The recovery curve of anatomic total shoulder arthroplasty for primary glenohumeral osteoarthritis: midterm results at a minimum of 5 years

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Background: Excellent results have been reported for anatomic total shoulder arthroplasty (TSA) for the treatment of primary glenohumeral osteoarthritis (GHOA). We aim to assess the recovery curve and longitudinal effects of time, age, sex, and glenoid morphology on patient-reported outcomes (PROs) after primary anatomic TSA for primary GHOA.

Methods: Patients who underwent primary anatomic TSA over 5 years ago were included: Short-Form 12 Physical Component Summary, American Shoulder and Elbow Surgeons scores, Quick Disabilities of the Arm Shoulder and Hand Score, Single Assessment Numeric Evaluation, and patient satisfaction were assessed. Linear mixed-effects models were used to model progression in PROs longitudinally. Unadjusted models and models controlling for sex and age were constructed.

Results: Eighty-one patients (91 shoulders) were included. Significant improvements from the preoperative period to 1 year postoperatively in the median American Shoulder and Elbow Surgeons (48 to 93; \( P < .001 \)), Quick Disabilities of the Arm Shoulder and Hand Score (42 to 11; \( P < .001 \)), Single Assessment Numeric Evaluation (50 to 91; \( P < .001 \)), and Short-Form 12 Physical Component Summary (35 to 53; \( P = .004 \)) scores were noted. No significant decrease was observed for any of the outcome scores. Median satisfaction at the final follow-up was 10 out of 10. At 1, 2, 3, 4, 5, 6, and 7 years postoperatively, 77%, 64%, 79%, 57%, 86%, 56%, and 78% of patients, respectively, reported sports participation equal to or slightly below preinjury level. There was no association between the glenoid morphology and functional outcomes.

Conclusion: Patients undergoing anatomic TSA for primary GHOA showed excellent improvement in PROs and satisfaction in the first year, and these results were maintained postoperatively for a minimum of 5 years. Age- and sex-adjusted models or glenoid morphology did not substantially alter any trends in PROs postoperatively.

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Primary glenohumeral osteoarthritis (GHOA) can lead to significant disability. Young and active patients may benefit from nonoperative treatment including nonsteroidal anti-inflammatory medication, physical therapy, and intraarticular corticosteroid or hyalauronic acid injection or arthroscopic joint-preserving procedures such as comprehensive arthroscopic management. However, total shoulder arthroplasty (TSA) is still the preferred treatment strategy in most cases, particularly in older individuals and in those with joint incongruity, severe joint space narrowing, and glenoid deformity. In these cases, anatomic TSA offers...
significant improvements in pain relief, function, and quality of life.\(^{37,32,34,41}\) Over the past decade, the incidence of TSA for the treatment of primary GHOA has rapidly grown, making longer term follow-up studies to evaluate patient outcomes, safety, and implant longevity essential.\(^{38}\)

There is general consensus in the literature that patients with GHOA benefit significantly from TSA when it is performed correctly.\(^{37,33,42}\) While the majority of the aforementioned published studies report clinical results preoperatively and at the final follow-up, only very few studies analyze the clinical course of the recovery with an anatomic TSA design.\(^{36,43}\) Studying this recovery curve helps clinicians and patients understand how pain and function change following TSA, as well as how long results are maintained. Moreover, understanding the variables that influence longitudinal outcomes is helpful to counsel patients and to manage expectations.

Thus, the aim of this study was to assess the specific recovery curve and the longitudinal effects of time, age at surgery, and sex on patient-reported outcomes (PROs) and pain after primary anatomic TSA for primary GHOA with a minimum of 5 years of follow-up. The hypothesis was that pain and PROs would improve following anatomic TSA and that these results would be maintained over time. In addition, we postulated that advanced age, female sex, and B2 glenoid morphology would have lower outcome scores.

