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Mid- to long-term follow-up of total shoulder arthroplasty using a keeled glenoid in young adults with primary glenohumeral arthritis

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Background: The purpose of this study was to examine the mid- to long-term functional outcome and implant survival of total shoulder arthroplasty (TSA) in adults aged 55 years or younger with primary glenohumeral arthritis. The hypothesis was that TSA would lead to improvement in functional outcome but that implant survival would decline between 5 years and 10 years postoperatively.
Materials and methods: Between 1992 and 2004, 52 TSAs were implanted in 8 centers for primary glenohumeral arthritis in patients aged 55 years or younger. Minimum follow-up of 5 years was available in 50 patients at a mean of 115.5 months postoperatively. Kaplan-Meier survivorship analysis was performed, and clinical outcome was assessed.
Results: After TSA, adjusted Constant scores improved from 37.0% to 73.4% and forward flexion improved from 97° to 128° ($P < .001$). The adjusted Constant score was 80.0 in patients free of revision of the glenoid compared with 43.6 in the group requiring revision of the glenoid ($P < .001$). Survivorship of the glenoid component with revision surgery for glenoid loosening as the endpoint was 98% (95% confidence interval, 89.4%-100%) at 5 years and 62.5% (95% confidence interval, 40.6%-81.2%) at 10 years. Factors associated with survival of the glenoid included anatomic humeral component positioning and a compaction glenoid preparation technique.
Conclusions: At 5 years' follow-up, TSA leads to improvement in functional outcome and a satisfactory implant survival rate of 98% in young adults with primary glenohumeral arthritis. However, the 10-year survival rate of TSA was only 62.5% in patients aged 55 years or younger at the time of surgery.
Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Glenohumeral arthritis; young adult; total shoulder arthroplasty

In the majority of cases, total shoulder arthroplasty (TSA) provides predictable pain relief and functional improvement with satisfactory longevity.[10,12,14] However, for adults aged 55 years or younger, the ideal surgical management of glenohumeral arthritis is less well defined.[7]

This study was approved by the Centre Orthopédique Santy Institutional Review Board (study No. 39).

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Increased concerns in this population included higher activity levels, greater functional expectations, and implant longevity. The glenoid, in particular, remains the focus of concern in shoulder arthroplasty in the young adult.

Although hemiarthroplasty alone is an option, in older adult populations, it is well established that TSA provides more predictable pain relief and improved functional outcome compared with hemiarthroplasty.[4,8,10] Furthermore, whereas conversion of hemiarthroplasty to TSA improves symptoms, the results are inferior compared with primary TSA.[5,20] In an effort to avoid the potential complications of a glenoid polyethylene implant in the young adult, several authors have proposed a variety of forms of biological resurfacing of the glenoid. Unfortunately, these studies have shown mixed results, and few of them contain data beyond short-term follow-up.[1,9,13,17,25] Three reports from the same institution have compared the long-term survival of hemiarthroplasty and TSA in young adults with a variety of diagnoses. In the first two reports, the majority of patients had diagnoses other than primary arthritis (ie, rheumatoid arthritis, avascular necrosis, and post-traumatic arthritis).[21,22] The most recent report limited the cohort to primary or post-traumatic glenohumeral arthritis, but the portion of patients with each diagnosis was not provided.[2] Only one report has provided an analysis of TSA limited to young adults with primary osteoarthritis.[18]

The purpose of this study was therefore to examine the mid- to long-term functional outcome and implant survival of TSA in adults aged 55 years or younger with primary glenohumeral arthritis. The hypothesis of the study was that TSA would lead to improvement in functional outcome but that implant survival would decline between 5 years and 10 years postoperatively.

Materials and methods

A retrospective review was performed of all TSAs performed between 1992 and 2004 in 8 centers. The inclusion criteria included age of 55 years or younger at the time of surgery, a diagnosis of primary glenohumeral osteoarthritis, the use of either a convex-back or flat-back all-polyethylene keeled glenoid component, and a minimum follow-up of 5 years. Exclusion criteria included the use of a metal-back glenoid, revision arthroplasty, associated glenoid bone grafting, and diagnoses other than primary glenohumeral arthritis (eg, secondary arthritis, rotator cuff arthropathy, or avascular necrosis).

