Acta Orthop. Belg., 2009, **75**, 297-305

ORIGINAL STUDY

Comparison of early and delayed failed total shoulder arthroplasty

Christopher K. KEPLER, Shane J. NHO, Owen L. ALA, Edward V. CRAIG, Timothy M. WRIGHT, Russell F. WARREN

From the Hospital for Special Surgery, New York, NY, USA

The purpose of the present study is to determine what factors contribute to early failure after total shoulder arthroplasty (TSA). Implants were retrieved from 69 patients after failed TSA and were retrospectively assigned to two cohorts based on time of failure : Early, less than 2 years (N = 34) ; and Delayed, longer than 2 years (N = 35). The clinical information, intra-operative information, most recent radiographs, and damage mapping were collected for all patients. Patients in the Early failure group were significantly older (63.9 ± 9.5 years) than those in the Delayed group (49.9 ± 12.8 years) by an average of 14 years. The proportion of osteoarthritis cases was significantly higher for the Early group compared to the Delayed group (62% vs. 40%). The Delayed group had higher damage scores for several damage modalities. Elderly age and osteoarthritis were significant factors that were associated with early failures after TSA.

Keywords : total shoulder arthroplasty ; failure ; early failure ; late failure.

INTRODUCTION

Most patients who undergo total shoulder arthroplasty (TSA) have reliable improvement in pain levels, function, and patient satisfaction. Norris *et al* (*22*) demonstrated that 95% of cases have good or excellent results, and recent series have demonstrated 10-year survival rates of 93-96% (*1,3*). Despite this success, however, a subset of patients require revision TSA. Revision rates have been estimated to range from 0% (*21*) to 6.9% (*3*). In a study of 74 dissatisfied TSA patients, Hasan *et al* (*9*) found that nearly 60% had developed glenoid loosening and other studies have likewise identified glenoid loosening as the most frequent cause for TSA revision. In addition to glenoid loosening, many other factors have been implicated in TSA failure including inappropriate version of the implanted glenoid, poor bone quality, trauma, infection, improper design of the glenoid component, and improper fixation.

Conflict of Interest Statement: There are two authors that have financial relationships that lead to a conflict of interest. Dr. Edward V. Craig has a royalty agreement with Biomet. Dr. Russell F. Warren has royalty agreements with Biomet and Smith & Nephew, is a paid consultant for KFx and holds stock considerations with Zimmer. The remainder of the authors have no conflicts of interest, grants or other financial profit related to this study.

■ Christopher K. Kepler, MD, MBA, Resident.
■ Shane J. Nho, MD, MS, Resident.
■ Owen L. Ala, BS, Medical Student.
■ Edward V. Craig MD, Attending Orthopaedic Surgeon.
■ Russell F. Warren MD, Attending Orthopaedic Surgeon.
Sports Medicine and Shoulder Service, Department of Orthopaedic Surgery, Hospital for Special Surgery, New York, NY, USA.
■ Timothy M. Wright, PhD.
Department of Biomechanics, Hospital for Special Surgery, New York, NY, USA.
Correspondence : Christopher K Kepler, Hospital for Special Surgery, 535 East 70th Street New York, NY 10021.
E-mail : keplerc@hss.edu ; chris.kepler@gmail.com

Insight into the causes of loosening of tibial components from total knee arthroplasties and acetabular components from total hip arthroplasties has been gained by comparing early and delayed failures. For example, registry studies of total hip and knee replacements have shown that younger patients have worse outcomes with an increased risk of early failure (*6,10,12,15*), presumably due to the increased mechanical demand that younger patients place on their implant components with an increased incidence of catastrophic failure. Currently, no similar published studies report on early failures after TSA, and little is known of potential factors that may contribute to the need for early revision.

The purpose of this study was to compare demographic, radiographic, implant retrieval damage mapping, and clinical information of Early and Delayed failed total shoulder arthroplasty cases in hopes of identifying key factors related to premature TSA failure. Identifying these factors may improve patient selection, functional outcome, and implant survivorship.