**Materials and methods**

**Study design**

This was an institutional review board-approved (2017-04) retrospective outcomes study using prospectively collected data stored in a patient registry. All patients who underwent primary anatomic TSA for idiopathic GHOA by the senior surgeon (P.J.M.), who were at least 5 years out from surgery, were eligible for inclusion. Patients underwent TSA between December 2005 and October 2012. Patients with nonidiopathic osteoarthritis, for example, resulting from rheumatoid arthritis, previous glenohumeral dislocations, or fractures of either the proximal humerus or glenoid, were excluded. Moreover, patients were excluded from analysis if they refused to participate or died before the minimum follow-up period.

Failure and complications were recorded. Failure was defined as the need for revision TSA. This included revision surgery for component loosening, rotator cuff tear that necessitated conversion to reverse TSA (RTSA), or prosthetic loosening. Complications were defined as infection, wound dehiscence, nerve damage, stiffness requiring surgery, rotator cuff tendon tears that required repair, and persistent pain.

Shoulder-specific PRO scores were collected both preoperatively and postoperatively in yearly intervals and included the American Shoulder and Elbow Surgeons score (ASES), Quick Disabilities of the Arm Shoulder and Hand score (QuickDASH), Single Assessment Numeric Evaluation (SANE), and the overall general health Short Form-12 Physical Component Summary (SF-12 PCS) score, as well as pain levels according to the Visual Analog Scale (VAS). In addition, both subscales of the ASES score were separately recorded. Postoperative satisfaction scores were also collected (10-point scale: 1 = highly unsatisfied; 10 = highly satisfied). Additional questions assessed patients’ postoperative ability to return to specific recreational activities.

Glenoid morphology was categorized retrospectively according to the Walch classification for analysis based on preoperative axial magnetic resonance imaging or computed tomography scans.\(^{38}\)

**Surgical technique**

The senior surgeon (P.J.M.) performed the surgeries with an anatomic TSA implant (Univers II; Arthrex, Inc., Naples, FL, USA). After the combination of a peripheral nerve block and general anesthesia, the patient was placed in the beach chair position using a pneumatic arm holder. A standard delttopectoral approach was utilized. The biceps tendon was released for tenodesis later. A lesser tuberosity osteotomy was used to remove the subscapularis, and the humeral head was exposed.\(^{40}\) After removal of osteophytes and release of capsular contractures, the humeral head was osteotomized anatomically in the native version and inclination. The glenoid was then exposed, and the labrum and biceps anchor were removed. Additional anterior and inferior capsular releases were performed. The glenoid was then prepared and reamed to achieve a concentric fit of the prosthetic glenoid and to achieve the desired glenoid version. In B2 glenoids, corrective reaming was used to antever the glenoid as much as the implant could tolerate to ensure that the pegs remained within the glenoid vault, based on preoperative 3-D imaging planning. An all-poly glenoid component with hybrid 2 pegs superiorly and a keel inferiorly (Arthrex, Inc., Naples, FL, USA) was cemented in place after the cement was properly mixed. The prosthetic humeral head was cemented to the appropriate size and the stemmed humeral implant was inserted. If the bone quality was good, a short-stem humeral implant (Arthrex, Inc., Naples, FL, USA) was used (Fig. 1). Finally, the humeral head component was sized and inserted with the appropriate eccentricity to match the native head geometry. At this point, the shoulder was reduced and tested for stability. The subscapularis and lesser tuberosity were repaired utilizing #5 nonabsorbable sutures which were passed through the subscapularis tendon medial to the lesser tuberosity bone fragment, through the lesser tuberosity of the proximal humerus, and around the stem prior to final seating of the humeral implant, as has been described by Ponce et al.\(^{42}\) The rotator interval was only closed laterally. The long head of the biceps tendon was tenodesed at the level of the pectoralis major tendon with #2 nonabsorbable sutures. The wound was then thoroughly irrigated and closed in a standard layered fashion. A postoperative rehabilitation program was initiated immediately as has been described by Wilcox et al.\(^{41}\) Passive range of motion was begun on the first postoperative day with an external rotation limit of 30° for the first 3 weeks postoperatively. A sling was used for protection. At 3 weeks postoperatively, full passive and active range of motion were permitted, and the sling was discontinued. Return to full activities was permitted when full range of motion and strength were obtained. This was typically achieved by 4 months postoperatively.

