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Assessment of using thread joysticks results for fragment reduction and bone allografting in the treatment of bone defects in patients with proximal humeral fractures

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Abstract

Introduction Despite significant advances in the development of new fixation systems and improvements in surgical technologies, algorithms that guarantee anatomical reduction in proximal humerus fractures are lacking.

The **aim** of this study was to evaluate the clinical efficacy of using thread joysticks for fragment reduction and allogeneic bone grafting materials to repair bone defects in patients with proximal humerus fractures.

Material and methods A total of 219 patients with proximal humerus fractures were treated. The main group consisted of 123 patients and was treated according to the proposed by us osteosynthesis, while the comparison group included 96 patients was managed with traditional methods. Long-term outcomes were assessed at 1 to 4 years postoperatively using the Constant score, as well as two questionnaires: the Simple Shoulder Test (SST) and the Oxford Shoulder Score (OSS).

Results In the main group, the Constant score ranged from a maximum of 98 to a minimum of 6, with a mean of 69.8 and a median of 73. In the control group, the maximum score was 93, the minimum was 8, with a mean and median of 54. Poor results were observed in 9 patients (7.3 %) in the main group. Of these, 4 (3.3 %) were due to infection, 3 (2.4 %) to implant migration, and 2 (1.6 %) to poor compliance with rehabilitation, leading to shoulder joint contracture. In the comparison group, 32 patients (33.3 %) had poor outcomes. Among them, 15 (15.6 %) had persistent limitations in abduction and internal rotation, 10 (10.4 %) exhibited implant migration, 5 (5.2 %) developed infection requiring reoperation, and 2 (2.1 %) experienced severe post-traumatic arthritis and humeral head collapse.

Discussion The described technique has a number of advantages compared toexisting methods, which allows for stable fixation in cases of 3- and 4-part fractures and avoids the need for shoulder joint replacement. It features a clearly defined algorithm of procedures that simplifies the reduction and fixation of bone fragments, especially in defects of the proximal humerus.

Conclusion The application of this surgical technique reduced operative time and improved treatment outcomes in fractures of the proximal humerus.

Keywords: proximal humerus fracture, treatment of proximal humerus fractures, humeral osteosynthesis, bone grafting

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INTRODUCTION

Proximal humerus fractures are a pressing issue in current traumatology, accounting for 5–7 % of all fractures in the adult population. Among elderly patients, this pathology ranks third in incidence, following femoral neck fractures and distal radius fractures. Particularly noteworthy is the fact that in individuals over 60 years of age, such injuries account for up to three-quarters of all humerus fractures, with the gender distribution showing a clear predominance of women with a ratios of 2:1–3:1 compared to men in the same age group [1, 2]. Epidemiological studies in recent years have recorded a steady trend toward an increase in their incidence, and the most growth have been observed among older patients [3, 4]. According to statistics, over the past decades, the incidence of such fractures has almost doubled in the population over 65 years of age.

Modern traumatology offers a significant arsenal of treatment methods, ranging from conservative management to a variety of surgical options [5–8]. However, the lack of uniform, standardized approaches to selecting optimal treatment tactics remains a serious problem, due to the wide range of possible treatment options and significant differences in the technical provision of medical institutions.

The timing of surgical treatment deserves special consideration. Numerous clinical observations indicate that a delay of more than five days in surgical intervention significantly increases the risk of serious complications such as avascular necrosis of the humeral head and secondary displacement of bone fragments. Split fractures of the humeral head and fracture-dislocations are particularly important. In these cases, anatomical reduction should be performed urgently, preferably within the first 48 hours after injury, to minimize the risk of ischemic complications [9].

The choice of the optimal fixation method remains controversial. Comparative studies of various osteosynthesis techniques, including osteosynthesis with locking plates and intramedullary osteosynthesis with locking nails, have not revealed significant differences in long-term treatment outcomes, even for comminuted fractures [10–12]. However, it should be noted that in patients with severe osteoporosis, even modern fixation devices may not provide sufficient stability.

The analysis of complications associated with plating indicates that up to 40 % of adverse outcomes, including impingement syndrome, migration of fixing elements, and so-called screw "cut-through", are associated with technical errors during surgical intervention [13]. It is important to note that increasing the number of fixing screws in the proximal fragment beyond four does not improve outcomes but may increase the risk of iatrogenic injury [14].

Blood supply to the humeral head is particularly important for prognosis. According to various authors, the incidence of avascular necrosis of the humeral head, as a complication of a proximal humeral fracture, varies widely, from 21 % to 75 % of cases [15]. Impaired vascularization can also lead to complications such as delayed consolidation or nonunion of the fracture and bone resorption of the humeral tuberosities.

In recent years, various bone defect augmentation techniques aimed at preserving the anatomical integrity of the joint have been actively discussed in the literature [16–21]. However, even with the use of modern technologies, osteosynthesis of some complex comminuted fractures of the proximal humerus remains technically unfeasible.

Researchers continue to refine the indications for primary shoulder arthroplasty due to proximal humerus fractures. It is now generally accepted that shoulder joint replacement may be the treatment of choice for complex three- and four-part fractures with significant damage to the articular surface, as well as in cases of previous osteosynthesis failures, when preservation of the natural humeral head is not possible. It should be noted that although current implant designs provide satisfactory pain relief, restoration of full limb function often remains challenging [20, 21, 22, 23].

