ORTHOPAEDIC SURGERY

Is malunion of the greater tuberosity after reverse shoulder arthroplasty in patients with complex proximal humerus fracture associated with worse clinical outcomes? A prospective cohort study

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Abstract

Purpose To assess patient outcomes following reverse shoulder arthroplasty in patients with complex proximal humerus fracture and the clinical implications of greater tuberosity malunions.

Methods This prospective study included 56 patients who underwent RSA (DELTA XTEND™, DePuy Synthes, Warsaw, IN, USA) to treat proximal humerus fractures. We used a standardized suture technique to reattach the tuberosities. Demographic, comorbidity, and radiological parameters were collected. Assessments at 2-year follow-up ($n = 49$) are given as follows: range of motion (ROM), pain level, Constant Murley scores (CS), subjective shoulder value (SSV), and tuberosity healing.

Results Anatomic tuberosity healing was achieved in 31 (55%) patients (group 1), 14 (25%) had a malunion (group 2), and complete migration occurred in 11 (20%) (group 3). No statistically significant differences between groups 1 and 2 were detected: CS ($p = 0.53$), SSV ($p = 0.07$), ROM (forward flexion (FF) $p = 0.19$, internal rotation (IR) $p = 0.34$, and external rotation (ER) $p = 0.76$). Group 3 had poorer outcomes (median [IQR]) than group 1: CS (59 [50–71]) vs. 72 [65–78]), FF (120 [100–150]) vs. 150 [125–160] and ER (− 20 [− 20 to 10] vs. 30 [20–45], respectively. Three complications (group 1) occurred: one-stage revision after low-grade infection, haematoma due to early rivaroxaban intake, and open reduction and internal fixation for acromion insufficiency fracture. No patients showed signs of stem or glenoid loosening after 2 years.

Conclusion Cases with complete superior migration experienced poorer clinical outcomes than those with anatomic healing. Despite a relatively high malunion rate, the outcomes were not significantly worse in these patients compared to anatomically healed GT cases.

Keywords Reverse shoulder arthroplasty · Proximal humerus fracture · Tuberosities · Shoulder function

Introduction

Proximal humeral fractures are the third most frequent fall-related fractures in elderly patients. Many of these fractures in this vulnerable patient population can be treated conservatively with satisfactory long-term functional and quality-of-life outcomes [1]. Nevertheless, reverse shoulder arthroplasty (RSA) is increasingly used to treat complex fractures [2–9].

RSA aims to improve the deltoid lever arm function by medializing the centre of rotation and lowering the humerus, which enhances forward flexion and abduction. However, the delta muscle plays a more critical role in regaining adequate shoulder function than it does in achieving an intact rotator cuff [10]. Since the absence of the infraspinatus and teres minor muscles hinders external rotation, current treatment approaches reported in the literature tend to favour anatomical reattachment of the greater tuberosity.

However, the merits of reattaching the tuberosity to the stem during RSA are widely debated. Proponents of reattachment report improved range of motion, function, and

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patient satisfaction with adequately positioned and healed tuberosities. Likewise, fewer complications (e.g., infections, stem loosening, and instability) have been reported among patients with an anatomically healed tuberosity [3–5, 11–13]. Despite osseous bone contact with the humeral stem, partial migration and thinning of the reattached greater tuberosity have been observed in postoperative assessments [14].

Concerning healing rates following tuberosity reattachment procedures, varying rates (37–84.6%) have been reported [15–18] based on the type of technique used [15, 17, 19]. According to previous investigations, the categories of possible outcomes for the tuberosity are (1) healed after adequate reattachment, (2) cranial migration but with a bone bridge to the humeral shaft (partial migration or plastic deformation), and (3) complete dislocation (see Fig. 1). Unfortunately, divergent definitions of partial and complete migration can be found in the literature [15, 18, 20]. While complete cranial migration has been shown to hinder clinical outcomes, the role of partial migration on clinical outcomes remains unclear. We hypothesize that partial migration does not result in poorer clinical functioning; therefore, our study prospectively assessed functioning and outcomes over 2 years.

