SURGICAL TREATMENT OF INTRA-ARTICULAR FRACTURES OF THE PROXIMAL HUMERUS

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ABSTRACT

Background. *The most severe category of fractures of the proximal humerus are intra-articular injuries which are accompanied with humeral head ischemia caused by an injury and aggravated by surgical intervention. Due to frequent disruption of vascularization with subsequent necrosis of the humeral head, there is a need to stimulate reparative osteogenesis in intra-articular injuries to prevent ischemic changes in the humeral head.*

The aim of the study. *To improve the results of surgical treatment of intra-articular fractures of the proximal humerus based on the development of a new osteosynthesis technique using non-free osteomuscular graft.*

Material and methods. *We analyzed the results of treatment of 48 patients with 11-C1 and 11-C2 intra-articular fractures of the proximal humerus, who had hospital treatment at the emergency department of traumatology of the Novosibirsk City Clinical Hospital No. 1 and were subsequently observed on an outpatient basis. An analysis of literature data using search words was carried out in the PubMed and eLibrary databases.*

Results. *According to the data obtained during the study, the functional and radiological results of the patients who were treated using the method of reparative stimulation with a non-free osteomuscular graft from the coracoid process are statistically significantly higher than the results of the control group.*

Conclusion. *Using autoplasty with a non-free osteomuscular graft from the coracoid process improves the results and reduces the risk of developing post-traumatic aseptic necrosis of the humeral head.*

Key words: *intra-articular fracture of the proximal humerus, stimulation of reparative osteogenesis, non-free osteomuscular graft, aseptic necrosis of the proximal humerus*

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ХИРУРГИЧЕСКОЕ ЛЕЧЕНИЕ ВНУТРИСУСТАВНЫХ ПЕРЕЛОМОВ ПРОКСИМАЛЬНОГО ОТДЕЛА ПЛЕЧЕВОЙ КОСТИ

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РЕЗЮМЕ

Введение. *Наиболее тяжёлой категорией переломов проксимального отдела плечевой кости являются внутрисуставные повреждения, при которых в результате травмы развивается ишемия головки, усугубляемая оперативным вмешательством. В связи с частым нарушением васкуляризации с последующим некрозом головки возникает необходимость стимуляции репаративного остеогенеза при внутрисуставных повреждениях для профилактики ишемических изменений головки плечевой кости.*

Цель исследования. *Улучшить результаты хирургического лечения внутрисуставных переломов проксимального отдела плечевой кости на основе разработки новой методики остеосинтеза с использованием несвободного костно-мышечного трансплантата.*

Материал и методы. *Материалом исследования послужил анализ результатов лечения 48 пациентов с внутрисуставными переломами проксимального отдела плечевой кости категорий 11-С1 и 11-С2, лечившихся стационарно в отделении неотложной травматологии ГБУЗ Новосибирской области «Городская клиническая больница № 1» и в дальнейшем наблюдавшихся амбулаторно. В базах данных электронных информационных ресурсов PubMed, eLibrary проведён анализ литературных данных по поисковым словам.*

Результаты. *Согласно данным, полученным в ходе исследования, функциональные и рентгенологические результаты группы пациентов, оперированных с использованием метода репаративной стимуляции несвободным костно-мышечным трансплантатом из клювовидного отростка лопатки, статистически значимо выше результатов контрольной группы.*

Заключение. *Использование метода аутопластики несвободным костно-мышечным трансплантатом из клювовидного отростка лопатки улучшает результаты и уменьшает риск развития посттравматического асептического некроза головки плечевой кости.*

Ключевые слова: *внутрисуставной перелом проксимального отдела плечевой кости, стимуляция репаративного остеогенеза, несвободный костно-мышечный трансплантат, асептический некроз проксимального эпифиза плечевой кости*