Despite significant progress in the development of new fixation systems and the refinement of surgical technologies, there are still no clear algorithms to guarantee anatomical reduction for all types of proximal humeral fractures. Therefore, an analysis of the results of new surgical treatment techniques for this category of injuries is relevant [24, 25, 26].

Purpose To evaluate the clinical effectiveness of using thread joysticks for reduction of fragments and bone-grafting allogeneic materials for compensating bone tissue defects in patients with proximal humerus fractures.

MATERIALS AND METHODS

The study was conducted at the Sklifosovsky Research Institute of Emergency Care with the support of Grant No. 1603-22/23 dated April 21, 2023. The work used an original technique for osteosynthesis of the proximal humerus, protected by a Russian patent [27], the effectiveness of which was assessed during this prospective clinical study.

A total of 219 patients who completed the full course of treatment and follow-up were included in the study. The follow-up period ranged from one to four years. To compare treatment outcomes, two groups of patients were formed which clinical characteristics, gender, and age matched.

The study group included 123 patients who underwent osteosynthesis using the proposed technique. The gender distribution of the group was 27 men (22.0 %) and 96 women (78.0 %). Age ranged from 31 to 89 years (median 62 years). A distinctive feature of the surgical technique was the use of thread joysticks for fragment repositioning; in cases of severe bone mass deficiency, bone allografts were used.

The comparison group consisted of 96 patients, including 26 men (27.1 %) and 70 women (72.9 %), aged 18 to 84 years (median 62.5 years). In this group, reduction was performed using traditional methods such as wire joysticks, bone holders, and single-pronged hooks, without the use of allogeneic fibular head grafts. Screw fixation was performed according to standard recommendations to the subchondral zone of the humeral head.

Surgical interventions in both groups were performed four to five days after injury using a standard deltopectoral approach. Locking plates specifically designed for the proximal humerus were used for osteosynthesis. During surgery, the achieved neck-shaft angle, the condition of the medial calcarine edge, and the overall duration of the procedure were assessed. Postoperatively, the limb was immobilized with a sling for three to four weeks, while active therapeutic exercises were prescribed, the intensity of which was gradually increased as pain subsided.

To objectively evaluate long-term treatment outcomes, we used a comprehensive monitoring system, including the Constant systeme and two specialized questionnaires: the Simple Shoulder Test (SST) and the Oxford Shoulder Score (OSS). For SST results, a positive response was assigned 1 point and a negative one 0 points; the maximum possible total score was 12 points. The OSS assessed 12 parameters, ranging from 0 (worst outcome) to 4 points (optimal outcome), yielding a maximum score of 48 points. Patients' subjective satisfaction with the functional state of their operated limb was also considered.

To detect possible inflammatory reactions to the suture material, all patients underwent ultrasound examination of the shoulder joint at 1.5, three, and six months postoperatively. The ultrasound study criteria for inflammation included the presence of edema (thickening of the tendons), abnormal blood flow, fluid inclusions, and decreased tissue echogenicity.

Statistical analysis was performed using Statistica 13.3. Since most of the data had a non-normal distribution, nonparametric statistical methods were used. Continuous variables are presented as median (Me), interquartile range (Q1;Q3), minimum and maximum values, discrete data as absolute (*n*) and relative (%) values. The Mann–Whitney test was used to compare unrelated groups, and a probability calculator was used to analyze discrete data. Differences were considered statistically significant at $p < 0.05$, and values in the range of 0.05–0.1 were considered a trend.

Description of surgical intervention

The surgery was performed under local anesthesia with the patient in the supine position. For optimal approach, the injured humerus was shifted eccentrically toward the center of the operating table. The head was immobilized with additional supports, and the image intensifier was positioned on the side of the healthy shoulder. A standard deltopectoral approach allowed for sequential identification of key anatomical structures: the pectoralis major muscle, tendons of the long and short heads of the biceps, the intertubercular groove, and the greater and lesser tubercles of the humerus.

The first step of the technique involved isolating and suturing the subscapularis tendon with non-absorbable sutures (Terylene 5, FiberWire 2), which were then secured to a holder (Fig. 1). Next, the acromiocoracic ligament was identified, retracted superiorly, and the supraspinatus tendon was sutured. Selection of suture material is of particular importance; thinner and stronger sutures minimized knot size after fixation. Finally, the infraspinatus tendon was isolated and sutured, using traction on the previously sutured supraspinatus tendon to facilitate approach.

As a result, three suture joysticks (subscapular, supraspinatus, and infraspinatus) were created, providing complete control of the position of the bone fragments and the humeral head. A significant advantage of this technique was the absence of the risk of their cut-through, typical of traditional wire joysticks, especially in elderly patients with low bone mass. All suturing stages were performed using a single algorithm and the same type of suture material for all components of the rotator cuff (RC).

