УДК 616.717.4-001.5-007.234:617.572-089.168

DOI: http://dx.doi.org/10.15674/0030-59872025137-44

Analysis of postoperative complications in the surgical treatment of proximal humeral fractures in patients with decreased mineral bone density

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Objective. To conduct a comparative retrospective analysis of the impact of postoperative complications on functional outcomes following different surgical treatment methods for proximal humeral fractures of AO/OTA types 11-B and 11-C in patients over 45 years old with decreased bone mineral density. Methods. The study analyzed the surgical treatment outcomes and postoperative complications in 102 patients aged (61.1 ± 8.1) years, who were divided into three groups based on the treatment method: (1) open reduction and internal fixation (ORIF) using a PHILOS plate (n = 50); (2) ORIF with a PHILOS plate combined with 3D-printed PLA implants (n = 44); (3) primary reverse total shoulder arthroplasty (RTSA) using a newly developed total reverse endoprosthesis (n = 8). Functional outcomes in patients with complications were assessed using the Constant-Murley Score at 3, 6, and 12 months postoperatively and analyzed based on individual preoperative parameters and treatment methods. Results. A total of 30 postoperative complications were recorded, the most common being superficial infection (7.8 % of the total population), secondary displacement (6.9 %), varus malalignment of fragments (6.9 %), and avascular necrosis of the humeral head (3.9 %). The highest number of complications was observed in Group (1), with 19 patients affected, accounting for 38 % . For all complications except avascular necrosis, a significant improvement in functional outcomes was observed between 3 and 12 months postoperatively. The mean Constant-Murley Score in patients with complications at 12 months postoperatively was (78.7 ± 8.5). Conclusions A retrospective analysis of postoperative complications following different surgical treatment methods established that, compared to other options, reverse total shoulder arthroplasty (RTSA) is a modern and optimal surgical treatment option for proximal humeral fractures of AO/OTA types 11-B or 11-C in the context of severe bone mineral density reduction, particularly in elderly patients.

Мета. Провести порівняльний ретроспективний аналіз впливу післяопераційних ускладнень на функціональні результати за різних методик хірургічного лікування переломів проксимального відділу плечової кістки типів АО/ОТА 11-В, 11-С у пацієнтів старших за 45 років із зниженням мінеральної щільності кісткової тканини. Методи. Вивчено результати хірургічного втручання та післяопераційні ускладнення в 102 осіб віком (61,1 ± 8,1) року, які за методом лікування розділені на 3 групи: (1) відкрита репозиція та накістковий металоостеосинтез пластиною PHILOS (n = 50); (2) відкрита репозиція та накістковий металоостеосинтез пластиною PHILOS із використанням 3D–імплантатів PLA (n = 44); (3) первинне RTSA розробленим тотальним реверсивним ендопротезом (n = 8). Функціональні результати пацієнтів із ускладненнями оцінювали за системою Constant-Murley Score через 3, 6, 12 міс. після хірургічного втручання й аналізували залежно від індивідуальних передопераційних показників і методики лікування. Результати. Усього зафіксовано 30 випадків післяопераційних ускладнень, з яких найпоширенішими були поверхнева інфекція (7,8 % від загальної популяції), вторинне зміщення (6,9 %), варусне зміщення відламків (6,9 %), аваскулярний некроз головки плечової кістки (3,9 %). Найбільша кількість ускладнень зафіксована в (1) групі — 19 осіб (38 %). Для всіх видів ускладнень, окрім аваскулярного некрозу, встановлено достовірне покращення функціональних результатів у терміни з 3 до 12 міс. Середній бал Constant-Murley Score в осіб з ускладненнями через 12 міс. після втручання становив (78,7 ± 8,5). Висновки. Ретроспективний аналіз післяопераційних ускладнень за різних методик хірургічного лікування довів, що RTSA є сучасним і оптимальним варіантом операції проксимальних переломів плечової кістки АО/ОТА 11-В або 11-С на фоні вираженого зниження мінеральної щільності кісткової тканини, особливо в пацієнтів похилого віку. Ключові слова. Перелом проксимального відділу плечової кістки, реверсивна тотальна артропластика плечового суглоба, RTSA, ускладнення, Constant-Murley Score, мінеральна щільність кісткової тканини, функціональне оцінювання

Keywords. Proximal humerus fracture, reverse total shoulder arthroplasty, RTSA, complications, Constant-Murley Score, reduced bone mineral density, functional assessment

