

Which lateralization designed prosthesis of reverse total shoulder arthroplasty (glenoid-based lateralization vs humerus-based lateralization) would be better? Network Meta-analysis

Journal of Orthopaedic Surgery
30(2) 1–11
© The Author(s) 2022
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/10225536221122307
journals.sagepub.com/home/osj
 SAGE

Hyojune Kim^{1,†}, Sang Beom Ma^{1,†}, Kwang Won Lee¹ and Kyoung Hwan Koh²

Abstract

Purpose: To demonstrate the differences between outcomes and complications after reverse total shoulder arthroplasty (rTSA), according to the types of lateralized prosthesis designs: glenoid-based lateralization (LG) and humerus-based lateralization (LH).

Methods: PubMed, Embase, and the Cochrane Library databases were systematically searched for studies published before 1 April 2021, using the PRISMA guidelines. A network meta-analysis was applied for indirect comparison, incorporating studies including medialized or conventional Grammont prosthesis and each lateralized prosthesis (LG vs control and LH vs control). Out of 1,989 screened studies, 11 studies were included to compare functional scores, range of motion (ROM), radiologic outcomes, and revision rates. In addition, six articles from the included studies, which had repaired subscapularis after rTSA were analyzed to exclude the potential influence of subscapularis repair on the outcomes. The data were pooled using a random-effects model. The pooled estimates of the mean differences (MDs) and 95% confidence intervals (CIs) were calculated for continuous data, while dichotomous data were analyzed using the pooled relative risk (RR) and their 95% CIs.

Results: The ROM, complications, and functional scores were similar between the two groups. In subgroup analysis of 6 studies involving concomitant subscapularis repair, the LH group showed higher American Shoulder and Elbow Surgeons (ASES) scores and Constant scores than the control group. Regarding the ROM, LH group showed better forward elevation than the LG group (LH vs LG: MD 10.07, 95% CI –9.05–29.19).

Conclusion: Overall, the outcomes and occurrence of complications were not significantly different between the two lateralized prosthesis groups. However, when the subscapularis was repaired, LH prosthesis seems to be more suitable to obtain a better ASES score and ROM.

Level of Evidence: Level III, network meta-analysis.

¹Department of Orthopaedic Surgery, Eulji University Hospital, Daejeon, Republic of Korea

²Department of Orthopaedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Republic of Korea

[†]First Authors: Hyojune Kim, MD, and Sang Beom Ma, MD

Corresponding author:

Kyoung Hwan Koh, Department of Orthopaedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, 88 Olympic-ro 43-gil, Songpa-gu 05535, Republic of Korea.

Email: osdoc.koh@gmail.com



Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).

Keywords

reverse total shoulder arthroplasty, glenoid-based lateralization, humerus-based lateralization, range of motion, scapular notching, clinical outcomes, suspensory repair

Date received: 28 December 2021; Received revised 12 June 2022; accepted: 7 August 2022

Introduction

Reverse total shoulder arthroplasty (rTSA) has been used as an effective treatment option for rotator cuff arthropathy and massive irreparable rotator cuff tears.¹ However, despite the favorable clinical outcomes of the traditional rTSA prosthesis, the Grammont design has high rates of scapular notching and subsequent polyethylene wear in long-term follow-up.² The medialization of the center of rotation and the 155° neck shaft angle of the Grammont style rTSA can also lead to several additional limitations, including decreased range of motion (ROM) without impingement, decreased tension of the intact cuff (associated with potential instability and weakness in external rotation), and altered anatomic contour of the shoulder.³

Therefore, there have been efforts to decrease the scapular notching and improve biomechanics in rTSA, including modification of the implant position or design, such as lateralization.⁴ Several studies have investigated the effects of lateralization, and a recent systematic review showed decreased scapular notching and increased external rotation with these recent lateral offset prostheses.^{4,5} However, there has been significant limitations arise from a variety of products and types of the lateralized prosthesis used. And it makes difficult to draw clear conclusions when demonstrating the effectiveness of the lateralized prosthesis over the conventional Grammont design.⁶ Furthermore, a direct comparison has not yet been performed between the glenoid lateralization and humeral lateralization.

As lateralization can be achieved on the glenoid side, humeral side, or both, understanding the benefits or disadvantages of each mode of lateralization may be important for choosing the proper implant based on the patient's individual anatomy.² Therefore, we reviewed the published literatures to demonstrate differences in outcomes and complications after rTSA between the glenoid-based lateralization group (LG group) and the humerus-based lateralization group (LH group). We hypothesized that both LG- and LH-designed rTSA systems were not significantly different in terms of functional, radiological, and revision rates.

Materials and methods

Search strategy and study selection

This systematic review was performed on the outcomes and complications after rTSA using a lateralized center of rotation

(COR) prosthesis and followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines and Cochrane Reviews.^{7,8} A comprehensive literature search was performed in PubMed, Scopus, and the Cochrane Library from January 2005 to April 2021. The search identified articles published until 1 April 2021, using an *a priori* search strategy.

Two authors independently screened titles and abstracts by the literature search. Texts of potentially relevant studies were included based on eligibility criteria. If the title and abstract did not provide adequate information to determine whether the eligibility criteria were met, the study was included for full text review. Then, the same two authors independently assessed the full-text studies according to the inclusion and exclusion criteria. If no consensus was reached, the senior shoulder expert as the third reviewer decided as the final authority after discussion. The following search terms were used: "rTSA" OR "reverse TSA" OR "reverse arthroplasty" OR "reverse shoulder arthroplasty" OR "reverse total shoulder arthroplasty" OR "reverse shoulder replacement" AND "arthritis" OR "osteoarthritis" OR "rotator cuff tear" OR "cuff tear" OR "rotator cuff tears" OR "cuff tears" OR "cuff tear arthropathy" OR "rotator cuff tear arthropathy" OR "massive cuff tear" OR "massive rotator cuff tear" OR "massive cuff tears" OR "massive rotator cuff tears" OR "proximal humerus fracture" OR "humerus fracture". There were no restrictions on language or publication year. After the initial electronic search, relevant articles and their bibliographies were manually searched (Figure 1).

