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Arthroplasty for treatment of multifragment fractures of the proximal humerus

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Abstract

Introduction: Proximal humerus fractures are common and often require surgical intervention to restore function.

Aim: The study aimed to evaluate the effectiveness of arthroplasty in the treatment of multifragment fractures of the proximal humerus by comparing clinical outcomes of reverse shoulder arthroplasty and osteosynthesis, including functional outcomes, complication rates, postoperative pain, and the need for revision surgery.

Material and methods: The results were assessed using the Constant-Murley, DASH and visual analogue pain scales. The study was conducted from November 2019 to December 2024 and included 68 patients with complex proximal humerus fractures. All patients had multifragmentary fractures of the Neer 3–4 type.

Results and discussion: The primary comparative analysis was based on the 12-month follow-up assessment. At this time point, the mean Constant-Murley score in the arthroplasty group was 72.8 ± 6.3 points, compared with 58.4 ± 7.2 points in the osteosynthesis group ($p < 0.05$), while the mean DASH score was 22.3 ± 4.1 and 34.7 ± 5.6 points, respectively. The percentage of patients with good or excellent functional outcomes after arthroplasty reached 82%, while after osteosynthesis, it was only 54%. Pain levels according to the visual analogue scale at the 3-month follow-up were lower in the arthroplasty group (2.1 ± 0.7 points vs. 4.5 ± 1.1 points). The incidence of complications was 18% in the arthroplasty group and 36% in the osteosynthesis group, with repeat surgeries required in 10% and 24% of cases, respectively.

Conclusions: Arthroplasty was associated with better functional outcomes and lower pain intensity than osteosynthesis during the 12-month follow-up period and may represent a useful surgical option for selected patients with complex proximal humerus fractures.

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1. INTRODUCTION

Multifragment fractures of the proximal humerus are common in elderly patients in Ukraine and remain difficult to manage. According to national clinical protocols, complications following osteosynthesis, including nonunion and avascular necrosis, occur in more than 20%–30% of cases.[1] In older adults, these fractures are associated with reduced bone density and are among the most frequent upper extremity injuries.[2] They account for 5–6% of all fractures and rank as the third most common osteoporotic fracture.[3,4] Most cases result from low-energy trauma, such as a fall on an outstretched arm.

These injuries are often accompanied by marked displacement of bone fragments, which complicates treatment and rehabilitation. In practice, conservative treatment and osteosynthesis do not always ensure stable functional recovery, particularly in patients with comorbidities. Comparative studies have reported variable outcomes and persistent complications, including secondary displacement, nonunion, and avascular necrosis.[5,6]

Attempts to improve osteosynthesis have focused on implant design. Contemporary fixation systems may enhance stability and rehabilitation; however, their effectiveness remains limited in elderly patients.[7] Plate osteosynthesis has shown inconsistent results, with no significant differences between operated and contralateral shoulders in some studies,[8] while others report complication rates of up to 40% and reoperation rates of approximately 25%.[9]

Given these limitations, arthroplasty is increasingly considered as an alternative approach. Recent reviews have emphasised that treatment selection should be individualised according to patient age, fracture complexity, bone quality, and functional demands, with reverse shoulder arthroplasty increasingly used in elderly patients with complex fractures.[10] It has been associated with improved functional outcomes in selected cases,[5] while current evidence suggests that results depend on patient characteristics, fracture severity, and surgical technique.[11] Contemporary prosthetic designs aim to improve biomechanics and reduce complication risk, supporting earlier recovery.[12–14] However, outcomes remain variable, as also reflected in studies of osteosynthesis in unstable fractures.[15]

However, despite these developments, the comparative effectiveness of arthroplasty and osteosynthesis in patients with multifragment proximal humerus fractures remains insufficiently defined.

2. AIM

The aim of this study was to compare the effectiveness of arthroplasty and osteosynthesis in patients with multifragment fractures of the proximal humerus. The primary outcome was functional recovery assessed using the Constant-Murley score at 12 months after surgery. Secondary outcomes included upper limb function assessed by the DASH score, pain intensity measured by the visual analogue scale (VAS), complication rate, and the need for revision surgery.

3. MATERIAL AND METHODS

The study assessed the effectiveness of arthroplasty compared to osteosynthesis in the treatment of multifragment fractures of the proximal humerus. The study was conducted at the clinical base of the Department of Surgery No. 3 of Poltava State Medical University, Trauma Department of the Municipal Enterprise "1st City Clinical Hospital of Poltava City Council", from November 2019 to December 2024 and included 68 patients with multifragment fractures of the proximal humerus aged 18 to 85 years (mean age 61.5 years), including 30 men (44.1%) and 38 women (55.9%). All patients had Neer III-IV type multifragment fractures with a displacement of more than 1 cm or a rotational deviation of more than 45°. Concomitant rotator cuff injury was detected in 41 of 68 patients (60.3%).