Materials and methods

This single-centre prospective study aimed to assess patient outcomes following reverse shoulder arthroplasty used to treat proximal humerus fractures, with an emphasis on the impact of malunion on clinical outcomes. All patients with proximal humerus fractures eligible for treatment with RSA

(June 2016–June 2018) at our institution were assessed for enrolment. The initial preoperative inclusion criteria were acute displaced and dislocated 3- or 4-part fractures [21], displaced head-split fractures, or secondary displaced fractures after failed conservative treatment in patients 50 and older. The exclusion criteria were patients with a previous humerus fracture or a bone deformity due to any cause. The decision to perform joint reconstruction with reverse shoulder arthroplasty was made according to Spross et al. guidelines [22]. For definitive postoperative inclusion in the analysis, anatomic refixation of the greater tuberosity had to be present in the first postoperative X-ray. Patients with intraoperative malpositioned tuberosities were excluded from the study. The other exclusion criteria were any fractures older than 6 weeks, previously failed haemiarthroplasty, prior surgery to treat the fracture, or a postoperative malpositioning of the greater tuberosity. Of the 67 patients who were assessed for enrolment, 56 were included. The study design was approved by the local ethics committee (EKOS 2019-00414), and written consent was obtained from all participants.

Operative technique

The implant used for treatment in this study was the DELTA XTEND™ RSA System (DePuy Synthes, Warsaw IN, USA). All patients were operated on by a senior orthopaedic shoulder specialist (F.H.) or by a surgeon under his direct supervision. Patients were positioned in the beach chair position, and a standard deltopectoral approach was used. Both tuberosities were carefully dissected and dressed with fibres. Next, the long head of the biceps was released at the glenoid level, and tenodesis was performed. When possible,

Fig. 1 Healing of the greater tuberosity (GT). **a** Anatomic healing as seen during the surgical procedure. **b** Partial migration. The GT is higher than the inlay but still has contact to the bony humeral shaft. **c** Complete migration of the GT (postoperatively) without bony contact to the humerus

no further tendon release or resection was done, and the remaining parts of the rotator cuff were left attached to the tuberosities. Following circular capsular release and excision of the humeral head, the glenoid was reamed. A central peg hole was drilled to place and fix the baseplate using two stable angular screws. The humeral component was cemented in all but three of 56 cases.

Rotation of the humeral component was set at between 5°–10° internal rotation. Tuberosities were reattached with five ForceFiber® (Stryker, San Jose, CA) using a standard technique [14] (see Fig. 2), and fluoroscopy was used to confirm anatomic reduction of the tuberosity after fixation was achieved. After confirming correct prosthetic implantation and a stable anatomical reduction of the tuberosity, the surgical wound was closed in a standard manner using absorbable skin sutures.

Postoperative care

All patients wore a neutral rotation sling with 15° abduction for 6 weeks postoperatively. Passive mobilisation was started on the first postoperative day. The sling was removed 6 weeks after surgery, and active movements without restriction (full range of motion) were allowed. However, weight-bearing restrictions continued for an additional 6 weeks. Three months after surgery, the patients began lifting heavier objects and doing strengthening exercises and physical activities.

Clinical and radiological assessment

Patients were clinically and radiologically evaluated during follow-up visits at 1.5, 3, 6, 12, and 24 months after surgery. Data were collected before (demographics and comorbidities) and immediately after surgery (radiological parameters). Forty-nine of the initial 56 patients were evaluated 2 years postoperatively; seven died due to unrelated causes before the 2-year follow-up.

At the 2-year follow-up, range of motion (ROM), pain level, Constant Murley scores (CS) [23], subjective shoulder value (SSV) [24, 25], and tuberosity healing were assessed. The range of motion was measured and documented in degrees (forward flexion, abduction, internal and external rotation). Pain levels were assessed using the visual analogue scale (VAS) from low to high (0–10 points).

Radiologic evaluations, performed in the standard AP view and Y views, were done postoperatively at 1.5, 3, 6, 12, and 24 months. To ensure the radiological measurements were done correctly, extra effort was made to achieve a true AP view in the postoperative and final follow-up evaluations. These were reviewed by a trained musculoskeletal senior-level radiologist (G.S). The radiologic parameters evaluated were as follows: GT healing, inferior scapular notching according to the Nérot–Sirveaux classification [26, 27], signs of implant loosening as radiolucent lines around the components [28], and heterotopic ossifications.