MATERIALS AND METHODS

From 1979 to 2005, 69 consecutive patients with a mean age of 60.8 ± 11.7 years underwent revision TSA at a single institution (HSS) at a mean implant survivorship of 4.0 ± 4.4 years after their index surgery. Our institution is a tertiary specialty hospital in a large metropolitan city that contains many other hospitals that also perform primary and revision shoulder arthroplasty. All patients who underwent revision total shoulder arthroplasty and had components retrieved by our biomechanics department were included. The patients were retrospectively assigned to two cohorts based on time of failure : Early, less than 2 years (N = 35) ; and Delayed, longer than 2 years (N = 34). The decision to utilize 2 years as the division between Early and Delayed time of failure was informed by the histogram of number of failures at our institution per period of time after index surgery (fig 1) which demonstrated a decrease in the number of revision surgeries between the second year and third year after index TSA.

Clinical information was available for all patients. Information obtained from medical records included patient demographics, medical co-morbidities, shoulder history, clinical assessment (pain, range of motion), intra-operative findings, implant information, and post-operative complications. All patients received preoperative antibiotics for infection prophylaxis and the surgeries detailed here represent the first revision after total shoulder arthroplasty. The primary diagnosis prompting the TSA was osteoarthritis in 56/69 patients (81%) and rheumatoid arthritis in 13/69 patients (19%) of patients. The diagnosis requiring revision surgery was aseptic glenoid loosening in 55/69 (79.8%), septic loosening for 7/69 (10.1%), instability for 4/69 patients (5.8%), component malposition in one patient and the diagnosis was unknown for the remaining two patients.

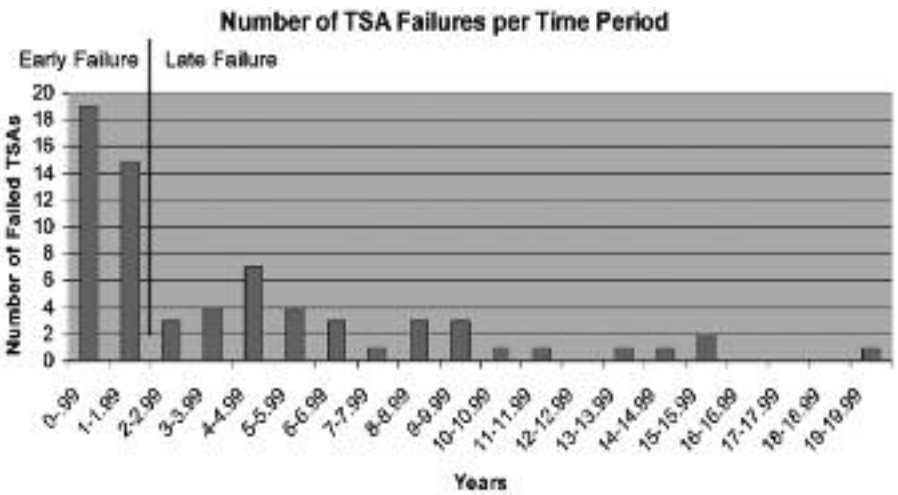

Fig. 1. — Histogram of the number of TSA failures with time after index surgery

Forty-six glenoid prostheses were manufactured by Biomet (Bio-Modular models), 15 were Neer II prostheses (manufacturers not identified), 5 patients had custom prostheses made by the hospital biomechanics department, one patient had a DePuy prosthesis (Global model) and two prostheses were of unknown origin. Five glenoid components utilized screw fixation, 2 were pegged components and the remainder were cemented keeled components.

The most recent anteroposterior (AP) and axillary (AX) radiographs prior to removal of the glenoid were examined and scored according to previously described classification systems for glenoid loosening (*5,20,26*). The Molé system was utilized to measure radiolucency in the AP view using digital calipers (*20*). Radiolucent lines were assigned a numeric value based on the thickness for all 6 zones, and the values were summed to give the radiolucency score. A cumulative score of 0 to 6 points corresponds to no loosening, 7 to 12 points represents possible loosening, and 13 to 18 points represents definite loosening. The AX radiographs were analysed in similar method using three distinct zones : the anterior rim (zone 1), adjacent to the fixation keel (zone 2), and the posterior rim (zone 3). The Torchia glenoid loosening (*26*) and Franklin glenoid lucency (*5*) classifications were determined for each glenoid component based on the AP and AX views. The amounts of subluxation in the coronal plane (AP view) and sagittal plane (AX view) were measured as the percent of translation and graded as mild (< 25%), moderate (25 to 50%), or severe (> 50%) (*26*). The glenoid version was also calculated by measuring the angle formed by a line perpendicular to the scapular axis and a line along the maximum AP diameter of the glenoid cavity (*23*).