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INTRODUCTION

According to modern domestic literature, fractures of the proximal humerus (PH) comprise from 5 to 15 % of human skeletal bone injuries, and in 15 % of cases they are accompanied by dislocation of the fragments [1]. Fractures of the proximal humerus are most common in the elderly; in young adults, this injury is more common in high-energy traumas such as falls from a height or road traffic accidents [2]. The increasing demands on the quality of life, the increase in the duration of active life, and the improvement of osteosynthesis methods have led to an appropriate expansion of indications for surgical treatment of fractures occurring in this localisation. Concurrent with the increase in surgical activity, there has been an increased interest in studying complications of the results of both surgical and nonsurgical treatments, one of which is humeral head avascular necrosis (HHAN). A complete cessation of the blood supply to the humeral head (AO classification – type C fractures and fracture dislocations, Neer classification – quadrilateral fractures) at the time of injury is the basis for the development of this condition; subsequently, the incidence of HHAN depends not only on the severity of the injury, but also on the traumatic nature of the surgical intervention. The surgical treatment tactics for proximal humerus fractures are represented by three main directions: osteosynthesis with angular stability plates; intramedullary blocking osteosynthesis with various modifications of proximal humeral nails (PHN); shoulder joint endoprosthesis (hemi and total). Alongside the mainstream techniques, there are original author's fixations that have limited prevalence. Transosseous osteosynthesis of PH fractures is not widespread due to technical complexity and the need for constant monitoring of the external fixation apparatus.

The use of PHN intramedullary osteosynthesis in the treatment of intra-articular PH fractures is controversially interpreted in the scientific literature as being associated with a persistent risk of humeral head avascular necrosis, as well as other complications specific to this technique, such as nail head impingement syndrome and migration of non-fixed screws with persisting fragment micromobility. As a consequence of technical difficulties in restoring anatomical relationships in the case of closed repositioning, techniques of "mini-access repositioning with additional stabilisation of the tuberosities" are being introduced [3]. Many studies have focused on primary shoulder arthroplasty procedures as a result of posttraumatic disruption of the blood supply to the fragments, technical difficulties in fracture correction, and a high incidence of complications in the long-term outcome of PH intra-articular fractures. The majority of recent reports are indicating that primary endoprosthesis replacement is usually preferred over arthroplasty in the remote period, as primary surgery is technically easier to perform [4]. As more information becomes available, however, endoprosthesis replacement-specific complications such as recurrent dislocations and aseptic instability of the endoprosthesis replacement components have been reported.

An increasing number of reports describing the unsatisfactory results of shoulder endoprosthesis replacement for proximal humerus fractures have recently appeared. D. Den Hartog et al. in 2010 published the results of a meta-analysis of 33 outcome studies in 1096 patients with three- and four-fragment fractures of the proximal humerus. Patients who underwent endoprosthesis replacement were found to have a worse functional outcome compared to those who did not undergo surgery, with a difference of 10.9 points on a 100-point Constant scale [5]. In a comparative study of the long-term consequences of endoprosthesis replacement, moderate and severe impairment of limb function was noted in up to 30 % of cases [6].

Clinical and experimental data indicate impaired vascularization with subsequent necrosis of the humeral head in 30–100 % of cases after intra-articular fractures [7]; therefore, there is a need to stimulate reparative osteogenesis in intra-articular injuries to achieve fusion and prevent ischaemic changes in the humeral head. The use of free spongy bone autografts from the wing of the iliac bone, which in the bulk of publications are considered exclusively for the replacement of bone defects of the proximal part of the shoulder, is the most widely used when considering this issue. This option of bone grafting is optimal for many parameters, including the absence of immune response, the presence of living osteogenic stromal cells; the disadvantages include prolongation of the surgery time, the emergence of additional infection gates, and patient discomfort. In addition, the lack of a blood supply source to the graft increases the risk of graft lysis.

The most perspective for osteogenesis stimulation appears to be the use of non-free autografts.

In this area of application (shoulder and humerus), the method of non-free bone grafting for the treatment of false joints in the upper third of the humerus draws attention from the available sources [8]. The essence of the method is the formation of an osteomuscular graft (osteomyocutaneous graft), including a fragment of the lower angle of the scapula, which is moved to the reconstruction zone in the upper third of the shoulder. The authors have obtained good to excellent results in the treatment of false joints of the upper third of the humerus through this method. Stimulation of osteogenesis by non-free osteomuscular gratfs (osteomyocutaneous grafts) in intra-articular pathology has been studied for the hip joint region, for which predominantly good results have also been noted, including in the treatment of avascular necrosis of the femoral head. The use of a non-free osteomuscular graft (osteomyocutaneous graft) from the clavicular process of the scapula on the feeding pedicle of the short head of the biceps brachii muscle is mainly used in the correction of shoulder joint instability (Latarger surgery); the study of the long-term consequences of this method revealed the main regularities of bone block remodelling and resorption.