During the study period, 52 TSAs performed in 49 patients (3 bilateral TSAs) met the study criteria. An attempt was made to contact all patients. One patient had died before the 5-year follow-up, and one patient did not return for follow-up after 4.5 years. Complete preoperative and postoperative data, including physical examination and functional outcome scores, were available for 50 TSAs at a mean of 115.5 months (range, 60-211 months). Eighteen patients had 10 years of follow-up or greater. Radiographs were available for 48 of these TSAs. Both preoperative and postoperative radiographs were available in 37 cases. Eleven cases had only postoperative radiographs available for analysis. The mean patient age at the time of surgery was 50.5 years (range, 35-55 years). Men comprised 56% (28 of 50) of the cohort, and 74% (37 of 50) of the TSAs were performed on the dominant shoulder.

Clinical analysis

At each institution, an independent reviewer (not the surgeon) examined each patient. A preoperative Constant score adjusted for age and sex was obtained in all patients. This score consists of pain, activity, mobility, and strength components.[6] Active forward flexion in the plane of the scapula and external rotation with the arm at the side were recorded with a goniometer. Postoperatively, the Constant score and range-of-motion assessments were repeated. In addition, patients subjectively graded their outcome as very satisfied, satisfied, uncertain, or disappointed, and they rated their subjective shoulder value.[11]

Radiographic analysis

A standardized radiographic protocol was used with fluoroscopic control to limit variability among the study centers. At a minimum, a true anteroposterior view and an axillary view were obtained preoperatively, immediately postoperatively, and at the final follow-up. An independent reviewer (P.J.D.) evaluated postoperative radiographs for humeral head component positioning, periprosthetic radiolucency, and displacement of the components. Humeral head component positioning was subjectively graded as anatomic when the head was seated flush with the humeral metaphysis, did not overhang the metaphysis on the anteroposterior or axillary view, and appeared appropriately sized. The humeral head was considered nonanatomic when any of the aforementioned criteria were not met. Glenoid radiolucent lines (RLL) were assessed at 6 locations as 0 to 3 and summed for an overall grade of 0 to 18.[15] Overall scores were divided into no loosening (0 to 6), possible loosening (7 to 12), and definite loosening ($\geq$13). Shift or migration of the glenoid component was considered to indicate definite loosening and given a maximum score of 18.

Preoperative advanced imaging, allowing analysis of the status of the rotator cuff and glenoid morphology in the axial plane, consisted of a computed tomography arthrogram in 29 cases (58%) and magnetic resonance imaging in 11 cases (22%). Rotator cuff tears identified preoperatively or intraoperatively included a partial articular-side tear of the supraspinatus in 2 cases (4%) and a full-thickness supraspinatus tear in 3 cases (6%). Glenoid morphology was classified into 5 types according to Walch et al[23]: type A1 was found in 10 glenoids (25%), type A2 in 7 glenoids (17.5%), type B1 in 12 glenoids (30%), and type B2 in 11 glenoids (27.5%). There were no type C glenoids.

Operative technique

The same unconstrained TSA system (Aequalis; Tornier, Edina, MN, USA) was implanted in all cases. A deltopectoral approach was used in all cases. Access to the glenohumeral joint was obtained through a subscapularis tenotomy in 43 cases (86%), subscapularis peel from the lesser tuberosity in 6 cases (12%), and a lesser tuberosity osteotomy in 1 case (2%). The proximal humerus was exposed, osteophytes were removed, and the humeral head was cut at the anatomic neck. The humeral cut was

Table I Overall clinical results

	Preoperative (mean ± SD)	Postoperative (mean ± SD)	*P* value
Total Constant score (100 points)	31.6 ± 13.7	58.4 ± 20.7	<.001
Pain (15 points)	3.9 ± 2.3	10.1 ± 4.6	<.001
ADL (20 points)	7.2 ± 2.7	13.8 ± 5.5	<.001
Mobility (40 points)	15.3 ± 7.2	27.5 ± 9.4	<.001
Strength (25 points)	5.1 ± 5.4	7.1 ± 4.5	.028
Age-adjusted Constant score	37.0 ± 15.3	73.4 ± 25.9	<.001
Active forward flexion (°)	97 ± 27	128 ± 36	<.001
External rotation (°)	12 ± 19	33 ± 24	<.001
Subjective shoulder value	NA	70 ± 23	NA

