

# The Effect of Humeral Inclination on Range of Motion in Reverse Total Shoulder Arthroplasty: A Systematic Review

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## Abstract

Reverse total shoulder arthroplasty (RTSA) is a treatment option for patients with rotator cuff tear arthropathy, pseudoparalysis, and a functional deltoid.

Our hypothesis was that no significant difference in postoperative active range of motion (ROM) will be observed in patients with 135° and 155° humeral cup inclination.

A systematic review was registered with PROSPERO and performed with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Studies evaluating RTSA that reported the type of prosthesis as well as active postoperative ROM were eligible for inclusion. Minimum follow-up was 12 months. Pre- and postoperative ROM (and difference,  $\Delta$ ) was compared between RTSA humeral components with cup inclination 135° and 155°. Descriptive statistics were calculated, and the 2 groups were compared using 2-proportion z-test.

Sixty-five studies with 3302 patients (3434 shoulders; 1211 in the 135° group and 2223 in the 155° group) were included. Mean patient

age was  $71.1 \pm 7.6$  years, 71% were female, and mean follow-up was  $37.2 \pm 16.5$  months. No significant difference existed between patient age at the time of surgery; the average age of patients in the 135° lateralized glenosphere group was  $71.67 \pm 3.8$  years, while the average age of patients in the 155° group was  $70.97 \pm 8.8$  years. Forward elevation, abduction, and external rotation all significantly improved following surgery in the 135° and 155° groups ( $P < .05$ ). Patients in the 135° group had significantly greater improvement in external rotation ( $P < .001$ ) and significantly more overall external rotation compared to the 155° group ( $P < .001$ ). No significant difference existed between 135° and 155° groups in ROM improvements ( $\Delta$ ) in forward elevation ( $P = .142$ ) or abduction ( $P = .217$ ).

Patients with a 135° humeral cup inclination in RTSA gain significantly more external rotation from pre- to postsurgery and have an overall greater amount of external rotation than patients who receive a 155° prosthesis.

**R**everse total shoulder arthroplasty (RTSA) has become a reliable treatment option for many pathologic conditions of the shoulder,

including rotator cuff arthropathy, proximal humerus fractures, and others.<sup>1-4</sup> While the treatment outcomes have generally been reported as good,

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some concern exists over the postoperative range of motion (ROM) in patients following RTSA, including external rotation.<sup>5-7</sup> The original RTSA design was introduced by Neer in the 1970s and has undergone many modifications since that time.<sup>1,2</sup> The original Grammont-style prosthesis involved medialization of the glenoid, inferiorizing the center of rotation (with increased deltoid tensioning), and a neck-shaft angle of 155°.<sup>1,8</sup> While clinical results of the 155° design were encouraging, concerns arose over the significance of the common finding of scapular notching, or contact between the scapular neck and inferior portion of the humeral polyethylene when the arm is adducted.<sup>9,10</sup>

To address this concern, a prosthesis design with a 135° neck-shaft angle was introduced.<sup>11</sup> This new design did significantly decrease the rate of scapular notching, and although some reported a concern over implant stability with the 135° prosthesis, recent data has shown no difference in dislocation rates between the 135° and 155° prostheses.<sup>3</sup> A different variable that has not been evaluated between these prostheses is the active ROM that is achieved postoperatively, and the change in ROM from pre- to post-RTSA.<sup>12,13</sup> As active ROM plays a significant role in shoulder function and patient satisfaction, the question of whether a significant difference exists in postoperative ROM between the 135° and 155° prostheses must be addressed.

The purpose of this study was to perform a systematic review investigating active ROM following RTSA to determine if active postoperative ROM following RTSA differs between the 135° and 155° humeral inclination prostheses, and to determine if there is a significant difference between the change in preoperative and postoperative ROM between the 135° and 155° prostheses. The authors hypothesize that there will be no significant difference in active postoperative ROM between the 135° and 155° prostheses, and that the difference between preoperative and postoperative ROM (that is, the amount of motion gained by the surgery) will not significantly differ between the 135° and 155° prostheses.

