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Observations on retrieved humeral polyethylene components from reverse total shoulder arthroplasty

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Hypothesis: Analyses of polyethylene components retrieved at revision of total knee, hip, and shoulder replacements have been used to study the effect of design, patient, and surgical factors on initial implant performance, but no studies have reported similar types of findings in retrieved humeral polyethylene components in reverse total shoulder arthroplasty. Our hypothesis is that while the conforming surface of the humeral polyethylene may predispose it to surface wear modalities, as seen in total hip arthroplasty, the presence of clinical instability may also increase the occurrence of focal contact stresses leading to subsurface fatigue failure.
Materials and methods: Fourteen humeral polyethylene components were retrieved from revision surgery at a single institution. Each polyethylene was analyzed for 9 modes of damage in each of 4 quadrants into which the bearing surface was divided. For each implant, the most recent radiographs before removal were scored using an adapted radiolucency score, and glenosphere positioning was measured.
Results: Despite the short mean length of implantation (0.46 ± 0.5 years), scratching and abrasion were seen in 14 and 13 components, respectively, followed by third-body debris and pitting. The modes of damage observed were most severe in the inferior quadrant of the humeral polyethylene. Scapular notching, glenoid, and humeral radiolucencies were prevalent on preoperative radiographs, but their long-term significance has not yet been elucidated. Increased glenosphere inclination was associated with decreased superior and total glenoid radiolucency, along with total polyethylene wear scores.
Discussion: Promising early, functional results with the use of reverse total shoulder arthroplasty has led to the increased expansion of its use, but high complication and revision rates continue to raise concerns regarding implant longevity. The presence of a clinical, adduction deficit may predispose patients to inferior quadrant polyethylene wear.
Conclusions: Impingement of the humeral polyethylene at the lateral edge of the scapula leads to inferior quadrant wear and associated polyethylene failure, and implant instability may predispose the components to fatigue wear mechanisms. Analysis of retrieved humeral polyethylene components, along with patient, design, and surgical factors, provide important information on the causes of component failure.
Level of evidence: Basic Science Study.

Keywords: Reverse total shoulder arthroplasty; polyethylene; damage modes; impingement; fatigue failure; instability

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Table I Patient demographics and clinical information

Variable*	DePuy	Encore
Patients, No.	6	5
Humeral polyethylenes, No.	9	5
Age at revision, y	64.6 ± 10.3	72.0 ± 7.8
Time since primary surgery, y	0.4 ± 0.3	0.6 ± 0.4
Gender, No		
Male	1	4
Female	5	1
Affected extremity, No.		
Right	6	5
Left	0	0
Forward elevation, deg	122.0 ± 27.7	74.0 ± 28.8
External rotation, deg	46.0 ± 35.2	52.5 ± 46.0
Primary diagnosis, No†		
Failed hemiarthroplasty	2	1
Failed total shoulder	0	1
Arthroplasty		
Rotator cuff arthropathy	4	3
Revision diagnosis, No†		
Dislocation/instability	4	2
Glenosphere dissociation	0	2
Infection	5	1
Revision procedure, No†		
Component revision	4	2
Conversion to hemiarthroplasty	0	2
Explant, placement of antibiotic spacer	5	1

* Continuous data are presented as the mean ± standard deviation.
† Number of patients.

Rotator cuff arthropathy is a difficult pathologic process to adequately treat. Treatment options include nonoperative management, glenohumeral arthrodesis, constrained and unconstrained total shoulder arthroplasty (TSA), and hemiarthroplasty.[9,31,42,43] However, patient dissatisfaction with functional outcomes and high long-term complication rates with traditional management has led to the continued search for an improved solution. When introduced in the 1970s, reverse TSA found minimal clinical success because its constrained design combined with a lateralized glenohumeral center of rotation led to excessive shear forces transmitted through the glenoid component and failure.[1,29] Newer designs, emphasizing a larger radius of curvature of the hemispherical glenoid component and movement of the center of rotation medially and distally, create a more stable fulcrum and decreased shear forces at the glenosphere-bone interface.[4] Since its approval by the U.S. Food and Drug Administration in 2003, reverse TSA has gained widespread acceptance within the United States. However, questions regarding major complication rates as high as 26%,[38] limited implant longevity, and a lack of long-term functional outcome data continue to raise concerns.[29]

Analyses of polyethylene components retrieved from revision of total knee, hip, and conventional shoulder arthroplasty have been effective in defining the effect of design, patient, and surgical factors on implant performance.[17] Such an approach should be applicable to reverse TSA components as well, and to our knowledge, no prior studies have presented the failure modes seen in humeral polyethylene components from reverse TSA. We hypothesized that although the conforming surface of the humeral polyethylene may predispose it to surface wear modalities, as seen in total hip arthroplasty, the presence of clinical instability may also increase the occurrence of focal contact stresses leading to subsurface fatigue failure. Therefore, the objective of our study was to establish associations between prerevision radiographic assessment, clinical performance, and polyethylene wear analysis in patients with failed reverse TSAs.