For preoperative planning, dual-projection radiography was used, which was performed on the Calypso F MTOes Medical Marate SpA Digital X-ray system (Italy), which provided high image quality with minimal radiation exposure. Computed tomography with 3D reconstruction was performed on a GE Revolution EVO (64 slices) GE Healthcare Japan Corporation (Japan), which ensured accurate volumetric images for a detailed assessment of the fracture. In some cases, angiocontrast was additionally performed to assess the risk of avascular necrosis, which provided a high-precision visualisation of the vascular bed in the affected area.

Patients were allocated into two groups after inclusion in the study. This was a prospective comparative non-randomised study. Treatment allocation was determined by the treating surgical team based on patient age, fracture characteristics, bone quality, and the presence of rotator cuff injury. Reverse shoulder arthroplasty was preferentially selected for older patients with complex multifragment fractures and concomitant rotator cuff pathology, whereas osteosynthesis was performed in patients considered suitable for fixation. Consecutive eligible patients were enrolled during the study period.

The main group included 34 patients who underwent implantation of an artificial shoulder joint. Given the predominance of older patients and the presence of concomitant damage to the rotator cuff muscles, arthroplasty with a reverse implant design was used. The control group consisted of 34 patients who underwent combined osteosynthesis using PHILOS type LCP angle plates + transosseous through deltopectoral or transdeltoid access. Intraoperative X-ray control was used in both groups to assess the correctness of repositioning and fixation. During arthroplasty, cementless fixation of the components was used in 91% of cases due to the use of a traumatised stem, and cemented fixation in 9%.

Surgical interventions were performed under general or regional anaesthesia using Sevoflurane (manufacturer: Abbott Laboratories, USA), an inhaled anaesthetic with a rapid onset and end of action that is well tolerated by elderly patients. In the case of regional anaesthesia, Bupivacaine (manufacturer: AstraZeneca, Sweden) was used, which provided long-term blockade of peripheral nerves. The choice of anaesthesia type and dosage calculation was performed by

anaesthesiologists with appropriate qualifications and experience, including the patient's age, comorbidities and functional state of the cardiovascular system.

Postoperative treatment in both groups included early mobilisation of the arm, passive movements from the first day after surgery, thrombosis prophylaxis and antibiotic prophylaxis according to the current protocols of the Ministry of Health of Ukraine.[16]

Physical rehabilitation included a gradual load: isometric exercises were started in 4–6 weeks, active exercises in 2–3 months. In the early postoperative period, passive joint mobilisation under the supervision of a physiotherapist was applied, with low-load exercises aimed at preventing contractures. From the third month, active exercises with gradually increasing load were introduced. The rehabilitation programme was developed in accordance with contemporary recommendations for proximal humerus fracture recovery, including staged progression from passive mobilisation to active exercises and strengthening activities.[17]

Functional outcomes were assessed at 3, 6, and 12 months after surgery. However, the primary comparative analysis was based on the 12-month follow-up, which represented the predefined endpoint of the study. Pain intensity (VAS) was additionally evaluated at 3 months to assess early postoperative recovery, while complications and reoperations were recorded throughout the 12-month follow-up period.

Pain intensity was assessed using the VAS, which is a widely used tool for measuring subjective pain perception. The scale consists of a 10-cm horizontal line ranging from 0 (no pain) to 10 (the worst pain imaginable). Patients were asked to indicate the point that best corresponded to their perceived pain intensity, and the score was determined by measuring the distance from the starting point of the scale to the marked point. This method allowed for a standardised quantitative assessment of postoperative pain.

The study used additional methods to assess the patients' condition. All participants underwent examinations, including laboratory tests to determine their general health status, as well as additional studies, such as ultrasound examination of the joint using the Versana Active™, Solingen, Germany, to monitor possible complications. During the postoperative period, patients were regularly monitored to assess functional recovery. Antibiotics of three main groups were used: cephalosporins, glycopeptides and carbapenems, each of which had its indications depending on the severity of the infectious process and the pathogens isolated. The drugs were selected individually for each patient, depending on the patient's allergic history and their efficacy.

Statistical analysis was performed using standard statistical software. Continuous variables were presented as mean ± standard deviation (SD), while categorical variables were expressed as absolute numbers and percentages. The normality of data distribution was assessed using the Shapiro-Wilk test. For comparisons between the two study groups, the independent samples Student's t-test was applied for normally distributed variables, while the Mann–Whitney U test was used for non-normally distributed data. Categorical variables were compared using the chi-square test or Fisher's exact test when appropriate. A p-value of less than 0.05 was considered statistically significant.

The study was conducted as a prospective comparative study and approved by the Ethics Commission of the Poltava State Medical University (No. 13118). It was carried out in accordance with the Declaration of Helsinki.[18] All patients provided written informed consent to participate.