## Methods

A systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines using a PRISMA checklist.<sup>15</sup> Systematic review registration was performed using the PROSPERO interna-

tional prospective register of systematic reviews (registration date 3/9/15, registration number CRD42015017367).<sup>16</sup> Two reviewers independently conducted the search on March 7, 2015 using the following databases: Medline, Cochrane Central Register of Controlled Trials, SportDiscus, and CINAHL. The electronic search citation algorithm utilized was: (((((reverse[Title/Abstract]) AND shoulder[Title/Abstract]) AND arthroplasty[Title/Abstract]) NOT arthroscopic[Title/Abstract]) NOT cadaver[Title/Abstract]) NOT biomechanical[Title/Abstract]). English language Level I-IV evidence (2011 update by the Oxford Centre for Evidence-Based Medicine<sup>17</sup>) clinical studies that reported the type of RTSA prosthesis that was used as well as postoperative ROM with at least 12 months follow-up were eligible. All references within included studies were crossreferenced for inclusion if missed by the initial search. If duplicate subject publications were discovered, the study with the longer duration of follow-up or larger number of patients was included. Level V evidence reviews, letters to the editor, basic science, biomechanical studies, arthroscopic shoulder surgery, imaging, surgical technique, and classification studies were excluded. Studies were excluded if both a 135° and 155° prosthesis were utilized and the outcomes were not stratified by the humeral inclination. Studies that did not report ROM were excluded.

A total of 456 studies were located, and, after implementation of the exclusion criteria, 65 studies from 2005-2015 were included in the final analysis (**Figure**). Subjects of interest in this systematic review underwent a RTSA. Studies were not excluded based on the surgical indications (rotator cuff tear arthropathy, proximal humerus fractures, osteoarthritis) and there was no minimum follow-up or rehabilitation requirement. Study and subject demographic parameters analyzed included year of publication, journal of publication, country and continent of publication, years of subject enrollment, presence of study financial conflict of interest, number of subjects and shoulders, gender, age, the manufacturer and type of prosthesis used, and the degree of the humeral inclination (135° vs 155° humeral cup). Preoperative ROM, including forward elevation, abduction, external rotation with the arm adducted, and external rotation with the arm at 90° of abduction, were recorded. The same ROM measurements were recorded for the final follow-up visit that was reported. Internal rotation was recorded, but because of the variability with how this measurement was reported, it was not

analyzed. Clinical outcome scores and complications were not assessed. Study methodological quality was evaluated using the Modified Coleman Methodology Score (MCMS).<sup>18</sup>

## Statistical Analysis

Descriptive statistics were calculated, including mean  $\pm$  standard deviation for quantitative continuous data and frequencies with percentages for qualitative categorical data. ROM comparisons between 135° and 155° components (pre- vs postoperative for each and postoperative between the 2) were made using 2 proportion z-test calculator (<http://in-silico.net/tools/statistics/ztest>) using alpha .05 because of the difference in sample sizes between compared groups.

## Results

Sixty-five studies with 3302 patients (3434 shoulders) were included in this study. There was a total of 1211 shoulders in the 135° lateralized glenosphere group and 2223 shoulders in the 155° group. The studies had an average MCMS of  $40.4 \pm 8.2$  (poor), 48% of studies reported a conflict of interest, 32% had no conflict of interest, and 20% did not report whether a conflict of interest existed or not. The majority of studies included were level

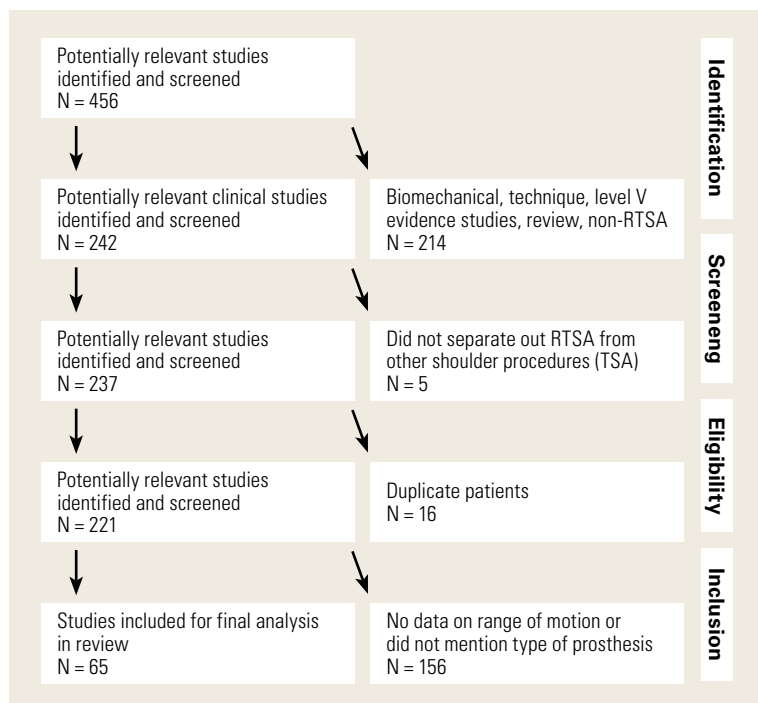
IV evidence (85%). Mean patient age was  $71.1 \pm 7.6$  years; 29% of patients were male and 71% were female. No significant difference existed between patient age at the time of surgery; the average age of patients in the 135° lateralized glenosphere group was  $71.67 \pm 3.8$  years, while the average patient age of patients in the 155° group was  $70.97 \pm 8.8$  years. Mean follow-up for all patients included in this study was  $37.2 \pm 16.5$  months. Of the 65 studies included, 3 were published from Asia, 4 were published from Australia, 24 were from North America, and 34 were from Europe. Of the individual countries whose studies were included, the United States had 23 included studies, France had 13 included studies, and Italy had 4 included studies. All other countries had <4 studies included.

