Internal Fixation Versus Shoulder Hemiarthroplasty for Displaced 4-part Proximal Humeral Fractures in Elderly Patients

MING CAI, MD; KUN TAO, MD; CHUNXI YANG, MD; SHAOHUA LI, MD

Abstract

The purpose of this single-center, randomized, controlled trial was to report on the 2-year outcomes of proximal humerus fractures in elderly patients treated with open reduction and internal fixation (ORIF) with either a locking plate or shoulder hemiarthroplasty.

Thirty-two patients (87% women) with a mean age of 71.9 years (range, 67-86 years) were treated with ORIF with either a locking plate or shoulder hemiarthroplasty after shoulder injury. The main outcome measures were the Constant score, Disabilities of the Arm, Shoulder and Hand (DASH) score, and health-related quality of life (HRQoL) according to the EQ-5D (EuroQol Group, Rotterdam, The Netherlands). At final 2-year follow-up, DASH and pain scores favored the shoulder hemiarthroplasty group. Mean flexion was 129° in the shoulder hemiarthroplasty group and 117° in the ORIF group (P=.27), and mean abduction was 123° in the shoulder hemiarthroplasty group and 111° in the ORIF group (P=.41). In the shoulder hemiarthroplasty group, the EQ-5D index score decreased from 0.85±0.21 before injury to 0.65±0.14 at 4 months postoperatively. The score was 0.79±0.24 at 12 months postoperatively and 0.81±0.17 at 24 months postoperatively.

The results of this study indicate an advantage in functional outcomes and HRQoL favoring shoulder hemiarthroplasty compared with ORIF with a locking plate, although most outcomes were not significantly different.

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proximal humeral fractures are the third most common fractures in elderly patients, after fractures of the hip and distal radius, and they are strongly associated with osteoporosis. The most frequently used classification for proximal humeral fractures is the Neer classification. This classification is based on the 4 anatomical segments of the proximal humerus—humeral head, shaft, and greater and lesser tubercles—and whether these segments are fractured or displaced. The surgical neck 4-part fracture is defined as a fracture with at least 10 mm of displacement and/or 45° of angulation between the head and shaft fragments and a fracture of the greater or lesser tubercle with at least 10 mm of displacement.

Four-part proximal humeral fracture accounts for approximately 10% of all proximal humeral fractures. Operative treatment of displaced 4-part fractures in younger patients is not controversial. The controversy pertains to elderly patients with varying degrees of osteoporosis and displaced fractures sustained after low-energy trauma. In this patient group, little evidence and poor consensus exist regarding the optimal treatment modality. Open reduction and internal fixation (ORIF) with locking plates has the potential to restore the anatomy; however, a risk of complications exists related to the implant and to the surgery itself. Shoulder hemiarthroplasty is indicated in patients with displaced and comminuted fractures, where avascular necrosis of the humeral head seems inevitable. According to Hertel et al., the predictors of humeral head ischemia are the integrity of the medial hinge, the length of the dorsomedial metaphyseal extension of the head fracture (calcar length), and the fracture type. In elderly patients, most displaced 3- and 4-part fractures, fracture-dislocations, and fractures with a split or impacted humeral head with a loss of more than 40% of the articular surface can be managed by hemiarthroplasty. In younger patients, if osteosynthesis cannot provide a stable anatomically reduced proximal humerus, replacement with a prosthetic head may be considered. However, the ability of hemiarthroplasty to restore normal shoulder kinematics and function remains controversial.

The purpose of this single-center, randomized, controlled trial was to report the 2-year outcome of proximal humerus fractures in elderly patients treated with a locking plate or shoulder hemiarthroplasty. The primary goal was to determine the health-related quality of life (HRQoL) according to the EQ-5D (EuroQol Group, Rotterdam, The Netherlands), and the secondary goal was to report functional outcomes according to the Constant score and the Disabilities of the Arm, Shoulder and Hand (DASH) score.

**Materials and Methods**

Thirty-two patients with an acute displaced 4-part fracture of the surgical neck of the humerus, according to the Neer classification, were allocated to treatment with ORIF with a locking plate or with shoulder hemiarthroplasty between April 2005 and March 2010. The fracture inclusion criteria, based on conventional radiographs and computed tomography, were displacement of the shaft of more than 10 mm and/or more than 45° of angulation in relation to the head fragment, combined with a displacement of the greater or lesser tubercle of more than 10 mm in relation to the head fragment. A minimally displaced or nondisplaced fracture of the other tubercle that did not meet Neer criteria to be considered a separate fracture segment was not considered to be an exclusion criterion. Patients with a completely displaced shaft in relation to the head fragment, such as a fracture without bony contact, were considered to have an absolute indication for surgery and, therefore, were not included, nor were patients with a valgus impact fracture.