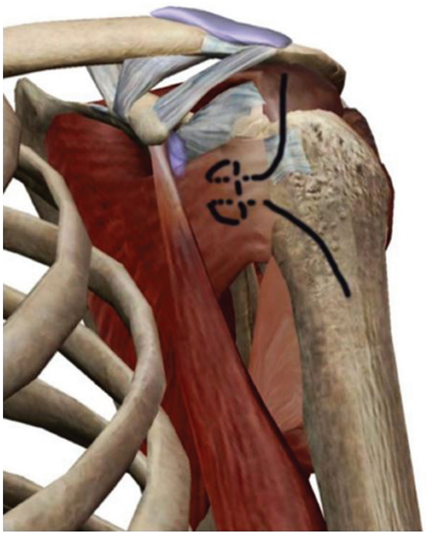

Fig. 1 Diagram of suturing the tendon with a stitch of the subscapularis muscle (other RC muscles are sutured in a similar way)

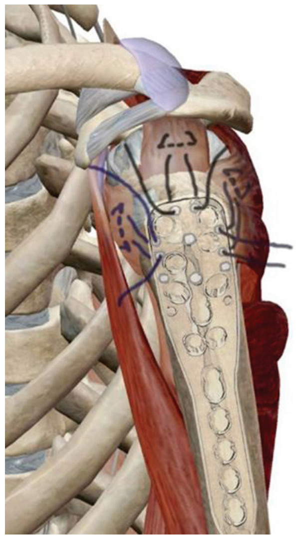

Fig. 2 Diagram of thread passing from RC tendons through the plate holes

At the next surgical stage, threads from the RC tendons were sequentially passed through special holes in the plate designed for osteosynthesis of the proximal humerus (Fig. 2). Of particular importance is the fact that most fractures in this location develop in the conditions of severe osteoporosis and bone tissue deficiency. In such clinical situations, we actively used various types of allogeneic bone grafts: cancellous bone grafts and combined grafts made from the head of the fibula, the technology for the use of which is protected by a Russian patent [27]. Osteoplastic defect filling was required in 70 patients, which constituted 49.3 % of the total number of patients.

The plate was then precisely positioned according to anatomical landmarks: behind the intertubercular groove, maintaining a distance of 5 mm from the superior edge of the greater tubercle. Primary fixation was performed using a central Kirschner wire, thereafter the plate position was monitored using an image intensifier tube (IIT), the position of the inserted wire was as a guide.

The next important manipulation was tensioning the sutures securing the RC elements while simultaneously applying finger pressure to the plate against the bony structures of the proximal humerus. This technique ensured precise and stable reduction of the bone fragments and a tight fit of the implant to the bone surface (Fig. 3).

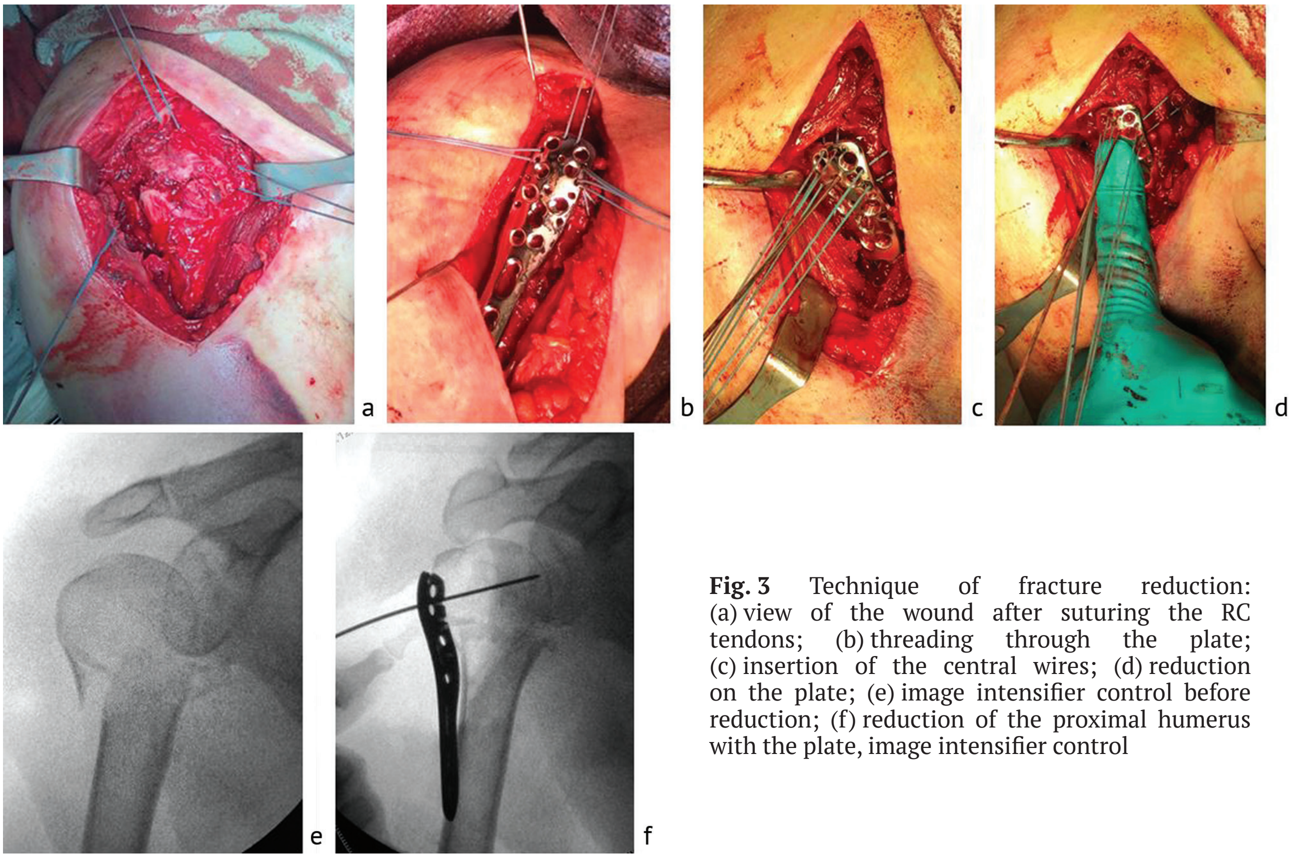

Fig. 3 Technique of fracture reduction: (a) view of the wound after suturing the RC tendons; (b) threading through the plate; (c) insertion of the central wires; (d) reduction on the plate; (e) image intensifier control before reduction; (f) reduction of the proximal humerus with the plate, image intensifier control