Materials and methods

This study was approved by the Institutional Review Board (IRB) at the Hospital for Special Surgery (Approval Number 22121).

From 2005 to 2008, 14 consecutive reverse TSA humeral polyethylene components were collected from revision surgeries of 11 patients as part of an ongoing, IRB-approved implant retrieval system at a single hospital. The implants were from 2 manufacturers: 9 components made by DePuy (Warsaw, IN) and 5 by Encore (Austin, TX). In 6 cases, the humeral polyethylene component and glenosphere were revised, 6 cases involved an irrigation, débridement, and explant of the reverse TSA, and in the remaining 2 cases, the reverse TSA was converted to a conventional hemiarthroplasty. During this collection period, 29 DePuy and 21 Encore reverse TSAs were implanted.

Retrospective review of the medical records and prerevision radiographs were available for all patients. The clinical information recorded included patient demographics, comorbidities, shoulder history, clinical assessment, including range of motion, intraoperative findings, length of implantation, and primary and revision diagnoses, and implant information. Ten patients underwent the index surgery at our institution with 4 different orthopedic surgeons. These 10 revision surgeries were performed by the surgeon who performed the index procedure. Three patients underwent 2 surgeries after their reverse TSA. Two were initially revised for dislocation, and then secondarily underwent hardware removal for deep infection involving the prosthesis. The third patient required 2 subsequent procedures for an infected prosthesis.

Average patient age was 64.6 ± 10.3 years and 72.0 ± 7.8 years for the patients with DePuy implants and Encore implants, respectively, at the time of revision surgery. The mean length of implantation was 0.4 ± 0.3 years and 0.6 ± 0.4 years for the patients with DePuy and Encore implants, respectively (range, 0.06 to 1.92 years). Primary diagnoses were a failed conventional hemiarthroplasty with superior escape in 3 patients, failed conventional total shoulder arthroplasty in 1, and rotator cuff arthropathy in 7. Revision diagnoses were dislocation in 6 cases, glenosphere dissociation in 2, and infection in 6. Before revision, the average forward elevation was 122.0° ± 27.7° and 74.0° ± 28.8° (range, 30°-160°), and the average external rotation was 46.0° ± 35.2° and 52.5° ± 46.0° (range, 10°-85°), for the patients with DePuy and Encore implants, respectively (Table I).

The polyethylene bearing surfaces of the humeral components were examined microscopically using ×31 magnification in a light stereomicroscope. Previously developed scoring systems for polyethylene joint replacements[12,17] were used to subjectively score 9 wear modes on each surface: burnishing, abrasion, scratching, pitting, delamination, focal damage, surface deformation, embedded third-body debris, and fracture. The surface was divided into anterior, posterior, superior, and inferior quadrants and given a subjective damage score of 0 to 3 for each mode in each quadrant. Quadrant scores were summed to arrive at a composite score with a maximum score of 12 for each damage mode[16] (Fig. 1). The measurements were performed by a single observer experienced with wear analysis.

The most recent plain shoulder radiographs before removal were available for 13 of the retrieved components. The radiographs included anteroposterior (AP) and axillary views and were scored according to the extent of the notch relative to the inferior metaglene screw after Boileau et al[2] (Fig. 2). In addition, periprosthetic lucencies of both the glenoid and humeral components were digitally measured using a modification of a previously established method in which the width of the lucencies (absent, <2 mm, or >2 mm) were measured in 4 zones around the glenoid and 7 zones around the humerus. The 4 glenoid zones were defined as the superior baseplate, inferior baseplate (independent from a notch if present), central pillar, and screws.[2,30,36] The 7 humeral zones were defined as zones 1 and 7 superior to the level of the neck, zones 2 and 6 at the proximal half of the stem, zones 3 and 5 at the distal half of the stem, and zone 4 distal to the end of the stem[32] (Fig 3). A score of 0 was assigned to the absence of radiolucent lines, 1 to the presence of a lucency <2 mm, and 2 for a lucency >2 mm. The values of the zones were summed to obtain the total glenoid radiolucency score (maximum value of 8), and total humeral radiolucency score (maximum value of 14). Periprosthetic radiolucencies were independently scored by 2 observers who arrived at a consensus regarding location and severity of the radiolucent lines.

Grade	Percent of Damage
0	No Damage
1	1%-10% Damage
2	11%-50% Damage
3	51-100% Damage

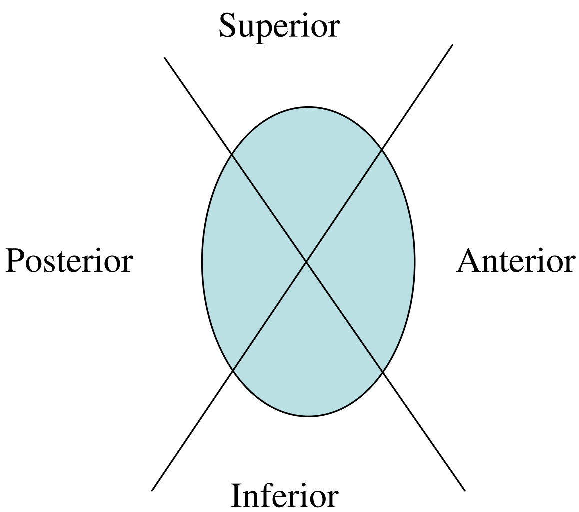

Figure 1 Damage and map score for humeral polyethylene components. From "Observations on retrieved glenoid components from total shoulder arthroplasty," by Nho SJ et al, 2009, J Shoulder Elbow Surg, 18(3):371-8. Reprinted with permission.