At each stage of the study selection, the κ -value was calculated to determine the inter-reviewer agreement regarding the study selection. Agreement between the reviewers was correlated *a priori* using the following κ -values: $\kappa = 1$ corresponded to "perfect" agreement; $1.0 > \kappa \geq 0.8$ to "almost perfect" agreement; $0.8 > \kappa \geq 0.6$ to "substantial" agreement; $0.6 > \kappa \geq 0.4$ to "moderate" agreement; $0.4 > \kappa \geq 0.2$ to "fair" agreement; and $\kappa < 0.2$ to "slight" agreement. Disagreements at each stage were resolved by consensus between the two investigators or by discussion with a third investigator, a board-certified orthopedic surgeon.

Given the lack of comparative studies published with high-quality evidence, we decided to perform a network meta-analysis with indirect comparisons, by

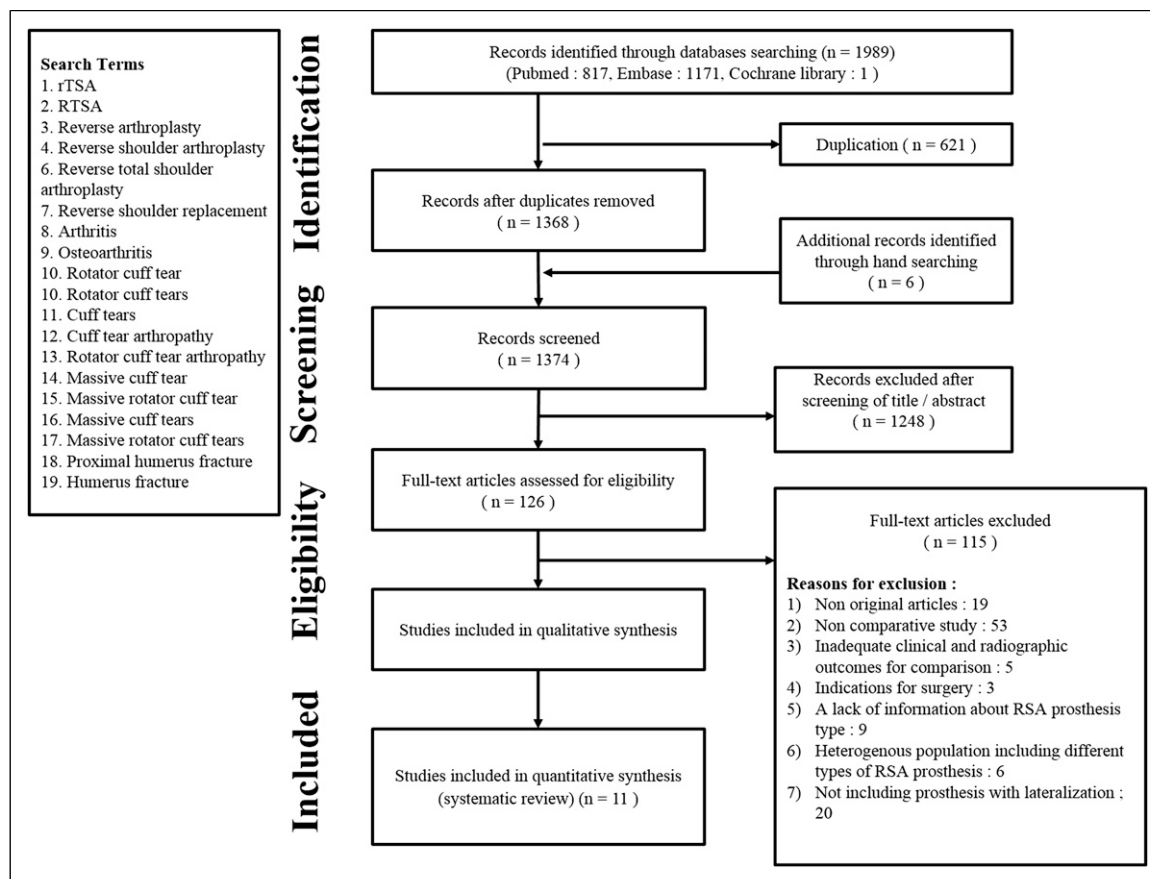


Figure 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram for the identification and selection of studies included in the meta-analysis.

selecting the literature, comparing the medialized prosthesis and the type of lateralized prosthesis (LG and LH).

Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) original studies; (2) reverse shoulder arthroplasty for cuff tear arthropathy, massive rotator cuff tear, osteoarthritis, or fractures; (3) comparative studies including rTSA prosthesis with lateralization; and (4) studies with a follow-up period of >1 year. The exclusion criteria were as follows: (1) non-original studies (case report, surgical technical report, and in situ/cadaveric/biomechanical studies); (2) papers which had fewer than 10 participants; (3) papers which had no clinical and radiographic outcomes; (4) indications for surgery included revision shoulder arthroplasty, chronic dislocation, rheumatoid arthritis, and severe bone loss; (5) studies that included concomitant tendon transfer; (6) inclusion of only one type of rTSA prosthesis; (7) a lack of information about the rTSA prosthesis type or manufacturer; and (8) heterogeneous population including

different types of rTSA prostheses, which make classification for comparison difficult.

Quality appraisal and risk of bias

Three reviewers independently reviewed each included article and decided whether to include or exclude any study based on discussion and consensus. The level of evidence of each study was determined according to the criteria stipulated by the Oxford Centre for Evidence-Based Medicine.⁹ The Methodological Index for Nonrandomized Studies (MINORS) was used to assess the risk of bias of each study.¹⁰ As there is no consensus regarding the cutoff point for MINORS assessment, a score >60% of the total score with the MINORS evaluation tool (14 of 24 points) was considered high quality.

Data extraction

The recorded data elements included the following: the study design, number of shoulders treated with rTSA, mean age, prosthesis brand, type, mean duration of follow-up,

ROM, and radiological outcomes. The functional scores, including constant score and American Shoulder and Elbow Surgeons Score (ASES), were scrutinized. Any disagreements in data extraction were resolved by group discussion.

Additionally, we performed a subgroup analysis for six articles, that involved subscapularis repair after reverse arthroplasty.¹¹⁻¹⁶ There has been a controversy on the role of concomitant subscapularis repair onto outcomes following shoulder arthroplasty. Therefore, we attempted to compare the outcomes of the LH- and LG-designed prostheses (functional, ROM, radiologic outcomes, and revision rates) when combined with subscapularis repair. The remaining studies from the 11 final articles were not included in this evaluation because they did not describe whether they performed subscapularis repair or not.