Introduction

Fractures of the proximal humerus (FPH) are the second most common upper extremity traumas and account for 40 to 82 % of all injuries, and 5–7 % of musculoskeletal ones [1, 2]. In recent times, particularly in developed nations, shoulder injuries have been increasingly recognized not only as a medical concern but also as a source of substantial economic loss. These injuries and the resultant pain significantly decrease the quality of life, often leading to a considerable number of hospital stay days on average. For example, among the working population, up to 30 % of patients report daily pain in the shoulder joint within a year after the injury [3, 4]. Impaired function of the upper extremity, in particular the shoulder, creates critical limitations in professional and daily activities, leads to deterioration of health due to reduced activity, reduced income and overall quality of life. Therefore, a significant proportion of complications and repeated interventions in the case of surgical treatment of shoulder injuries is becoming a real challenge for the healthcare system in the world [3, 4]. Mostly, FPHs are observed in patients over 50 years of age secondary to a decrease in bone mineral density, which complicates the choice of the optimal treatment method to ensure stable fixation and early mobilization of movements [5–8]. Unlike most two-fragmentary FPHs, when it is possible to obtain good functional results during conservative treatment, in the case of unstable 3- and 4-fragmentary FPHs (AO/OTA 11-B, 11-C), which are most common in the age group over 50 years, positive results can be achieved only with the help of surgical intervention [9, 10].

Recently, in the treatment of FPH fractures in patients with reduced bone mineral density, there has been an increase in the use of reversible total shoulder arthroplasty (RTSA), compared with open reduction and internal fixation (ORIF) and hemiarthroplasty (HA) [11–14]. Due to the biomechanically proven principles of operation and design features of reversible RTSA endoprostheses, functional outcomes as assessed by the Constant-Murley Score have been significantly improved, as they provide a relatively better impact on health-related quality of life than other treatment methods [15]. However, overall, the rate of complications and reoperations for shoulder injuries remains high, and the analysis of complications and functional outcomes in people with FPH fractures is relevant. Thus, according to a French study, patients with shoulder pain lost 1.8 to 8.1 years of work during a 9-year follow-up period, and the decrease in quality of life may persist even after retirement [4]. The literature highlights concerns regarding the insufficient quality of studies and the lack of data on the relative proportion and distribution by type of complications associated with the surgical treatment of FPH [16]. The indicators are mostly obtained from meta-analyses or information summarized by different clinics and even countries, which makes it difficult to predict the effectiveness of surgical treatment of FPH fractures and the dynamics of functional results acceptable to the patient or the need for repeated interventions.

Purpose: to conduct a comparative retrospective analysis of the impact of postoperative complications on functional results with different methods of surgical treatment of fractures of the proximal humerus of types AO/OTA 11-B, 11-C in patients older than 45 years with reduced bone mineral density.

Material and methods

The study materials were reviewed and approved by the Bioethics Committee at the State Establishment "Professor M. I. Sytenko Institute of Spine and Joint Pathology of the National Academy of Medical Sciences of Ukraine" (protocol No. 191 dated 22.04.2019, No. 229 dated 20.02.2023). All patients involved in the study were familiarized with the plan of surgical interventions and signed an informed consent.

The study involved an assessment of anatomical and functional results of surgical treatment of 102 patients (mean age 61.1 ± 8.1; range 45–78 years) with reduced bone mineral density and three- and 4-fragmentary fractures of the lumbar spine of types 11-B, 11-C according to the AO/OTA classification, as well as postoperative complications recorded in this population. The severity of bone mineral density loss was determined by radiographs of the humerus in the anteroposterior projection with the calculation of the cortical index (CI). According to the treatment method, patients were divided into groups as follows:

– I — open reduction, bone-on-bone metal osteosynthesis with a PHILOS plate, period 2009–2022 (n = 50);

– II — open reduction and bone-on-bone metal osteosynthesis with a PHILOS plate using 3D PLA implants were applied, period 2015–2022 (n = 44);

– III — primary RTSA was performed with a developed total reversible endoprosthesis, the indication for which in all cases was fractures of the AO/OTA 11-B or 11-C type secondary to a pronounced decrease in bone mineral density; period 2015–2023 (n = 8).

The detailed procedure for performing the operations, as well as the examinations in the pre- and postoperative periods, has been described in a previous study [17]. The functional results of the treatment itself were assessed using the Constant-Murley Score system 3, 6, and 12 months after surgery, and patients with complications were analyzed depending on individual preoperative indicators and treatment methods.