The glenoid components were retrieved at the time of revision surgery and cleaned and catalogued for damage mapping as part of an ongoing institutional implant retrieval program. The polyethylene bearing surfaces were examined microscopically for evidence of burnishing, abrasion, scratching, pitting, delamination, focal wear, surface deformation, embedded 3rd body debris, and fracture in accordance with previously described methodologies (*7,13*). The surface was divided into anterior, posterior, superior, and inferior quadrants, and each quadrant given a subjective damage score of 0 to 3 for each damage mode in each quadrant using an established grading system (*13*). A damage grade of 0 = no damage, 1 = 0 to 10% of the quadrant damaged, 2 = 11 to 50% of the quadrant damaged, and a damage grade of 3 = more than 50% of the quadrant damaged. Severe damage to a small portion of a quadrant resulted in an extra point for that quadrant's damage score. The damage scores for each quadrant were summed for a maximum score of 12 per damage mode for each glenoid specimen. Grading was done with the observers blinded to the demographic, clinical, and radiographic information.

The retrieval program, including collection of patient medical and radiographic data, was last approved by the Institutional Review Board in December 2007, study number 24097.

Statistical analysis was performed comparing data between the Early and Delayed patient groups using Student's t-Test and the Chi-Square Test. An alpha level of < 0.05 was considered significant.

RESULTS

Of the 69 glenoid components, 34 were retrieved from TSA's that had failed within the first two years after index surgery (Early). The mean length of implantation for this group was 11.7 ± 8.7 months. The remaining 35 (Delayed) implants survived an average of 7.2 years with a range of 2.0 to 19.2 years (fig 1). Patients in the Early failure cohort were significantly ($p < 0.0001$) older than those in the Delayed failure cohort. The age at time of index surgery was 63.9 ± 9.5 years for patients in the Early group and 49.9 ± 12.8 years for patients in the Delayed group. Figure 2 shows a plot of age vs. time to failure for all patients. This trend was also seen when age at revision surgery was calculated for osteoarthritis, rheumatoid arthritis, AVN and proximal humerus fracture groups separately after creating subgroup Early and Delayed failure groups. The age difference for osteoarthritis between Early and Delayed groups (64.1 years vs. 55.4 years) reached significance ($p = 0.01$) as did the age difference for AVN (61.0 years vs 34.7 years) ($p = .007$). Table I compares average ages in the Early and Delayed failure groups broken down by primary diagnosis. Figures 3 and 4 present overall trends in revision total shoulder arthroplasty at our institution by showing year of index surgery vs. age at index surgery for all included patients and year of index surgery vs. length of time of index TSA implantation for all included patients, respectively.

Osteoarthritis was the initial diagnosis for 21 of 34 (62%) of the Early group patients and 14 of 35

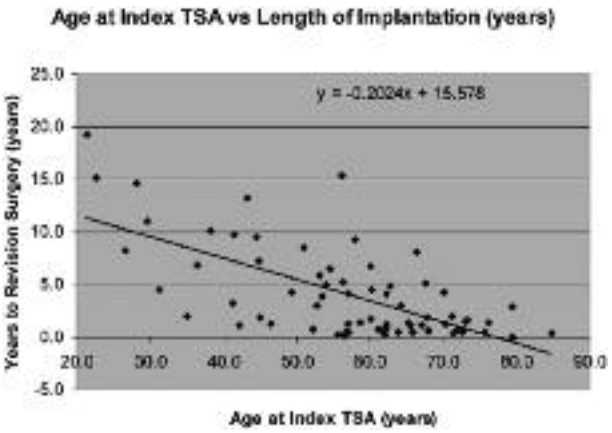

Fig. 2. — Plot of age at index TSA versus length of implantation.

