, a systematic search was undertaken using PubMed, EMBASE, and the Cochrane Database of Systematic Reviews. These electronic databases were searched from January 1980 to January 2020. Text searches used as '[{(notch*) OR (imping*) OR (abut*)} AND {(RTSA) OR (reverse arthroplasty) OR (reverse shoulder arthroplasty) OR (reverse total shoulder arthroplasty)}]' in the three databases.

The inclusion criteria applied were that they were written in English, reported clinical outcomes and radiological assessments of scapular notching, and had a minimum two years of follow-up. The exclusion criteria were biomechanical studies, cadaver studies, reviews, and consensus meetings.

Two authors (YHJ, JHL) independently reviewed the abstracts of each article and then jointly reviewed the full texts to determine whether they were suitable for inclusion in the study. When disagreements occurred, the third author (SHK) participated in discussions with the two authors to reach consensus. The methodological quality of each included study was appraised in accordance with the Oxford levels of evidence 2.[47]

Methodological quality assessment. Methodological quality was assessed using the Risk of Bias Assessment tool for Non-randomized Studies (RoBANS),[48] which consists of six components. The first is selection of participants, and evaluates the possibility of selection bias caused by the inadequate selection of participants; the second is confounding variables, which assesses selection bias caused by inadequate confirmation and consideration of confounding variables; The third is measurement of exposure, which evaluates performance bias caused by inadequate measurement of exposure; the fourth is blinding for outcome assessment, which assesses detection bias caused by inadequate blinding of outcome assessment; the fifth is incomplete outcome data, which evaluates attrition bias caused by inadequate handling of incomplete outcome data; the sixth is selective outcome reporting, which assesses reporting bias caused by selective outcome reporting. Two raters (YHJ and JHL) independently assessed each of the identified studies using this tool. The senior author (SHK) resolved disagreements. Final ratings were then discussed and agreed by all three authors. Results are given in detail in the online supplementary material.

Data extraction. A database was created from included studies using the following categories:

1. Study identification including author, journal, and year of publication.
2. References.
3. Study design.
4. Country in which the study was performed.
5. Study inclusion/exclusion criteria.
6. Number of patients included.
7. Patient age.
8. Minimum and length of follow-up.
9. Numbers of cases with and without scapular notching at final follow-up.
10. Grade of scapular notching as determined by the Nerot-Sirveaux classification[14] . These grades were converted into a severity index, defined as notching grades 3 + 4 divided by grades 1 + 2.
11. Name of implant used.
12. Implantation features of the glenoid (diameter, tilting. eccentricity, lateralization), and humeral component (neck-shaft angle, version, lateralization).
13. Postoperative absolute Constant-Murley score (CMS).
14. Postoperative American Shoulder and Elbow Surgeons (ASES) score.
15. Postoperative range of movement (ROM): forward flexion (FF), abduction, external rotation (ER).
16. Statistical power, calculated using the one-tailed test using an α value of 0.05. As some of the studies did not report the CMS on each study group, we calculated the study power using the mean reported CMS for each study and assumed a difference in the CMS of 5 points and assumed standard deviation (SD) of 10 points for each group, as previously described by Mollon et al.[25]

Data synthesis. Available quantitative data were pooled in a statistical meta-analysis using Review Manager (RevMan) software (version 5.3; The Cochrane Collaboration, London, UK). For continuous data, effect sizes with 95% confidence intervals (CIs) were expressed as weighted mean differences (WMDs). A random-effects model or a fixed-effects model with an inverse variance method for WMDs was used for the meta-analyses. If the I^2 was less than 50%, a fixed-effects model was used. If the I^2 was 50% or more, a random-effects model was used. Statistical heterogeneity was assessed using the standard I^2: values of less than 50% generally indicate consistent results and

Table I. Results of excluded and included studies for meta-analysis.