In the statistical analysis, categorical variables were presented as percentages, demographic data as means and ranges, and quantitative estimates were presented as sample means and standard deviations (SD), expressed as (M ± SD). To visualize the comparison of sample values, graphs with SD markers were constructed. When studying the differences in mean values, ANOVA and Tukey's test with a significance level of $p < 0.01$ were used.

Results

According to the results of the treatment of 102 patients, 30 cases of postoperative complications were recorded. Their distribution by type and treatment group (Table 1) showed a higher number of complications in group I both in absolute value and in proportion.

In group I, 4 patients (2 women, 2 men) were diagnosed with avascular necrosis of the humeral head due to an unfavorable ORIF outcome (no signs of consolidation, migration of the metal structure), so the structure was removed and RTSA was performed 6 to 12 months after the primary surgical intervention; in 6 patients, a secondary displacement of the greater tubercle up to 10-15 mm was detected a month after the operation; in 2 patients, varus migration of the head occurred without significant impairment of the function of the shoulder joint; in one patient, complete destabilization of the metal structure occurred, which led to its removal 3 months after installation.

In group II, in the postoperative period, in one patient, a perforation of the humeral head fragment occurred with a screw 6 weeks after the operation, and it was removed under C-Arm control through a skin puncture under local anesthesia; in one patient, 3 months after surgery, secondary displacement of the lesser tubercle up to 8-10 mm occurred; in 5 patients, varus displacement of the humeral head up to 5 mm was diagnosed, but this did not lead to perforation with screws. Signs of avascular necrosis of the humeral head were not recorded in patients of group II.

Table 1

Distribution of postoperative complications by type and treatment group

Complication	Group		
	I (n = 50)	II (n = 44)	III (n = 8)
Superficial infection	5	2	1
Secondary displacement	6	1	—
Varus displacement of fragments	2	5	—
Avascular necrosis of the humeral head	4	—	—
Perforation of the fragment of the humeral head with a screw	1	1	—
Destabilization of the metal structure	1	—	—
Dislocation of the endoprosthesis	—	—	1
Total	19	9	2

In group III, one case of superficial infection and one dislocation of the endoprosthesis were recorded among patients.

In all cases, superficial infection was eliminated by antibacterial local and systemic therapy.

Determination of the directions of further analysis implied consideration of the demographic and preoperative indicators of the patients (Table 2). Within the age range of patients 45–78 years, the division into age subgroups was carried out with a 10-year grouping interval, namely 45–54, 55–64 and 65–78 years; the last subgroup was expanded to 78 years, since in total there were only 6 subjects over 75 years of age and their allocation to a separate age subgroup was inappropriate.

There were no differences in mean age, sex ratios and side of injury between subgroups of patients with and without complications. Among patients in the age subgroups 55–64 and 65–78 years, complications were recorded on average twice as often as in patients aged 45–54 years. In the subgroup of patients with complications, the proportion of type 11-C fractures was higher, compared to patients without complications.

During the analysis of bone mineral density indicators for patients without complications, the cortical index was (0.386 ± 0.020), with complications (0.374 ± 0.025), and among patients who had a CI within 0.38 ÷ 0.40, the proportion of complications was 20.2 %, in the case of CI ≤ 0.36 it was as high as 53.6 %.

When comparing the functional results of patients on the CMS scale within each individual observation time (3, 6 and 12 months after the intervention), no significant difference was obtained between

Table 2

Patient demographics and preoperative characteristics (N = 102)

Indicator	Patient		Category	Person	
	with complications	without complications		with complications	without complications
Number (proportion)	30 (29.4 %)	72 (70.6 %)	Вікова група, кількість (частка):		
Age, years	63.2 ± 7.6	60.3 ± 8.2			
Sex, number (proportion): female/male	23 (76.7 %) / 7 (23.3 %) 22 (73.3 %) / 8 (26.7 %)	55 (76.4 %) / 17 (23.6 %) 56 (77.8 %) / 16 (22.2 %)	45–54 років (n = 19) 55–64 років (n = 44) 65–78 років (n = 39)	3 (15.8 %) 13 (29.5 %) 14 (35.9 %)	16 (84.2 %) 31 (70.5 %) 25 (64.1 %)
Side of injury, number (proportion): right/left	22 (73.3 %) / 8 (26.7 %)	56 (77.8 %) / 16 (22.2 %)	Методика лікування, кількість (частка):		
Type of fracture according to AO/OTA, number (proportion): 11-B / 11-C	17 (56.7 %) / 13 (43.3 %)	54 (75.0 %) / 18 (25.0 %)	I група (n = 50) II група (n = 44) III група (n = 8)	19 (38.0 %) 9 (20.5 %) 2 (25.0 %)	31 (62.0 %) 35 (79.5 %) 6 (75.0 %)