(40%) for the Delayed group, a significant difference (*p = 0.01*). The primary reason for failure in the Early group was aseptic loosening in 27 of 34 (79%) of patients, instability and infection each in 3 of 34 patients (9.6%) of patients with one failure of unknown cause. The Delayed group had a similar breakdown in reasons for failure : 82.8% of patients had aseptic loosening, 5.7% had instability and 11.4% presented with infection. There were no differences for cause of revision between Early and Delayed groups that reached statistical significance. Additionally, no significant differences existed between the two groups with respect to gender, hand dominance, tobacco history, range of motion, rotator cuff tears, conformity of the TSA bearing surfaces, implant type, or type of glenoid fixation. Glenoid version was -13.2° in the Early group compared with -2.1° in the Delayed group which approached but did not reach significance (p = 0.11). Of the Early group, 26 implants were made by Biomet (Bio-Modular model), 5 Neer II prostheses (manufacturers not identified) and 3 were custom prostheses made in the hospital biomechanics department compared to 20 Biomet implants (Bio-Modular models), 10 Neer II prostheses (manufacturers not identified), 2 custom prostheses, 1 DePuy prosthesis (Global model) and two of unknown origin in the Delayed group.

The Delayed group had greater radiolucency measurements in all six zones using the Mole classification compared to the Early group, but only Zones 2 and 5 demonstrated a significant increase (table II) (fig 5). No differences were observed between groups with respect to glenoid loosening (using the Torchia classification) or glenoid lucency (from the Franklin system).

The retrieved glenoid components from the Delayed group had higher scores for pitting, abrasion, wear through, and delamination compared to the Early group (table III). The other damage modes of burnishing, scratching, focal wear, 3rd body embedded objects, and fractures showed no difference in damage severity between delayed and early failure.

DISCUSSION

Limitations of the present study are its retrospective nature and the small number of patients included in the subgroup analyses, due in part to the relative rarity of revision total shoulder surgery requiring explantation of index components. Additionally, the long period of time spanned by the study means that different prostheses and cementing techniques were considered together. During the extended period

Table I. — Age comparison (in years) between Early and Delayed subgroups broken down by primary aetiology

	All	Osteoarthritis	Post-traumatic Arthritis	Avascular Necrosis	Rheumatoid Arthritis
Early	63.9	64.1	64.3	61.0	84.7
Delayed	49.9	55.4	61.4	34.7	45.1
p Value	**< 0.0001**	**0.013**	0.806	**0.007**	N/A