4. RESULTS

Baseline demographic and clinical characteristics of the study groups are presented in Table 1.

Functional outcomes were assessed during follow-up at 3, 6, and 12 months after surgery. The primary comparative analysis was performed using the 12-month assessment data. In the arthroplasty group, the mean Constant-Murley score at 12 months was 72.8 ± 6.3 points, compared with 58.4 ± 7.2

Table 1. Baseline demographic and clinical characteristics of the study groups.

Characteristic	Arthroplasty group (n = 34)	Osteosynthesis group (n = 34)	p-value
Age, years (mean ± SD)	68.4 ± 7.2	67.9 ± 6.8	0.74
Female, n (%)	24 (70.6%)	23 (67.6%)	0.79
Male, n (%)	10 (29.4%)	11 (32.4%)	–
Affected side (right), n (%)	19 (55.9%)	18 (52.9%)	0.81
Affected side (left), n (%)	15 (44.1%)	16 (47.1%)	–
Mean time from injury to surgery (days)	4.6 ± 1.3	4.8 ± 1.5	0.58
Neer fracture type III, n (%)	15 (44.1%)	16 (47.1%)	0.80
Neer fracture type IV, n (%)	19 (55.9%)	18 (52.9%)	–
Concomitant rotator cuff injury, n (%)	21 (61.8%)	20 (58.8%)	0.81
Diabetes mellitus, n (%)	6 (17.6%)	7 (20.6%)	0.76
Hypertension, n (%)	18 (52.9%)	17 (50.0%)	0.81

points in the osteosynthesis group ($p < 0.05$). The proportion of good or excellent outcomes was 82% in the arthroplasty group and 54% in the osteosynthesis group, with DASH scores of 22.3 ± 4.1 and 34.7 ± 5.6, respectively ($p < 0.05$). Key functional outcomes are summarised in Table 2.

At 3 months after surgery, the mean VAS pain score was 2.1 ± 0.7 points in the arthroplasty group, whereas it was 4.5 ± 1.1 points in the osteosynthesis group. One year after surgery, pain had virtually disappeared in 78% of patients in the arthroplasty group, whereas 41% of patients in the osteosynthesis group continued to report moderate pain.

Complications were recorded in 18% of cases in the arthroplasty group and 36% in the osteosynthesis group. Repeated surgical interventions were required in 10% of cases in the arthroplasty group and in 24% of patients after osteosynthesis.

Detailed complication profiles are presented in Table 3. The most frequent complications in the arthroplasty group were implant instability, limited shoulder mobility, and infection, whereas secondary displacement, nonunion, and avascular necrosis predominated in the osteosynthesis group.

Pain intensity was significantly lower in the arthroplasty group at 3 months after surgery. Overall complications and reoperations were numerically less frequent in the arthroplasty group, although these differences did not reach statistical significance.

5. DISCUSSION

Keun Oh et al.[19] investigated the use of minimally invasive osteosynthesis with plates for the treatment of unstable multifragmentary fractures of the proximal humerus. The researchers note that the technique of minimally invasive osteosynthesis with plates demonstrates reliable radiographic and functional results in the treatment of three- and four-fragment fractures of the proximal humerus. These findings are consistent with previous reports, indicating that while osteosynthesis can provide functional restoration, arthroplasty is associated with improved functional outcomes. Minarro and Sanchez-Sotelo[20] summarised current evidence indicating that reverse shoulder arthroplasty has become one of the preferred treatment options for complex proximal humerus fractures, particularly in elderly patients and in the presence of rotator cuff insufficiency. These conclusions align with the patient characteristics and outcomes observed in the present study.

This interpretation is supported by more recent evidence. Iking et al.,[21] in a systematic review comparing reverse total shoulder arthroplasty and locked plate fixation in elderly patients with proximal humeral fractures, reported superior functional outcomes and lower rates of mechanical failure following arthroplasty. Similarly, the present study demonstrated higher Constant-Murley scores and lower

Table 2. Functional outcomes of arthroplasty and osteosynthesis groups at 12 months after surgery.

Outcome	Arthroplasty group (n = 34)	Osteosynthesis group (n = 34)	*p*-value
Constant-Murley score (mean ± SD)	72.8 ± 6.3	58.4 ± 7.2	<0.05
Good/excellent results, n (%)	28 (82%)	18 (54%)	–
DASH score (mean ± SD)	22.3 ± 4.1	34.7 ± 5.6	<0.05

Note: *p*-value was not calculated for descriptive categorical outcome.

Table 3. Pain and complications in arthroplasty and osteosynthesis groups.