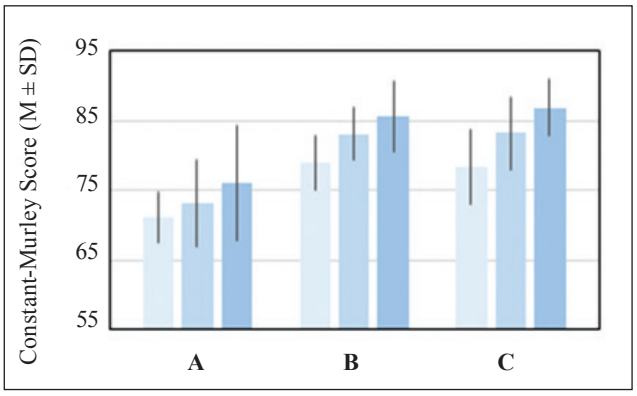

Fig. 1. Functional outcomes of patients with and without complications; X-axis — comparison subgroups: A — complications excluding superficial infection (n = 22), B — superficial infection (n = 8), C — without complications (n = 72). Values for different terms after intervention (months) are indicated by different colors: light blue — 3, blue — 6, blue — 12

the indicators of patients with superficial infection (n = 8) and people without complications: at the same time, the average values in these subgroups had significant ($p = 0.005 < 0.01$) positive changes from 3 to 12 months of observation (Fig. 1). Given that patients with superficial infection achieved a functional outcome at the level of those without complications, their data were not taken into account in further study of postoperative complications.

For the following study, three subgroups of common complications were selected in sufficient numbers for comparative analysis: secondary displacement (n = 7), varus displacement of fragments (n = 7), and avascular necrosis of the humeral head (n = 4). Since in the general population the proportion of complications varies for different types of fractures and values of bone mineral density indicators, a more detailed examination of the individual preoperative indicators of patients was carried out for the selected subgroups, which revealed different proportions of AO/OTA 11-B and 11-C fractures, as well as the average CI values for these subgroups (Table 3): varus displacement of fragments was observed mainly after type 11-B fractures, secondary displacement after 11-C, avascular necrosis of the humeral head in the case of 11-C with CI values ≤ 0.36.

For subgroups of patients with the three most common postoperative complications in this study, the dynamics of the Constant-Murley Score scale was also analyzed 3, 6, and 12 months after the intervention (Table 3). A significant improvement in functional outcomes was found in patients with secondary displacement from 3 to 6 months ($p = 0.001 < 0.01$), and for those with varus displacement of fragments from 3 to 12 months after the injury ($p = 0.003 < 0.01$). In patients with avascular necrosis of the humeral head, the Constant-Murley Score deteriorated from (72.5 ± 2.9) in 3 months to (62.5 ± 2.9) in 6 months after the intervention.

Discussion

The demographics of the patients who participated in the study, and in particular the subgroups with complications, correspond to the known global trends in the prevalence of FPH fractures mainly in the age category of people over 50 years [2] and the average European indicators of a 2–3 times higher rate of such fractures among women [1, 6, 7].

The overall rate of complications in the study population was 29.4 %, the highest value by treatment group — 38 % in group I. Systematic reviews and study reports of recent years contain conflicting values and assessments of the rate of postoperative com-

Table 3

Preoperative indicators and functional outcomes of patients by type of complications

Indicator	Secondary displacement (n = 7)	Varus displacement of fragments (n = 7)	Avascular necrosis of the humeral head (n = 4)
Proportion in the general population	6.9 %	6.9 %	3.9 %
Age, years	58.8 ± 9.5	67.9 ± 4.2	66.3 ± 8.2
Cortical index	0.380 ± 0.020	0.366 ± 0.018	0.358 ± 0.005
Number (proportion) of AO/OTA fractures 11-B / 11-C	2 (28.6 %) / 5 (71.4 %)	6 (85.7 %) / 1 (14.3 %)	1 (25 %) / 3 (75 %)
Constant-Murley Score in – 3 months;	70.9 ± 2.3* **	70.0 ± 5.0*	72.5 ± 2.9* **
– 6 months;	75.7 ± 1.9**	75.0 ± 5.0	62.5 ± 2.9**
– 12 months after intervention	77.1 ± 3.9*	81.4 ± 6.3*	62.5 ± 2.9*

Note. Different numbers of * indicate values that are significantly different from each other within the same column of the table according to the results of comparison using the Tukey test.

plications with different methods of surgical treatment of FPH fractures.