Upon reduction completion, plate fixation with locking screws was initiated. While holding the sutures taut and pressing the plate firmly against the bone, holes were sequentially drilled at the most convenient points on the plate, starting with the superoanterior quadrant. These holes were chosen for primary fixation due to their easy accessibility through the surgical approach and the ability to securely fix the proximal fragment. After inserting the proximal screws, the distal portion of the plate was fixed. A 3.5 mm cortical screw was inserted through the oval hole, carefully ensuring that the anterior edge of the plate was positioned behind the long head of the biceps brachii tendon. Throughout the fixation process, the position of the fragments and the implant was constantly monitored using the image intensifier; screw positioning was adjusted as necessary. Particular attention was paid to evenly distributing the force when tightening the screws to avoid plate distortion and ensure a tight fit across the entire bone surface. After completion of fixation, the stability of the structure and the quality of reduction were assessed (Fig. 4).

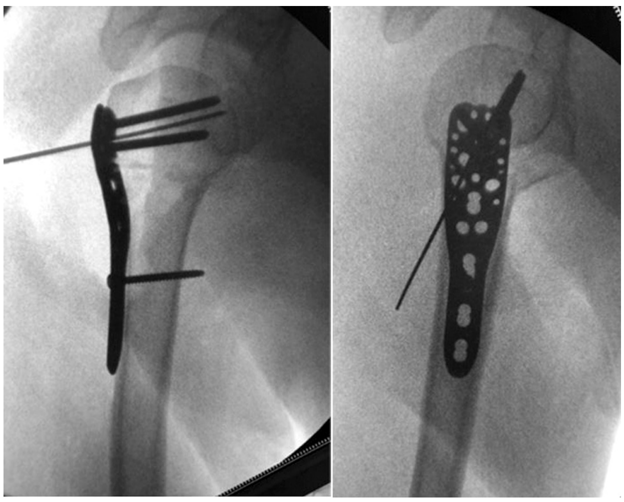

Fig. 4 Radiographic control of fracture reduction with the plate

The final stage of the surgery involved sequential tightening and fixation of the sutures to the plate, followed by removal of the temporary central Kirschner wire and insertion of additional locking screws. Particular attention was paid to the selection of proximal screw lengths. For AO-ASIF type C fractures, shortened screws were preferred due to the risk of developing partial avascular necrosis of the humeral head and the need to minimize the risk of bone cut through. Key aspects of successful reduction were: restoration of the anatomical volume of the humeral head through bone grafting and mandatory fixation of the rotator cuff tendons to the plate. A technical nuance associated with the initial fixation of the diaphysis deserves special mention: due to the excessive length of the reduction cortical screw, it was subsequently replaced with shorter screws (Fig. 5). This approach allowed us to optimize load distribution and reduce the risk of complications associated with excessive length of fixation elements.

