RESEARCH ARTICLE

Anatomic Reduction of Greater Tuberosity Fragment for Shoulder Hemiarthroplasty: a Predictor of Good Clinical Outcome

Francesco Lazzarini, MD; Marco Distefano, MD; Tony Shen, MD; Gregorio Secci, MD; Michael Cresci, MD; Raffaele Tucci, MD; Luigi Zanna, MD

Research performed at Department of Shoulder Surgery, AOU Careggi, University Hospital of Florence, Florence, Italy

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Abstract

Objectives: Proximal humerus fractures account for four-five % of all fractures. Shoulder hemiarthroplasty is indicated for complex fractures with high complication rates when treated with ORIF. This study aims to evaluate the correlation between the proper intraoperative tuberosity reduction, and the mid-to-long-term clinical outcome in a series of patients treated with hemiarthroplasty after proximal humerus fracture.

Methods: Forty-one patients with proximal humerus fractures who underwent hemiarthroplasty surgery between July 2009 and December 2019 were retrospectively reviewed. Quantitative analysis of the reduction of the tuberosities was performed on postoperative X-rays focusing on the distance between reconstructed greater tuberosity and the apex of the head of the prosthesis, (head-tuberosity distance), and contact between tuberosity and humerus diaphysis. The University of California Los Angeles Score (UCLA) was calculated for each patient.

Results: The mean time to surgery was 6.29 ± 2.8 days (range 2-18 days). Nine patients out of 41 (22%) had non anatomic tuberosity, and 32 (78%) were anatomic reduced. The UCLA score at the final follow-up was good and excellent (≥27) in 27 patients (66%), and poor (<27) in 14 (34%). A significant correlation was observed between proper tuberosity reduction and good/excellent UCLA scores (P<0.001).

Conclusion: Hemiarthroplasty is a valid and reliable technique for the treatment of proximal humerus fracture not eligible for internal fixation, with high risk of failure. The proper tuberosity reconstruction, paying special attention to the HTD and the contact between the cortical of the humeral diaphysis and the reconstructed tuberosity, is essential to reach a good clinical outcome.

Level of evidence: IV

Keywords: Clinical outcome, Hemiarthroplasty, Proximal humerus fractures, Shoulder, Tuberosities reduction

Introduction

Proximal humerus fractures account for four % - five % of all fractures, with an incidence of 6.6 out of 1000 people.[1,2] This incidence is expected to increase with the aging of population.[2–4] The gold standard of treatment is still debated and is based on fracture pattern, patients' age, and pre-operative shoulder function.[5]

Shoulder hemiarthroplasty (HA) is indicated for complex fractures that may result in a high complication rate when treated with open reduction and internal osteosynthesis (ORIF).[6–8] The clinical outcome of treatment with hemiarthroplasty depends on many factors both patient-related, such as sex, age and bone and rotator cuff quality, and surgery-related, such as tuberosity healing, implant characteristics, prosthesis height and version.[9–12] The potential healing of the tuberosities depends on the quality of the reconstruction intraoperatively. If the tuberosities do

Corresponding Author: Gregorio Secci, Department of Shoulder Surgery, AOU Careggi, University Hospital of Florence, Florence, Italy

Email: gregorio.secci@unifi.it

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not have satisfactory potential healing or the rotator cuff is not intact, prosthetic replacement surgery with reverse prosthesis should be considered.[6,13–16] To enhance the tuberosity healing, many fracture-specific implants were proposed: low-profile stems with metaphyseal slots for bone grafting, and implants with thicker metaphysis that allow an easier tuberosity reduction and works like a scaffold for bone ingrowth.[17–20] The thicker implants were characterized by a large metaphysis surrounded by metallic spikes, which showed a preservation of tuberosities reduction in 86-88% of the cases.[18,19]

This study aims to evaluate the correlation between proper intraoperative tuberosity reduction and clinical outcomes in a series of patients treated with HA after proximal humerus fracture, using only 1 type of fracture-specific stem. We hypothesize that medium to long-term outcomes of proximal humerus fractures are directly related to the reduction of the tuberosity fragments and their potential healing on the hemi prosthesis.