Inclusion criteria were age 67 years or older, a fracture sustained after a low-energy trauma (eg, a simple fall), no previous shoulder problems, independent living conditions (ie, not institutionalized), and no severe cognitive dysfunction (ie, 3 or more correct answers on a 10-item Short Portable Mental Status Questionnaire [SPMSQ]). After clearance by an anesthetist, the patients were randomized to treatment with ORIF with a locking plate or with shoulder hemiarthroplasty.

**Surgical Technique**

All patients underwent surgery performed by 1 of 2 orthopedic surgeons (M.C., S.L.), both experienced in shoulder surgery. All patients were given 1.5 g of cefuroxime preoperatively.

The Philos plate (Synthes, Stockholm, Sweden) was used in the ORIF group. This plate is anatomically shaped and is recommended to be placed at least 8 mm distal to the upper end of the greater tubercle (rotator cuff insertion) and slightly dorsal to the long head of the biceps. It allows for 9 locking screws in the proximal fragment and is available in different lengths, allowing for either locked or nonlocked screws in the shaft. Surgery was performed in a modified beach-chair position using a deltopectoral approach. Fractures of the lesser and/or greater tubercle with displacement and/or instability were fixed with nonabsorbable sutures. The reduction and position of the implant was verified with the aid of a radiographic image intensifier. The duration of surgery was recorded. The head/shaft angle, dorsal/ventral angle, and distance between the superior border of the greater tubercle and vertex of the head were measured postoperatively. In addition, the position and use of the plate was recorded, including the distance from the top of the greater tubercle, length of the plate (3 or 5 holes), number of screws in the head fragment, and whether screws penetrated the humeral head.

The hemiarthroplasty prosthesis (DePuy, Warsaw, Indiana) was used in the shoulder hemiarthroplasty group. Surgery
was performed in the beach-chair position on the edge of the table, with the operated arm positioned over the edge. This allowed for full mobility of the limb. A deltopectoral approach was used in all patients without detaching the anterior deltopectoral and the upper third of the pectoralis major. The long head of the biceps was used as a landmark to localize the tuberosities. The fracture line was slightly posterior to the bicipital groove in approximately 80% of cases. The humeral head was removed and its diameter measured. In patients with a 3-part fracture, the lesser tuberosity was resected while attached to the head, and the humeral head was removed without detaching the subscapularis tendon.

After isolating the tuberosities, non-absorbable sutures were placed at the bone–tendon junction. The humeral canal was then reamed, and a trial stem was inserted to determine the height and version (retroversion approximately 20°); in this phase, the device requires an extramedullary guide to correctly position the component, using preoperative radiographs of the contralateral arm as reference. The tuberosities were reduced, and the position and height of the implant were verified by fluoroscopy. The stems were cemented, sparing the epiphysis to avoid affecting bone repair. A bone graft from the humeral head was placed between the tuberosities to restore the humeral offset. The tuberosities were then sutured to one another and to the humeral shaft with nonabsorbable horizontal and vertical sutures.

Postoperatively, the arm was placed in a sling, and all patients were referred to physiotherapy. The sling was used for 4 weeks, after which patients were allowed to use it at their own convenience. Pendulum exercises and passive elevation/abduction up to 90° were started on postoperative day 1. After 4 weeks, the patients were allowed free active range of motion. Fracture reduction and implant position were assessed using postoperative radiographs.

**Primary Assessment and Follow-up**

Assessments of cognitive function according to the SPMSQ15 and of general health according to the American Society of Anesthesiologists (ASA) classification16 were performed. Moreover, patients were interviewed regarding their living conditions and their activities of daily living17 and were also asked to rate their HRQoL according to the EQ-5D18 during the week before the fracture as a baseline. Patient height and weight were measured, and body mass index (kg/m²) was calculated. Bone mineral density was measured by dual-emission x-ray absorptiometry.

The patients were followed up at 4, 12, and 24 (mean, 24.3±0.8) months. Final patient height and weight were measured, and body mass index (kg/m²) was calculated. Bone mineral density was measured by dual-emission x-ray absorptiometry.