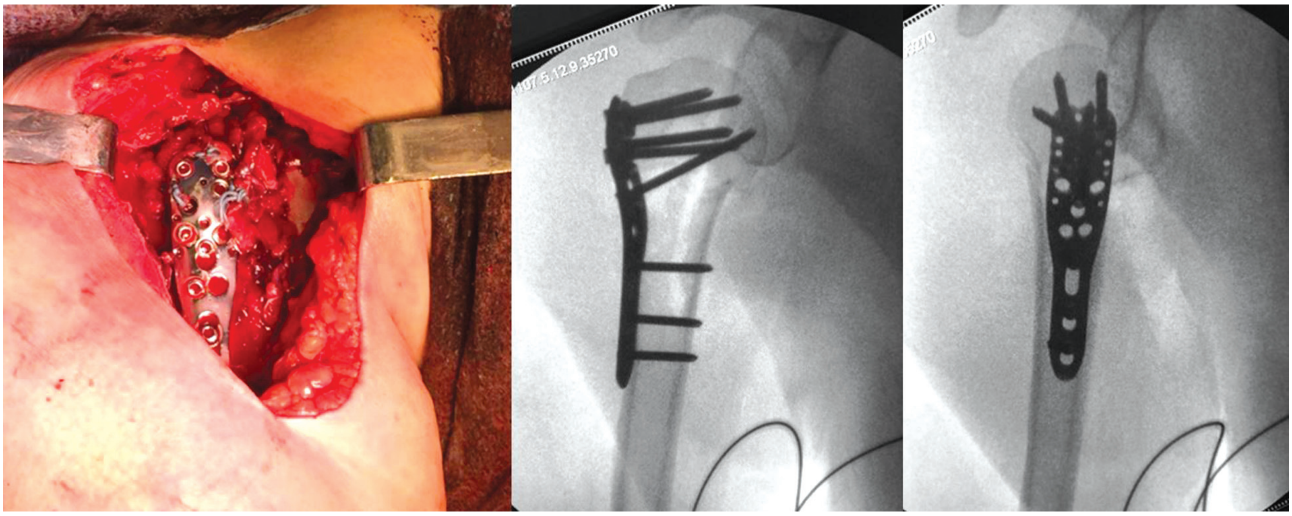

Fig. 5 Photo and radiographs of the final fixation of the fracture

In cases of severe bone defects, we systematically used various types of allogeneic grafts, which optimized conditions for fracture consolidation. Our arsenal included three main graft material types: compact cubes of cancellous bone, which provide good support; diaphyseal grafts from the fibula, which are characterized by high mechanical strength; and combined grafts from the head of the fibula, which combine the advantages of cancellous and compact bone (Fig. 6). The choice of a specific graft type was personalized in each case, and considered bone defect size and location, patient's age, and osteoporosis grade. Particular attention was paid to careful preparation of the graft bed and its close contact with the surrounding bone tissue, which was achieved by precisely adapting the graft shape to the characteristics of the defect. The use of allografts in combination with the proposed osteosynthesis technique allowed not only to restore bone integrity but also to create optimal biomechanical conditions for early functional rehabilitation of patients.

Cancellous bone grafts were used primarily to fill limited defects in the greater tuberosity region, where their porous structure optimally promoted revascularization and osteogenesis. In more complex cases (severe bone loss combined with damage to the cancellous and cortical components, as well as disruption of the medial calcarine edge), fibula allografts were used. These grafts provided the necessary mechanical support due to their anatomical shape and dense cortical structure. Precise graft modeling for tight contact with the fracture site was achieved through individual adjustment to a specific defect. The technical features of reduction with grafts, including the sequence of manipulations and fixation methods, are detailed in Fig. 7. This approach allowed for the restoration of not only the anatomical integrity but also the biomechanical function of the proximal humerus, even in the most complex clinical cases.

Fig. 6 Types of bone allografts: (a) cortical graft from the fibula; (b) cancellous bone graft; (c) combined bone graft from the head of the fibula

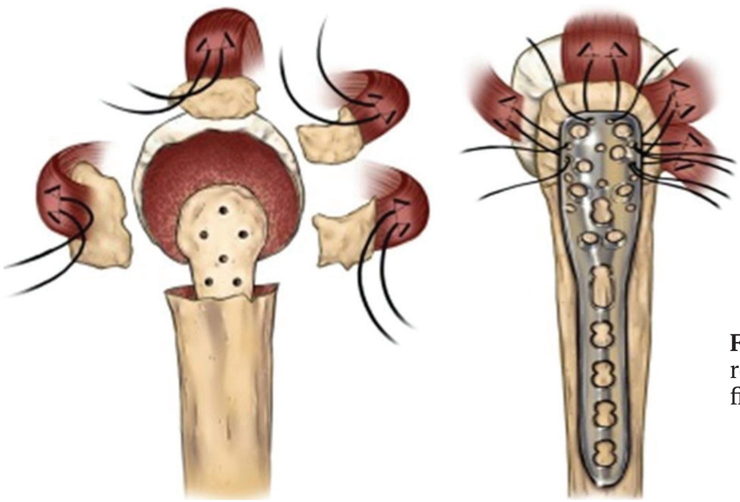

Fig. 7 Diagram of fracture reduction on an allogeneic fibula graft

RESULTS

According to SST score, good results were 9–12 points and poor ones were 1–8 points (Table 1). The patient groups matched by gender (study group — $p < 0.0001$, comparison group — $p < 0.0001$) and age; no statistically significant differences were found. The distribution of patients by fracture type is shown in Figure 8. In the study group, good results were achieved in 92.7 % which was significantly higher than in the comparison group (66.7 %, $p < 0.0001$, probability calculator).

Analysis of Constant – Murley data (Table 2, Fig. 9) showed that in the study group, the maximum score was 98 points and the minimum was 6 points, with an average of 69.8 points and a median of 73 points. In the comparison group, the maximum score was 93 points and the minimum was 8 points, with a lower average and median (both 54 points). These differences confirm the advantages of the proposed by us treatment method.

Table 1

Treatment results as a percentage according to questionnaire SST (n = 219)

SST points	Study group (n = 123)		Comparison group (n = 96)	
	n	%	n	%
1–8	9	7.3	32	33.3
9–12	114	92.7	64	66.7

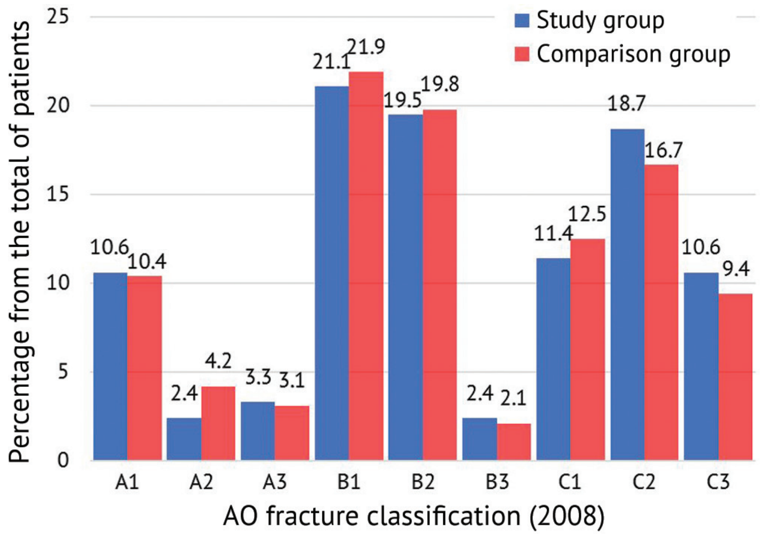

Fig. 8 Distribution of patients in two groups based on AO type of fracture (2008, AO)