**Statistical analysis**

The primary aim of this study was to characterize the recovery trajectory of patients following TSA as assessed by several PRO scores. To fully utilize the longitudinal nature of the available data and to allow for differential missing annual observation patterns among patients, random-intercepts linear mixed-effects (LMEs) models were constructed. Follow-up time for each collected questionnaire was rounded to the nearest anniversary year of surgery, and follow-up time was entered into the models as an ordinal variable. To ensure a sufficient patient count at each follow-up group, postoperative follow-up years were categorized as 1, 2, 3, 4, 5, 6, or 7+, where the single further follow-up available for a given patient beyond 7 years postoperatively was used. This framework adjusted for each patient’s baseline health status and allowed for pairwise comparison among the baseline and each postoperative time point via Tukey’s method. As a sensitivity analysis, additional otherwise
identical models were created that adjusted for age and sex at surgery. Statistical power for effect estimates within these models was protected by the rule of thumb that a maximum of 1 model parameter should be included for every 10 unique patients. We reported our primary follow-up rate to be the percent of patients eligible for analysis for whom minimum 5-year outcomes were acquired, but the LME models utilized outcome data from all eligible patients, even when the furthest follow-up was less than 5 years. Residual diagnostics were assessed to ensure model parameter assumptions were adequately met. The ordinal variables patient satisfaction and return to activity level were not well suited for this parametric LME modeling approach, and thus, their longitudinal behaviors were reported descriptively. The Kruskal-Wallis test was used to compare average baseline and postoperative PRO values among glenoid morphology (Walch) classification types. Summary statistics were reported for subjective outcome scores using medians and interquartile ranges (IQR). The statistical programming language R version 3.4.0 was used to produce all plots and analyses (R Core Team, Vienna, Austria, with additional package lme4; access date November 17, 2017).1,31

Results

Between December 2005 and October 2012, the senior surgeon (P.J.M.) performed 240 shoulder arthroplasties, 98 (86 patients) of which met the inclusion criteria. Two patients (3 shoulders) died, and 4 patients refused to participate. Ninety-one shoulders (81 patients; 24 women and 57 men) remained in the final study population. The mean age was 63 years (range, 18-80 years), and minimum 5-year follow-up data were obtained for 74 of 91 (81%) shoulders. Among the 17 shoulders lacking complete 5-year follow-up data, 13 had follow-up for at least 1 earlier postoperative time point, and these data were used in the longitudinal modeling. Details on inclusion and exclusion criteria are outlined in Fig. 2.

Three shoulders failed, and 4 additional shoulders experienced complications requiring further surgery. Among the failures, 1 patient was revised to RTSA for rotator cuff tear, and 1 patient was revised to RTSA for chronic instability. One patient required revision TSA due to glenoid component loosening. Of the 4 patients requiring further surgery, 1 patient underwent revision surgery with subscapularis repair and lysis of adhesions, 1 patient underwent lysis of adhesions alone, and 2 patients underwent surgical irrigation and debridement for superficial infections, neither of whom had to have their implants removed and had good long-term outcomes (Fig. 2).

Clinical outcomes

Subjective PROs were available for 87%, 55%, 48%, 56%, 40%, 36%, 27%, and 45% of patients at baseline, 1, 2, 3, 4, 5, 6, and 7 years after surgery, respectively. LME modeling found significant improvements from preoperative period to 1 year postoperatively in the median [IQR] ASES (48 [37-60] to 93 [83-98]; P < .001), QuickDASH (42 [34-59] to 11 [5-25]; P < .001), SANE (50 [45-64] to 91 [68-99]; P < .001), and SF-12 PCS (35 [31-40] to 53 [46-57], P = .004) scores. Median (IQR) scores at 5 years postoperatively were 92 (81-97) for ASES, 11 (7-27) for QuickDASH, 89 (82-94) for SANE, and 50 (39-55) for SF-12 PCS.