In [18], it was reported that, in 173 patients over 60 years of age, ORIF for the treatment of FPH had a complication rate of 44 % and a reoperation rate of 11 %; the failure rate was 39 % for 3-fragment fractures and 45 % for 4-fragment fractures. The average complication rate after shoulder surgery was 42.6 % [1]. According to [19], the overall complication rate after RTSA was 12.1 %, with dislocation being the most common (2.5 %). It was also noted that compared to patients after ORIF or hemiarthroplasty, older or female patients who underwent RSA had a higher Charlson comorbidity index. Patients who underwent ORIF had a higher incidence of both complications (23.03 % vs. 18.62 %) and reoperations (20.3 % vs. 10.3 %) than patients who underwent RSA [12]. After revision shoulder arthroplasty, complications occurred in 34 % of cases, with 20 % requiring reoperation [20].

The proportion of patients with avascular necrosis reported in these studies, 3.9 %, is consistent with the results of other investigators (4 %) [1].

Thus, the overall proportion of complications and the percentage of their individual types found in this study are generally within the ranges of postoperative complication estimates reported in the literature for similar types of surgical procedures.

The mean CMS in the subgroup of patients with complications is lower than in the remaining patients (Fig. 1), but the results 12 months after surgery, except for those with avascular necrosis, are satisfactory. The average CMS score for patients with complications after 12 months was (78.7 ± 8.5). This suggests an effective selection of treatment method and management of complications, aligning with current RTSA practices as the complication rate is lower than the group average.

Analysis of negative ORIF results in patients of group I, where porous PLA implants could be used, allowed us to propose a differentiated approach to the choice of surgical treatment for people with AO/OTA 11-B, 11-C type FPH fractures, according to which in case of CI = 0.4–0.5, ORIF is considered appropriate and necessary; under CI < 0.4, ORIF is possible, with the mandatory use of 3D-porous polylactide implants as a reinforcing material; for AO/OTA 11-C type; CI < 0.4, in case of technical impossibility of stable ORIF, primary reversible total hip arthroplasty is necessary [17].

The initial use of RTSA in cases of AO/OTA 11-B, 11-C type AO/OTA fractures and in conditions where ORIF was technically impossible allowed for positive results in 75 % of cases 6 to 12 months after surgery with an average CMS score in the subgroup (81.2 ± 6.4) with restoration of shoulder joint function in the absence of signs of instability of the endoprosthesis components [17]. However, a limitation of this study is the relatively small number of both the total number of people with RTSA and the number of patients with complications among them, which makes it impossible to conduct a quantitative analysis to identify the main risk factors for postoperative complications during this treatment method. The recommendations of the European Society of Trauma and Emergency Surgery (ESTES) for FPH in the elderly indicate that the risk factors for failure in the case of HA are age, sex, the presence of comminuted tubercles, avulsion fractures, and decreased bone mineral density. There is a clear trend towards reverse shoulder arthroplasty, especially in people over 75 years of age, while RTSA, especially secondary to

other surgical interventions, provides good clinical results with a low number of revisions [21]. This technique is considered the gold standard for the treatment of 3- and 4-part displaced fractures in the elderly [16].