Table 2

Descriptive statistics of the Constant – Murley questionnaire (1 to 100)

Variables	Value	
	Study group (*n* = 123)	Comparison group (*n* = 96)
Mean	69.8	54.0
Median	73.0	54.0
Minimum	6.0	8.0
Maximum	98.0	93.0
25th Percentile	58.0	42.0
75th Percentile	84.0	74.0
Geometric distribution	65.7	48.0
Standard deviation	19.2	22.0
Dispersion	371.0	493.0
Average deviation	15.3	22.0
Range	92.0	85.0
Interquartile range	26.0	32.0

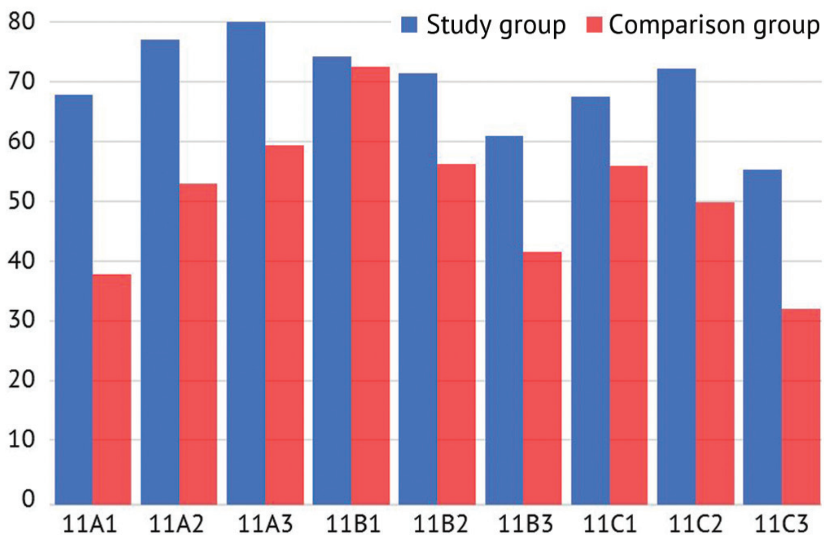

Fig. 9 Comparison of satisfaction with shoulder function according to the Constant – Murley system in the study group and the comparison group based on AO type of fracture

In the study group, nine (7.3 %) cases of poor treatment outcomes were recorded. The complication rate was as follows:

— infectious complications (suppuration) — 3.3 % (*n* = 4);

— migration of fixators — 2.4 % (*n* = 43);

—contractures due to non-compliance with the rehabilitation regimen— 1.6 % (*n* = 42).

In the comparison group, poor outcomes were recorded in 32 patients (33.3 %), including:

— persistent limitations of motion (abduction and placement behind the back) — 15.6 % (*n* = 415);

— migration of fixators — 10.4 % (*n* = 410);

— infectious complications — 5.2 % (*n* = 45);

— severe arthrosis with collapse of the humeral head — 2.1 % (*n* = 42).

The analysis of patient satisfaction using the SST score revealed a clear correlation between two key factors: patient age and the intraoperatively achieved neck-shaft angle (Fig. 10). The graphical dependence demonstrates a direct correlation between the neck-shaft angle value and functional outcome, which is particularly observed in young patients (blue curve). In older age patients, a decrease in satisfaction with the result was noted, even with anatomically correct angle restoration, which is explained by a combination of factors: an increased incidence of age-associated complications, decreased physical activity, and insufficient adherence to rehabilitation measures. The developed technique achieved a neck-shaft angle value of > 125° in all cases of the study group, creating optimal conditions for functional restoration. A group of patients (marked with a black circle) expressed low satisfaction despite adequate anatomical parameters. This fact is primarily associated with purulent complications, which significantly impair functional outcomes.

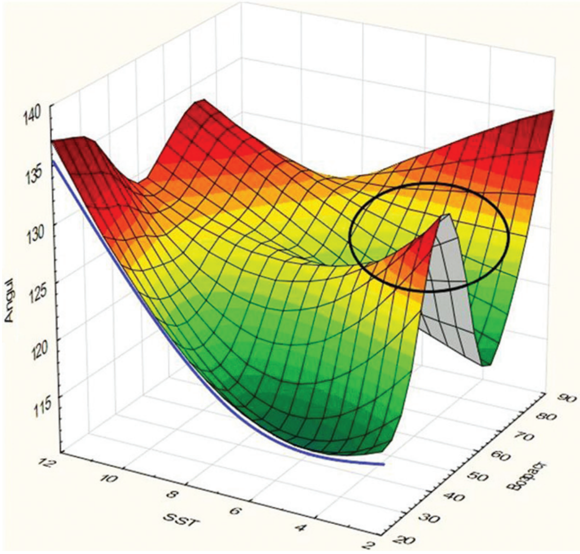

Fig. 10 Dependence of functional satisfaction on age and neck-shaft angle. 3D graphics