First author	Year	Statistical significance	Power*	Severity Index†	Reason of exclusion	Description of results
Studies which were excluded from meta-analysis						
Sirveaux	2004	+	67.2	0.36	No specific data was presented	"The presence of the notch significantly affected the Constant score when the notch was either over the screw or extensive ($p < 0.05$)."
Werner	2005	+	16.9	0.84	No specific data was presented	"Inferior notching negatively correlated with the Constant score ($r = 0.3184$; $p = 0.0311$)."
Boileau	2006	-	49.4	0.22	No specific data was presented	"Neither the presence nor the size of the notch had a negative effect on the Constant score, the adjusted Constant score, or the ASES score."
Stechel	2010	-	36.4	0.06	No specific data was presented	"There were no statistically significant differences between the groups. No effect on the Constant score could be seen."
Sadoghi	2011	+	18.8	0.20	No specific data was presented	"We did not find any significant correlations at mid-term follow-up, ranging from 24 to 60 months. In long-term follow-up (60 months and more), we found significant positive correlations between infraglenoidal notching and the Constant pain score ($p = 0.3$), and active anteversion ($p < 0.01$) and active external rotation ($p < 0.01$)."
Sershon	2014	+	29.1	0.00	No specific data was presented	"There was no correlation between preoperative or postoperative radiological findings and clinical outcomes."
Athwal	2015	-	45.6	0.05	Risk of selection bias due to study design	"There was no significant differences with respect to range of movement ($p > .491$) or functional scores ($p > .556$)."
Torrens	2016	-	66.9	0.63	Risk of selection bias due to study design	"Scapular notching did not significantly affect the total Constant score or range of movement."
Erbstbbrunner	2017	+	19.4	0.43	Difference in grouping of comparison	"Patients with scapular notching of grade 2 or higher ($n = 10$) had a significantly lower mean relative Constant score (57% vs 81%; $p = 0.006$) ... at the time of final follow-up compared with patients with no or grade-1 notching ($n = 11$)."
Kirzner	2018	+	46.2	0.05	Risk of selection bias due to study design	"Statistically significant differences could be seen; however, when comparing ASES, SSV, WOOS and pain scores between the two groups with the notching cohort showing worse outcomes."
Pastor	2018	+	50.7	0.09	No specific data was presented	"Inferior notching negatively correlated with the Constant score ($r = 0.3184$; $p = 0.0311$). However, the Constant score did not significantly differ between each grade of notching."
Torrens	2019	-	62.3	0.05	Risk of selection bias due to study design	"The functional outcomes (Constant scores) were not significantly different between patients with and without a scapular notch."
Studies which were included in meta-analysis						
Simovitch	2007	+	69.6	0.70		Results are reflected in meta-analysis
Levigne	2008	-	99.7	0.53		Results are reflected in meta-analysis
Favard	2011	-	34.2	1.25		Results are reflected in meta-analysis
Levigne	2011	-	99.9	0.51		Results are reflected in meta-analysis
Mizuno	2012	-	50.4	0.06		Results are reflected in meta-analysis
Torrens	2013	-	40.8	0.29		Results are reflected in meta-analysis
Birgorre	2014	-	85.2	0.05		Results are reflected in meta-analysis
Feeley	2014	-	49.2	0.14		Results are reflected in meta-analysis
Katz	2015	-	84.9	0.05		Results are reflected in meta-analysis
Mollon	2017	+	94.9	0.09		Results are reflected in meta-analysis
Simovitch	2019	+	93.5	0.21		Results are reflected in meta-analysis

*Statistical power was calculated from a one-tail test using an $\alpha = 0.05$. As some of studies did not report any functional score on each study group, we calculated the study power using the mean of the Constant-Murley score (CMS) for each study and assumed a difference in CMS of 5 points and also assumed standard deviation of ten points for each group as Mollon et al.[25]
†The severity index were defined as notching grade 3 + 4 divided by grade 1 + 2 by Nerot-Sirveaux classification.[14]

study homogeneity. Sensitivity analysis was carried out by the method of single elimination of individual studies. Funnel plots of effect size versus standard error (SE) were assessed by visual inspection to determine publication bias.