The information provided [15] proves that conservative therapy and RTSA are associated with a lower risk of need for re-intervention. At the same time, a number of authors believe that due to the complexity of the RTSA technique, the surgeon should have a complete design of the fracture characteristics, available surgical options and possible complications that may occur, as this will increase safety and ensure satisfactory clinical results [1]. According to the observations of Tagliero et al. [20], among patients with negative consequences of RTSA, 12 % had persistent dislocations, and 10 % had radiological signs of loosening of the endoprosthesis stem. Analysis of the results of RTSA, including the assessment of previous conservative or surgical treatment of FPH, type of fracture, type of reversible endoprosthesis, type of prosthesis or osteosynthesis of the tubercles, proved the lack of statistical significance of factors affecting the risk of endoprosthesis dislocation [20]. Younger age and diabetes mellitus at RTSA significantly increased the risk of reoperation ($p = 0.013$ and $p = 0.037$, respectively). The authors noted a trend towards an increased risk of reoperation in patients who had failed ORIF in FPH at the first stage (hazard ratio = 2.95), but without reaching statistical significance [20]. When comparing the two groups (total 125 people, ORIF in 66 (52.8 %), RTSA in 59 (41.2 %), both groups had comparable Charlson indices) it was shown that the overall complication rate was 37.8 for ORIF and 22.0 % for RTSA, with revision rates of 12.1 % and 5.1 %, respectively [22]. Multivariate analysis did not show significant differences between the two types of surgery ($P = 0.500$), but age was an independent significant factor in overall complications ($P = 0.018$) [22]. Risk factors for serious complications after ORIF were low bone mineral density, varus impression FPH, posteromedial fracture line with a distance between fragments greater than 8 mm, diaphyseal displacement > 4 mm, and multifragmentary tubercle fractures. For RTSA, more complications were observed in patients with a higher Charlson index, diabetes mellitus, and tubercle fractures, although the authors emphasize that the Neer classification system was not predictive in either group [22].

It should be noted that for each surgical technique for the treatment of FPH, the incidence of complications has been decreasing in recent years [13]. This is due to the improvement of biomechanical characteristics and implant design for both ORIF and RTSA, combined with the accumulation of experience of surgeons [23]. An important factor is the abandonment of hemiarthroplasty and the preference for RTSA in FPH, especially in patients over 65 [14].

Thus, the choice of RTSA compared to other surgical options is a modern and optimal way to treat proximal humeral fractures AO/OTA 11-B or 11-C against the background of a pronounced decrease in bone mineral density, especially in elderly patients.

However, evidence-based recommendations are still lacking [21]. In patients with AO/OTA 11-B, 11-C FPH, RTSA is a reliable surgical treatment option with predictable functional outcomes and few revisions [21]. Hemiarthroplasty is appropriate if fixation and healing of the tubercles are achievable. Unfortunately, this is not the case in most fractures. Risk factors for failure include age, sex, comminuted tubercle fractures, avulsion fractures, and low bone mineral density [21].

So, can RTSA be considered the gold standard for the treatment of proximal humeral fractures in the elderly when ORIF is not technically feasible and conservative treatment fails to relieve pain and restore upper limb function? The answer is currently unknown. The literature suggests mostly low-quality studies, which requires further work to achieve a complete understanding of this important issue.

Conclusions

Retrospective analysis of postoperative complications with different surgical methods of treating proximal humeral fractures of types AO/OTA 11-B, 11-C in patients over 45 with reduced bone mineral density revealed a higher proportion of complications in patients who underwent open reduction and bone-on-bone metal osteosynthesis with the PHILOS plate (38% of the group).

Comparative analysis of functional outcomes with complications established that patients with superficial infection did not differ from those without complications in terms of the dynamics of functional changes during the observation period ($p = 0.005 < 0.01$); patients with secondary and varus displacement of fragments had a significant improvement in functional outcomes in the period from 3 to 12 months ($p = 0.001 < 0.01$; $p = 0.003 < 0.01$, respectively).

Avascular necrosis of the humeral head in this population was recorded only in patients who underwent open reduction and bone-on-bone metal osteosynthesis with the PHILOS plate, mainly after type 11-C

fractures with CI values ≤ 0.36. In them, CMS indicators deteriorated from (72.5 ± 2.9) in 3 months to (62.5 ± 2.9) in 6 months after the intervention.

RTSA, compared with other techniques, is a modern and optimal option for surgical treatment of proximal humeral fractures AO/OTA 11-B or 11-C against the background of a pronounced decrease in bone mineral density, especially in elderly patients.

Conflict of interest. The authors declare no conflict of interest.

Prospects for further research. In the future, studies with a more detailed analysis of the results of reverse arthroplasty of the shoulder joint using individually printed on a 3D laser printer from porous titanium endoprosthesis components are of interest.

Funding information. No benefit in any form has been and will not be received from a commercial party related directly or indirectly to the subject of this article.

Authors' contribution. Makarov V. B. — concept and design, collection and processing of materials, analysis of the obtained data, writing the text. Korzh M. O. — writing and editing the text.