We compared the amount of lateralization of each offset (glenoid offset, humeral offset, and global offset) based on which of the Delta III (DePuy, WarTSAw, IN).² In this study, we classified into two groups (LG group and LH group) based on the lateral offset measurements and the classification described by Werthel et al.² Missing data (such as confidence interval and standard deviation) were requested by contacting the corresponding author.

Data analysis

We calculated the pooled estimates of the mean differences (MDs) and 95% confidence intervals (CIs) for continuous outcomes, as well as the pooled relative risk (RR) and their 95% CIs for dichotomous outcomes. The dichotomous outcomes that were not reported in the included article for complication in both design systems were not included in network meta-analysis. The estimate of the treatment effect was determined between the LG and LH by synthesizing the pooled treatment effect estimate of each treatment compared to the common comparator indirectly in the network meta-analysis.¹⁷

Statistical heterogeneity and inconsistency were assessed with p -values and I^2 statistics. A random-effect model was performed based on the result of heterogeneity and inconsistency analysis. Potential publication bias was assessed through visual inspection of funnel plots and Begg and Mazumdar's test for rank correlation. Statistical analyses were performed using STATA version 13 (StataCorp, College Station, Texas, USA) and "netmeta" package in R version 4.0.4 software (<http://www.r-project.org>).

Results

Study identification

The details of the study identification and selection are summarized in Figure 1. The initial electronic literature

search yielded 1,989 articles; after removing 621 duplicates, 1,368 studies were screened. Additional records were included through manual searching ($n = 6$); of these, 1,248 were excluded after screening the titles and abstracts, and 115 were excluded after full-text review. Thus, eleven studies were eligible for qualitative and quantitative data analysis.^{11-16,18-22} The agreement between the two reviewers regarding the study selection was "substantial" at the title review stage ($\kappa = 0.728$), "almost perfect" at the abstract review stage ($\kappa = 0.829$), and "perfect" at the full-text review stage ($\kappa = 1.0$).

Study characteristics

Among the twelve included studies, two studies were prospective randomized controlled studies,^{11,14} one was a prognosis study,¹⁵ and the remainder were retrospective cohort studies.^{12,13,16,18-22} In total, 737 cases treated with reverse total shoulder arthroplasty were reported, including 385 cases treated with medialized rTSA, 95 cases treated with lateralized humerus system rTSA, and 257 cases treated with lateralized glenoid system rTSA. The details of each variable are outlined in Table 1.

Methodological quality assessment

The MINORS score for methodological quality assessment was 19.1/24 (range, 16–22) (Table 1). Regarding the eight main evaluation parameters, 10 studies lost a point for their retrospective study design and for not clearly describing the assessments (bias) of their endpoint; one study lost a point for inappropriate descriptions about the reason for patient exclusion; three studies lost a point for an insufficient follow-up period to assess the main endpoint or possible adverse effects; eight studies lost a point due to a lost-to-follow-up rate of >5% of the initial patients, or inadequate explanation about the lost-to-follow-up rate; and eight studies lost a point as they had no or inadequate information of the size of the detectable difference of interest, calculating 95% confidence interval.

Quantitative data synthesis

Range of motion. The pooled analysis showed no significant difference in the degree of forward elevation (FE) between the two arthroplasty systems (LG^{12, 18-20} vs LH¹³⁻¹⁵) (mean difference [MD] = 1.03, 95% CI: -13.43–15.49, $I^2 = 73.5\%$; Figure 2(a)). Regarding the ROM for external rotation (ER), the pooled analysis showed no significant difference (LG^{11,12,18-20} vs LH¹³⁻¹⁵) (mean difference [MD] = 3.14, 95% CI: -8.95–15.23, $I^2 = 69\%$; Figure 2(b)).

Functional scores. The evaluated functional scores, including the ASES and Constant score, were pooled and analyzed to

Table 1. Studies included in the network meta-analysis.

Study	Prosthesis model	Age, years	Follow-up time, months $\pm$ SD (range)	Study design, evidence level	MINORS score
Glenoid-based lateralization group (LG)					
Greiner et al. (2015)(11)	Aequalis reversed shoulder prosthesis (Tornier) 1) Lateralization group: BIO 2) Medialization group: Standard	34 patients, 75.4 (range, 66–88)	22 $\pm$ 8.1	Prospective randomized study, I	21
Athwal et al. (2015)(18)	Aequalis system (Tornier) 1) Lateralization group: BIO 2) Medialization group: Standard	40 patients, 74 $\pm$ 6	34 $\pm$ 13	Retrospective cohort study, III	19
Kirzner et al. (2018)(16)	Aequalis reversed prosthesis (Wright-Tornier) 1) Lateralization group: BIO 2) Medialization group: Standard	40 patients, 74.7 (range, 59–91)	20 (range, 12–48)	Retrospective cohort study, III	17
Collin et al. (2018)(19)	Aequalis reversed shoulder prosthesis system (Wright medical) 1) Lateralization group: BIO 2) Medialization group: Standard	130 Shoulders 1) Lateralization group: 74.4 $\pm$ 6.0 (range, 58–90) 2) Medialization group: 75.4 $\pm$ 5.5 (range, 60–86)	1) Lateralization group: 24.3 $\pm$ 0.7 (range, 24–27) 2) Medialization group: 24.4 $\pm$ 0.8 (range, 24–27)	Retrospective cohort study, III	20
Zitkovsky et al. (2020)(20)	1) Lateralization group : Reversed shoulder prosthesis (DJO/Encore medical corporation) 2) Medialization group: Humeral component - anatomical shoulder reversed system (Zimmer); glenoid component-Bigliani/Flatow system (Zimmer)	107 patients, 70.6 $\pm$ 7.2	29 (range, 22 – 62)	Retrospective cohort study, III	20
Kennon et al. (2020)(12)	1) Lateralization group: Encore/DJO prosthesis(DJO Surgical) 2) Medialization group: Delta III prosthesis (DePuy) or Delta Xtrend prosthesis (DePuy)	100 patients, 73.7 (range, 55–86)	77	Retrospective cohort study, III	21
Huri et al. (2016)(22)	1) Lateralization group: prosthesis with lateral-based COR (DJO/Encore medical corporation) 2) Medialization group: Grammont-type prosthesis (Tornier)	65 Shoulders 1) Lateralization group: 70 $\pm$ 8.4 years 2) Medialization group: 69 $\pm$ 7.3	1) Lateralization group: 32 $\pm$ 7.9 2) Medialization group: 43 $\pm$ 15	Retrospective cohort study, III	20
Humerus-based lateralization group (LH)					
Merolla et al. (2018)(13)	1) Lateralization group: Aequalis ascend flex (Wright medical) 2) Medialization group: Aequalis reversed II (Wright medical)	74 Shoulders 1) Lateralization group: 74.7 (range, 55– 91) 2) Medialization group: 75.8 (range, 55–88)	1) Lateralization group: 29.1 (range, 24–31) 2) Medialization group: 35.1 (range, 24–49)	Retrospective cohort study, III	21
Gobezie et al. (2019)(14)	Uniers revers (Arthrex) 1) Lateralization group: 135° NSA 2) Medialization group: 155° NSA	68 patients, 73 (range, 43–94)	38 (range, 29 – 45)	Randomized controlled trial, I	22
Verdano et al. (2018) (23)	1) Lateralization group: Equinox reverse system (ExacTech) 2) Medialization group: Bigliani-Flatow reverse shoulder system (Zimmer)	32 patients, 77.4 (range, 67–92)	14.3 months	Retrospective cohort study, III	18