The degree of GT healing was classified as anatomical, malunion, or complete superior migration. The criteria for anatomical healing were visible GT in neutral rotation of the arm in AP view and no migration above the upper end of the polyethylene. A GT positioned cranially of the upper end of the polyethylene, with contact to the humerus or prosthesis, was considered a malunion. Complete superior migration was defined as a GT with complete detachment from the humeral shaft or prosthesis without contact to the bony shaft. If the GT was initially anatomically healed but no longer visible on the standard AP view in neutral rotation at the final follow-up, we classified the outcome as lysis. A specialist musculoskeletal senior radiologist did the radiological assessments.

Fig. 2 Illustration of the greater tuberosity fixation technique
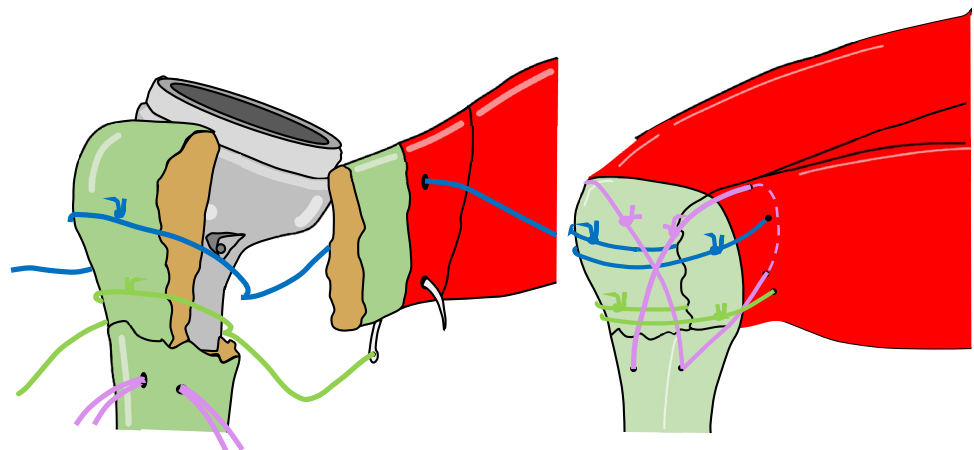
Statistical analysis

In addition to basic descriptive analyses, the data were compared according to groups based on outcomes of GT healing. For categorical outcomes, the Fisher's exact test was used for intergroup comparisons. Continuous variables were assessed using the Mann–Whitney U or T test. To account for multiple group comparisons, the Bonferroni correction was used. As such, p values less than 0.016 were considered statistically significant. Analyses were conducted in Stata (version 15, StataCorp, College Station, TX). All tests were two-sided.

Results

After undergoing RSA, 31 (55%) patients (group 1) achieved anatomic healing of the tuberosity, 14 (25%) had a malunion (group 2), and a complete migration occurred in 11 (20%) (group 3). Baseline demographic and clinical characteristics are shown in Table 1 according to these outcome groups. Ninety-five percent of the patients were female, the median age was 81 years (IQR 72–85, range 53–91), the mean body mass index was 27.6 ($\pm$5), and 30% had osteoporosis. The only significant difference at baseline was the ASA score ($p = 0.008$), which was worse in group 3. Table 2 presents the surgical characteristics by outcome group.

Table 2 Surgical characteristics according to outcome group ($n = 56$)

Parameter	Healed—group 1 ($n = 31$)	Malunion—group 2 ($n = 14$)	Not healed—group 3 ($n = 11$)
Glenosphere			
38	13 (42)	6 (43)	4 (36)
42	18 (58)	8 (57)	7 (64)
Stem			
8	4 (13)	4 (29)	3 (27)
10	14 (45)	6 (43)	5 (46)
12	12 (39)	3 (21)	3 (27)
14	1 (3)	1 (7)	0
Cemented (yes)	29 (94)	13 (93)	11 (100)
Size epiphysis			
Epi1	21 (68)	9 (64)	9 (82)
Epi2	10 (32)	5 (36)	2 (18)
Inlay			
Standard	21 (68)	11 (79)	6 (55)
High mobility	9 (29)	3 (21)	5 (45)
Retentive	1 (3)	0	0

Data are n (%)

Outcome data gathered at 2-year follow-up visits were available for 48 patients (Table 3). Seven patients died from unrelated causes and one was lost to follow-up. No statistically significant differences between groups 1 and 2 were