Missing SDs in the studies were dealt with as described by Walter et al[49] and Ma et al.[50] One study presented only ranges of the value, and in this study, the difference between minimum and maximum values was divided by four to estimate the SD.[33] Four studies did not provide the SD; SDs were estimated using weighted averages of variances observed in other studies.[34,37,39,44]

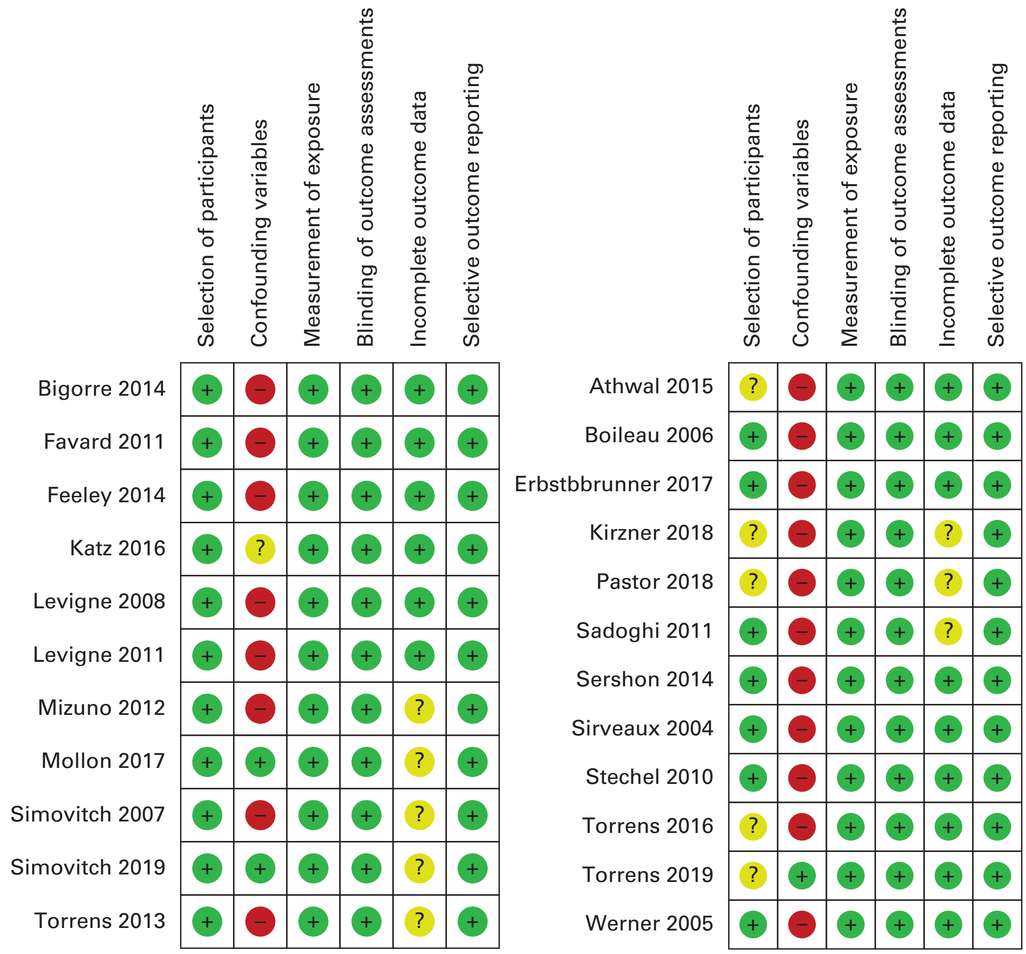


Fig. 1

Methodological quality assessment using the Risk of Bias Assessment tool for Nonrandomized Studies (RoBANS). '+' refers to low risk, '-' refers to high risk, and '?' refers to unclear risk, with showing assessment of the included studies for the meta-analysis (left), and showing the assessment of the excluded studies for the meta-analysis (right).

Results

Systematic review and study properties. An initial search resulted in 764 articles (335 from PubMed, 412 from EMBASE, and 17 from Cochrane Database of Systematic Reviews). After deleting 268 duplicates, title reviews were carried out on 496 articles, which left 60 articles for abstract review. After abstract reviews, 23 articles were included for full-manuscript review.[8,14,16,22–30,32–37,39,41–44] The properties of these 23 studies are detailed in Table I.

Overall, 17 of the 23 studies included in the full-manuscript review were sub-analyses of consecutive case series on outcomes after RTSA.[8,14,16,22,24,26–28,30,33–37,39,41,44] Two were sub-analyses of randomized clinical trials on other topics,[42,43] two were prospective or retrospective cohort comparative studies on other topics,[23,32] and two were retrospective cohort comparative studies primarily on the effect of scapular notching on clinical outcomes after RTSA.[25,29] Ten of the 23 studies concluded that effect of scapular notching was significant,[14,16,22,23,25–30] and 13 failed to demonstrate significance.[8,24,32–37,39,41–44] Other properties and the results of the 23 studies are summarized in Table I and in the online supplementary material.