(continued)

Table 1. (continued)

Study	Prosthesis model	Age, years	Follow-up time, months $\pm$ SD (range)	Study design, evidence level	MINORS score
Boutsiadis et al. (2018) *(15)	1) Lateralization group: Ascend flex (Wright medical group Inc.) 2) Medialization group: Aequalis reversed (Wright medical group Inc.)	23 patients, 77 ± 7.5 (range, 62–90)	39 ± 18	Prognosis study, II	21

MINORS: Methodological index for non-randomized studies, BIO: Bony increased offset, COR: Center of rotation.

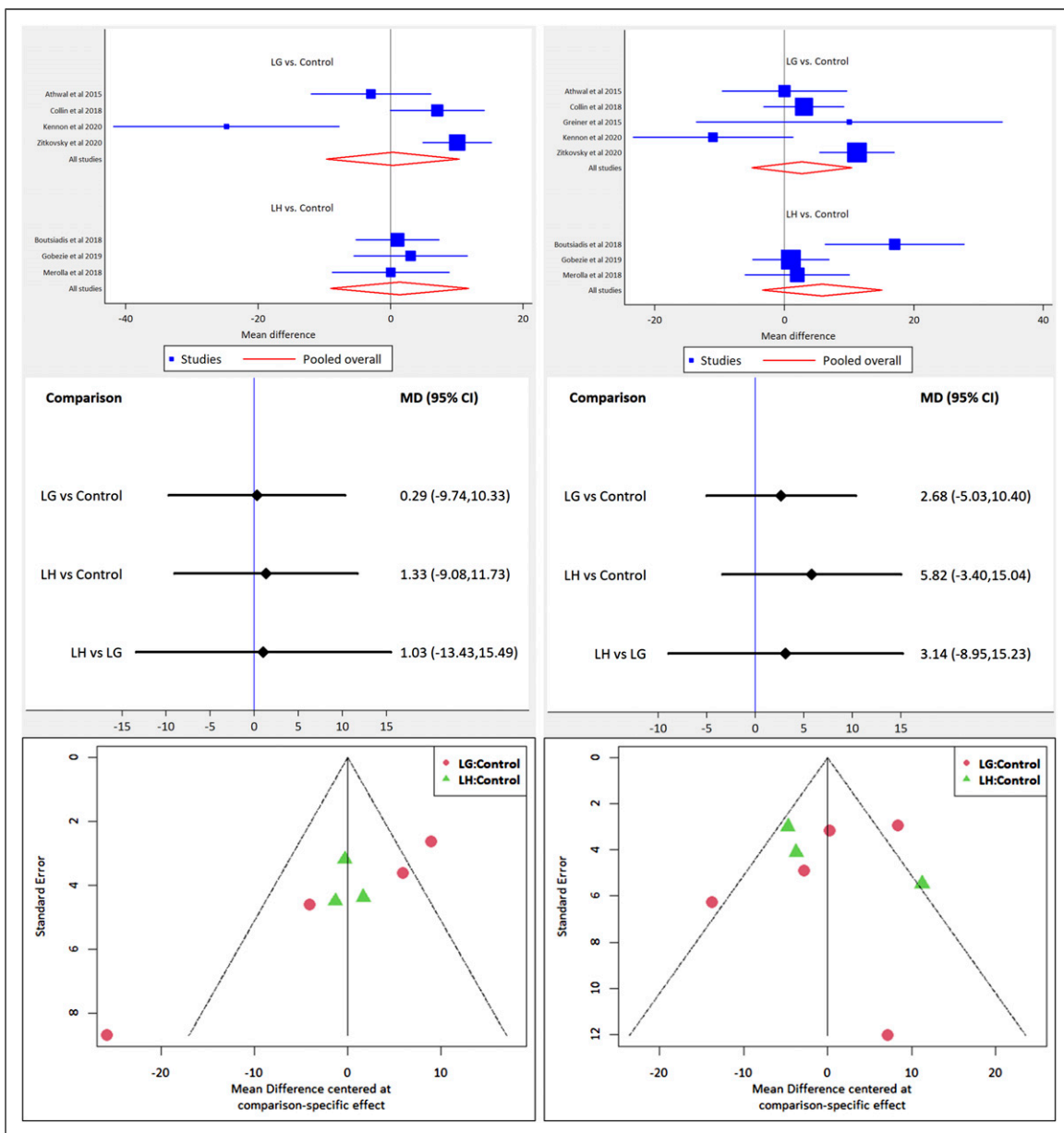


Figure 2. Forest plot showing the difference in the range of motion: (a) FE and (b) ER. FE, forward elevation; ER, external rotation.