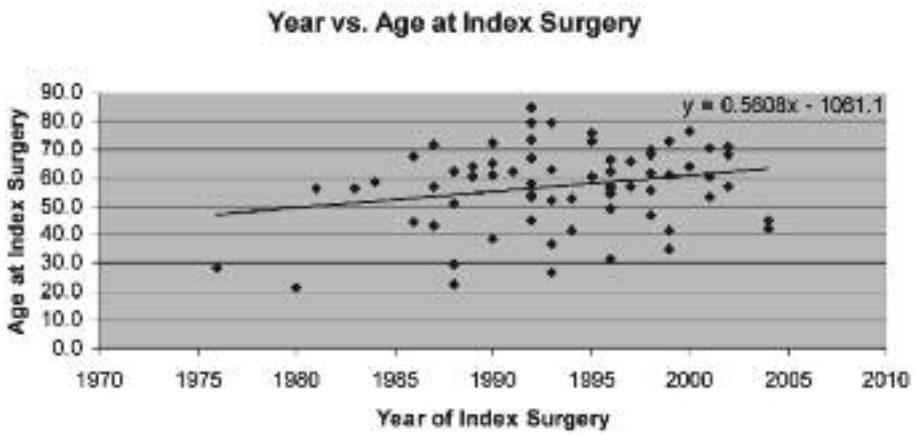

Fig. 3. — Plot of year of index surgery vs. age at index surgery

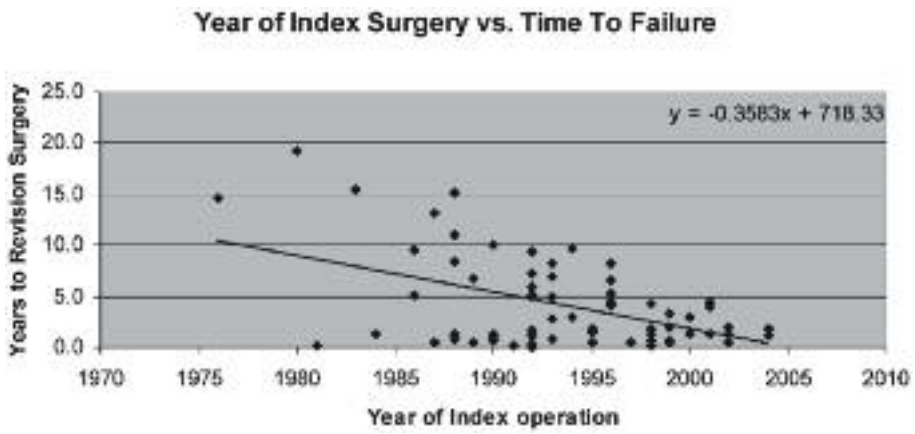

Fig. 4. — Plot of year of index surgery vs. time to revision surgery

Table II. — Radiolucency measurements of glenoid components made on AP radiographs

Group	Zone 1 (mm)	Zone 2 (mm)	Zone 3 (mm)	Zone 4 (mm)	Zone 5 (mm)	Zone 6 (mm)
Early	1.4 ± 0.9	1.2 ± 0.7	1.3 ± 0.7	1.8 ± 1.6	1.2 ± 0.5	1.6 ± 0.8
Delayed	2.1 ± 1.5	2.2 ± 1.9	1.5 ± 0.6	1.8 ± 0.6	1.9 ± 0.8	2.1 ± 0.7
p Value	p = 0.094	**p = 0.023**	p = 0.416	p = 0.954	**p = 0.005**	p = 0.179

of time included in the study, the pharmacologic treatment of rheumatoid arthritis has undergone many advances which have significantly decreased upper extremity arthroplasty rates (*23*). This difference is not well captured by the present study and an analysis of the number of rheumatoid patients undergoing revision TSA on a year by year basis did not demonstrate a discernible pattern, likely due again to the relative rarity of the procedure.

Factors that differentiated the Early failure group from the Delayed failure group included patient age and the initial diagnosis leading to TSA. The Early

Table III. — Damage modes on the polyethylene articular surface with significant differences between the Early and Delayed groups

Group	Pitting	Abrasion	Wear Through	Delamination
Early	5.6 ± 3.3	2.4 ± 3.0	0.6 ± 1.1	0.0 ± 0.0
Delayed	7.8 ± 3.1	4.3 ± 4.0	2.3 ± 3.1	1.1 ± 2.6
p Value	p = 0.007	p = 0.027	p = 0.004	p = 0.016

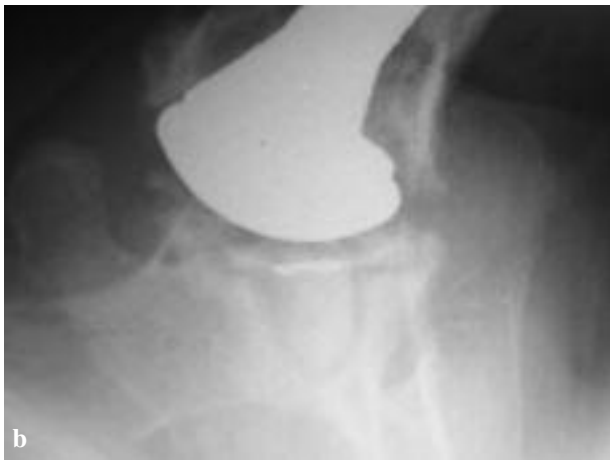

Fig. 5. — AP and axillary radiographs of late failure TSA demonstrating radiolucent lines around the glenoid component and osteolysis around the humeral component.