The patients were followed up at 4 (mean, 4.1±0.4), 12 (mean, 12.1±0.5), and 24 (mean, 24.3±0.8) months. Final 24-month follow-up was performed by an independent orthopedic surgeon (K.T.) not involved in treatment. In the outcome analyses, all patients remained in their randomized group, regardless of secondary procedures, according to the intention-to-treat principle.

Each follow-up visit included radiographs with standardized frontal and lateral projections. In the ORIF group, fracture healing and displacement were assessed with changes in the head–shaft angle and dorsal–ventral angle. Any additional screws penetrating the head or any plate loosening were recorded. In the hemiarthroplasty group, the position in which the shoulder finally moved was assessed.

Additional surgeries after the primary treatment, including the indication and date of the surgery, were recorded. Functional outcome was assessed using the Constant score19,20 and DASH scores,21 and the HRQoL was assessed using the EQ-5D.22 Pain was assessed on a visual analog scale (0=no pain; 100=worst possible pain). The Constant score is a widely used system for measuring shoulder function regardless of the diagnosis. The normal population values depend on age, sex, and activity level of the patient. The best possible score is 100 and includes an assessment of shoulder function in 4 dimensions: pain (15), activities of daily living (20), range of motion (40), and strength (25).

The DASH questionnaire is a region-specific outcome instrument developed to measure upper-extremity disability and symptoms. The main component, the 30-item disability/symptom scale, was used in this study. The scores from each of the items are used to calculate DASH score ranging from 0 (no disability) to 100 (most severe disability).

The HRQoL was rated using the EQ-5D. The EQ-5D has 5 dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each dimension is classified according to its severity: no problem, some problems, and major problems. An EQ-5D index score of 0 indicated the worst possible state of health and a score of 1 indicated the best possible state of health.

**Statistical Analysis**

SPSS version 11.0 software (SPSS, Inc, Chicago, Illinois) was used. Scale variables and ordinal variables were tested using Mann-Whitney U test. Wilcoxon signed rank test was used to compare the EQ-5D index score before injury and at follow-up. Nominal variables were tested using chi-square or Fisher’s exact test. All tests were 2-sided. A P value less than .05 was considered significant. To maximize the power of the statistical tests, a correction factor was not applied for the P values (eg, the Bonferroni correction), which may increase the possibility of a type I error.

**RESULTS**

A flow chart for all patients is shown in Figure 1. According to radiological examination, one patient had a 4-part fracture with a displaced greater tubercle and a minimally displaced lesser tubercle (2 mm). However, a displacement of both tubercles that exceeded 10 mm was diagnosed intranoperatively (ie, it was a true 4-part fracture according to the Neer classification). One
patient died after 3.5 months due to causes unrelated to the surgery. The overall mortality rate at 24 months was 3.12% (1/32) in the ORIF group and 5% (1/19) in the hemiarthroplasty group. Three patients in hemiarthroplasty group and 1 in the ORIF group were lost before final follow-up (Figure 1).

Baseline data for all patients are shown in Table 1. Mean patient age was 71.9 years, and 87% of patients were women. Mean age was 73.1 years for women and 69.2 years for men. Mean EQ-5D index score before injury was 0.85, and 98% of patients were assessed as being independent in all 6 functions of activities of daily living. According to the inclusion criteria, no patient had no severe cognitive dysfunction (SPMSQ less than 3), and all patients came from independent living conditions. Mean dual-emission x-ray absorptiometry total body T-score was below the mean for young adults, and, consequently, satisfied the criteria for osteoporosis according to the World Health Organization definition.23 Three (9.37%) of 32 fractures were 4-part fractures with a dislocation.

Clinical and Radiological Outcomes
In the hemiarthroplasty group, mean operative time was 93 minutes (range, 79 to 135 minutes). In the ORIF group, mean operative time was 86 minutes (range, 67 to 111 minutes). Assessment of postoperative fracture reduction in the ORIF group revealed a mean head–shaft angle (frontal projection) of 121° (range, 103° to 132°) and a mean dorsal–ventral angle (lateral projection) of 11° (range, −10° to 28°). A good reduction (ie, head–shaft angle of 135°±20° and dorsal–ventral angle of 0°±25°) was achieved in 12 (92%) patients. The plate was positioned at a mean of 5 mm (range, −3 to 17 mm) below the top of the greater tubercle.

In the ORIF group, 3 (23.1%) patients underwent additional surgery during the 2-year follow-up period (Table 2): 1 due to nonunion and 2 due to fixation failure. In the hemiarthroplasty group, 3 (15.8%) patients underwent additional surgery during the 2-year follow-up period (Table 2): 1 each due to dislocation and prosthesis loosening. All but 1 of these patients had improved function in DASH scores between 12- and 24-month follow-up, with a mean of 6.7 points (range, 0 to 14.9 points).