Patients who received either a 135° or a 155° prosthesis showed significant improvements in external rotation with the arm at the side ( $P < .05$ ), forward elevation ( $P < .05$ ), and abduction ( $P < .05$ ) following surgery (Table). When comparing the 135° and 155° groups, patients who received a 135° prosthesis showed significantly greater improvements in external rotation with the arm at the side ( $P < .001$ ) and had significantly more overall external rotation postoperatively ( $P < .001$ ) than patients who received a 155° prosthesis. The only preoperative ROM difference between groups was the 155° group started with significantly more forward elevation than the 135° group prior to surgery ( $P = .002$ ).

## Discussion

RTSA is indicated in patients with rotator cuff tear arthropathy, pseudoparalysis, and a functional deltoid.<sup>1,2,4</sup> The purpose of this systematic review was to determine if active ROM following RTSA differs between the 135° and 155° humeral inclination prostheses, and to determine if there is a significant difference between the change in preoperative and postoperative ROM between the 135° and 155° prostheses. Forward elevation, abduction, and external rotation all significantly improved following surgery in both groups, with no significant difference between groups in motion or amount of motion improvement, mostly confirming the study hypotheses. However, patients in the 135° group had significantly greater postoperative external rotation and greater amount of external rotation improvement compared to the 155° group.

Two of the frequently debated issues regarding implant geometry is stability and scapular notching



**Figure.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Flowchart  
Abbreviations: RTSA, reverse total shoulder arthroplasty; TSA, total shoulder arthroplasty.

between the 135° and 155° humeral inclination designs. Erickson and colleagues<sup>3</sup> recently evaluated the rate of scapular notching and dislocations between the 135° and 155° RTSA prostheses. The authors found that the 135° prosthesis had a significantly lower incidence of scapular notching vs the 155° group and that the rate of dislocations was not significantly different between groups.<sup>3</sup> In the latter systematic review, the authors attempted to evaluate ROM between the 135° and 155° prostheses, but as the inclusion criteria of the study was reporting on scapular notching and dislocation rates, many studies reporting solely on ROM were excluded, and the influence of humeral inclination on ROM was inconclusive.<sup>3</sup> Furthermore, there have been no studies that have directly compared ROM following RTSA between the 135° and 155° prostheses. While studies evaluating each prosthesis on an individual level have shown an improvement in ROM from pre- to postsurgery, there have been no large studies that have compared the postoperative ROM and change in pre- to postop-

erative ROM between the 135° and 155° prostheses.<sup>11,13,19,20</sup>

One study by Valenti and colleagues<sup>21</sup> evaluated a group of 30 patients with an average age of 69.5 years who underwent RTSA using either a 135° or a 155° prosthesis. Although the study did not directly compare the 2 types of prostheses, it did report the separate outcomes for each prosthesis. At an average follow-up of 36.4 months, the authors found that patients who had the 135° prosthesis implanted had a mean increase in forward elevation and external rotation of 53° and 9°, while patients who had the 155° showed an increase of 56° in forward elevation and a loss of 1° of external rotation. Both prostheses showed a significant increase in forward elevation, but neither had a significant increase in external rotation. Furthermore, scapular notching was seen in 4 patients in the 155° group, while no patients in the 135° group had evidence of notching.