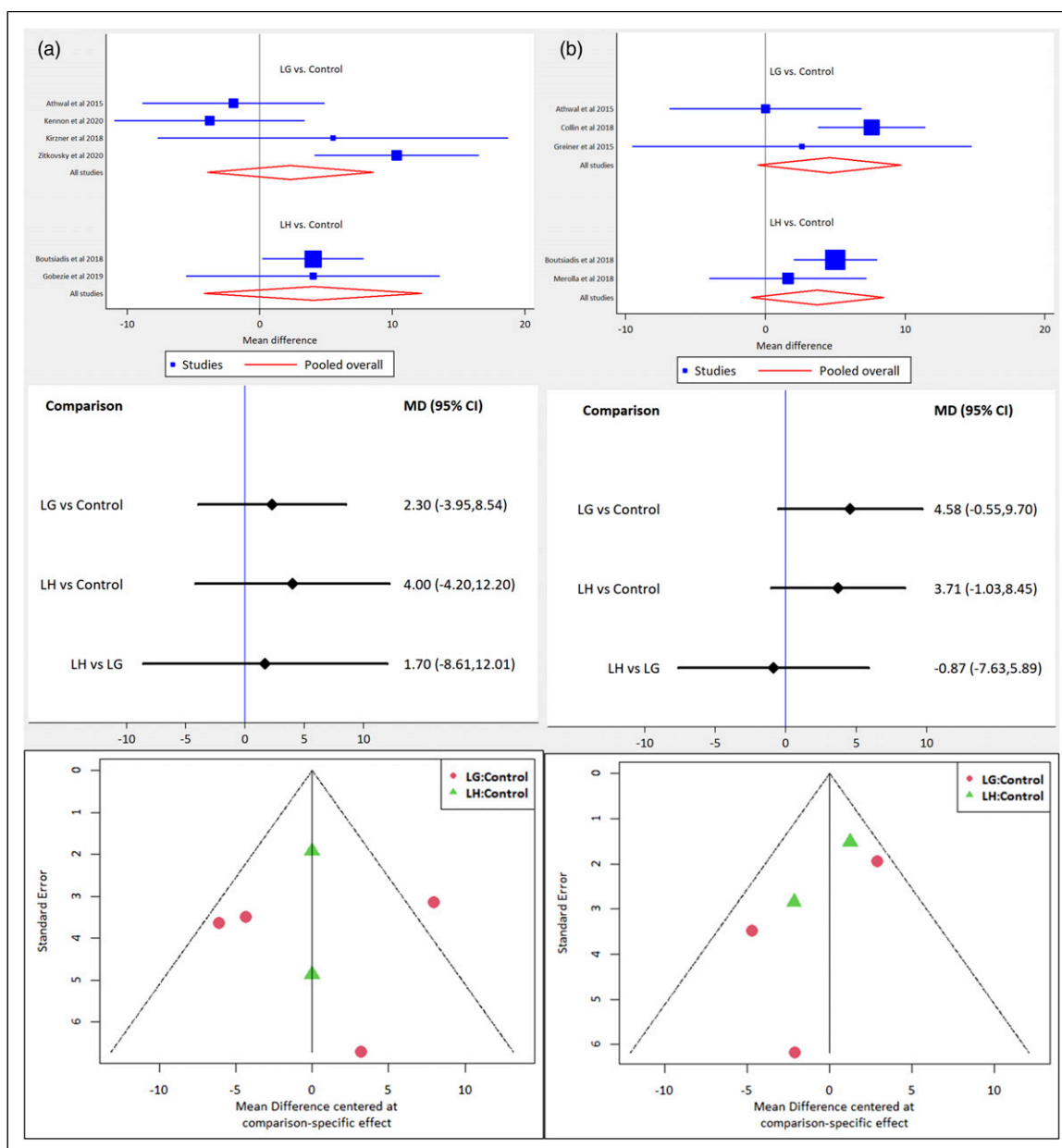


Figure 3. Forest plot showing the difference in the functional scores: (a) ASES score and (b) Constant score. ASES, American Shoulder and Elbow Surgeons.

compare the two systems. No significant differences were observed in ASES (Figure 3(a)), while, the LG and LH groups showed higher Constant scores than the control group (LG vs control: MD = 2.30, 95% CI: -3.95–8.54; LH vs control: MD = 4.00, 95% CI: -4.20–12.20; Figure 3(b)). In addition, there was no significant difference between the LH and LG groups in Constant.

Radiologic outcomes and revision rates. Scapular notching, acromial stress fracture, and glenoid loosening were reported in the included studies. In six of the studies

comparing the LG with the control group,^{12,16,18–20,21} scapular notching was lower in the LG-type prosthesis than the control group, with a pooled relative risk (RR) of 0.40 (95% CI: 0.22–0.73, Figure 4(a)). There was no significant difference in other comparisons (LH vs control, and LH vs LG; Figure 4(a)). Four studies reported postoperative acromial stress fracture in each comparison: LG versus control,^{11,16} LH versus control.^{13,14} In comparison analysis, there was no significant difference (Figure 4(b)). Regarding the report of glenoid base plate loosening, two studies^{13,14} were included, and both described that LH had lower