ADL, Activities of daily living; *NA*, not applicable.

made with an attempt to reproduce the original inclination and retroversion of the humeral head. The humeral component was press fit in 4 cases (8%) and cemented in 46 cases. Glenoid resurfacing was accomplished with 2 different preparation techniques and 2 different glenoid types. In 25 cases (50%), the glenoid was reamed followed by compaction of a keel slot.[3] In the other 25 cases (50%), the glenoid was prepared by avoiding reaming and by using a curettage technique.[16] An all-polyethylene keeled glenoid component with a flat back (27 cases [54%]) or a convex back (23 cases [46%]) was then cemented into place. High-viscosity cement was used in 35 cases (70%), and low-viscosity cement was used in 15 cases (30%). Concomitant procedures included a subacromial decompression in 2 cases (4%), supraspinatus repair in 1 case (2%), and a biceps tenotomy or tenodesis in 29 cases (58%).

Statistical analysis

Preoperative clinical scores were compared with postoperative clinical scores by use of the paired *t* test or signed rank test depending on variable distribution. In the subanalysis of factors associated with glenoid survival greater than 10 years, the *t* test or Wilcoxon rank sum test was used to assess quantitative variables; the Fisher exact test was used to assess categorical variables. Survival analyses of glenoid components were conducted by use of the Kaplan-Meier method and hazards ratio calculated by Cox proportional hazards modeling. All statistical analysis was carried out with SAS software, version 9.2 (SAS Institute, Cary, NC, USA). Significance was assessed with a 2-tailed $\alpha = .05$.

Results

Clinical results

The clinical results are summarized in Table I. Compared with preoperative values, postoperatively, there were statistically significant improvements in all components of the Constant score. Subjectively, 23 patients (46%) were very satisfied, 11 (22%) were satisfied, 11 (22%) were disappointed, and 5 (10%) were unhappy. At final follow-up, patients rated their shoulder as 70% of normal according to the subjective shoulder value.

The adjusted Constant score was 80.0 in patients free of revision of the glenoid compared with 43.6 in the group requiring revision of the glenoid ($P < .001$). Among patients free of revision of the glenoid, the adjusted Constant score was 86.0 when the glenoid was not radiographically loose or had possible loosening compared with 75.1 when the glenoid was definitely radiographically loose ($P = .084$).

Radiographic results

On the immediate postoperative radiographs, the mean glenoid RLL score was 1.2 ± 1.5 (range, 0-5). At final follow-up, the mean glenoid RLL score was 10.9 ± 6.7 (range, 0-18). At final follow-up at a mean of 115.5 months, 37.5% of glenoids showed no loosening, 18.8% showed possible loosening, and 43.8% had definite radiologic loosening. Survivorship of the glenoid component with radiographic loosening as the endpoint was 56.3% (95% confidence interval [CI], 41.2%-70.5%) at final follow-up.

Complications and component survivorship

A postoperative complication requiring revision surgery was observed in 17 patients (34%). Glenoid loosening was the most frequent complication that required revision and was observed in 12 cases (24%). Additional complications included 2 subscapularis ruptures, 1 case of loosening of a humeral component that had been press fit, 1 oversized humeral head component, and 1 case of postoperative stiffness. A total of 21 revision surgeries were performed in these 17 patients. The first revision occurred at a mean of 88.5 ± 44.4 months after the initial surgery.

Survivorship of the glenoid component with the endpoint being revision surgery for glenoid loosening was 98% (95% CI, 89.4%-100%) at 5 years and 62.5% (95% CI, 40.6%-81.2%) at 10 years (Fig. 1).