Quality assessment and selection of studies for meta-analysis. The results of quality assessments conducted using RoBANS are given in Figure 1. Six studies were found to have possible enrolment selection bias. Four of the six studies were comparative cohort studies[23,32] or randomized clinical trials[42,43] on other topics (e.g. implant type, size, or orientation), one study confined enrolment of the study group to a specific surgical indication (fracture sequalae),[26] and the other study defined the grouping differently when comparing notching and non-notching group.[22] Therefore, these six studies were excluded from the analysis.[22,23,26,32,42,43]

Most of the 17 remaining studies were assessed to lack confirming and considering confounding variables, which were known to influence the occurrence of scapular notching and clinical outcomes, and this, can possibly cause selection bias in the analysis.[8,14,16,24,27,28,30,33–35,37,39,41,44] However, we decided to include studies with unclear confounding variable risks because the aim of this meta-analysis was primarily to describe phenomena and not to investigate specific cause and effect relationships. Moreover, eight studies did not disclose follow-up losses, and thus present unclear risks with respect to incomplete

Study or Subgroup	Notching Mean	Notching SD	Notching Total	Non-notching Mean	Non-notching SD	Non-notching Total	Weight	Mean Difference IV, Fixed, 95% CI
Bigorre 2014	66.6	11	59	69.3	7.3	58	30.9%	–2.70 (–6.08 to 0.68)
Favard 2011	58.3	16.7	36	52.7	14.1	4	1.6%	5.60 (–9.26 to 20.46)
Katz 2016	64	10.5	41	64	9.8	99	25.0%	0.00 (–3.75 to 3.75)
Mizuno 2012	72.2	16.7	19	71.6	14.1	28	4.2%	0.60 (–8.55 to 9.75)
Mollon 2017	66	13.9	48	71	14.2	428	20.4%	–5.00 (–9.16 to –0.84)
Simovitch 2007	72	26	34	83	20	43	3.1%	–11.00 (–21.59 to –0.41)
Simovitch 2019	58.8	18.2	47	66.8	14.7	277	11.7%	–8.00 (–13.48 to –2.52)
Torrens 2013	49.2	16.7	13	52	14.1	23	3.0%	–2.80 (–13.55 to 7.95)
Total (95% CI)			297			960	100.0%	–3.11 (–4.98 to –1.23)

Heterogeneity: Chi^2 = 10.64, df = 7 (p = 0.16); I^2 = 34%
Test for overall effect: Z = 3.24 (p = 0.001)

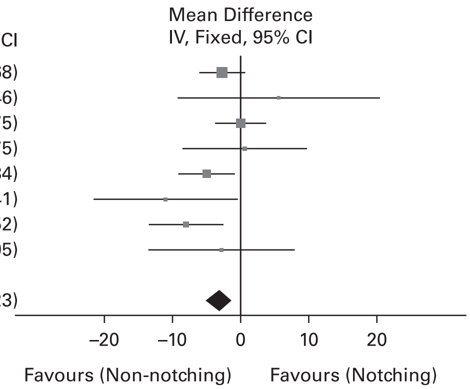


Fig. 2

Forest plot of weighted mean difference in postoperative Constant-Murley score (CMS) between notching and non-notching group. SD, standard deviation; IV, inverse variance; CI, confidence interval; DF, degrees of freedom.