group included older patients with an average age of 63.9 years at the time of index surgery compared to the Delayed failure group with an average age of 49.9 years. Deshmukh *et al* (*2*) recently published data that support this observation, reporting on patients requiring TSA revision in the first two years that were on average eight years older (63 years compared to 51 years) than patients whose TSAs had failed more than two years post-operatively. This result is somewhat surprising in that it differs from findings in total hip and knee replacement patients, for whom earlier failures generally occur in younger patients (*6,10,12,15*). Lonner *et al* (*15*) described a failure rate of 12.5% at 8 years for TKA patients younger than 40 years of age and cautioned that activity levels must be curtailed after TKA to protect the implant from excessive demand through repetitive loading. Our observations after TSA, however, suggest the opposite. Namely, early failure of total shoulder arthroplasty tends to occurs in relatively older patients while younger patients who ultimately require revision surgery undergo revision at a significantly longer time after their index operation. Additionally, this age difference is not limited to any one aetiologic group as the same trend appeared when age at revision surgery for Early and Delayed groups was calculated for each primary diagnosis separately. The mechanics of a non-weight bearing joint such as the shoulder may result in smaller forces transmitted to the components when compared to either TKA or THA, mitigating to some extent the increased activity expected in younger patients. This is a retrospective study of a cohort of failed glenoid prostheses and

does not necessarily explain the cause of the differences seen between groups.

The majority (62%) of cases with early failure occurred in patients with osteoarthritis. Haines *et al* (*8*) recently published data demonstrating a three-fold increased risk of glenoid loosening in osteoarthritic patients if evidence of glenoid erosion existed at the index operation, with 40% of the patients having erosion of the posterior glenoid. Glenoid component retroversion has been previously implicated as leading to instability and component failure after TSA, and several recent studies have found retroverted glenoid components to have a deleterious effect on the biomechanical environment after total shoulder arthroplasty (*19,29*). Shapiro *et al* (*25*) reported that glenoid components placed in 15° of retroversion had decreased glenohumeral contact areas, increased contact pressure, and eccentric loading of the glenoid component compared to components implanted in neutral alignment in a cadaveric model. Similarly, Nyffeler *et al* (*24*) found increased posterior glenoid loading and increased posterior prosthetic head displacement after retroverted glenoid implantation in cadaver shoulders. Severity of glenoid erosions has been correlated with patient age (*27*), likely because of the tendency for a longer course of disease prior to surgical intervention. Our Early (older) failure group may have been at a distinct disadvantage because of higher native glenoid wear accumulated during their extended disease course prior to primary TSA. While it did not reach significance, our data demonstrates a trend toward increased glenoid component retroversion in the Early (older) group ($p = 0.11$). Once a patient with clear evidence of degenerative joint disease becomes symptomatic enough to warrant arthroplasty, proceeding with TSA in an undelayed fashion may offer advantages in terms of the quality of fixation that can be achieved in the absence of bony erosion, a recommendation echoed by Haines *et al* (*8*).

Figures 3 and 4 demonstrate what might be interpreted as a greater willingness of surgeons to perform revision surgery in older patients. Length of implantation has decreased over time as seen in figure 4, a trend which may represent earlier consideration of revision surgery. Increases in age at index TSA over time could suggest either that TSA is being performed on older patients who are subsequently older when they require revision surgery or, alternately, that the age threshold for which revision surgery is considered has been increased.

Patients with rheumatoid arthritis made up 32% of the Late failure group. Overall, 11 of the 12 patients with rheumatoid arthritis fell into the late failure group. This finding is counterintuitive because of the known associations between rheumatoid arthritis, osteopenia, and periarticular erosions (*16*), relationships that could be expected to also make component fixation problematic. But rheumatoid patients place lower baseline mechanical demands on prosthetic joint replacements than osteoarthritis patients (*4,14,28*), a factor favouring longer implant survival (*17*).