Survivorship of the glenoid was affected by positioning of the humeral component. The mean survival was 8.0 years when the humeral head was oversized or incompletely seated compared with 13.0 years when the

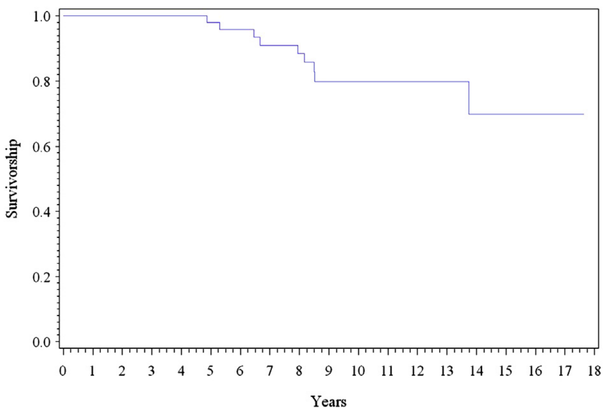

Figure 1 Glenoid survivorship after TSA for primary arthritis in adults aged 55 years or younger. The estimated revision-free survival rate for TSA was 98% (95% CI, 89.4%-100%) at 5 years and 62.5% (95% CI, 40.6%-81.2%) at 10 years.

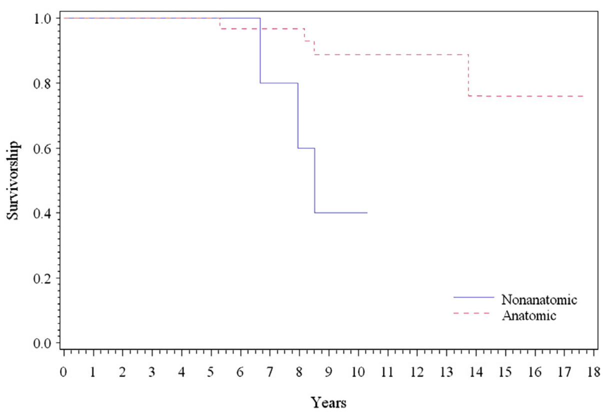

Figure 2 Glenoid survivorship based on humeral component positioning (anatomic vs nonanatomic) after TSA for primary arthritis in young adults. Mean survival was 8.0 years when the humeral head was nonanatomic compared with 13.0 years when the humeral head was positioned anatomically ($P = .008$).

humeral head was positioned anatomically ($P = .008$) (Fig. 2). When the humeral head was not positioned anatomically, the glenoid was 6.6 times more likely to require removal (95% CI, 1.3-32.8) (Figs. 3 and 4). All glenoids that were removed had been placed in the dominant shoulder ($P = .089$). There was no difference in the immediate glenoid RLL score between glenoids that were removed and those that did not require removal (1.2 vs 1.6, $P = .433$). The glenoid survival rate at final follow-up was 91.6% (22 of 24) for glenoids prepared with a compaction technique compared with 72% (18 of 25) for glenoids prepared with a curettage technique ($P = .138$). Although this difference did not reach statistical significance in univariate analysis, it did reach statistical significance in multivariate analysis controlling for humeral component positioning (Table II).

Preoperative glenoid morphology was also assessed for its influence on glenoid survival. At final follow-up, the glenoid survival rate was 90.0% (9 of 10) for A1 glenoids, 100% (7 of 7) for A2 glenoids, 66.7% (8 of 12) for B1 glenoids, and 90.9% (10 of 11) for B2 glenoids ($P = .295$). In comparing the cases with 10-year survival versus those that required removal before 10 years postoperatively, we observed a similar trend. The glenoid survival rate was 83.3% (5 of 6) for A1 glenoids, 100% (2 of 2) for A2 glenoids, 42.9% (3 of 7) for B1 glenoids, and 66.6% (2 of 3) for B2 glenoids ($P = .401$). The 10-year survival rate was 87.5% for concentric glenoids (A1 and A2) compared with 50% for non-concentric glenoids (B1 and B2) ($P = .178$).

Glenoid survival of 10 years or greater was observed in 15 cases. In 9 cases, the glenoid was removed before 10 years postoperatively. A subanalysis of these 2 groups was performed to identify factors that may be associated with long-term survival versus failure before 10 years. This analysis therefore excluded cases with follow-up between 5 and 10 years postoperatively that had not failed. There was no difference in age (50.3 years vs 49.8 years, $P = .546$) or immediate mean glenoid RLL (1.9 vs 1.6, $P = .685$) between the group in which the glenoid was in place at 10 years postoperatively and the group in which the glenoid had been removed before 10 years. In the intact group, 92% of humeral heads had been sized anatomically compared with 57% in the group that required glenoid removal ($P = .117$).