Lastly, the glenosphere inclination and height were measured digitally on the AP radiographs. "Glenosphere inclination" was measured as the angle formed between a line passing through the most superior and inferior points of the medial aspect of the glenosphere and a vertical line passing through the same inferior point. An increased inclination value corresponds to a caudally tilted glenosphere (Fig 4, *A*). "Glenosphere height" was measured as the length of a vertical line connecting the most inferior point of the native glenoid to its intersection with a horizontal line tangential to the most inferior aspect of the glenosphere (Fig. 4, *B*). This value was positive if the most inferior aspect of the glenosphere was located inferior to the most inferior aspect of the bony glenoid. These values were independently measured twice by 2 observers in separate sessions, then analyzed for interobserver and intraobserver variability.

Statistical methods

Intraclass correlation coefficients for glenosphere positioning measurements were graded using previously described semiquantitative criteria: excellent for 0.9–1.0, good for 0.7–0.89, fair/moderate for 0.5–0.69, low for 0.25–0.49, and poor for 0.0–0.24.[26]

Correlation coefficients were used to determine associations between prerevision radiographic notching, periprosthetic

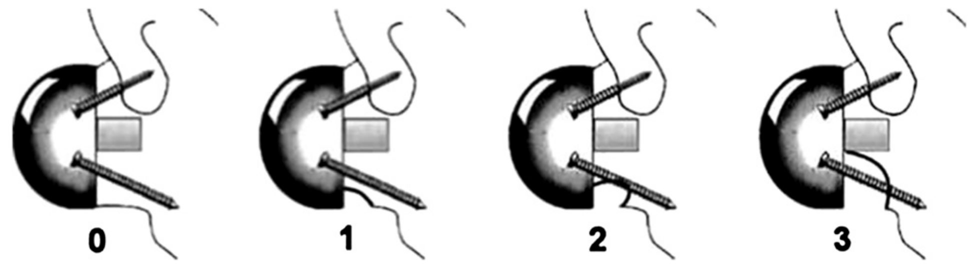

Figure 2 Classification of extent of notch: 0, no notch; 1, small notch stopping short of inferior screw; 2, medium notch reaching inferior screw; 3, large notch extending beyond inferior screw. From "The Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty," by Boileau P et al, 2006, J Shoulder Elbow Surg, 15(5):527-540. Reprinted with permission.

radiolucencies, glenosphere positioning, and polyethylene wear. Correlation coefficient values from 0.20 to 0.40, 0.40 to 0.60, 0.60 to 0.80, and 0.80 to 1.00 were described as having weak, moderate, strong, and very strong associations, respectively.[10] A 2-tailed *t* test was calculated to compare differences in severity of wear between respective quadrants and to compare average wear scores for each damage mode. A value of $P < .02$ was statistically significant.

Results

Humeral polyethylene component wear analysis

Scratching was the most common damage mode, present on all 14 components, closely followed by abrasion, present in 13 components (Fig 5, *A-D*). Scratching was noted in each quadrant in all 14 components, with no significant difference in overall severity among regions. In contrast, abrasive wear was most prevalent and severe in the inferior quadrant ($P = .02$). Abrasion was appreciated in both the articular surface and the extraarticular region of the polyethylene as it contacted the lateral edge of the scapula, and both these regions were considered when calculating the damage score. Embedded third-body debris and pitting were seen in 8 and 6 components, respectively, consistent with metallic debris generated from the glenosphere or metaglene components. Burnishing was present in 4 polyethylene components, surface deformation in 3, and both fracture and focal wear were each found once in a single component in which the glenosphere had eroded and fractured the inferior aspect of the humeral polyethylene. Delamination was not found in any of the retrieved components.

Scratching was the most severe damage mode, with an average score of 8.8 of 12; next was abrasion, with an average score of 3.7, followed by embedded third-body debris (1.3) and pitting (1.1). The differences in scores between scratching and abrasion, and abrasion and third-body debris, were both significant ($P < .02$). When the average score was calculated including only the humeral components that demonstrated that damage mode, scratching and abrasion were the most severe and fracture and wear through were next, followed by pitting, embedded third-body debris, and burnishing (Table II).