Materials and Methods

We performed a retrospective analysis of a series of 99 consecutive patients with proximal humerus fractures who underwent hemiarthroplasty surgery between July 2009 and December 2019 performed by four different experienced surgeons in our Shoulder and Upper Limb Surgery Unit. Inclusion criteria were a minimum follow-up of 24 months, fracture pattern associated with a high risk of failure and/or necrosis when treated with ORIF such as three and four-part fracture (Neer's classification), humeral head split, medial wall fragmentation, valgus-impacted fracture with more than one cm of lateral humeral head split relative to the humeral diaphysis and patients who were treated with the Anatomical Shoulder ™ Fracture System (Zimmer-Biomet).[21] A single implant was selected to make the cohort as homogeneous as possible. The chosen implant is characterized by large metaphyseal volume surrounded by metallic spikes allowing an easy anchoring of the tuberosities to the stem. Exclusion criteria were: follow-up of lower than 24 months (n=8), shoulder prosthesis models other than the selected one (n=42), intraoperative periprosthetic fractures (n=5), or revision to a reverse arthroplasty (n=3, traumatic periprosthetic fracture, revised with reverse arthroplasty with fracture osteosynthesis) during follow-up. Standard shoulder radiographic views, consisting of a true AP, a trans scapular Y, and an axillary were performed in each patient. CT scans with 3D reconstruction views were routinely performed to evaluate bone quality, fracture displacement, or the presence of an articular or head-splitting component. Pre-operatively the fractures were classified according to Neer's classification.[21] Demographic data, baseline characteristics, associated fractures (as any other fracture reported with the trauma) cementation of the stem, and time to surgery were recorded for each patient.

Surgical Technique

Patients were placed in the beach-chair position. General anesthesia was used along with an intra-scalene block. The deltopectoral approach was used for all cases. The glenohumeral joint was exposed by extending the fracture line between the tuberosities and incising the rotator interval over the long head of the biceps tendon. After removal of the fracture hematoma in the subacromial bursa, the greater tuberosity (GT) and lesser tuberosity (LT) were identified, mobilized, and debrided, with care to preserve the rotator cuff insertion. The greater and lesser tuberosity fragments must be sufficiently freed up so that they can be easily repaired around the implant and to each other at the time of closure. The humeral head was removed, measured, and preserved for use the cancellous bone as bone graft under the greater tuberosity. A stem positioning guide was used to ensure the correct height and retroversion, respectively 5.5 cm from the pectoralis major insertion and 30° of retroversion.[22] The size of the head component was chosen according to the dimension of the humeral head. The stem was finally positioned at the measured height and the selected version. Stability and range of motion are assessed with a trial humeral head. Correct positioning was confirmed with fluoroscopy for the definitive metallic humeral head fixation. The decision of cemented or press-fit stem was based on the bone stock and stability of the trial implant. Suture repair of the tuberosity fragments was performed with six non-resorbable sutures passed in the tendons of the rotator cuff, at the tendon–bone junction: four passed through the holes in the prosthesis design and two in the two holes previously performed in the humeral diaphysis.[23] The cancellous bone obtained from the removed head was used as a graft under the greater tuberosity, to enhance the osteointegration. Before tightening the sutures, and providing compression to the humeral shaft, the tuberosities' positioning was confirmed with fluoroscopy. The direction of the sutures was opposed to the pulling forces of each cuff muscle, to decrease the risk of early tuberosity migration. A negative pressure drain was placed to prevent hematoma formation followed by layered wound closure.

Clinical Evaluation

The standardized evaluation was performed 15 days after surgery for suture removal. Radiographs were obtained at one, three, 12 months postoperatively and final follow-up. The drain was removed on postoperative day one. The patients were discharged one day postoperatively with a sling in abduction (30°) and neutral rotation positioned. The post-operative rehabilitation program was the same for each patient. Passive assisted mobilization in the supine position was begun after two weeks of immobilization. Assisted passive rotations were permitted after four weeks. Active mobilization was allowed after four weeks postoperatively and after six weeks of a shoulder isometric strengthening program. Patients underwent a physical examination, in the absence of clinical signs of complications, and functional outcomes were measured. In case of complication, such as periprosthetic joint infection, dislocation or stem loosening, it was registered and reported.[24,25] At the clinical examination at the time of the study, the University of California Los Angeles Score (UCLA) and the radiographs analysis were performed.[26] The minimum score is two, the maximum is 35. The clinical outcome is good/excellent if the UCLA score is ≥ 27, while it is poor if < 27. The cohort was divided into two groups according to the UCLA score Good/excellent >27 and poor < 27.[27]