Discussion

The purpose of this study was to examine the mid- to long-term functional outcome of TSA in young adults with primary glenohumeral arthritis. Management of glenohumeral arthritis in the young adult is one of the most difficult and controversial subjects within the shoulder. The results of this study show that TSA is a viable option for young adults with primary shoulder arthritis. However, there is a substantial risk for revision at long-term follow-up.

The mid-term outcome of TSA for young adults with primary glenohumeral arthritis is encouraging. In this study, the survival rate of the glenoid implant was 98% at 5 years postoperatively. Raiss et al[18] recently reported similar success at mid-term follow-up. Twenty-one patients aged under 60 years (mean age, 55 years) were followed up at a minimum of 5 years and mean of 7 years after TSA. As in our study, the authors used a modular humeral component with variable inclination and a keeled glenoid, which were both cemented. Age-adjusted Constant scores improved from 30 to 83, and no revisions were required. However, radiolucencies were observed in 48% of glenoids and appeared at a mean of 51 months postoperatively.

Not surprisingly, in our study functional outcome was related to the need for revision. In individuals who required revision of the glenoid, functional outcome was much less than that in individuals without revision. Moreover, after

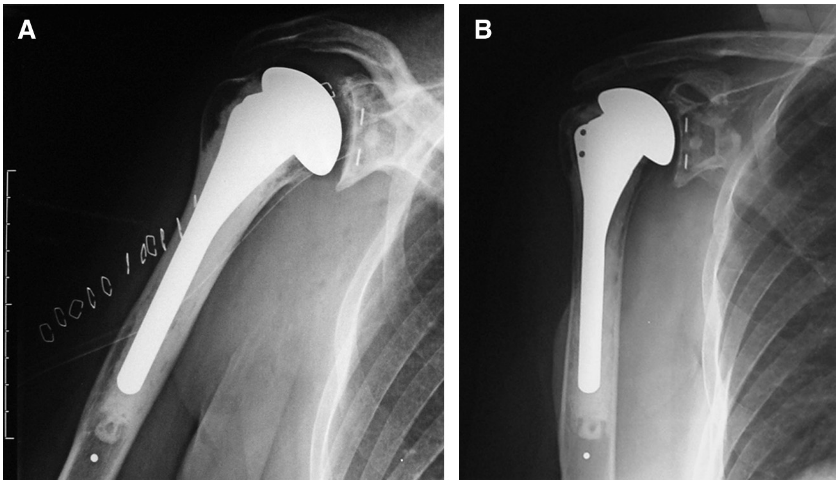

Figure 3 Anteroposterior radiographs of an anatomically positioned humeral component. (**A**) On the radiograph obtained immediately postoperatively, the humeral component is well seated, does not overhang the metaphysis, and appears appropriately sized. (**B**) Repeat radiograph obtained at 117 months postoperatively shows only minimal radiolucency around the glenoid implant. The patient's adjusted Constant score was 100.