THE AIM OF THE STUDY

To improve the results of surgical treatment of intra-articular fractures of the proximal humerus by means of the development of the osteosynthesis technique using a non-free osteomuscular graft (osteomyocutaneous graft).

MATERIALS AND METHODS

We analyzed the results of treatment of 48 patients with 11-C1 and 11-C2 intra-articular fractures of the proximal humerus, who had hospital treatment at the emergency department of traumatology of the Novosibirsk City Clinical Hospital No. 1 and were subsequently observed on an outpatient basis.

Inclusion criteria for the study group were the following parameters: male or female patients aged 20 to 80 years inclusive with diagnosed AO/ASIF (Association for Osteosynthesis/Association for the Study of Internal Fixation) type C (C1–C2) fractures of the proximal humerus in need of surgical treatment. Patients with extra-articular PH fractures (types A and B) and fracture dislocations (type C3); patients not tolerant or not agreeing to surgical treatment were not included in the study.

Two groups were formed out of the total number of patients: control or comparison group – 25 patients who underwent surgery using traditional methods (osteomuscular graft osteosynthesis with an angular stability plate or intramedullary blocked osteosynthesis with proximal humeral pins); study group – 23 patients whose treatment was additionally based on the method of transplantation of a non-free osteomuscular graft (osteomyocutaneous graft) from the clavicular process of the scapula into the fracture zone. The mean age of the patients was 65 years for the study group and 67 years for the comparison group; all patients were underwent surgery within 7–10 days after the injury, except for 2 patients in the study group who underwent transplantation of the clavicle fragment 6–8 weeks after the injury as a consequence of primary osteosynthesis failure. Both groups of patients were examined in the preoperative and postoperative periods using clinical (anamnesis, complaints, local status), X-ray (radiographs of the shoulder joint in 2 or 3 projections) methods and multi-layer spiral computed tomography (X-ray dynamics of changes in the fracture zone and bone structure of the humeral head were studied). In the long-term period, histological examination of intraoperative biopsy specimens was selectively performed to determine the severity of posttraumatic ischemic impairment of the humeral head bone tissue. Functional outcomes of surgical treatment were assessed using the American Shoulder and Elbow Surgeons' (ASES) scale. The obtained data were assessed in three main areas: presence and severity of pain syndrome (PS) index of the ASES scale, in points); range of shoulder joint motion (flexion, abduction, external and internal rotation); patient satisfaction with the ability to use the affected limb for household activities (ADL) index of the ASES scale, in points), and X-ray expression of signs of postischemic impairment of the PC head. The degree of aseptic necrosis of the head was assessed using the ARCO (Association Research Circulation Osseous) scale. Functional and X-ray changes in patients were observed over the period 2015–2022.

The conduct of the study was approved by the ethical committee of the Novosibirsk City Clinical Hospital No. 1 and the Biomedical Ethics Committee of the Novosibirsk Research Institute of Traumatology and Orthopedics n. a. Ya.L. Tsivyan (No. 42/19 dated November 11, 2019; No. 001/23 dated January 17, 2023).