Radiological Evaluation

The post-operative radiographs analysis was performed by two experienced independent shoulder orthopedic surgeons. Anteroposterior projection (AP) radiographs of the shoulder in neutral rotation were examined. All radiographic measurements were performed on PACS systems. The analysis of the tuberosities reduction was performed focusing on the contact between tuberosity and humerus diaphysis and on the distance between the reconstructed greater tuberosity and the apex of the articular component of the prosthesis. Tuberosity reduction was assessed as head-tuberosity distance (HTD) and the contact between humeral diaphyseal cortical and tuberosity. HTD in the healthy humerus is obtained by measuring the height of the superior articular surface of the humerus relative to the superior margin of the greater tuberosity [Figure 1]. The HTD, as measured in cadaveric specimens, is eight ± three mm (range, 3-20 mm).[6] In the literature, placement of the tuberosity approximately 10mm (range, 5-20mm) from the apex of the prosthetic articular component is recommended.[6,28] The contact between humeral shaft and the greater tuberosity was considered as a point of overlap between the tuberosity cortex and the shaft cortex[Figure 2]. We considered the tuberosity misplaced: if the tuberosity fragment on postoperative radiographs was greater than the apex of the prosthetic joint component; if the HTD was greater than 20mm or less than five mm; if there was no contact between the humeral diaphysis and reconstructed tuberosities. Conversely, the tuberosities were considered correctly reduced.

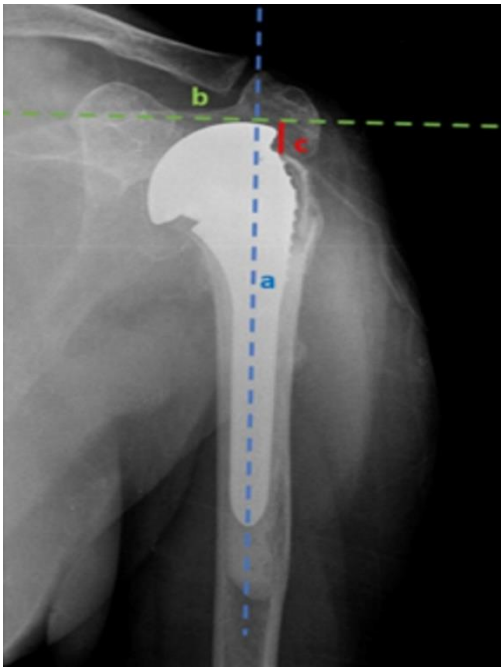

Figure 1. Head-Tuberosity Distance (HTD is obtained by measuring the height of the superior articular surface of the humerus relative to the superior margin of the greater tuberosity. (a): long axis of the implant, (b): line perpendicular to the long axis of the implant and tangent to the top of the prosthesis head, (c): Head-Tuberosity Distance

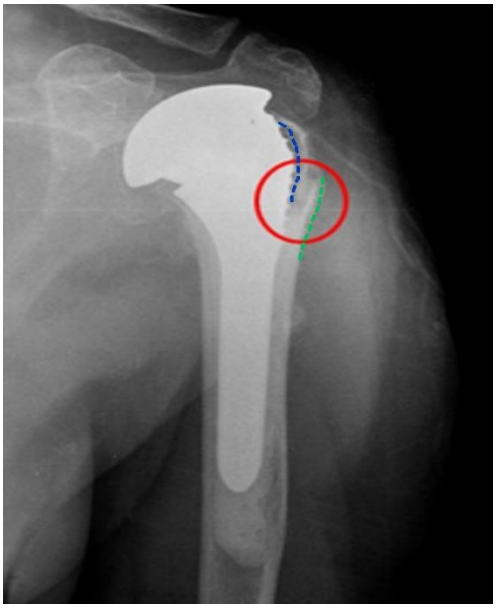

Figure 2. Contact (red circle) between the humeral diaphysis (green line) and reconstructed greater tuberosity (blue line)

Data Analysis

The Shapiro-Wilk tests were used to assess the normality of the distribution of continuous variables. Descriptive statistics (mean, standard deviation, range, and median as appropriate) were used to describe the patients' variables and radiological data. Categorical variables were assessed using the chi-square test or Fisher's exact test for statistical significance. Continuous variables were compared using paired and unpaired t-test, and continuous and ordinal variables with the Wilcoxon test as appropriate. P values <0.05 were considered statistically significant. The intraclass correlation coefficients (ICC) were used to quantify all radiographic measurements' inter- and intra-rater reliability. ICC values greater than 0.90 indicated excellent reliability. Statistical analysis was performed using SPSS statistics software version 25.0 for MACINTOSH (IBM, Armonk, New York).