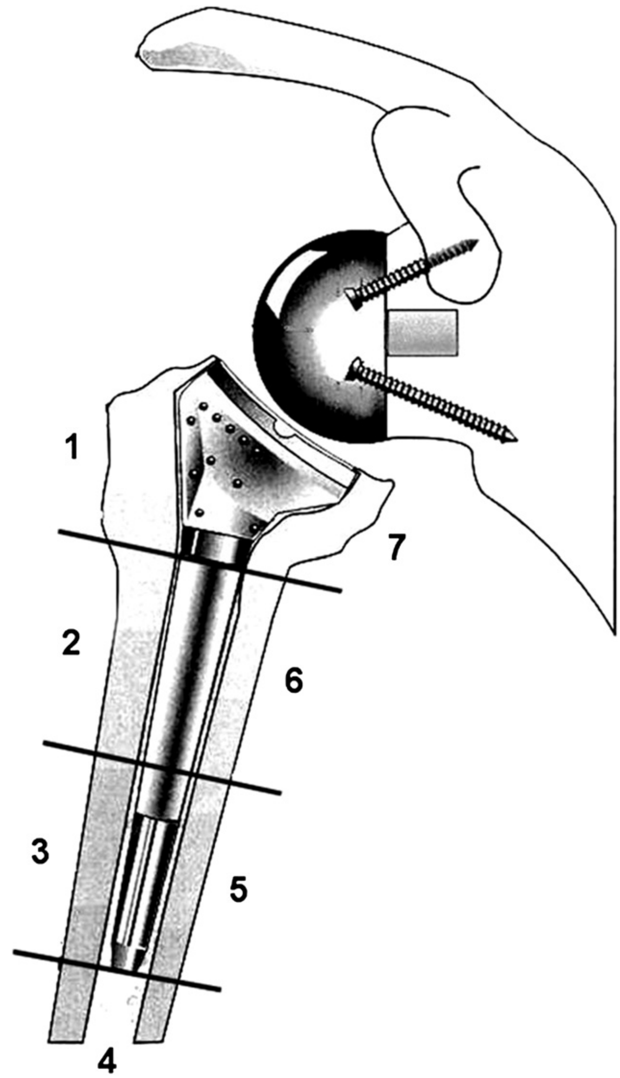

Figure 3 Classification of humeral zones: the humerus was divided into 7 zones around the prosthesis. From "The Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty," by Boileau P et al., 2006, J Shoulder Elbow Surg, 15(5):527-540. Reprinted with permission.

Irrespective of damage mode, the inferior quadrant suffered the greatest amount of wear damage, with a mean total score of 5.9, followed by the anterior (4.2), posterior

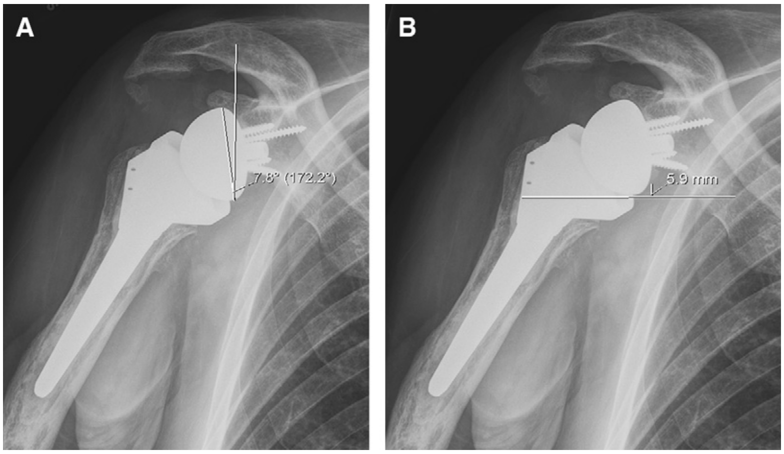

Figure 4 Radiographic examples of the measurement of **(A)** glenosphere height and **(B)** glenosphere inclination.

(3.3), and superior (3.1) regions (Fig. 6). The difference between inferior and anterior wear was significant (P = .02), indicating that the inferior quadrant was subjected to the greatest amount of cumulative wear. Abrasion was the only damage mode that was seen in multiple polyethylene components that also demonstrated a significant difference among the 4 regions because the inferior quadrant suffered greater abrasive wear than the other 3 (P = .02).

No significant differences in overall polyethylene wear, inferior polyethylene wear, or inferior abrasion were appreciated between the 5 Encore and 9 DePuy implants. In addition, no significant correlation was found between overall polyethylene wear and patient age at the time of revision, length of implantation, or prerevision range of motion. Observationally, however, higher total wear scores were seen in those components that were grossly unstable—3 components revised for dislocation and 2 revised for glenosphere dissociation comprised the 5 highest total wear scores.

Radiographic analysis

Scapular notching was found in only 6 of the 13 cases available for review. Of these, 5 were grade 1, and 1 was grade 2. Only 1 of the 5 radiographs (20%) with Encore implants exhibited grade 1 scapular notching (Fig. 5, *D*), whereas 5 of the 9 radiographs (59%) available for DePuy implants demonstrated notching. No correlation was found between scapular notching and total wear scores of the humeral polyethylene components. However, a strong, positive correlation occurred between notching and inferior quadrant surface deformation ($r = 0.67$). Also, a moderate correlation was present between notching and inferior (r = 0.54) and anterior quadrant ($r = 0.46$) third-body debris. Interestingly, the inferior quadrant of the humeral polyethylene components had the highest propensity for both cumulative and abrasive wear, but no association was found between the presence of inferior quadrant abrasive wear and scapular notching.