Functional Outcome and HRQoL
Functional outcomes according to Constant and DASH scores are shown in Table 3, and the HRQoL based on the EQ-5D index score is shown in Figure 2. The Constant and DASH scores and the EQ-5D index score favored the hemi-
arthroplasty group at all follow-ups, although not statistically significant. Mean pain score according to the visual analog scale at final follow-up was 13 in the hemiarthroplasty group and 21 in the ORIF group ($P=.67$). Mean range of flexion at final follow-up was $129^\circ$ in the hemiarthroplasty group and $117^\circ$ in the ORIF group ($P=.27$), and mean range of abduction was $123^\circ$ vs $111^\circ$, respectively ($P=.41$).

In the ORIF group, the EQ-5D index score before injury was $0.85\pm0.21$; 4 months later it had decreased to $0.63\pm0.17$. The score was $0.71\pm0.19$ at 12 months and $0.74\pm0.26$ at 24 months (Figure 2). The values at all follow-up visits were significantly lower than those before injury ($P<.001$, $P=.006$, and $P=.004$, respectively).

In the hemiarthroplasty group, the EQ-5D index score decreased from $0.85\pm0.21$ before injury to $0.65\pm0.14$ at 4 months postoperatively. The score was $0.71\pm0.24$ at 12 months and $0.81\pm0.17$ at 24 months (Figure 2). The values at all follow-up visits were significantly lower than those before injury ($P<.001$, $P=.008$, and $P=.007$, respectively).  

**DISCUSSION**

The results of this study indicate an advantage in functional outcome and quality of life in favor of shoulder hemiarthroplasty when compared with ORIF with a locking plate in elderly patients with a displaced 4-part fracture of the proximal humerus partly, although most outcomes were not significantly different. However, despite a modern fixation technique and overall good primary reductions in the ORIF group, 23% of the patients had a severe complication requiring a reoperation. Regardless of the primary treatment, surgical or nonsurgical, the fracture resulted in a functional impairment of the shoulder and arm and a substantial negative effect on the patients’ HRQoL. The range of motion, functional, and HRQoL results favored the hemiarthroplasty group; however, the study failed to confirm the statistical significance of these differences in all fields. The analysis based on the current data indicates that 32 patients would have been required to provide enough data to identify a difference in the EQ-5D index or DASH scores between ORIF and hemiarthroplasty, but this provides valuable prospective data regarding the 2 treatments. In addition, data from the study can be used in future meta-analyses. The negative effect on the HRQoL was considerable, regardless of

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**Table 2**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex/Age, y</th>
<th>Group</th>
<th>Fracture Type</th>
<th>T-score</th>
<th>Valgus–Dorsal Angle, deg</th>
<th>Indication</th>
<th>Reoperation</th>
<th>Time Between Primary and Secondary Surgeries, mo</th>
<th>24-mo DASH Score</th>
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<tbody>
<tr>
<td>F/69</td>
<td>ORIF</td>
<td>4-GT</td>
<td>–1.5</td>
<td>130±21</td>
<td>120±16</td>
<td>Nonunion</td>
<td>Reosteosynthesis</td>
<td>11.4</td>
<td>23.7</td>
</tr>
<tr>
<td>F/74</td>
<td>ORIF</td>
<td>4-GT</td>
<td>–2.1</td>
<td>125±22</td>
<td>120±16</td>
<td>Fixation failure</td>
<td>Plate extraction</td>
<td>15.3</td>
<td>68.2</td>
</tr>
<tr>
<td>F/72</td>
<td>ORIF</td>
<td>4-GT</td>
<td>–2.4</td>
<td>125±22</td>
<td>120±16</td>
<td>Fixation failure</td>
<td>Plate extraction</td>
<td>11.6</td>
<td>33.9</td>
</tr>
<tr>
<td>F/79</td>
<td>HA</td>
<td>4-GT</td>
<td>–1.7</td>
<td>125±22</td>
<td>120±16</td>
<td>NA</td>
<td>Prosthesis replacement</td>
<td>3.3</td>
<td>0</td>
</tr>
<tr>
<td>M/76</td>
<td>HA</td>
<td>4-GT</td>
<td>–1.7</td>
<td>125±22</td>
<td>120±16</td>
<td>NA</td>
<td>Wound revision</td>
<td>3.8</td>
<td>15.1</td>
</tr>
<tr>
<td>F/79</td>
<td>HA</td>
<td>4-GT</td>
<td>–1.1</td>
<td>125±22</td>
<td>120±16</td>
<td>Prosthesis loosening</td>
<td>Prosthesis replacement</td>
<td>23.2</td>
<td>21.4</td>
</tr>
</tbody>
</table>