References

1. Czarnecki, P., Falis, M., Bonczar, M., Ostrowski, P., Wcisłek, J., & Romanowski, L. (2024). Assessing complications and functional outcomes in proximal humerus fracture management: a retrospective comparison between conservative and intramedullary nailing treatments. *European journal of orthopaedic surgery and traumatology: orthopedie traumatologie, 34*(3), 1427–1433. https://doi.org/10.1007/s00590-023-03822-5
2. Iglesias-Rodríguez, S., Domínguez-Prado, D. M., García-Reza, A., Fernández-Fernández, D., Pérez-Alfonso, E., García-Piñeiro, J., & Castro-Menéndez, M. (2021). Epidemiology of proximal humerus fractures. *Journal of orthopaedic surgery and research, 16*(1), 402. https://doi.org/10.1186/s13018-021-02551-x
3. Yanik, E. L., Alvarez, C., Cleveland, R. J., Nelson, A. E., & Golightly, Y. M. (2024). Occupational tasks associated with shoulder pain and upper extremity disability: a cross-sectional study in the Johnston County Osteoarthritis Project. *BMC musculoskeletal disorders, 25*(1), 374. https://doi.org/10.1186/s12891-024-07487-x
4. Godeau, D., Fadel, M. & Descatha, A. (2022/) Factors associated with limitations in daily life and at work in a population with shoulder pain. *BMC musculoskeletal disorders, 23*, 777. https://doi.org/10.1186/s12891-022-05638-6
5. Leino, O. K., Lehtimäki, K. K., Mäkelä, K., Äärimaa, V., & Ekman, E. (2022). Proximal humeral fractures in Finland: trends in the incidence and methods of treatment between 1997 and 2019. *The bone and joint journal, 104-B*(1), 150–156. https://doi.org/10.1302/0301-620X.104B1.BJJ-2021-0987.R1
6. Patel, A. H., Wilder, J. H., Ofa, S. A., Lee, O. C., Iloanya, M. C., Savoie, F. H., 3rd, & Sherman, W. F. (2021). How age and gender influence proximal humerus fracture management in patients older than fifty years. *Journal of shoulder and elbow surgery international, 6*(2), 253–258. https://doi.org/10.1016/j.jseint.2021.11.007
7. Patel, A. H., Wilder, J. H., Ofa, S. A., Lee, O. C., Savoie, F. H., 3rd, O'Brien, M. J., & Sherman, W. F. (2021). Trending a decade of proximal humerus fracture management in older adults. *Journal of shoulder and elbow surgery international, 6*(1), 137–143. https://doi.org/10.1016/j.jseint.2021.08.006
8. Relvas Silva, M., Linhares, D., Leite, M. J., Nunes, B., Torres, J., Neves, N., & Ribeiro Silva, M. (2022). Proximal humerus fractures: epidemiology and trends in surgical management of hospital-admitted patients in Portugal. *Journal of shoulder and elbow surgery international, 6*(3), 380–384. https://doi.org/10.1016/j.jseint.2021.12.003
9. Samborski, S. A., Haws, B. E., Karnyski, S., Soles, G., Gorczyca, J. T., Nicandri, G., Voloshin, I., & Ketz, J. P. (2022). Outcomes for type C proximal humerus fractures in the adult population: comparison of nonoperative treatment, locked plate fixation, and reverse shoulder arthroplasty. *Journal of shoulder and elbow surgery international, 6*(5), 755–762. https://doi.org/10.1016/j.jseint.2022.05.006
10. Lin, C. C., Karlin, E., Boin, M. A., Dankert, J. F., Larose, G., Zuckerman, J. D., & Virk, M. S. (2022). Operative Treatment of Proximal Humeral Fractures with Reverse Total Shoulder Arthroplasty in Patients ≥65 Years Old: A Critical Analysis Review. *The journal of bone and joint surgery. reviews, 10*(5), e21.00245. https://doi.org/10.2106/JBJS.RVW.21.00245
11. Larose, G., & Virk, M. S. (2022). The Evolution of Reverse Total Shoulder Arthroplasty and Its Current Use in the Treatment of Proximal Humerus Fractures in the Older Population. *Journal of clinical medicine, 11*(19), 5832. https://doi.org/10.3390/jcm11195832
12. Alrabaa, R. G., Ma, G., Truong, N. M., Lansdown, D. A., Feeley, B. T., Zhang, A. L., & Ma, C. B. (2022). Trends in Surgical Treatment of Proximal Humeral Fractures and Analysis of Postoperative Complications Over a Decade in 384,158 Patients. *The journal of bone and joint surge: open access, 7*(4), e22.00008. https://doi.org/10.2106/JBJS.OA.22.00008
13. Cognetti, D. J., Arana, A. A., Hoof, M., Mason, G., Lin, A., & Sheean, A. J. (2022). Short-term Complications for Proximal Humerus Fracture Surgery Have Decreased: An Analysis of the National Surgical Quality Improvement Program Database. *Clinical orthopaedics and related research, 480*(11), 2122–2133. https://doi.org/10.1097/CORR.0000000000002391
14. George N. E. (2022). CORR Insights®: Short-term Complications for Proximal Humerus Fracture Surgery Have Decreased: An Analysis of the National Surgical Quality Improvement Program Database. *Clinical orthopaedics and related research, 480*(11), 2134–2136. https://doi.org/10.1097/CORR.0000000000002430
15. Zheng, Y., Tang, N., Zhang, W. J., Shi, W., Zhao, W. W., & Yang, K. (2024). Comparative efficacy and safety of medical treatments for proximal humerus fractures: a systematic review and network meta-analysis. *BMC musculoskeletal disorders, 25*(1), 17. https://doi.org/10.1186/s12891-023-07053-x
16. Vall, M., Natera, L., Witney-Lagen, C., Imam, M. A., Narvani, A. A., Sforza, G., Levy, O., Relwani, J., & Consigliere, P. (2022). Reverse shoulder replacement versus hemiarthroplasty for proximal humeral fracture in elderly patients: a systematic review. *Musculoskeletal surgery, 106*(4), 357–367. https://doi.org/10.1007/s12306-022-00761-y
17. Korzh, M., Makarov, V., Gupalov, I., Pertseva, O., Boyko, K., & Pidgaiska, O. (2023). Results of a differential approach to surgical treatment of proximal humerus fractures in patients with osteoporosis. *Orthopaedics, Traumatology and Prosthetics,* (3-4), 13–21. https://doi.org/10.15674/0030-598720223-413-21
18. Barlow, J. D., Logli, A. L., Steinmann, S. P., Sems, S. A., Cross, W. W., Yuan, B. J., Torchia, M. E., & Sanchez-Sotelo, J. (2020). Locking plate fixation of proximal humerus fractures in patients older than 60 years continues to be associated with a high complication rate. *Journal of Shoulder and Elbow Surgery, 29*(8), 1689–1694. https://doi.org/10.1016/j.jse.2019.11.026
19. Dolci, A., Melis, B., Verona, M., Capone, A., & Marongiu, G. (2021). Complications and Intraoperative Fractures in Reverse Shoulder Arthroplasty: A Systematic Review. *Geriatric orthopaedic surgery & rehabilitation, 12*, 21514593211059865. https://doi.org/10.1177/21514593211059865'