Table 1 Demographic and clinical characteristics of the patients at baseline, according to outcome group ($n = 56$)

Characteristic	Healed—group 1 ($n = 31$)	Malunion—group 2 ($n = 14$)	Not healed—group 3 ($n = 11$)
Median age at operation (IQR)—years	80 (71–86)	79 (69–85)	83 (80–84)
Gender (female)—no. (%)	29 (94)	14 (100)	10 (91)
Mean BMI (standard deviation)	27 ($\pm$5)	27 ($\pm$4)	29 ($\pm$6.7)
Mean ASA (standard deviation)	2.7 ($\pm$0.68)	2.4 ($\pm$0.65)	3.2 ($\pm$0.60)
Comorbidities			
Neurological disease—no. (%)	11 (35)	8 (57)	4 (36)
Diabetes—no. (%)	7 (23)	2 (14)	2 (18)
Renal disease—no. (%)	9 (29)	4 (29)	3 (27)
Osteoporosis—no. (%)	8 (26)	5 (36)	4 (36)
Operation side of body (right)—no. (%)	16 (52)	8 (57)	6 (55)
Fracture on dominant side—no. (%)	16 (52)	9 (64)	8 (73)
Fracture classification—no. (%)			
2-Part	4 (13)	1 (7)	1 (9)
3-Part	11 (35)	1 (7)	4 (36)
4-Part	13 (42)	10 (72)	6 (55)
Head split fractures	3 (10)	2 (14)	0
Median delay to surgery (IQR)—days	3 (2–10)	2 (1–4)	1 (1–2)
Median length of hospitalization (IQR)—days	10 (7–12)	9 (8–11)	10 (9–15)

BMI body mass index is weight in kilograms divided by the square of the height in metres, *ASA* American Society of Anaesthesiology score, *IQR* interquartile range

Table 3 Radiological and clinical outcomes (n = 48)

Clinical parameter	Healed—group 1 (n = 29)	Malunion—group 2 (n = 11)	Not healed—group 3 (n = 8)	Gr. 1 vs. 2	Gr. 1 vs. 3	Gr. 2 vs. 3
Median range of motion (IQR)[a]						
Abduction	150 (125–160)	160 (150–160)	115 (100–115)	0.1789	0.0485	0.0508
Flexion	150 (125–160)	160 (150–160)	120 (100–150)	0.1916	0.0867	0.034
Internal rotation	8 (4–8)	6 (4–8)	6 (4–8)	0.3387	0.3312	0.8974
AR1	30 (20–45)	30 (15–45)	− 20 (− 20 to 10)	0.7598	**0.0001**	**0.0002**
AR2	65 (60–70)	60 (50–70)	− 20 (− 20 to 0)	0.253	**0.0001**	**0.0022**
Constant Murley score (CS)	72 (65–78)	77 (61–79)	59 (50–71)	0.5339	0.036	0.0435
Subjective shoulder value (SSV)	90 (80–90)	88 (80–95)	80 (70–95)	0.7374	0.3864	0.2374
Radiological parameter						
Scapular notching[b]				0.17	0.106	0.83
1	29 (100)	9 (82)	6 (75)			
2	0	0	1 (13)			
3	0	1 (9)	0			
4	0	1 (9)	1 (12.5)			
Radiolucency humerus[b]	1 (3)	2 (18)	1 (12.5)	0.17	0.381	0.999
Heterotopic ossification[b]	14 (48)	7 (64)	6 (75)	0.484	0.238	0.999

Bold font indicates statistical significance based on Bonferroni correction (p-value < 0.016)

IQR interquartile range

[a]Mann–Whitney *U* test (post hoc)

[b]Fisher's exact test

detected for any of the variables analysed. However, group 3 had poorer results than Groups 1 and 2, especially with external rotation. Three minor complications occurred in the entire cohort: (1) one-stage revision after low-grade infection, (2) haematoma due to early rivaroxaban intake, and (3) acromion insufficiency fracture treated with open reduction and internal fixation. No patients showed signs of stem or glenoid loosening after 2 years.

Discussion

We found satisfactory results in elderly patients with complex proximal humerus fractures who underwent reverse shoulder arthroplasty. The rate of complete migration was 20%, which is comparable to findings from previously published studies [15–18]. Although our results showed a high rate of partial migration with malunion of the greater tuberosity, there was no significant impact on the clinical results when compared to those patients who achieved anatomic healing.