Ethical approval

The study and follow-up, respecting the criteria of the Declaration of Helsinki, have been approved by Institutional Review Board (IRB) of our Hospital.

Results

According to the inclusion and exclusion criteria, 41 patients were enrolled for the final analysis [Figure 3], seven (17%) men and 34 (83%) women. The mean age at the time of surgery was 73.9 ± 1.4 years (range 56-87). The right side was involved in 26 patients (63%) and the left in 15 (37%), in 14 (34%) the nondominant upper limb, and in 27 (66%) the dominant. The mean time to surgery was 6.29 ± 2.8 days (range 2-18 days). The mean clinical follow-up was 70.39 ± 58 months (range 24 - 147 months). The fracture pattern

was a four-fragment fracture in 17 cases (42%), fracture-dislocation in 12 cases (29%), and in 12 cases (29%) three-fragment fracture, according to Neer's classification. Nine patients out of 41 (22%) had non-anatomic reduced tuberosity, and 32 (78%) were anatomic reduced. 17 (41%) prostheses had been implanted press-fit and 24 (59%) were cemented. No other associated fractures were reported in 38 (93%) cases and three (seven %) we registered associated fractures (1 ipsilateral nondisplaced radial head fracture, 1 ipsilateral nondisplaced wrist fracture, 1 contralateral displaced wrist fracture). No complications in terms of periprosthetic joint infection, dislocation or stem loosening, were reported. The UCLA score at final follow-up was good/excellent (≥27) in 27 patients (66%), and poor (<27) in 14 (34%) [Table 1, 2]. The statistical analysis demonstrated a significant correlation between anatomic tuberosity reduction in the postoperative radiographs and good/excellent UCLA scores (P<0.001). Anatomic reduction, and thus appropriate radiographic positioning of the tuberosities, in the postoperative period correlated significantly with a UCLA score ≥ 27. However, gender, side of the limb affected by the fracture, involvement of the dominant limb, prosthesis implantation technique, cemented or press-fit, and presence of associated fractures, did not show any significant correlation with the UCLA score <27 or ≥ 27. [Table 3]. Furthermore, the time between fracture diagnosis and surgery (P=0.668) and the patient's age at the time of fracture (P=0.414) did not show a statistically significant correlation with clinical outcome.

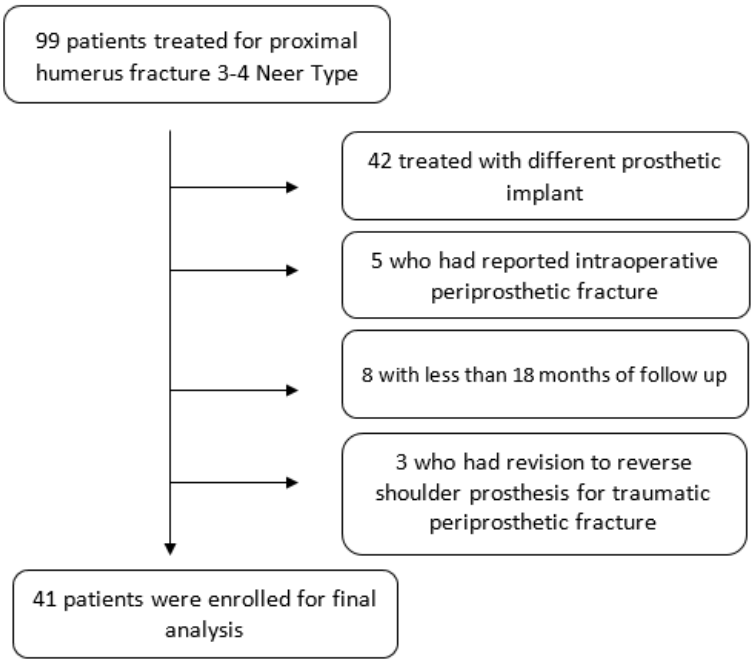

Figure 3. The flowchart shows the patients who were included in the study

Table 1.Patients with UCLA score ≥ 27

Patient	Sex	Time to surgery (days)	Age (years)	Affected side	Dominanat Arm	Stems Type	Associated Fracture	UCLA Score	Good Tuberosity Reduction
1	F	2	69	Left	No	Cemented	No	27	Yes
2	F	6	73	Right	Yes	Uncemented	Yes	33	Yes
3	M	7	56	Left	No	Uncemented	No	34	Yes
4	F	2	78	Right	Yes	Cemented	No	27	Yes
5	F	11	65	Right	Yes	Uncemented	No	33	Yes
6	F	4	75	Right	Yes	Cemented	Yes	27	Yes
7	M	9	58	Left	No	Uncemented	No	28	Yes
8	F	8	80	Left	No	Cemented	No	27	Yes