Important negative findings in the study include the lack of significant differences between the Early and Delayed groups with respect to gender, hand dominance, smoking, range of motion, infection, presence of rotator cuff tear on revision surgery, instability, and glenoid component conformity. The lack of significant difference between the two groups with respect to the presence of rotator cuff tear at the time of revision surgery may at first seem surprising given previous studies which have found inferior results after TSA in the presence of rotator cuff pathology (*11,26*), but is not without precedent in the literature. Edwards *et al* (*3*) described a cohort of more than 500 shoulders in which the presence of supraspinatus tears in patients with osteoarthritis did not influence primary total shoulder outcome with respect to Constant score, patient satisfaction, radiographic results, complication rate or need for re-operation.

Radiolucency scores in zones correlating to the areas adjacent to the superior aspect of the glenoid base and the inferior pole were significantly higher in the Delayed failure cohort compared to the Early cohort. Progression of radiolucent lines around glenoid components has been a controversial topic in the literature. Mileti *et al* (*18*) found that 76% of radiolucent lines progressed over a follow-up of less than 4 years, but other studies, including an early report by Neer (*21*), found little progression over long-term follow-up. Our study was not longi-

tudinal and is exclusive to patients with failed TSA, but nonetheless suggests that longer lengths of component implantation are associated with larger amounts of radiolucency.

Similarly, polyethylene wear of the Delayed failure cohort was significantly increased with regard to four specific wear modes, namely : pitting, abrasion, wear through, and delamination, which are all associated with significant surface damage and release of large amounts of polyethylene. Similar to our radiolucency findings, greater amounts of polyethylene damage are likely related to increased length of implantation, but also suggest that osteolysis may be a contributing factor to later failures.

In conclusion, we evaluated characteristics associated with early failure of total shoulder arthroplasty. Older patients with osteoarthritis were most likely to require revision total shoulder arthroplasty within 2 years. Surprisingly, younger patients and those with rheumatoid arthritis were more likely to require revision later within this group of patients with TSA failure. Greater glenoid component wear was noted on those implants retrieved from the Delayed cohort and measurements of radiolucent lines were significantly higher in the Delayed cohort group, suggesting steady wear of components over time as opposed to catastrophic failure.