Study or Subgroup	Notching Mean	Notching SD	Notching Total	Non-notching Mean	Non-notching SD	Non-notching Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Feeley 2014	67.3	15.2	15	74.9	14.4	39	23.3%	–7.60 (–16.52 to 1.32)	2014
Mollon 2017	78.1	21.8	48	84.1	17.1	428	45.6%	–6.00 (–12.38 to 0.38)	2017
Simovitch 2019	72.6	25.6	47	79	20.6	277	31.2%	–6.40 (–14.11 to 1.31)	2019
Total (95% CI)			110			744	100.0%	–6.50 (–10.80 to –2.19)	

Heterogeneity: Chi^2 = 0.08, df = 2 (p = 0.96); I^2 = 0%
Test for overall effect: Z = 2.96 (p = 0.003)

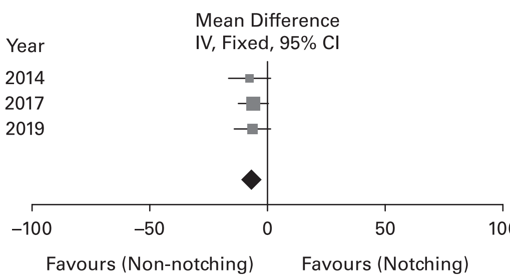


Fig. 3

Forest plot of weighted mean difference in postoperative American Shoulder and Elbow. Surgeons (ASES) score between notching and non-notching group. CI, confidence interval; DF, degrees of freedom; SD, standard deviation; IV, inverse variance.

outcome data.[23,25–27,29,30,39,44] Nevertheless, we decided to include these studies because the possibility of unbalanced follow-up losses between two groups (notching vs non-notching) which might cause selection bias was determined to be low.

Six of the 17 studies were excluded from the meta-analysis because they did not provide specific data for synthesis.[8,14,16,27,28,40,41] Finally, 11 studies were eligible for the meta-analysis,[24,25,29,30,33–37,39,44] that is, two retrospective cohort studies (Level III),[25,29] and nine sub-analyses of pro- and retrospective case series (Level IV).[24,30,33–37,39,44] As shown in Table I, the mean statistical power of the 11 studies included for meta-analysis was greater than that of the six excluded studies. (72.9 vs 42.4 respectively, p = 0.002), though the severity indices were similar (0.35 vs 0.30 respectively, p = 0.441).

Meta-analysis

Functional scores: CMS and ASES scores. In all, eight of the 11 studies provided specific CMS data.[25,29,30,33,34,36,39,44] The WMD of the CMS between notching and non-notching groups was 3.11, and the notching group had significantly lower scores than the non-notching group (Figure 2). Three studies gave specific data on the ASES scores (Figure 3).[25,29,35] The WMD of the ASES score between notching and non-notching groups was 6.50; the notching group had a significantly lower score than the non-notching group.

Range of motion: forward flexion, abduction, and external rotation. Six of the 11 studies provided specific data sufficient for meta-analysis of FF,[25,29,30,35–37] five studies for meta-analysis of abduction,[25,29,30,35,36] and four studies for meta-analysis of ER.[25,29,35,36] Calculated WMD were 6.3° for FF (with significance), 9.4° for abduction (with significance), and 0.6° for ER (without significance), and all three results were lower in the notching group than the notching group (Figure 4).

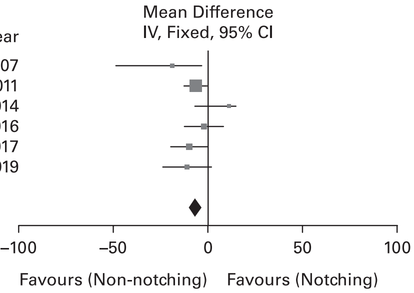
Sensitivity analysis and publication bias. Single elimination of individual studies did not affect the overall results in terms of the analysis of any of the five variables of interest. The notching group maintained a statistically significant difference with respect to the CMS, the ASES score, and FF, but not with respect to abduction and ER. The funnel plots were symmetrical about the mean effect for all variables, indicating an absence of publication bias within the studies.

Discussion

This meta-analysis study shows that scapular notching has a significant negative effect on clinical outcome after RTSA. Although the studies included gave mixed results about whether scapular notching has an effect on clinical outcome, the results of this meta-analysis showed that patients with scapular notching after RTSA had significantly worse results when