Every PRO score maintained a statistically significant improvement over baseline at every postoperative time point between 1 and 7 years. Moreover, comparisons among postoperative time points (1, 2, 3, 4, 5, 6, or 7 years) did not show any statistically significant differences for any of the 4 PROs. Fig. 3 displays observed median, quartiles, and ranges at baseline and each postoperative time point for ASES, QuickDASH, SANE, and SF-12 PCS. Median satisfaction after surgery was 10 out of 10 points at every postoperative time point except at 5 years, when the median satisfaction was 9 (Fig. 4).

Age- and sex-adjusted models did not substantially alter any trends in PROs during the 7 years after surgery, compared to the unadjusted models. Increased patient age at surgery was significantly associated with a higher ASES score (slope estimate = −0.21 per year of age, P = .046), holding sex and length of follow-up constant. Males exhibited lower QuickDASH scores than females (estimate = −6.95, P = .025), holding age and length of follow-up constant. SF-12 PCS and SANE scores were not significantly associated with either age or sex (all P > .05).

LME modeling found significant improvements from the preoperative period to 1 year postoperatively in the median [IQR] pain levels according to VAS (5 [2-7] to 0 [0-1]; P < .001). The median [IQR] VAS at 5 years postoperatively was 0 (0-2) (Fig. 5).

Patient-reported functional evaluation

Using a subjective questionnaire, patients who participate in sports were asked the following question: “With regard to your shoulder, at what grade can you now participate in sports?” Preoperatively, 91% of patients reported participation at least moderately below the preinjury level. At 1, 2, 3, 4, 5, 6, and 7 years postoperatively, 77%, 64%, 79%, 57%, 86%, 56%, and 78% of
responding patients reported participation equal to or slightly below their preinjury level, respectively (Fig. 6).

Patients were also asked to evaluate the difficulty of usual activities relative to their shoulder function. At baseline, 87%, 96%, 97%, and 74% reported at least some difficulty performing their usual work, usual recreational activities, carrying 20 pounds at their side, and performing their usual sports, respectively. Across each of the 7 follow-up time periods, 72%-90%, 63%-84%, 50%-79%, and 62%-78% reported normal function for the same 4 activities, respectively (Fig. 7).

**Effect of glenoid morphology on postoperative outcome**

Thirty-seven patients showed concentric glenoid wear with A1 glenoids according to the Walch classification. Eighteen patients had A2 glenoids, 13 patients had B2 glenoids, and 9 patients had B1 glenoids. Surprisingly, there was no statistically significant association between the glenoid morphology and functional outcomes either preoperatively or at the furthest follow-up time point postoperatively.

**Discussion**

The main finding from this study is that patients undergoing anatomic TSA for primary GHOA showed excellent improvement in their PROs and satisfaction in the first year, and these results were maintained postoperatively for a minimum of 7 years. Moreover, SF-12 PCS and SANE scores were not significantly associated with either age or sex. Men exhibited significantly lower QuickDASH scores than women, while increased patient age at surgery was significantly associated with higher ASES scores. Glenoid morphology did not seem to play a major role in PROs in this cohort at up to 7 years of clinical follow-up. These results are consistent with the previous report by Raiss et al showing clinical improvement after TSA, plateauing at 1 year postoperatively and remaining stable without substantial worsening for 8 years.34 The same has been shown by Razmjou et al who showed that the most significant improvements in disability, physical symptoms, and range of motion were made by 6 months following TSA. In their study, the improvements in ASES and relative Constant Murley scores continued up to 12 months and then began to plateau.35 The current study shows the trajectory of recovery after TSA in an active population. This information is important when communicating the expected timeframe for maximal improvement to patients and when setting realistic expectations and appropriate postoperative goals.

The results of this study are consistent with other published series in that there was prolonged pain relief and functional improvement following TSA.5,7,16,17,35 For example, in a recent study of 67 patients who underwent TSA, the ASES score improved from 37.9 to 78.8 after 2 years of follow-up.37 In another study, Eichinger et al reported a postoperative ASES of 78.1 in patients younger than
50 years after a mean follow-up of 4.9 years and 95% survival.  
Furthermore, Favard et al showed a significant increase in Constant score (from 30.6 to 60.9) in 72 who underwent TSA, with an 11% complication rate after a minimum follow-up of 8 years. 
Finally, the patients in another study reached an ASES score of 71.5 when a metal-back glenoid component was used for TSA after a mean follow-up of 44 months.