Table 1.Continued

9	F	6	72	Right	Yes	Uncemented	No	30	Yes
10	F	8	80	Right	Yes	Cemented	No	29	Yes
11	F	3	67	Right	Yes	Uncemented	No	34	Yes
12	M	4	71	Left	No	Uncemented	No	28	Yes
13	F	18	81	Right	Yes	Cemented	No	27	Yes
14	F	4	76	Right	Yes	Uncemented	No	33	Yes
15	F	6	87	Right	Yes	Cemented	No	30	Yes
16	F	10	70	Left	Yes	Cemented	No	29	Yes
17	F	3	60	Right	Yes	Uncemented	No	34	Yes
18	M	8	65	Right	Yes	Cemented	No	31	Yes
19	M	9	71	Right	Yes	Uncemented	No	35	Yes
20	M	7	83	Left	No	Cemented	No	28	Yes
21	F	10	71	Right	Yes	Cemented	No	33	Yes
22	F	3	71	Right	Yes	Cemented	No	27	Yes
23	F	4	78	Left	No	Cemented	No	34	Yes
24	F	9	77	Right	Yes	Cemented	Yes	28	Yes
25	F	4	68	Left	No	Cemented	No	27	Yes
26	M	7	80	Left	Yes	Cemented	No	33	Yes
27	F	6	67	Right	Yes	Uncemented	No	29	Yes

Age: patient's age at the time of surgery; F: female, M: male,UCLA score: University of California Los Angeles Score

Table 2.Patients with UCLA score < 27

Patient	Sex	Time to surgery (days)	Age (years)	Affected Side	Dominant Arm	Stems Type	Associated Fracture	UCLA score	Good Tuberosity Reduction
1	F	10	73	Right	Yes	Cemented	no	23	Yes
2	F	9	72	Left	No	Uncemented	no	8	No
3	F	12	86	Right	Yes	Cemented	no	15	No
4	F	3	74	Right	Yes	Uncemented	no	12	No
5	F	5	84	Left	No	Cemented	no	22	No
6	F	5	70	Left	No	Uncemented	no	26	No
7	F	9	73	Right	Yes	Cemented	no	24	No
8	F	6	87	Right	Yes	Cemented	no	25	Yes
9	F	2	72	Right	Yes	Uncemented	no	8	No
10	F	3	77	Left	No	Cemented	no	18	Yes
11	F	8	80	Right	Yes	Uncemented	no	18	No
12	F	4	83	Left	No	Cemented	no	10	No
13	F	2	79	Right	Yes	Cemented	no	18	Yes
14	F	2	73	Right	No	Cemented	no	12	Yes

Age: patient's age at the time of surgery; F: female, M: male,UCLA score: University of California Los Angeles Score

Table 3.Significant predictors of good clinical outcome (UCLA score ≥ 27)

		UCLA ≥ 27	UCLA < 27	P-value
Sex	Female	20	14	P=0.075
	Male	7	0	
Affected Side	Left	10	5	P=0.934
	Right	17	9	
Dominant Arm	No	9	5	P=0.879
	Yes	18	9	
Stems Type	Uncemented	11	6	P= 0.896
	Cemented	16	8	
Associated Fracture	No	24	14	P= 0.539
	Yes	3	0	
Correct Reduction	No	0	9	P<0.001
	Yes	27	5	

UCLA score: University of California Los Angeles Score. P < .05 significant

Discussion

Hemiarthroplasty for proximal humerus fractures is a technically challenging procedure with variable and unpredictable outcomes. High rates of satisfaction, in terms of pain relief and functional recovery, are described in the literature. However, poor outcomes have also been described.[1,29–31] The result of our study was concordant with the literature demonstrating that anatomic reduction of the great tuberosity was the only factor to have demonstrated a significant correlation with good clinical outcomes. According to our analysis the most important factor for HA clinical success is the anatomical reduction and healing of tuberosities, which may be achieved by avoiding their fixation above the apex of the articular surface of the prosthesis or too far from it (HTD > 20), a necessary condition to provide proper rotator cuff function.[9,14,32,33]