Glenoid periprosthetic lucencies were present in 11 of 13 cases (85%) available for review. Radiolucent lines were noted in zone 1 (superior part of the baseplate) in 7 radiographs, in zone 2 (inferior part of the baseplate) in 7, in zone 3 (surrounding the central pillar) in 2, and in zone 4 (surrounding the screws) in 1. Lucencies were >2 mm in 5 cases, and <2 mm in 2 cases for both the superior and inferior aspects of the baseplate, indicating that both the prevalence and severity of radiolucent lines were the same for these regions. No correlation was found between glenoid notching scores and periprosthetic lucencies around the inferior baseplate. A moderate to strong positive correlation was present between the total wear score for the humeral polyethylene components and the total glenoid radiolucency score ($r = 0.60$). Also, the total glenoid radiolucency score was positively related to inferior abrasive wear ($r = 0.78$) and inferior pitting ($r = 0.57$). Radiolucent lines surrounding the inferior baseplate were moderately related to inferior quadrant pitting of the humeral polyethylene ($r = 0.47$); no correlations were found with other wear damage modes. Two radiographs demonstrated frank glenosphere dissociation from its baseplate.

For the humeral components, periprosthetic lucencies were present in 9 of 13 cases (69%) available for review. All 13 components were cemented. Humeral radiolucent lines were noted with the greatest frequency in zone 3 (7 radiographs), followed by zone 1 and zone 7 (each present in 6 radiographs), then zone 2 and zone 5 (each present in 5 radiographs). Zone 3 had the highest average radiolucency score with a value of 0.92 (sum of radiolucent line scores in zone 3 for the 13 components, divided by 13), followed by zone 7 and zone 1, each with an average score of 0.67. The differences between severity of radiolucent lines between these 2 zones were not significant (P = .49). No correlation was found between the total humeral radiolucency scores

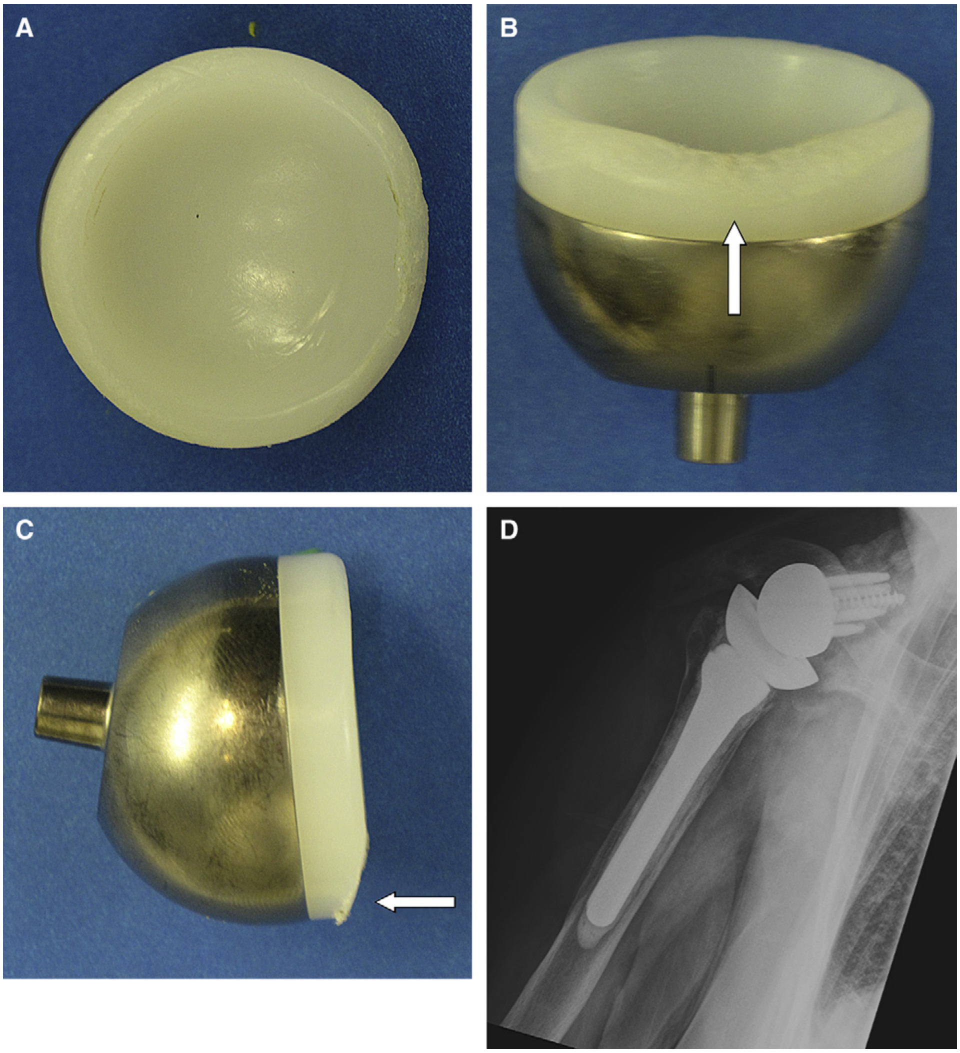

Figure 5 (**A**) Humeral polyethylene demonstrates scratching and pitting consistent with adhesive surface wear. (**B, C**) Humeral polyethylene demonstrates abrasive wear in the inferior quadrant consistent with a clinical adduction deficit (**D**). Anteroposterior radiograph of the implant shown in Panels B and C is consistent with scapular notching.

and the glenoid notching scores, or between the total humeral radiolucency scores and the total polyethylene wear scores.