Differing rates of anatomic tuberosity healing following RSA used to treat proximal humerus fracture can be found in the literature [16, 18]. Chun et al. [16] reported a 37% healing rate, while Grubhofer et al. reported a considerably higher rate at 84% [15, 18]. The mean tuberosity healing rate

of seven studies (382 shoulders) included in a meta-analysis by Jain et al. [29] was 68.3% (± 15.9) [16–18, 30–32]. In a recently published paper, we achieved a healing rate of 90% with our technique, despite the advanced age of the patient population treated at our institution [33].

One contentious issue affecting RSA outcomes is how to treat the GT. Some authors do not recommend reattachment or excising the tuberosity [3–5, 34]. However, complications such as infections and instability can develop when the tuberosity does not heal properly [15]. Boileau et al. [15] and Garofalo et al. [17] reported better outcomes (e.g., active forward elevation, external rotation, patient satisfaction) after reattaching the tuberosity. The results of the functional scores (e.g., constant score) can also be contradictory. Grubhofer et al. [18] found significantly better CS in patients with healed GT, although other researchers did not [16, 20, 32]. No differences in ASES or DASH scores have been found [16, 30, 31], which adds more uncertainty to the proper handling of the GT. Nevertheless, our research findings indicate that better active external rotation can be achieved when the GT is healed, which is similar to findings by Jain et al. [29].

Complications rates upwards of 40% have been reported in cases of GT migration or excision after RSA [2–5, 11, 12, 34]. Instability may occur in GT migration or excision cases due to limited availability of soft tissue, which only allows for distal stabilization of the humeral stem. Furthermore,

haematomas and infections can develop in the "dead space" around the proximal humerus stem when the GT has been resected. According to Boileau et al. [15], the absence of GT healing or excision can lead to a higher postoperative complication rate.

Based on our observations, plastic deformation or complete lysis after initial anatomic healing may occur at the greater tuberosity, leading to a partial migration in cases of deformation. In this present study, three patients had this type of plastic deformation and two patients had lysis. To our knowledge, the impact of these circumstances has not yet been investigated. According to our results, it does not seem to influence the clinical outcomes. It may be comparable to the anatomical healing of the tuberculum. We believe this deformity may arise from the bone remodelling in the context of avascular necrosis of the tuberculum.

Given our current findings, we adapted our surgical technique by doing the following: (1) we use tapes to reduce the likelihood of fibre failures, and (2) we use a specific fracture epiphysis to improve the tuberosity fixation rigidity and rotational stability of the GT against the prosthesis. Through our experience with this reattachment technique and the prosthetic design, we identified several factors we believe are necessary for achieving adequate tuberosity healing. First, a rigid construct between the bone fragments and prosthetic epiphysis should be maintained to avoid rotational instability. This rigidity should also be employed between the bone fragments to prevent interfragmentary movement [35]. Consequently, the humerus shaft can provide enough anchoring holes to fix the fibres. Second, bone grafts appear to lower the likelihood of GT migrations [12, 15]. Third, when cementing is required, we avoid the most proximal zone to prevent contact with the reattached GT—contact should be with the stem and the underlying bone graft only [12, 36, 37]. Lastly, achieving a shorter operation time helps decrease exposure to general anaesthesia and the development of periprosthetic infections, which is a risk for elderly patients with this fracture type.

Our study design had limitations. Tuberosity healing was assessed using conventional radiology rather than CT scans, and the assessments were done by only one musculoskeletal senior radiologist rather than two. By comparing another specialist's assessment of the healing, we could have evaluated the interobserver variability, thus strengthening the reliability of these findings. Furthermore, healing of the lesser tuberosity was not analysed in this study. Finally, rigorous group comparisons were limited by our small sample size and lack of a priori power estimation.

In conclusion, we found that plastic deformation of the greater tuberosity with partial migration or lysis, after proper healing, was not detrimental to clinical results. However, complete migration did negatively impact outcomes.

Therefore, we recommend using a reliable fixation technique to improve the rate of anatomically healed GTs.

Declarations

Conflict of interest The authors have no conflicts of interest to declare.

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Eastern Switzerland (EKOS 2019-00414).

Informed consent Informed consent was obtained from all individual participants included in the study.

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