Outcome	Arthroplasty group (n = 34)	Osteosynthesis group (n = 34)	*p*-value
Pain (VAS, 3 months, mean ± SD)	2.1 ± 0.7	4.5 ± 1.1	<0.001
Moderate pain at 12 months, n (%)	7 (22%)	14 (41%)	0.114
Overall complications, n (%)	6 (18%)	12 (36%)	0.168
Reoperations, n (%)	3 (10%)	8 (24%)	0.186
Most frequent complications, n (%)			
Infection	1 (2.9%)	–	–
Implant instability	2 (5.9%)	–	–
Limited mobility	3 (8.8%)	–	–
Secondary displacement	–	4 (11.8%)	–
Nonunion	–	5 (14.7%)	–
Avascular necrosis	–	3 (8.8%)	–

Note: *p*-values were calculated for the main comparative outcomes. Percentages are calculated within each treatment group. Individual complication subtypes were reported descriptively because of the small number of events.

pain levels in the arthroplasty group. These findings are further supported by the systematic review conducted by Mekhail et al.,[22] who compared reverse total shoulder arthroplasty with other surgical fixation methods for proximal humerus fractures in elderly patients. The authors reported that reverse shoulder arthroplasty was associated with better clinical outcomes and a lower likelihood of revision procedures compared with fixation techniques in appropriately selected patients. These results correspond with the present findings, where arthroplasty was associated with better functional recovery and fewer reoperations during follow-up.

Bents et al.[23] reported that complications remain an important concern following reverse shoulder arthroplasty for proximal humeral fractures, although overall functional outcomes are generally favourable. Their systematic review identified instability, infection, and revision surgery among the most frequently reported complications. Similar patterns were observed in the present study, although complication rates remained lower in the arthroplasty group than after osteosynthesis.

Lee et al.[24] highlighted that avascular necrosis of the humeral head remains a clinically significant complication following proximal humerus fractures and shoulder reconstruction procedures. This observation underscores the importance of careful postoperative monitoring in patients undergoing shoulder arthroplasty. Postoperative infection represents another clinically relevant complication. Li et al.[25] found that 15.7% of patients experienced infectious complications at the surgical site. In their study, the most detected pathogen was *Staphylococcus aureus*. Smokers were more prone to infectious complications after surgery ($p = 0.03$). Similar concerns regarding postoperative infection were identified in this cohort, although the overall incidence of infectious complications remained low.

The study by Nguyen Manh et al.[26] also analysed the clinical and radiological characteristics of complex fractures of the proximal humerus and evaluated the results of shoulder hemiarthroplasty for such injuries. These observations align with the present results, indicating that hemiarthroplasty provides satisfactory functional outcomes, although complications may still occur. Similarly, reverse arthroplasty has been shown to be effective in patients with rotator cuff pathology, providing stable shoulder function with generally low pain levels. Tấn et al.[27] also reported that most patients experienced mild or no pain on the VAS, with no surgery-related failures. This is consistent with previous reports demonstrating favourable functional outcomes following reverse arthroplasty, although some complications may occur. A recent meta-analysis by Han et al.[28] demonstrated that reverse shoulder arthroplasty provides superior functional recovery and range of motion compared with hemiarthroplasty in elderly patients with osteoporotic proximal humerus fractures. These results further reinforce the favourable outcomes observed after arthroplasty in the current study.

Longer-term evidence also supports the effectiveness of reverse shoulder arthroplasty in proximal humerus fractures. Allio et al.[29] reported that satisfactory functional outcomes can be maintained beyond five years after surgery, particularly when tuberosity healing and reinsertion are achieved. Although the follow-up period in the present study was limited to 12 months, these findings suggest that favourable early outcomes may translate into sustained long-term shoulder function.

In addition to current implant designs, emerging materials may further expand treatment options in shoulder arthroplasty. Fine et al.[30] highlighted the potential role of pyrocarbon implants, although further evidence is required before their routine use in fracture management can be recommended.

The present findings are in agreement with contemporary evidence supporting the use of arthroplasty for the management of complex proximal humerus fractures. At the same time, the results underline the role of implant selection, surgical technique, and postoperative management in shaping clinical outcomes. Several limitations should be considered when interpreting the findings. The study included a relatively small number of patients and was conducted at a single clinical centre. In addition, the follow-up period was limited to 12 months and therefore did not allow assessment of long-term implant durability and functional outcomes. Consequently, the results should be interpreted with caution. Further multicentre studies involving larger patient populations and longer follow-up periods are required to confirm these findings.

6. CONCLUSIONS

In this prospective comparative study, arthroplasty was associated with better shoulder function and lower pain intensity than osteosynthesis in patients with multifragment proximal humerus fractures during the 12-month follow-up period. Postoperative complications and reoperations were also numerically less frequent in the arthroplasty group. These findings suggest that arthroplasty may represent a useful surgical option for selected patients with complex proximal humerus fractures.

Conflict of interest
None declared.

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