REFERENCES

1. **Adams JE, Sperling JW, Schleck CD, Harmsen WS, Cofield RH.** Outcomes of shoulder arthroplasty in Olmsted County, Minnesota : a population-based study. *Clin Orthop* 2007 ; 455 : 176-182.
2. **Deshmukh AV, Koris M, Zurakowski D, Thornhill TS.** Total shoulder arthroplasty : long-term survivorship, functional outcome, and quality of life. *J Shoulder Elbow Surg* 2005 ; 14 : 471-479.
3. **Edwards TB, Boulahia A, Kempf JF *et al.*** The influence of rotator cuff disease on the results of shoulder arthroplasty for primary osteoarthritis : results of a multicenter study. *J Bone Joint Surg* 2002 ; 84-A : 2240-2248.
4. **Fex E, Larsson BM, Nived K, Eberhardt K.** Effect of rheumatoid arthritis on work status and social and leisure time activities in patients followed 8 years from onset. *J Rheumatol* 1998 ; 25 : 44-50.
5. **Franklin JL, Barrett WP, Jackins SE, Matsen FA 3rd.** Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. *J Arthroplasty* 1988 ; 3 : 39-46.
6. **Furnes O, Espehaug B, Lie SA *et al.*** Early failures among 7,174 primary total knee replacements : a follow-up study from the Norwegian Arthroplasty Register 1994-2000. *Acta Orthop Scand* 2002 ; 73 : 117-129.
7. **Gunther SB, Graham J, Norris TR, Ries MD, Pruitt L.** Retrieved glenoid components : a classification system for surface damage analysis. *J Arthroplasty* 2002 ; 17 : 95-100.
8. **Haines, JF, Trail IA, Nuttall D, Birch A, Barrow A.** The results of arthroplasty in osteoarthritis of the shoulder. *J Bone Joint Surg* 2006 ; 88-B : 496-501.
9. **Hasan SS, Leith JM, Campbell B *et al.*** Characteristics of unsatisfactory shoulder arthroplasties. *J Shoulder Elbow Surg* 2002 ; 11 : 431-441.
10. **Havelin LI, Espehaug B, Vollset SE, Engesaeter LB.** Early failures among 14,009 cemented and 1,326 uncemented prostheses for primary coxarthrosis. The Norwegian Arthroplasty Register, 1987-1992. *Acta Orthop Scand* 1994 ; 65(1) : 1-6.
11. **Hawkins RJ, Bell RH, Jallay B.** Total shoulder arthroplasty. *Clin Orthop* 1989 ; 242 : 188-194.
12. **Herberts P, Malchau H.** Long-term registration has improved the quality of hip replacement : a review of the Swedish THR Register comparing 160,000 cases. *Acta Orthop Scand* 2000 ; 71 : 111-121.
13. **Hood RW, Wright TM, Burstein AH.** Retrieval analysis of total knee prostheses : a method and its application to 48 total condylar prostheses. *J Biomed Mater Res* 1983 ; 17 : 829-842.
14. **Katz PP.** The impact of rheumatoid arthritis on life activities. *Arthritis Care Res* 1995 ; 8 : 272-278.
15. **Lonner JH, Hershman S, Mont M, Lotke PA.** Total knee arthroplasty in patients 40 years of age and younger with osteoarthritis. *Clin Orthop* 2000 ; 380 : 85-90.
16. **Madsen OR, Egsmose C, Hansen B, Sorensen OH.** Soft tissue composition, quadriceps strength, bone quality and bone mass in rheumatoid arthritis. *Clin Exp Rheumatol* 1998 ; 16 : 27-32.
17. **Mancuso CA, Rincon M, Sayles W, Paget SA.** Comparison of energy expenditure from lifestyle physical activities between patients with rheumatoid arthritis and healthy controls. *Arthritis Rheum* 2007 ; 57 : 672-678.
18. **Mileti J, Boardman ND 3rd, Sperling JW *et al.*** Radiographic analysis of polyethylene glenoid components using modern cementing techniques. *J Shoulder Elbow Surg* 2004 ; 13 : 492-498.
19. **Moeckel BH, Altchek DW, Warren RF, Wickiewicz TL, Dines DM.** Instability of the shoulder after arthroplasty. *J Bone Joint Surg* 1993 ; 75-A : 492-497.
20. **Molé D, Roche O, Riand N, Levigne C, Walch G.** Cemented glenoid component : results in osteoarthritis and rheumatoid arthritis. Walch G & Boileau P (eds). *Shoulder Arthroplasty*. Springer, New York, 1999, pp 163-171.
21. **Neer CS 2nd, Watson KC, Stanton FJ.** Recent experience in total shoulder replacement. *J Bone Joint Surg* 1982 ; 64-A : 319-337.

22. Norris TR, Iannotti JP. Functional outcome after shoulder arthroplasty for primary osteoarthritis : a multicenter study. *J Shoulder Elbow Surg* 2002 ; 11 : 130-135.

23. Nyffeler RW, Jost B, Pfirrmann CW, Gerber C. Measurement of glenoid version : conventional radiographs versus computed tomography scans. *J Shoulder Elbow Surg* 2003 ; 12 : 493-496.

24. Nyffeler, RW, Sheikh R, Atkinson TS *et al.* Effects of glenoid component version on humeral head displacement and joint reaction forces : an experimental study. *J Shoulder Elbow Surg* 2006 ; 15 : 625-629.

25. Shapiro TA, McGarry MH, Gupta R, Lee YS, Lee TQ. Biomechanical effects of glenoid retroversion in total shoulder arthroplasty. *J Shoulder Elbow Surg* 2007 ; 16(3 Suppl) : S90-5.

26. Torchia ME, Cofield RH, Settergren CR. Total shoulder arthroplasty with the Neer prosthesis : long-term results. *J Shoulder Elbow Surg* 1997 ; 6 : 495-505.

27. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. *J Arthroplasty* 1999 ; 14 : 756-760.

28. Wikstrom I, Book C, Jacobsson LT. Difficulties in performing leisure activities among persons with newly diagnosed rheumatoid arthritis : A prospective, controlled study. *Rheumatology (Oxford)* 2006 ; 45 : 1162-1166.

29. Wirth MA, Rockwood CA Jr. Complications of shoulder arthroplasty. *Clin Orthop* 1994 ; 307 : 47-69.