Mighell et al analyzing a cohort of 72 patients treated by hemiarthroplasty for proximal humerus fractures reported how the tuberosities' malreduction was related to worse clinical outcomes than patients with anatomical reduction.[6] In the same cohort, the rate of malreduction was 21% (HTD > 20mm), in line with the data of our cohort in which nine patients (22%) had no anatomical tuberosity reduction. Antuña et al reported the importance of tuberosities' anatomical reconstruction to achieve good/excellent clinical outcomes, even though the authors analyzed a dis-homogenous cohort of patients treated by 20 surgeons and through two different surgical approaches.[28] Similarly, in our homogenous cohort of patients treated with the same approach by four highly experienced shoulder surgeons, we reported the same results in terms of clinical outcome. Furthermore, Reuther et al and Gronhagen et al reported that anatomical tuberosity healing around the prosthesis improved functional outcome and range of motion, but they did not show a correlation between the anatomical reduction and post-operative pain.[34,35] On the other hand, Valenti et al reported how the patients' post-operative satisfaction was related to the improvement of pain other than the recovery of the shoulder function.[10] This analysis might justify why patients with limited functional outcomes, but with no pain, report high grades of satisfaction, likely due to the frequency of this injury among lower-demand elderly patients.

Differing from our results, some authors reported a correlation between time to surgery and the clinical outcome.[6] A time to surgery of more than two weeks was related to bad clinical outcomes.[6] Our cohort did not find a significant correlation between time to surgery and clinical outcome because the meantime was 6, 29 ± 2, 8 days. Only one patient underwent surgeries two weeks after trauma (18 days). The short mean time to surgery might be the reason we did not register any significant correlation with the UCLA score. As reported by Mighell et al we feel confident to underline the importance to perform the surgery as soon as possible to improve the outcome.[6]

In the literature, many authors reported a significant correlation between patient age and tuberosities' healing

and consequently with good/excellent clinical outcomes.[10,31,33–36] In our study, this correlation did not agree with Valenti et al Reuther et al reported gender as a significant factor related to tuberosity healing, describing that men are eleven times more likely to achieve tuberosity healing than women.[10,34] Boileau et al also describes the male gender as one of the most important predictors of tuberosity healing.[31] In our study, all seven men included had a UCLA ≥ 27, in line with the literature even though we did not find any significant correlation between the male sex and UCLA (P=0.075).

Christoforakis et al highlighted how the functional outcomes of patients with hemiarthroplasty are closely dependent on an adequate rehabilitation program, describing how the maximum clinical outcome is achieved in the first six months after surgery.[37] The best rehabilitation approach was not uniquely defined in the literature, and some studies recommended early aggressive rehabilitation for good functional recovery, others recommended delaying aggressive rehabilitation until radiographic evidence of tuberosity healing.[28,37,38] In addition, there does not appear to be a significant correlation between clinical outcome and rehabilitation performed at home versus in a rehabilitation facility.[10] There are limitations to this study. This study was performed retrospectively in a single center, including a relatively small population. Range of motion data and bone healing rate weren't available, so their correlation with the tuberosity positioning wasn't evaluated. Further larger multicenter studies will be important for further characterization. Furthermore, accurate retrospective classification of the fracture type was not always possible. This might result in a weaker statistical power as potential differences between patients with healed versus unhealed tuberosities could not be accounted for. Despite these limitations, we may report on a relatively uniform cohort of patients and highlight the importance of anatomical tuberosities reduction to reach good clinical outcomes. By providing this recent original work to the literature we aim to inform future systematic reviews considering the topic and demonstrate satisfactory outcomes of this surgical procedure. Furthermore, we aim to provide significant information for future comparative study with more recent data on this surgical procedure in order to improve the treatment of this common fracture.

Conclusion

Shoulder hemiarthroplasty is a valid and reliable technique for the treatment of proximal humerus fractures with a high risk of failure when treated with ORIF. Clinical outcomes for most patients are excellent and good. The proper reconstruction of the tuberosities, paying special attention to the HTD, which should be between five and 20 mm, and the contact between the cortical of the humeral diaphysis and the reconstructed tuberosity, is essential to reach a good clinical outcome.

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Francesco Lazzarini MD [1]
Marco Distefano MD [1]
Tony Shen MD [2]
Gregorio Secci MD [3]
Michael Cresci MD [3]
Raffaele Tucci MD [3]
Luigi Zanna MD [1]

1 Department of Orthopaedic Surgery, Santa Maria Annunziata Hospital, Florence, Italy

2 Adult Reconstruction and joint Replacement, Hospital of Special Surgery, New York, NY, USA

3 Department of Shoulder Surgery, AOU Careggi, University Hospital of Florence, Florence, Italy

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