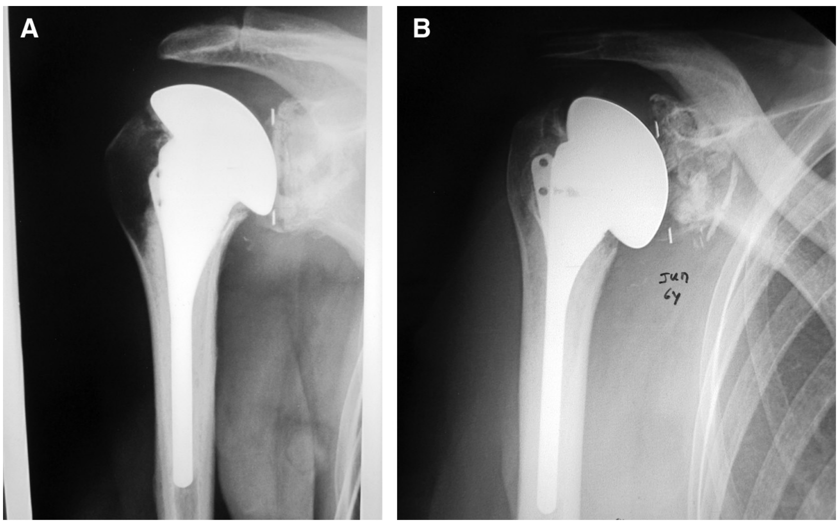

Figure 4 Anteroposterior radiographs of a poorly positioned humeral component. (**A**) On the radiograph obtained immediately postoperatively, the humeral component appears to be incompletely seated and overhangs the metaphysis inferiorly. (**B**) At 67 months postoperatively, there is definite radiographic loosening of the glenoid. This patient required revision and had an adjusted Constant score of 27 at final follow-up of 90 months.

Table II Risk factors for glenoid component removal

Factor	Odds ratio	95% CI	*P* value
Nonanatomic humeral component	19.6	2.5-151.9	.004
Glenoid preparation with curettage	7.9	1.0-73.6	.046

revision of the glenoid, the improvement in function was marginal compared with baseline scores. Thus, survival of the glenoid component is crucial to maintaining a satisfactory functional outcome.

In large series in which the majority of patients are older adults, the survival of TSA has been encouraging at 10 years postoperatively, with rates consistently over 90% in recent reports.[19,24,26] Unfortunately, the survival of TSA may be less predictable in adults aged younger than 55 years. In our study, survivorship of the glenoid component was only 62.5% at 10 years postoperatively. Bartelt et al[2] reported a 92% survival rate at 10 years for TSA in patients aged younger than 55 years with either primary or post-traumatic glenohumeral arthritis. However, most patients had less than 5 years of follow-up, and few had more than 10 years' follow-up; among the 46 TSAs, 24 patients had follow-up of less than 5 years, 12 patients had between 5 and 10 years' follow-up, 8 patients had greater than 10 years' follow-up, and 2 patients had greater than 15 years' follow-up.

Several factors have been implicated in survivorship of the glenoid component and were examined in our study. A preoperative concentric glenoid had greater survivorship, although this difference did not reach statistical significance with the numbers studied. In addition, all failures of the glenoid occurred in the dominant extremity, suggesting that use is associated with survivorship. Interestingly, modifiable technical factors were crucial to glenoid survival. Failure to anatomically position the humeral component was associated with the greatest risk of glenoid failure. This finding lends support to the concept of attempting to reproduce the normal anatomy as closely as possible to restore the mechanics of the glenohumeral joint and, thus, survival of the TSA. In addition, glenoid preparation appears to be important, with a compaction technique being associated with greater survival than a curettage technique. We did not examine other glenoid preparation factors such as reaming, which has previously been shown to affect glenoid survival.[24]

The strengths of this study include the cohort size and length of follow-up. These provided a unique opportunity to examine the functional outcome and implant survival of TSA among young adults with the same diagnosis of primary glenohumeral arthritis. However, because this was a multicenter study, there was likely variability in technique, which may have influenced the results but was not possible to examine in this size of cohort. Walch and colleagues,[26] for instance, recently showed that glenoid preparation technique can influence long-term glenoid survival. In addition, we did not perform a comparison with hemiarthroplasty alone or hemiarthroplasty in conjunction with glenoid resurfacing. These techniques have previously been reported, and our goal was only to report on TSA. Further studies are needed to compare techniques and clarify preoperative factors associated with survivorship of TSA in young adults. The analysis of humeral component positioning was subjective. Although the radiographic assessment was performed by an independent reviewer (P.J.D.) not involved in the surgeries, this interpretation is subject to limitation. Finally, although this study adds to the knowledge about mid- to long-term follow-up of TSA in young adults, 10-year follow-up was available in a smaller subset of patients, which limits conclusions about 10-year survivorship and outcome.

Conclusions

At 5 years' follow-up, TSA leads to improvement in functional outcome and a satisfactory implant survival rate of 98% with revision as the endpoint in young adults with primary glenohumeral arthritis. However, the 10-year survival rate of TSA was only 62.5% in this series. Surgeons should counsel young adults about the high risk of the need for revision in the long-term after TSA.

Disclaimer

Gilles Walch is a consultant for and receives inventor royalties from Tornier for work related to the subject of this article. All the other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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