The average value for glenosphere height was −1.0 mm (range −14.2 to 7.1 mm), indicating that on average, the inferior aspect of the glenosphere was positioned above the inferior aspect of the glenoid. No correlations were found between glenosphere height and scapular notching, total glenoid radiolucency, or total polyethylene wear scores, but a moderate, negative correlation was found with the total humeral radiolucency score ($r = -0.55$), inferior pitting ($r = -0.41$), and anterior third-body debris ($r = -0.52$). Thus, superior positioning of the glenosphere (corresponding to negative values for glenoid height) was associated with an increased propensity for specific types of humeral polyethylene wear. The average glenosphere inclination was 9.0° (range, −3.8° to 23.2°), and no association was appreciated between glenosphere inclination and scapular notching. However, a strong, negative correlation with superior glenoid radiolucencies ($r = -0.70$), and moderate, negative associations with total glenoid lucency ($r = -0.58$) and total polyethylene wear scores ($r = -0.51$) were present (Fig 7). Thus, increasing the glenosphere inclination, or caudal tilt, is associated with decreased glenoid radiolucencies and polyethylene wear scores.

No significant difference was appreciated between glenosphere height and glenosphere inclination between the Encore and Depuy implants. In addition, no association was appreciated between glenosphere inclination and scapular notching. Interobserver correlation for glenosphere height and glenosphere inclination were excellent and good, respectively, whereas both values for intraobserver correlation for each respective observer were excellent (Table III).

Table II Humeral polyethylene wear mode: frequency and severity of damage

Damage mode	Humeral polyethylenes involved	Average polyethylene wear score			
	No (%)	For all 14	Per polyethylene involved	DePuy (for all 9 polys)	Encore (for all 5 Polys)
Scratching	14 (100)	8.79	8.79	2.00	9.60
Abrasion	13 (93)	3.71	4.00	4.44	2.4
Embedded third body	8 (57)	1.29	2.25	1.00	1.80
Pitting	6 (43)	1.07	2.50	0.78	1.6
Burnishing	4 (29)	0.57	2.00	0.67	0.4
Surface deformation	3 (21)	0.36	1.67	0.56	0
Fracture	1 (7)	0.21	3.00	0.33	0
Wear-through	1 (7)	0.21	3.00	0.33	0
Delamination	0 (0)	0.00	0.00	0	0

Discussion

Reverse TSA has become a viable option for treatment of rotator cuff arthropathy and is used for the treatment of failed TSAs, rheumatoid arthritis with irreparable cuff tears, proximal humerus tumors, and proximal humerus fractures with anterosuperior escape.[25,35] Biomechanical studies showed that reverse TSAs medialize the glenohumeral center of rotation, stretch the deltoid muscle (thus increasing the deltoid lever arm), and restore shoulder kinematics more effectively than that of a hemiarthroplasty.[7,15,21] Clinical results after reverse TSA have been encouraging, with excellent pain relief and improved active flexion and abduction.[11,36,37]

However, high revision rates of 4.2% to 13% have been reported despite relatively short follow-up periods.[5,8,28,37] Complications include aseptic loosening, instability, glenosphere dissociation, humeral disassembly, infection, humeral fracture, neurapraxia, and scapular notching.[4,23,25,37] Sirveaux et al[37] noted survivorship of 88% at 5 years, 72% at 7 years, and 29% at 8 years, with "failure" defined as revision of a component or significant pain. Boileau et al[4] noted a 24% complication rate with reverse TSA (45% if performed as a revision surgery) and concluded that it should remain a salvage procedure, limited to elderly patients with poor function and severe pain secondary to rotator cuff deficiency.[4] Therefore, although reverse TSA is a treatment option with promising potential, complication rates remain high.