The results of the current study were similar in that both the 135° and 155° prosthesis showed

**Table. Preoperative, Postoperative, and Change From Preoperative to Postoperative Range of Motion Between the 135° and 155° Prostheses (N = 3434 Shoulders)**

	135°	155°	Difference between 135° and 155°
Number of shoulders	1211	2223	
Preop			
ER at side	12.6 (3.3-27)	13.5 (3-29)	.469
Postop			
ER at side	33.0 <sup>a</sup> (17.6-51)	20.5 <sup>a</sup> (6-39)	<b>&lt;.001</b>
Improvement			
ER at side	Δ 20.4	Δ 7.0	<b>&lt;.001</b>
Preop			
FE	51.6 (4-85)	61.2 (29-96)	<b>.002</b>
Postop			
FE	118.3 <sup>a</sup> (72.7-149.3)	123.3 <sup>a</sup> (87-157)	.091
Improvement			
FE	Δ 66.7	Δ 62.1	.142
Preop			
Abduction	52.1 (34.1-70)	50.6 (29-89)	.707
Postop			
Abduction	116.3 <sup>a</sup> (70.4-129)	109.7 <sup>a</sup> (78-149)	.068
Improvement			
Abduction	Δ 64.2	Δ 59.1	.217
Preop			
ER in abduction	Only one study to compare	30.3	
Postop			
ER in abduction		43.7 <sup>a</sup>	
Improvement			
ER in abduction		Δ 13.4	

<sup>a</sup>P < .05 for all pre vs post comparisons.

Abbreviations: ER, external rotation; FE, forward elevation. Ranges for each variable are included within the parentheses.

improvements in forward elevation following surgery, and the 135° group showed a significantly greater gain in external rotation than the 155° group. A significant component of shoulder function and patient satisfaction following RTSA is active ROM. However, this variable has not explicitly been evaluated in the literature until now. The clinical significance of this finding is unclear. Patients with adequate external rotation prior to surgery likely would not see a functional difference between prostheses, while those patients who were borderline on a functional amount of external rotation would see a clinically significant benefit with the 135° prosthesis. Studies have shown that the 135° prosthesis is more anatomic than the 155°, and this could explain the difference seen in ROM outcomes between the 2 prostheses.<sup>19</sup> Ladermann and colleagues<sup>22</sup> recently created and evaluated a 3-dimensional computer model to evaluate possible differences between the 135° and 155° prosthesis. The authors found a significant increase in external rotation of the 135° compared to the 155°, likely related to a difference in acromio-humeral distance as well as inlay vs onlay humeral trays between the 2 prostheses. The results of this study parallel the computer model, thereby validating these experimental results.

It is important to understand what the minimum functional ROM of the shoulder is (in other words, the ROM necessary to complete activities of daily living (ADLs)).<sup>23</sup> Namdari and colleagues<sup>24</sup> used motion analysis software to evaluate the shoulder ROM necessary to complete 10 different ADLs, including combing hair, washing the back of the opposite shoulder, and reaching a shelf above their head without bending their elbow in 20 patients with a mean age of 29.2 years. They found that patients required 121° ± 6.7° of flexion, 46° ± 5.3° of extension, 128° ± 7.9° of abduction, 116° ± 9.1° of cross-body adduction, 59° ± 10° of external rotation with the arm 90° abducted, and 102° ± 7.7° of internal rotation with the arm at the side (external rotation with the arm at the side was not well defined).<sup>24</sup> Hence, while abduction and forward elevation seem comparable, the results from the current study do raise concerns about the amount of external rotation obtained following RTSA as it relates to a patients' ability to perform ADLs, specifically in the 155° prosthesis, as the average postoperative external rotation in this group was 20.5°. Therefore, based on the results of this study, it appears that, while both the 135° and 155° RTSA prostheses provide similar gain in forward eleva-

tion and abduction ROM as well as overall forward elevation and abduction, the 135° prosthesis provides significantly more external rotation with the arm at the side than the 155° prosthesis.

## Limitations

Although this study attempted to look at all studies that reported active ROM in patients following a RTSA, and 2 authors performed the search, there is a possibility that some studies were missed, introducing study selection bias. Furthermore, the mean follow-up was over 3 years following surgery, but the minimum follow-up requirement for studies to be included was only 12 months. Hence, this transfer bias introduces the possibility that the patient's ROM would have changed had they been followed for a standard period of time. There are many variables that come into play in evaluating ROM, and although the study attempted to control for these, there are some that could not be controlled for due to lack of reporting by some studies. Glenosphere size and humeral retroversion were not recorded, as they were not reliably reported in all studies, so motion outcomes based on these variables was not evaluated. Complications and clinical outcomes were not assessed in this review and as such, conclusions regarding these variables cannot be drawn from this study. Finally, indications for surgery were not reliably reported in the studies included in this paper, so differences may have existed between surgical indications of the 135° and 155° groups that could have affected outcomes.

## Conclusion

Patients who receive a 135° RTSA gain significantly more external rotation from pre- to postsurgery and have an overall greater amount of external rotation than patients who receive a 155° prosthesis. Both groups show improvements in forward elevation, external rotation, and abduction following surgery.

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