Study or Subgroup	Notching Mean	Notching SD	Notching Total	Non-notching Mean	Non-notching SD	Non-notching Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Simovitch 2007	110	31	34	127	31	43	7.0%	–17.00 (–30.94 to –3.06)	2007
Lavigne 2011	128	31.3	312	134	26.5	149	44.9%	–6.00 (–11.49 to –0.51)	2011
Feeley 2014	151	29	15	141	22.7	39	5.1%	10.00 (–6.31 to 26.31)	2014
Katz 2016	130	25	41	132	27	99	15.6%	–2.00 (–11.32 to 7.32)	2016
Mollon 2017	130	30	48	139	26	428	17.3%	–9.00 (–17.84 to –0.16)	2017
Simovitch 2019	122	39	47	132	27	277	10.1%	–10.00 (–21.59 to 1.59)	2019
Total (95% CI)			497			1035	100.0%	–6.25 (–9.93 to –2.57)	

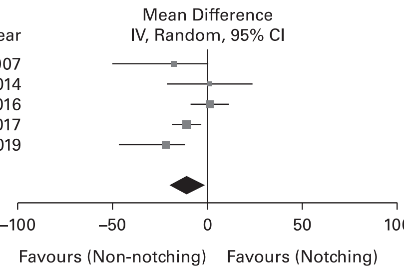
Heterogeneity: Chi² = 7.68, df = 5 (p = 0.18); I² = 35%
Test for overall effect: Z = 3.33 (p = 0.0009)



a

Study or Subgroup	Notching Mean	Notching SD	Notching Total	Non-notching Mean	Non-notching SD	Non-notching Total	Weight	Mean Difference IV, Random, 95% CI	Year
Simovitch 2007	102	34	34	118	39	43	14.7%	–16.00 (–32.32 to 0.32)	2007
Feeley 2014	141	35	15	140	32	39	11.2%	1.00 (–19.36 to 21.36)	2014
Katz 2016	109	25	41	108	25	99	23.7%	1.00 (–8.10 to 10.10)	2016
Mollon 2017	103	23	48	113	27	428	26.8%	–10.00 (–16.99 to –3.01)	2017
Simovitch 2019	96	30	47	116	29	277	23.6%	–20.00 (–29.23 to –10.77)	2019
Total (95% CI)			185			886	100.0%	–9.39 (–17.79 to –0.99)	

Heterogeneity: Tau² = 55.73; Chi² = 11.73, df = 4 (p = 0.02); I² = 66%
Test for overall effect: Z = 2.19 (p = 0.03)



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Study or Subgroup	Notching Mean	Notching SD	Notching Total	Non-notching Mean	Non-notching SD	Non-notching Total	Weight	Mean Difference IV, Fixed, 95% CI
Feeley 2014	33.4	16.5	15	34.9	21.5	39	8.3%	–1.50 (–12.24 to 9.24)
Katz 2016	27	17	41	30	17	99	25.0%	–3.00 (–9.19 to 3.19)
Mollon 2017	35	16	48	35	17	428	41.6%	0.00 (–4.80 to 4.80)
Simovitch 2019	34	20	47	33	20	277	25.1%	1.00 (–5.18 to 7.18)
Total (95% CI)			151			843	100.0%	–0.63 (–3.72 to 2.47)

Heterogeneity: Chi² = 0.92, df = 3 (p = 0.82); I² = 0%
Test for overall effect: Z = 0.40 (p = 0.69)

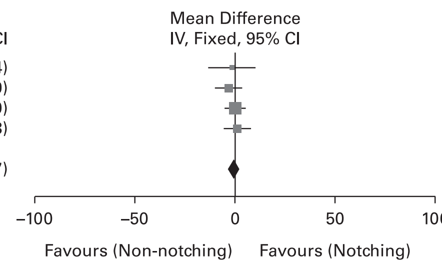

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Fig. 4

Forest plot of weighted mean difference in postoperative range of movement between notching and non-notching group. (a) forward flexion; (b) abduction; and (c) external rotation at side. CI, confidence interval; DF, degrees of freedom; SD, standard deviation; IV, inverse variance.

evaluated by the CMS, the ASES score, and the range of flexion and abduction.

Although the WMDs were rather small, the observed mean differences in CMS, flexion and abduction met or exceeded the minimal clinically important difference (MCID) thresholds previously established by Simovitch et al[51] for RTSA for the CMS (MCID threshold 0.3; observed mean difference 3.11), flexion (MCID threshold 2.9°; observed mean difference 6.3°), and abduction (MCID threshold 1.9°; observed mean difference 9.4°), which confirms that these differences in outcome are clinically meaningful.