20. Tagliero, L. E., Esper, R., Sperling, J. W., Morrey, M. E., Barlow, J. D., & Sanchez-Sotelo, J. (2024). Complications after reverse shoulder arthroplasty for proximal humerus nonunion. *Journal of shoulder and elbow surgery*, S1058-2746(24)00466-X. Advance online publication. https://doi.org/10.1016/j.jse.2024.05.020
21. Wendt, K. W., Jaeger, M., Verbruggen, J., Nijs, S., Oestern, H. J., Kdolsky, R., & Komadina, R. (2021). ESTES recommendations on proximal humerus fractures in the elderly. *European journal of trauma and emergency surgery: official publication of the European Trauma Society, 47*(2), 381–395. https://doi.org/10.1007/s00068-020-01437-7
22. Klug, A., Wincheringer, D., Harth, J., Schmidt-Horlohé, K., Hoffmann, R., & Gramlich, Y. (2019). Complications after surgical treatment of proximal humerus fractures in the elderly-an analysis of complication patterns and risk factors for reverse shoulder arthroplasty and angular-stable plating. *Journal of shoulder and elbow surgery, 28*(9), 1674–1684. https://doi.org/10.1016/j.jse.2019.02.017
23. Nabergoj, M., Denard, P. J., Collin, P., Trebše, R., & Lädermann, A. (2021). Mechanical complications and fractures after reverse shoulder arthroplasty related to different design types and their rates: part I. *European federation of national associations of orthopaedics and traumatology open reviews, 6*(11), 1097–1108. https://doi.org/10.1302/2058-5241.6.210039

The article has been sent to the editors	Received after review	Accepted for printing
10.01.2025	18.02.2025	19.02.2025

ANALYSIS OF POSTOPERATIVE COMPLICATIONS IN THE SURGICAL TREATMENT OF PROXIMAL HUMERAL FRACTURES IN PATIENTS WITH DECREASED MINERAL BONE DENSITY

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