A comparative analysis showed that the average duration of surgery in the study group (96 min) was significantly shorter than in the comparison group (141 min) (Fig. 11). A clear relationship was observed between the duration of the procedure and functional outcomes: with an operation time of less than 110 min, patients demonstrated better SST scores (10–12 points). A particularly pronounced relationship was noted in young and middle-aged patients, where a reduction in the surgical time with the proposed technique led to a significant increase in satisfaction with the functional results. In the older age group, despite the relatively short average duration of surgery (80–90 min), such a pronounced relationship was not observed, which may be due to a combination of age-related factors, including comorbidities and specific rehabilitation potential. The obtained data

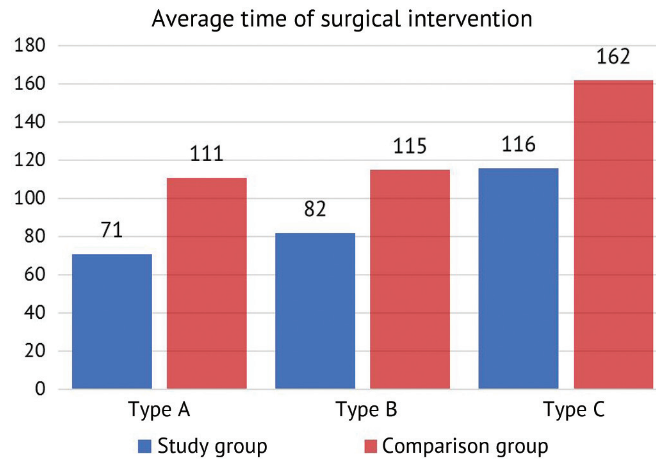

Fig. 11 Distribution of patients by the time of surgical intervention based on the AO type of fracture

convincingly demonstrate that the developed technique is not only technically effective but also allows for a significant reduction in surgical time, which has a positive effect on functional outcomes, especially in young and middle-aged patients (Fig. 12).

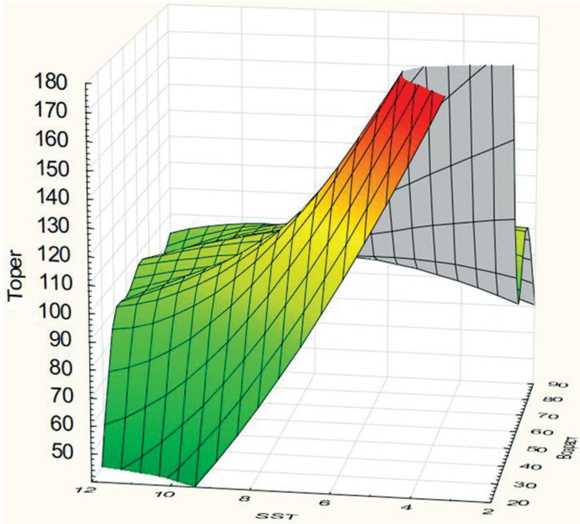

Fig. 12 Comparison of surgical intervention duration (Z-axis) in relation to functional satisfaction and patient age. 3D graphic presnetation

Postoperative ultrasound revealed that restricted range of motion and pain in the first 1.5 to 3 months after surgery were associated with persistent swelling of the rotator cuff tendons, most pronounced in the supraspinatus tendon. A comparative analysis of ultrasound data revealed no statistically significant differences in the intensity or duration of inflammatory changes between the study and comparison groups. The results confirm that the swelling was a natural reaction to surgery and not a consequence of the sutures used. The absence of differences between the groups indicates good biocompatibility of the materials used and the safety of the technique. It is particularly important that ultrasound signs of inflammatory changes were most often observed in the supraspinatus tendon, emphasizing the need for special attention to this area during rehabilitation. The obtained data substantiate the importance of ultrasound monitoring for timely adjustments in rehabiltation and confirm that the developed technique does not increase the risk of inflammatory complications compared to traditional approaches.

DISCUSSION

In three- and four-part humeral head fractures, the complex surgical challenge is precise alignment of the fragments, optimal plate positioning, and tight contact with the bone [28, 29, 30].

The most common method for reducing humeral head fragments is the use of joystick wires. However, this approach has a significant drawback, namely, the difficulty in accurately positioning the wires due to the displacement of the humeral head fragments under the acromion of the scapula. The acromial process significantly limits the manipulation of the joystick wires, often requiring repeated insertion, resulting in trauma to the bone tissue and surrounding soft tissues. Active manipulation of the fragments with wires often leads to their cutting, especially in elderly patients with osteoporosis. Each instance of wire extraction is accompanied by the loss of the achieved reduction and the need for reinsertion of the joystick. Formation of bone defects at the sites of poor wire placement worsens the conditions for definitive fracture fixation with a plate, as it reduces the supporting function of the screws. The thread joysticks, as described in this article, do not have these drawbacks.

Some authors additionally suggest using compression screws to ensure optimal plate contact with the bone surface, which is difficult to achieve in the conditions of low bone mass. There are recommendations for using holes in the plate to insert wire loops to achieve more secure fixation of small bone fragments. The combination of thread joysticks and a central pin allows for secure plate fixation to the bone in the conditions of osteopenia.