In this study, we measured implant performance and used retrieval analysis to establish associations between prerevision radiographic assessment and humeral polyethylene wear in patients who required revision of their reverse TSAs. Scratching and abrasion, the most common types of wear damage, have been described in nearly all reports of wear of polyethylene joint replacement bearing surfaces.[12,16,17,41] Scratching, most likely caused by asperities on the metallic glenoid surface, was uniformly distributed across the bearing surface. However, abrasion

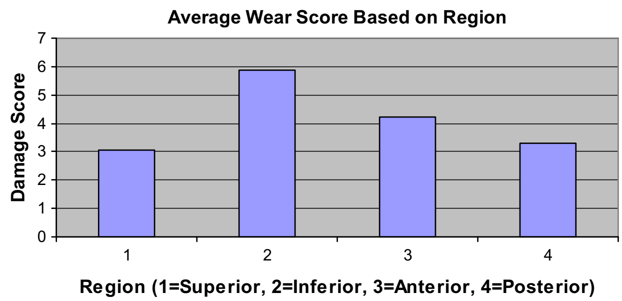

Figure 6 Graph demonstrates the regional damage score, regardless of mechanism.

occurred with the greatest frequency and severity in the inferior quadrant, consistent with impingement between the medial edge of the humerosocket (equivalent to the inferior quadrant in our wear analysis) and the lateral edge of the scapula. This impingement has been referred to as an adduction deficit, and occurs with the arm in a resting position[3,37] (Fig. 5, *D*). Although abrasion was the only damage mode seen in multiple polyethylene components that also demonstrated a significant difference among the 4 quadrants, our data also demonstrated that humeral polyethylene wear was not uniformly distributed across the bearing surface. Regardless of the mode, the inferior region sustained the greatest amount of damage, emphasizing the importance of proper component positioning, as a superiorly positioned or superiorly tilted glenosphere can increase the propensity for scapular neck impingement.[13,14]

Embedded third-body debris was demonstrated in 57% of the polyethylene components, and 43% showed pitting, indicating that despite the short average period of implantation (0.46 ± 0.50 years), fatigue failure mechanisms still affect polyethylene wear. Therefore, as in prior conventional TSA glenoid retrieval studies, the humeral polyethylene in reverse TSAs is subjected to both abrasive and adhesive surface wear mechanisms and subsurface fatigue failure.[12,16,22,27,33] Retrievals after total hip arthroplasty have demonstrated surface wear modalities such as

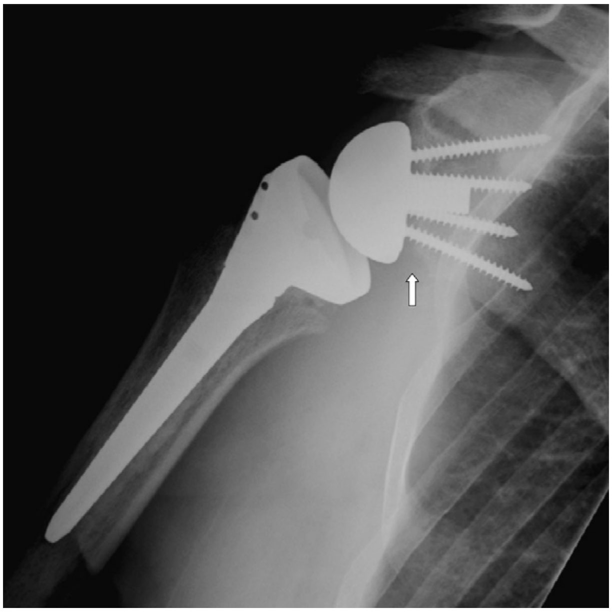

Figure 7 Radiograph demonstrates severe scapular notching.

Table III Interobserver and intraobserver variability of glenosphere positioning measurements

Variable	Correlation coefficients	
	Glenosphere height	Glenosphere inclination
Interobserver variability	0.985	0.892
Independent observer 1	0.994	0.961
Independent observer 2	0.983	0.995

scratching, abrasion, and burnishing to be the most prominent damage modes, because the conforming bearing surface of the prosthesis creates a large contact surface area and limits subsurface stresses that could lead to fatigue failure.[19,24,34] In contrast, the bearing surface in total knee arthroplasties is less conforming and can be subjected to subsurface stress that leads to delamination, pitting, and deformation.[6,35] Despite the deep, conforming concavity of the humeral articular surface in reverse TSAs, the presence of pitting and surface deformation suggests that focal, contact stresses are still a concern regarding survivorship of these prostheses.

Although one of the goals of the deep, conforming surface is to prevent glenohumeral translation, it is clear that glenohumeral instability persists as a significant complication of reverse TSA. Wall et al,[38,39] in a review of 199 cases, showed a dislocation rate of 7.5%, and 43% of the patients in our study were revised for instability. Therefore, despite the conforming surface design of reverse TSAs, instability can lead to increased stresses on the polyethylene, possibly predisposing the implant to fatigue failure. The importance of soft tissue tensioning and closure, implant positioning, and prevention of impingement cannot be overemphasized but are difficult to achieve even for experienced shoulder surgeons.[29,30]

Scapular notching was demonstrated on 46% of prerevision radiographs, with progressive bone resorption at the inferior aspect of the glenoid secondary to repetitive impingement.[20] Levigne et al[20] noted the presence of scapular notching in 62% of 337 shoulders at an average follow-up of 47 months and found the frequency and extension of notching was correlated with the length of follow-up. However, Werner et al[40] found notching in 98% of 48 cases, but noted that in 79% the notch did not progress beyond 1 year of follow-up. They did not find a correlation between scapular notching and any objective or subjective clinical result or complication.