In the present study, we observed significantly lower Quick-DASH scores (better outcome) in men than in women. These results are in concordance with a previous study, which reported better outcomes for male patients. However, that study had a heterogeneous collection of patients with various conditions ranging from primary to rheumatoid osteoarthritis and with various procedures such as primary and revision cases including TSA and hemiarthroplasty unlike the present study which only included primary GHOA. In the present study, with the numbers available, there were no differences across sexes for the other PROs which were measured. These results are also in concordance with previous studies. It has been stated that global health measures such as the SF-12 may demonstrate an inferior responsiveness to changes in a patient’s upper extremity functionality compared with shoulder-specific measures. While another study showed only modest improvement in SF-12 score (from 36.0 to 40.6), our patients had significant improvements. This finding could be attributed to the lower demands on shoulder activity in older patients.

In contrast to the findings in some prior studies, preoperative glenoid morphology was not associated with worse outcomes in the present study. This may be secondary to the effectiveness of the surgical technique in managing the potentially adverse effects of these pathoanatomic factors. Matsen et al showed no association between preoperative glenoid version or significant differences between sexes as well.

In the present study, age did affect ASES scores, and interestingly increasing patient age at surgery was significantly associated with higher ASES scores. This may be due to the large influence pain plays in the ASES score and the effectiveness of TSA in alleviating pain. With the numbers available, there were no differences across age for the other PROs which were measured. These results are also in concordance with previous studies.
posterior decentering of the humeral head on the glenoid and the outcomes. Petri et al analyzed 95 shoulders following TSA at a mean follow-up of 3 years and showed similar outcomes between concentric and eccentric glenoid wear. Hussey et al showed similar clinical improvements in patients with concentric and eccentric glenoid wear in GH OA treated with TSA at a mean follow-up of 51 months. However, patients with preoperative eccentric glenoid wear had a significantly higher rate of gross glenoid component loosening, raising concerns that this may translate to a higher rate of revision in the eccentric group after longer follow-up. Longer term follow-up on the subjects from this series who underwent corrective reaming for B2 glenoids will be interesting.

Another important finding of our study was the high rate of return to activity after TSA. Despite the expected decrease in activity levels with the slow progression of osteoarthritis, preoperatively, 91% of patients reported participation at least moderately below the preinjury level while the majority could participate equal to or slightly below their preinjury level postoperatively with 71%
Figure 6 Longitudinal response percentages for sports participation.

Figure 7 Longitudinal response percentages for several patient-reported functional evaluations.
achieving this at 7 years postoperatively. This is consistent with the study by Mannava et al who showed that return to recreational sports can be achieved at participation levels that are comparable with preoperative levels after a minimum of 2 years. Similar results were shown by another study with an overall sports participation of 57% following TSA at the final mean follow-up of 6.2 years. Moreover, the current study showed improvement in performing usual activities following TSA with 63%-84% reporting normal function in recreational activities and 72%-90% in usual work across each of the 7 follow-up time periods. These results support the previous literature that TSA allows for the participation of 57% following TSA at the final mean follow-up of 6.2 years.

Disclaimers:

This study has several limitations. First, this study was performed retrospectively. Furthermore, this study is comprised of a single surgeon’s experience at a referral practice with highly motivated and active patients, so the findings may not apply to other surgical practices or patient populations. This study involved an anatomical implant design, so the results may not be generalizable to other prosthetic designs. Although we were able to obtain minimum 5-year follow-up on 74 out of 91 patients (81%), it was not always possible to get PROs or sports participation data on a yearly basis from every patient. Therefore, we used statistical models to overcome this problem. Finally, we were not able to obtain radiographic images on all patients at the final follow-up. We did however know the status for all patients as to whether the implant had survived or not.

Conclusion

Patients undergoing anatomic TSA for primary GHOA showed excellent improvement in PROs and satisfaction in the first year, and these results were maintained postoperatively for a minimum of 5 years. Age- and sex-adjusted models or glenoid morphology did not substantially alter any trends in PROs postoperatively.

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