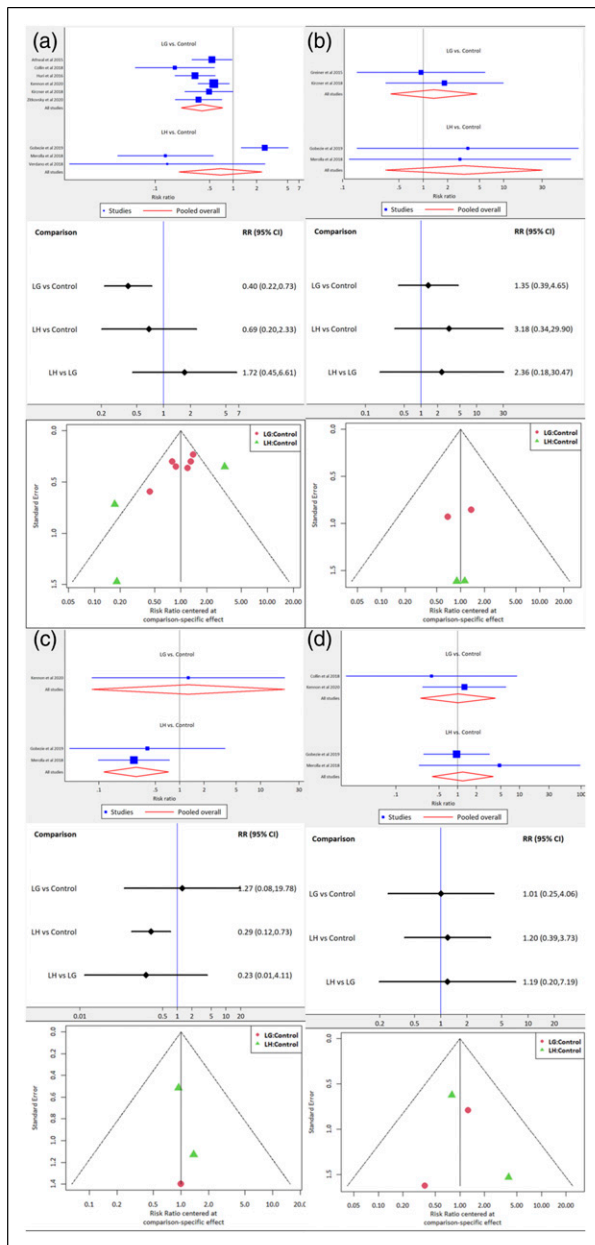


Figure 4. Forest plot showing the relative risk of complications: (a) scapular notching, (b) acromion stress fracture, (c) loosening, and (d) revision.

loosening than the control design prosthesis (RR: 0.29, 95% CI: 0.12–0.73; Figure 4(c)).

Five of the included studies reported revision^{11,12,16,18,19} for LG versus control, and two studies^{13,14} reported revision for LH versus control. Among the 255 patients in the control design prosthesis group, 9 patients (3.5%) underwent revision surgery for the following reasons: dislocation (2), periprosthetic fracture (2), acromial fracture (1), persistent instability (2), baseplate loosening (1), and infection (1). In the LG

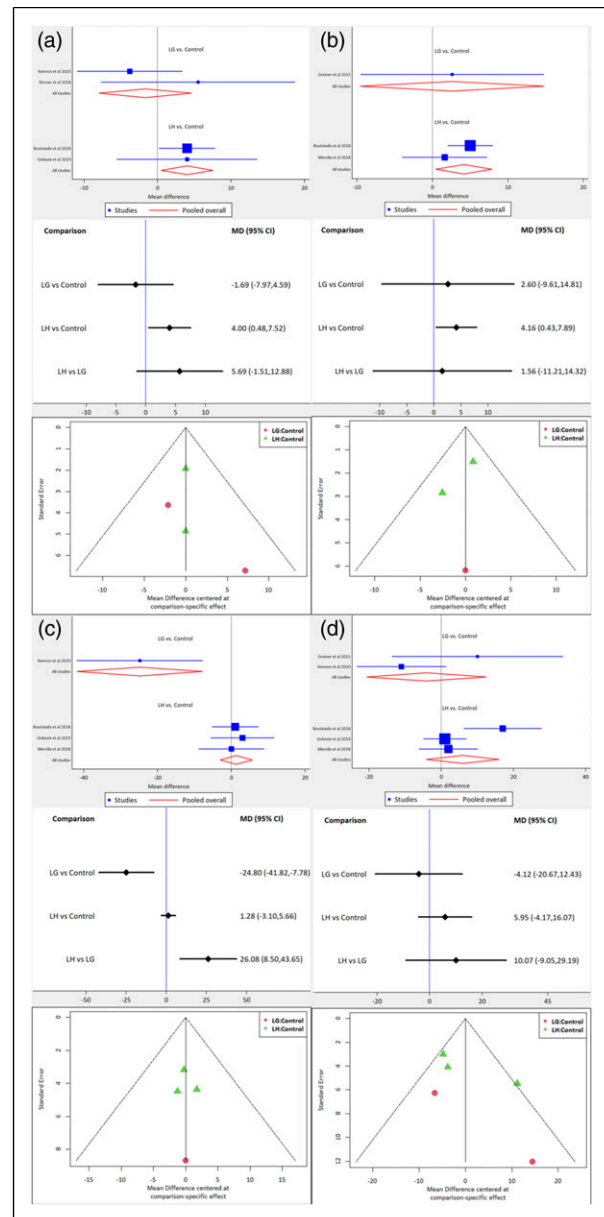


Figure 5. Forest plot showing the difference in the functional scores and ROM: (a) ASES score, (b) Constant score, (c) FE, and (d) ER. ASES, American Shoulder and Elbow Surgeons; FE, forward elevation; ER, external rotation.

prosthesis group (159 patients), 3 patients (1.9%) underwent revision surgery for recurrent dislocation (1) and infection (2). In the LH prosthesis group (69 patients), 6 patients (8.7%) had revision surgery for dislocation (3), infection (2), and broken baseplate screw (1). The overall revision rate was not significantly different between each system (Figure 4(d)).

Subgroup analysis for subscapularis repair after rTSA. In subgroup analysis of 6 studies involving concomitant

subscapularis repair, the lateralized prosthesis showed similar radiologic complications and revision rates compared to the medialized system. Moreover, the LH group showed better ASES score^{12,14-16} and Constant score^{11,13,15} than control group. Compared to the LG group, the LH had a tendency to achieve higher scores than the LG group, although with no significant difference (Figure 5(a) and (b)). Regarding the ROM, the LH group showed better forward elevation than the LG group¹²⁻¹⁵ (LH vs LG: MD: 26.08, 95% CI: 8.50–43.65; Figure 5(c)). In terms of external rotation, there was no significant difference between the two groups¹¹⁻¹⁵ (Figure 5(d)).

Discussion

The main findings of this study were that the LG-designed prosthesis had a lower rate of scapular notching complications than the medialized design, and the LH-designed prosthesis had less loosening than the medialized design. Both lateralized prostheses tended to achieve better Constant scores than the medialized design. In the network meta-analysis, two lateralized prostheses of reverse total shoulder arthroplasty showed similar outcomes in terms of function, ROM, radiological outcomes, and revision rates. However, if reverse arthroplasty was performed in combination with subscapularis repair, the LH-designed prosthesis had better functional scores and ROM than the LG prosthesis.