Our analysis found no association between scapular notching and glenosphere positioning, or between scapular notching and overall polyethylene wear scores, but a positive correlation was present with inferior quadrant surface deformation ($r = 0.66$). The relationship between scapular notching, functional outcomes, and polyethylene wear has not been elucidated, but descriptions of this problem have led to implant design changes such as inferior placement of the glenosphere, increased inferior glenosphere tilt, and lateralization of the center of rotation, although this raises concerns of increased shear stress at the bone-implant interface.[20,30] In our analysis, 59% of the radiographs available for Depuy components demonstrated notching vs 20% of the radiographs available for Encore, although no significant difference in overall polyethylene wear or inferior quadrant wear was appreciated. The single, Encore implant that demonstrated scapular notching on preoperative radiographs had significant humeral polyethylene inferior abrasive wear (Fig. 5, *B-D*).

Glenoid periprosthetic lucencies were present in 11 of 13 cases (85%) available for review, with the superior and inferior aspects of the baseplate affected with equal frequency and severity. A strong correlation was found between both the total glenoid radiolucency score and the total polyethylene wear. In addition, a moderate correlation was noted between the presence of superior baseplate radiolucencies and inferior abrasive wear, possibly indicating the presence of superior and inferior translation of the humeral component on the glenosphere, analogous to the rocking horse phenomenon described in unconstrained TSAs, often considered the primary cause of glenoid loosening.[18] In their review of 45 reverse TSAs, Boileau et al[5] noted radiolucent lines at the superior aspect of the baseplate in 44%, but glenosphere loosening was not encountered in that review, and thus they concluded that the concept of medialization of the glenohumeral center of rotation proved valuable in prevention of early glenoid loosening. Similarly, in our analysis, loosening of the baseplate was not appreciated intraoperatively despite the presence of radiolucent lines surrounding the glenoid baseplate. Therefore, as with scapular notching, the significance of glenoid periprosthetic lucencies in reverse TSA have yet to be elucidated, and long-term, prospective studies are required.

In addition, humeral radiolucencies were appreciated in 9 of 13 cases (69%) available for review, with moderately positive correlation present between zone 7 radiolucencies (at the proximal, medial aspect of the stem) and inferior pitting, but no correlation was found between the total humeral radiolucency score and the total polyethylene wear score. Boileau et al[2] appreciated humeral radiolucencies at a similar rate (64% of cases), but with only 1 of 45 requiring revision of the humeral component for aseptic loosening.[2] In our study, as with the glenoid baseplate components, no frank loosening of the humeral component was noted intraoperatively; thus, longer follow-up is needed to determine the significance of humeral radiolucent lines.

Finally, we developed a systematic method for measuring glenosphere height and inclination. Improper glenosphere positioning increases the propensity for scapular notching, inferior impingement, and increased contact stress at the bone-implant interface of the glenoid component.[13,14] Using this method to describe component positioning allows the evaluation of various glenosphere positions and their clinical association with implant survival. We had excellent intraclass correlation coefficients for both interobserver and intraobserver variability, except for the interobserver variability of glenosphere inclination, which was still deemed to be good ($P = .892$).

Gutierrez et al[13] demonstrated that superior positioning of the glenosphere and decreased glenosphere tilt could place the patient at risk for decreased impingement-free abduction, an increased adduction deficit, and likely an increased risk of scapular notching.[13] Although superior glenosphere positioning in our study was not associated with increased notching, as the average glenosphere inclination increased (corresponding to increased glenosphere tilt), superior glenoid radiolucency, total glenoid radiolucency, and total polyethylene wear scores decreased. Thus, increasing tilt could be beneficial not only for range of motion but also for component stability and polyethylene wear.

A study design that allowed comprehensive analysis of retrieved reverse TSA components, radiographs, and clinical data was implemented with the goal of establishing associations among these factors in patients with reverse TSAs requiring revision. Like any study evaluating retrieved implants, the conclusions we can draw are limited in that the implants were retrieved at revision surgery and might not represent well-functioning reverse TSAs. Other limitations include the small number of polyethylene components available for analysis and the short period of implantation before revision. Although our retrieval study is limited by the fact that all the implants had failed and by the short period of implantation, nonetheless our results suggest that impingement may be common in reverse TSAs. With the continued collection of a larger number of prostheses and long-term follow-up, analyses of patient, design, and surgical factors can provide vital information on the causes of component failure in reverse TSA.

Conclusions

Analyses of polyethylene components retrieved at revision of total knee, hip, and shoulder replacements have been used to study the effect of design, patient, and surgical factors on initial implant performance, and for the first time, this study presents observational data for retrieved humeral polyethylene components from reverse total shoulder arthroplasty. The propensity for wear to most frequently occur in the inferior quadrant is consistent with impingement of the humeral polyethylene at the lateral edge of the scapula. In addition, despite the short periods of implantation, fatigue failure mechanisms such as embedded third-body debris and pitting were present, indicating that implant stability likely increases focal contact stresses. The long-term consequences of scapular notching, glenoid, and humeral radiolucencies have yet to be fully elucidated. Analysis of retrieved humeral polyethylene components, along with patient, design, and surgical factors, provide important information on the causes of component failure.

Disclaimer

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