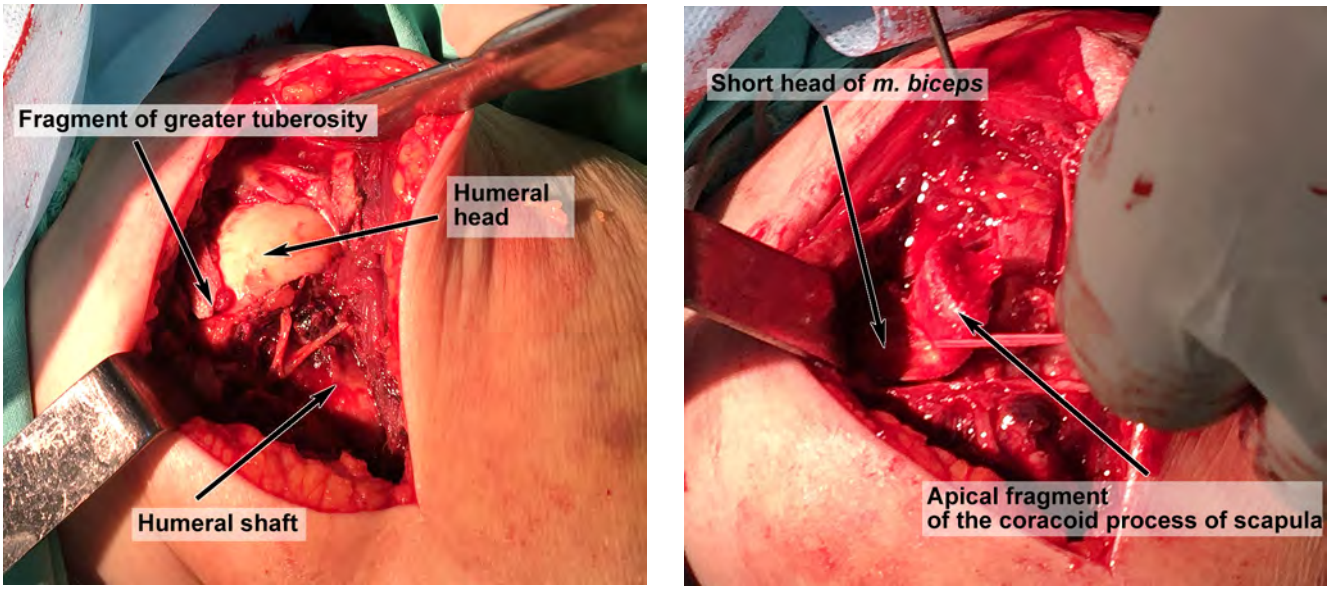
The course of the surgery

The main stages of the surgery are schematically shown in Figure 1.

a ***b*** ***c*** ***d***

FIG. 1.

*Revision of the fracture zone (**a**); reposition of fragments (**b**); taking and carrying into the fracture zone a graft from the coracoid process on the muscle-tendon pedicle of the short head of the biceps muscle (**c**); bone osteosynthesis with an LCP plate (**d**)*



a *b*

FIG. 2.
*Revision of the fracture zone (**a**); carrying into the fracture zone a graft from the coracoid process on the muscle-tendon pedicle of the short head of the biceps muscle (**b**)*

Surgical intervention was performed in the supine position using general and conduction anaesthesia of the upper extremity. From the anterior deltoideopectoral access, the fracture zone was isolated layer by layer, and after revision of the fragments and rotator cuff tendons, gentle repositioning of the fragments with minimal periosteum separation was performed (Fig. 2a). After conventional osteosynthesis with the LCP proximal humeral plate, the clavicular process of the scapula and the tendon of the short head of the biceps brachii and the coracoacromial ligament attached to it were subfascially isolated. The coracoacromial ligament was partially incised according to the length of the graft; after performing a 1–1.5 cm long osteotomy of the coracoid process of the scapula, the short head of the biceps brachii muscle was mobilised.

The osteomuscular graft formed in this way was guided into the fracture zone under the fragment of the small tuberosity of the humerus using a ligature (Fig. 2b) with its ends brought to the outer part of the greater tuberosity, which provides additional fixation of the greater tuberosity (Fig. 3a, b).