Two studies, which failed to show significant results, were excluded because they did not provide specific data (Table I),[8,41] and this exclusion may have caused errors in our results. However, these two studies were underpowered with statistical powers below 0.5, and it can therefore be inferred that the non-significant results obtained were probably due to insufficient statistical power.

Because of the nature of the subject, randomized controlled trials are not possible. The best possible study design would be a retrospective cohort comparison study with adjustment for major potential confounders. From this perspective, the conclusions of Mollon et al[25] and Simovitch et al[29] should be weighted more than others. These two studies had higher statistical power than other studies determined by post hoc analysis (Table I). Furthermore, their results were grossly consistent with ours, in that they agree that scapular notching has a negative effect on the clinical outcome of RTSA.

Mollon et al[25] reviewed the minimum two-year outcome of consecutive patients who underwent RTSA at a single centre, and excluded patients with a history of previous shoulder surgery or arthroplasty, a diagnosis of infection or acute proximal humeral fracture, and arthroplasty with a constrained implant. They also concluded that patients with scapular notching had significantly poorer clinical outcomes, significantly less strength and ROM, and a significantly higher complication rate than patients without scapular notching at short-term follow-up. Simovitch et al[29] reported on the impact of scapular notching on mid-term outcomes after RTSA by investigating the minimum five-year outcome of consecutive patients who underwent RTSA in a multicentre study after excluding patients with revision arthroplasty, a history of infection, or of acute fracture or fracture sequalae. They concluded that patients with scapular notching had a significantly worse clinical outcome and a significantly higher complication and revision rate compared to patients without scapular notching at mid-term follow-up.

The results of the current study should be interpreted carefully because most of the studies included did not consider various confounding factors. There is a possibility that other factors could cause notching and a worse outcome after RTSA.[5,25,29,45,52] In particular, placing the glenoid component with an inferior overhang of the scapular neck during implantation may result in a low rate of scapular notching and a better functional outcome. Biomechanically, inferior overhang of the glenoid component can widen the impingement-free arc of rotation and distalize the centre of rotation, which might possibly give a better functional outcome after RTSA.[18,31,45,46,53,54] Therefore, more studies are needed to verify how scapular notching causes a worse functional outcome after RTSA by stratifying factors related to the occurrence of scapular notching and clinical outcome. Nevertheless, we believe that the meta-analysis is valid regardless of this limitation. This is because this study confirmed the association of scapular notching with worse clinical outcomes regardless of the existence or not of confounders, and we can justify the various efforts to avoid scapular notching when performing RTSA.

The possible reasons for the mixed results of previous studies are insufficient statistical power due to small cohort size and inconstantly observed rate of scapular notching, which can cause sample size inconsistencies uncontrolled or poorly controlled confounding factors, such as various patient factors (obesity, body mass index, body weight and range of adduction, activity level) and implant factors (humeral or glenoid lateralization, glenosphere size and orientation), which can affect notching occurrence and clinical outcomes simultaneously.[5,25,29,45,46,55] The limitations of this meta-analysis reflects the deficiencies in the current body of literature on scapular notching and clinical outcomes. Most of these studies are of short- or medium-term, non-randomized, and non-controlled. They also involve heterogeneous patient populations, a variety of implant types, and different surgical techniques.

Despite this lack of standardization, the present study gives an important perspective on the clinical relevance of scapular notching. The literature should be interpreted in the light of its statistical power. Studies of low power should be weighted less and those of high-power weighted more, and it should be recognized that simple reviews of the literature usually lack such a weighting procedure. Systemic review and meta-analysis by qualification and weighting procedures can provide conclusions that are more powerful. We believe that this meta-analysis contributes to our understanding by increasing the level of evidence and providing support to those who seek a means of avoiding scapular notching by refining the design of implants or their means of implantation. A meta-analysis of the available literature suggests that patients with scapular notching have significantly worse results after RTSA than those who do not.

Take home message

- The available literature suggests that patients with scapular notching after reverse total shoulder arthroplasty have significantly inferiorworse results when evaluated by the Constant-Murley scores, the American Shoulder and Elbow Surgeons score, and range of movement of forward flexion and abduction.

Supplementary material

Tables showing risk of bias by the Risk of Bias Assessment tool for Non-randomized Studies (RoBANS), and property of studies.

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