First, the constant score showed a tendency for increased scores in the LG- and LH-designed prosthesis groups than the control design group. As a result, although we expected that the difference would be significant clinically, we found no significant difference. Moreover, we were unable to demonstrate statistically significant differences in terms of ROM and clinical scores because of the heterogeneity of the available data. We assumed that the non-anatomical circumstance from reverse arthroplasty makes latissimus dorsi, and teres major tendons' role different as internal rotators.

Second, when compared to the medialized prosthesis, both lateralized prostheses showed a decreased prevalence of scapular notching, especially the LG-designed prosthesis. The concept of lateralization for reducing the complication of scapular notching was realized. Our integrated data analysis also demonstrated that the lateralization functioned to reduce notching. Based on the previous study, which scapula notching could affect to reduce the Constant score, the tendency of increased Constant score in lateralized prosthesis could be explainable.²³

The occurrence of acromial fracture in the LG group was similar to the medialized prosthesis and the LH group. Previous biomechanical studies have highlighted concerns about the risk of acromial stress fracture with the glenoid-lateralized prosthesis, which is associated with a decrease in the deltoid moment arm and an increase in

deltoid force required for abduction.²⁴ As the LG-designed prosthesis was developed to reduce the risk of scapular notching, it would be an optimal rTSA prosthesis while the risk of the acromion stress fracture is equivalent to either of the traditional medialized prosthesis or the LH-designed prosthesis.

Third, through our subgroup analysis, the lateralized prosthesis showed similar radiologic complications and revision rates to the medialized system. There is some controversy regarding whether the subscapularis should be repaired or not in rTSA. Some previous studies have reported that subscapularis repair in the lateralized prosthesis did not contribute to the stability of the joint.²⁵ In addition, there are concerns regarding whether scapular notching or osteolysis may occur because of the increased joint contact pressure, hence why we performed subgroup analysis of the articles conducting subscapularis repair.²⁴ However, in our study, the anticipated complications (scapula notching, loosening, and revision rates) from increased contact pressure were not increased in the lateralized prosthesis compared to the medialized prosthesis.

Moreover, the LH-designed prosthesis was the appropriate treatment choice for achieving a better functional score and ROM than the LG-designed prosthesis when conducting subscapularis repair with arthroplasty. Recently, the role of the concomitant subscapularis repair following the rTSA has been on controversy in particularly for using lateralized prosthesis, and there was no significant difference of outcomes rates between the repairing and not repairing groups.^{26,27} However, the previous reports were based on the analysis mixing the two different subtypes of the lateralized prosthesis (LG and LH).^{26,27} In the present study, we found that in contrast to the LG prosthesis, subscapularis repair seemed to play some role in the LH group in terms of improving the function and FE. We suggest some reasons based on previously published studies. First, subscapularis repair with rTSA creates a biomechanically unfavorable condition during arm elevation, owing to an increase in the force required by the deltoid and the generally weak posterior rotator cuff.²⁷ Since the center of rotation of the joint ends closer to the deltoid line of pull in the LG prosthesis, the deltoid's efficiency could be decreased, even the moment arm of the deltoid could be maintained because of the lateralization at the glenoid side.² On the contrary, the LH prosthesis is believed to have a better deltoid's efficiency associated with the lateralization of greater tuberosity and the increased lever arm of posterior deltoid leading to external rotation moment arm, compared with the LG prosthesis.^{2,24} Finally, we concluded that the concomitant subscapularis repair with the LH prosthesis may lead to increased joint stability and the effectiveness of arm elevation with well-balanced reaction forces (equal counteract of external rotation force against the internal rotation forces of the repaired subscapularis), which was not

with the LG prosthesis. Therefore, along with those expectations, we thought that FE and ASES score was improved better in the LH prosthesis in our subgroup analysis.

In addition, here were no significant differences in the occurrence of complications between the LG-designed prosthesis and the LH prosthesis at an average follow-up >12 months, especially for evaluating the occurrence of implant loosening. Recent meta-analysis of humeral stem loosening after rTSA, including 75 studies, demonstrated that the prevalence of aseptic loosening was significantly higher in the group with a mean follow-up period ≥ 5 years compared to the group with a mean follow-up period <5 years.²⁸ Thus, it might be difficult to assess the occurrence of implant loosening due to the relatively short-term follow-ups and the heterogeneity of the glenoid lateralized groups.

This study is the first meta-analysis comparing the two different subtypes of lateralized prosthesis (LG and LH). Moreover, we suggested that the concomitant subscapularis repair may affect the outcomes along with the different types of lateralization. And it has not been demonstrated clinically in previous studies.

There were some limitations. First, although the number of studies investigated in our study was sufficient for analysis, there were few randomized control trials. Second, as the included studies have heterogeneity, including different study designs and indications of surgery, various implants, despite being classified as the same group, different reasons for rTSA by each case (not the same disease), and other unknown factors affecting the results of each study, this meta-analysis might have some risks of bias. Third, we assessed the outcomes comparing the groups classified according to the measurement of rTSA prosthesis offset described by Werthel et al.² In addition, as we classified the groups by focusing on the offset measurement of the prosthesis only, and not on the individual relative offset of each shoulder, which might be vary according to the patient characteristics, the real offset and biomechanics of the shoulder after surgery may not be reflected. Finally, the included literatures have relatively short follow-up periods for assessing the loosening of the humeral or glenosphere baseplate.

Conclusion

The outcomes and occurrence of complications were not significantly different between the two lateralized rTSA prosthesis groups. However, when subscapularis repair was performed after rTSA, LH prosthesis is likely to be more suitable to obtain a better ASES score and ROM.

Acknowledgements

This research was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry

Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (grant number : HI21C0196).

Authors' contributions

Co-First authors: HJK and SBM

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (grant number : HI21C0196).

Availability of data and material

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Study conceptualization

IHJ, JHS, WJY, and EK.

Data acquisition

HJK, SBM

Data interpretation

HJK, SBM, JHS, WJY, and EK

Drafting of the manuscript

HJK, and SBM

Revision and final approval of the manuscript

KHK, and KWL

ORCID iDs

Hyojune Kim  <https://orcid.org/0000-0001-7665-536X>

Kyoung Hwan Koh  <https://orcid.org/0000-0002-6181-9621>

References

1. Ramirez MA, Ramirez J and Murthi AM. Reverse total shoulder arthroplasty for irreparable rotator cuff tears and cuff tear arthropathy. *Clin Sports Med* 2012; 31(4): 749–759.
2. Werthel JD, Walch G, Vegehan E, et al. Lateralization in reverse shoulder arthroplasty: a descriptive analysis of different implants in current practice. *Int Orthop* 2019; 43(10): 2349–2360.