*Abbreviations: DASH, Disabilities of the Arm, Shoulder and Hand; deg, degrees; HA, hemiarthroplasty; ORIF, open reduction and internal fixation.*

**Table 3**

<table>
<thead>
<tr>
<th>Score</th>
<th>4 mo</th>
<th>12 mo</th>
<th>24 mo</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ORIF</td>
<td>HA</td>
<td>$P$</td>
</tr>
<tr>
<td>Constant</td>
<td>48.4</td>
<td>57.8</td>
<td>.048</td>
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<tr>
<td>Pain</td>
<td>9.2</td>
<td>8.8</td>
<td>.34</td>
</tr>
<tr>
<td>ADL</td>
<td>21.6</td>
<td>27.1</td>
<td>.047</td>
</tr>
<tr>
<td>ROM</td>
<td>21.6</td>
<td>27.1</td>
<td>.049</td>
</tr>
<tr>
<td>Strength</td>
<td>6.0</td>
<td>6.3</td>
<td>.63</td>
</tr>
<tr>
<td>DASH</td>
<td>31.7</td>
<td>33.4</td>
<td>.45</td>
</tr>
</tbody>
</table>

*Abbreviations: ADL, activities of daily living; DASH, Disabilities of the Arm, Shoulder and Hand; HA, hemiarthroplasty; ORIF, open reduction and internal fixation; ROM, range of motion.*
the primary treatment. The deterioration in EQ-5D index score group at 2 years in the ORIF group was 0.11. By comparison, the deterioration in EQ-5D index score in the hemiarthroplasty group was 0.04. Researchers believe that early functional outcomes of hemiarthroplasty for comminuted proximal humeral fractures are good in medically fit and cooperative patients.24

In the ORIF group, after 2 years, 23% of patients had a major reoperation. The fact that the majority of the reoperations were performed during the second year supports the recommendation that a 2-year follow-up should always be performed in studies with this type of fracture. The optimum technique for some of the more complex fracture patterns is not yet fully refined. Recent innovations, such as percutaneous pinning with a nail and 2 Schanz screws, have greatly increased the range of proximal humeral fractures that are amenable to open reduction and plate fixation. However, many complications were related to incorrect surgical techniques and, therefore, could be avoided.23,25,26

The results pertaining to functional outcomes after 2 years in the hemiarthroplasty group (DASH score, 9.2; Constant score, 78.4) are comparable with those in the ORIF group (DASH score, 15.3; Constant score, 65.1).

Three (23%) patients in the ORIF group experienced a complication (1 nonunion and 2 fixation failures) compared with 3 (15%) patients in the hemiarthroplasty group (1 dislocation, 1 infection, and 1 prosthetic loosening). These figures are similar to those previously reported in the literature.3 These studies comparable because they all included older patients with 4-part fractures. The comparison of Constant scores is highly age dependent. All fractures in the ORIF group healed, but the majority of patients were not satisfied with their results.

**CONCLUSION**

The results of this study indicate an advantage in functional outcomes and quality of life favoring shoulder hemiarthroplasty when compared with ORIF in elderly patients with displaced 4-part fractures of the proximal humerus, although most outcomes were not significantly different.

The main advantage appeared to be in pain and DASH scores at 24 months. However, although shoulder hemiarthroplasty achieved good results, most results were not significantly different, and 15.7% of patients had a severe complication requiring a major reoperation. The possible gain in function and HRQoL after treatment with hemiarthroplasty is likely justified in the healthy elderly patient with high functional demands and when an experienced surgeon performs the surgery. Conversely, the overall acceptable outcome and limited need for secondary surgical interventions in the ORIF group indicate that ORIF treatment is a sufficient method for elderly patients with lower functional demands or when a surgeon with adequate experience is not available.

**REFERENCES**


**Figure 2:** Health-related quality of life according to the EQ-5D (EuroQol Group, Rotterdam, The Nethelands) for all patients available at each follow-up (preinjury, n = 32; 4 mo, n = 31; 12 mo, n = 28; 24 mo, n = 27). 1 = best possible score, 0 = worst possible score. Abbreviations: HA, hemiarthroplasty; mth, months; ORIF, open reduction and internal fixation; Pre-OP, preoperatively.