Techniques described in the literature often require preliminary fixation of the fragments with wires (two or three, and sometimes more) [6, 29]. The use of provision wires creates significant technical difficulties during subsequent placement and precise positioning of the plate. This is due to the fact that temporary fixators are often located in areas with the greatest bone mass of the fragments, forcing the surgeon to place the plate avoiding the wires. As a result, the locking screws passing through the plate holes and fixing the bone fragments are inserted in the areas of lower bone density. Repeated insertion of the wires leads to disruption of the achieved reduction and secondary displacement of the fragments. The proposed by us technique is based on a different algorithm that speeds up and simplifies the procedure.

Currently, surgical practice utilizes a technique that involves suturing the tendons of the supraspinatus and subsequent fixation to the plate to enhance structural stability. This technique involves suturing only the tendons that attach to the damaged bone fragments: for greater tubercle fractures, the supraspinatus and infraspinatus tendons are sutured, while for lesser tubercle fractures, the subscapularis tendon is fixed [9, 29]. However, in this approach, the supraspinatus tendons are sutured only at the fracture site, which leads to asymmetry in the tension vectors of the sutures during reduction and significantly complicates the process of precise plate positioning. Similar difficulties arise in the absence of a central pin, which performs the important function of centering the plate and ensuring its tight fit to the bone. The main surgical challenge lies in the difficulty of achieving anatomically precise and minimally invasive reduction of fragments while simultaneously eliminating obstacles to optimal plate placement.

Reduction of fragments requires the use of a significant number of auxiliary instruments, including multiple bone clamps. However, this technical approach is associated with a number of significant drawbacks. Firstly, manipulation of the clamps leads to additional trauma to the surrounding soft tissues. Secondly, there is a real risk of damaging vascular structures, particularly the posterior circumflex humeral artery and the axillary nerve, what can results in serious clinical consequences.

The literature describes a technique for fixing three- and four-part fractures of the posterior humeral circumflex humeral artery based on suturing the posterior humeral tendons followed by the use of an intramedullary nail [8, 10, 31]. This approach requires a transdeltoid surgical approach and is associated with a number of anatomical limitations and technical difficulties. To ensure full access to all necessary tendon structures, it is necessary to create a sufficiently large surgical field, which leads to increased trauma to the deltoid muscle, the risk of neuropathy of the axillary nerve and atrophy of the anterior portion of the deltoid muscle.

The bone fragment reduction method under consideration carries a significant risk of secondary displacement during implant placement: after traction on the fixation threads is released, the fragments return to their original position under muscular traction, and insertion of the intramedullary wire does not provide the centralized application of forces necessary to maintain reposition.

Additional technical difficulties arise from the specifics of proximal locking screw fixation. The bulky guides used for this purpose significantly interfere with maintaining traction via the joysticks, forcing the surgeon to perform the procedure in stages. This approach not only increases the duration of the surgery but also increases the likelihood of losing the achieved reduction, especially when working with osteoporotic bone tissue. This osteosynthesis method also has significant time limitations, demonstrating maximum effectiveness only when performed within the first five to seven days after the injury. After this term, the interfragmentary connective tissue scars create significant technical difficulties or completely exclude the possibility of precise reduction without performing additional surgical approaches for their excision.

The use of this technique in patients with osteoporotic bone changes, which is typical for the majority of patients with proximal humerus fractures, presents a particular challenge. Bone grafting is significantly complicated if an intramedullary nail is used. Accurate nail positioning, especially at the insertion site, is crucial. The slightest deviation from the optimal position leads to fixation failure, and subsequent removal of the nail creates insurmountable obstacles to alternative plate osteosynthesis due to secondary damage to bone structures and loss of anatomical landmarks.

This new technique for plate osteosynthesis of proximal humerus fractures minimizes soft tissue trauma through the use of thread joysticks, bone grafting materials, and a strict intraoperative procedure algorithm. It improves fixation quality and reduces complications.

The technique incorporates several fundamental components: allografts to restore humeral head anatomy in cases of bone mass deficiency, mandatory rotator cuff tendon suturing for additional stabilization in older patients, and a standardized fixation technique adapted for osteoporotic bone. These elements, taken together, ensure reliable fixation even in the most complex cases. The proposed technique demonstrates consistently good results regardless of patient age, although the best functional outcomes are observed in younger patients.

The data obtained convincingly demonstrate that the proposed comprehensive approach significantly improves treatment outcomes for patients with proximal humeral fractures. The technique combines technical simplicity with highly reproducible results, and makes its use a promising approach in modern traumatology. The advantages of the technique are evident not only in immediate postoperative results but also in the long-term follow-up, providing patients with rapid restoration of limb function and a high level of treatment satisfaction.

CONCLUSION

The surgical technique developed for patients with complex fractures of the surgical neck of the humerus represents an effective solution and demonstrates significant advantages over traditional approaches. A clearly structured algorithm facilitates the surgeon's surgical procedure, ensuring precise fragment reduction in patients of various age groups. A key achievement of the technique is a reduction in the average surgical time by 45 minutes (from 141 to 96 minutes) and improvement of functional outcomes, as demonstrated by an increase in the Constant – Murley score from 54 to 73 points.

Conflict of interests *None.*

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