3. Gutiérrez S, Levy JC, Lee WE 3rd, et al. Center of rotation affects abduction range of motion of reverse shoulder arthroplasty. *Clin Orthop Relat Res* 2007; 458: 78–82.
4. Nelson R, Lowe JT, Lawler SM, et al. Lateralized center of rotation and lower neck-shaft angle are associated with lower rates of scapular notching and heterotopic ossification and improved pain for reverse shoulder arthroplasty at 1 year. *Orthopedics* 2018; 41(4): 230–236.
5. Nicholson GP, Strauss EJ and Sherman SL. Scapular notching: recognition and strategies to minimize clinical impact. *Clin Orthop Relat Res* 2011; 469(9): 2521–2530.
6. Helmkamp JK, Bullock GS, Amilo NR, et al. The clinical and radiographic impact of center of rotation lateralization in reverse shoulder arthroplasty: a systematic review. *J Shoulder Elbow Surg* 2018; 27(11): 2099–2107.
7. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009; 21(339): b2535.
8. Higgins JP, Thomas J, Chandler J, et al. *Cochrane handbook for systematic reviews of interventions*. 2nd ed. Chichester, UK: John Wiley & Sons, 2019.
9. Howick J, Chalmers I, Glasziou P, et al. The Oxford 2011 levels of evidence 2 (Table). 2011. <http://www.cebm.net/index.aspx?o=5653>
10. Slim K, Nini E, Forestier D, et al. Methodological index for non-randomized studies (minors): development and validation of a new instrument. *ANZ J Surg* 2003; 73(9): 712–716.
11. Greiner S, Schmidt C, Herrmann S, et al. Clinical performance of lateralized versus non-lateralized reverse shoulder arthroplasty: a prospective randomized study. *J Shoulder Elbow Surg* 2015; 24(9): 1397–1404.
12. Kennon JC, Songy C, Bartels D, et al. Primary reverse shoulder arthroplasty: how did medialized and glenoid-based lateralized style prostheses compare at 10 years? *J Shoulder Elbow Surg* 2020; 29(7S): S23–S31.
13. Merolla G, Walch G, Ascione F, et al. Grammont humeral design versus onlay curved-stem reverse shoulder arthroplasty: comparison of clinical and radiographic outcomes with minimum 2-year follow-up. *J Shoulder Elbow Surg* 2018; 27(4): 701–710.
14. Gobezi R, Shishani Y, Lederman E, et al. Can a functional difference be detected in reverse arthroplasty with 135° versus 155° prosthesis for the treatment of rotator cuff arthropathy: a prospective randomized study. *J Shoulder Elbow Surg* 2019; 28(5): 813–818.
15. Boutsiadis A, Lenoir H, Denard PJ, et al. The lateralization and distalization shoulder angles are important determinants of clinical outcomes in reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2018; 27(7): 1226–1234.
16. Kirzner N, Paul E and Moaveni A. Reverse shoulder arthroplasty vs BIO-RSA: clinical and radiographic outcomes at short term follow-up. *J Orthop Surg Res* 2018; 13(1): 256.
17. Rücker G, Krah U, König J, et al. netmeta: network meta-analysis using frequentist methods, 2019. <https://github.com/guido-s/netmeta>
18. Athwal GS, MacDermid JC, Reddy KM, et al. Does bony increased-offset reverse shoulder arthroplasty decrease scapular notching? *J Shoulder Elbow Surg* 2015; 24(3): 468–473.
19. Collin P, Liu X, Denard PJ, et al. Standard versus bony increased-offset reverse shoulder arthroplasty: a retrospective comparative cohort study. *J Shoulder Elbow Surg* 2018; 27(1): 59–64.
20. Zitkovsky HS, Carducci MP, Mahendraraj KA, et al. Lateralization and decreased neck-shaft angle reduces scapular notching and heterotopic ossification. *J Am Acad Orthop Surg* 2020; 28(23): e1073–e1080.
21. Huri G, Familiari F, Salari N, et al. Prosthetic design of reverse shoulder arthroplasty contributes to scapular notching and instability. *World J Orthop* 2016; 7(11): 738–745.
22. Verdano MA, Aliani D, Galavotti C, et al. Grammont versus lateralizing reverse shoulder arthroplasty for proximal humerus fracture: functional and radiographic outcomes. *Musculoskelet Surg* 2018; 102(Suppl 1): 57–65.
23. Delloye C, Joris D, Colette A, et al. Mechanical complications of total shoulder inverted prosthesis. *Rev Chir Orthop Reparatrice Appar Mot* 2002; 88(4): 410–414. (In French).
24. Giles JW, Langohr GD, Johnson JA, et al. Implant design variations in reverse total shoulder arthroplasty influence the required deltoid force and resultant joint load. *Clin Orthop Relat Res* 2015; 473(11): 3615–3626.
25. Clark JC, Ritchie J, Song FS, et al. Complication rates, dislocation, pain, and postoperative range of motion after reverse shoulder arthroplasty in patients with and without repair of the subscapularis. *J Shoulder Elbow Surg* 2012; 21(1): 36–41.
26. Friedman RJ, Flurin PH, Wright TW, et al. Comparison of reverse total shoulder arthroplasty outcomes with and without subscapularis repair. *J Shoulder Elbow Surg* 2017; 26(4): 662–668.
27. De Fine M, Sartori M, Giavaresi G, et al. The role of subscapularis repair following reverse shoulder arthroplasty: systematic review and meta-analysis. *Arch Orthop Trauma Surg* 2021. Epub ahead of print 26 Feb 2021. DOI: [10.1007/s00402-020-03716-9](https://doi.org/10.1007/s00402-020-03716-9).
28. Grey B, Rodseth RN and Roche SJ. Humeral stem loosening following reverse shoulder arthroplasty: a systematic review and meta-analysis. *JBJS Rev* 2018; 6(5): e5.