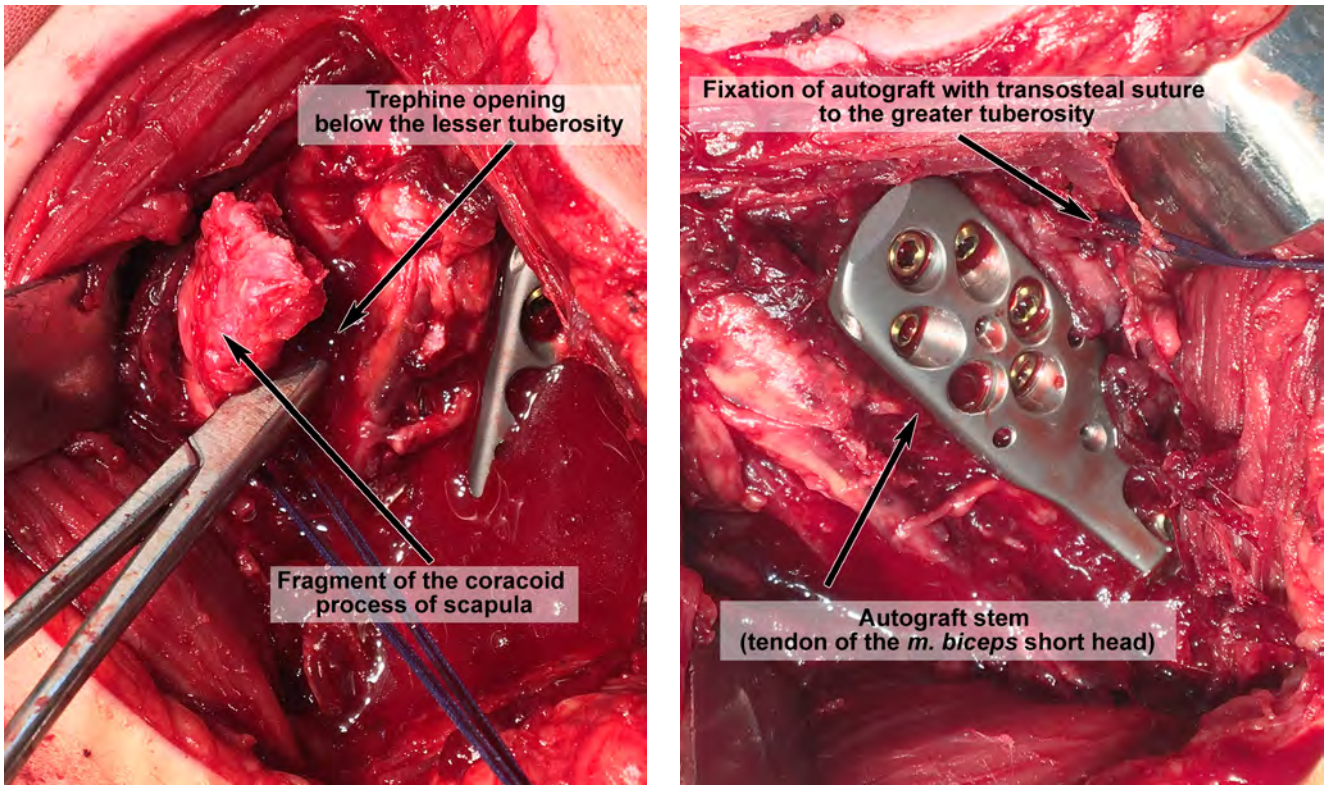
After being tested, the wound was sutured layer by layer, and immobilization was performed with a many-tailed bandage. Postoperative follow-up was typical for all patients in both groups: active elbow joint development from day 2; passive non-aggressive shoulder joint development standing and lying down after suture removal (day 9–10). Active shoulder joint development was allowed after 6 weeks from the time of surgery, from day 8–10 postoperatively. Treatment outcomes were assessed using the ASES scale at 6 to 12 months (1 month to 5 years) after surgery.

RESULTS AND DISCUSSION

The outcomes of patients' treatment with intra-articular fractures of the proximal humerus were assessed at two stages – immediate and long-term. Treatment outcomes at the time of hospital discharge and after 12 weeks from the date of surgery were considered to be the closest. Functional and X-ray results 18–24 months after surgery were considered as long-term outcomes. According to the data obtained in the course of the study, the functional results of the patient group who underwent surgery using the method of reparative stimulation with a non-free osteomuscular graft (osteomyocutaneous graft) from the clavicular process of the scapula were statistically significantly higher than those of the control group (Table 1).

Statistical data processing

Sample distributions of continuous measures of age, height, weight, postoperative examination time, PS and ADL according to the ASES scale, abduction, flexion, internal and external rotation were examined to ensure compliance with the law of normal distribution using the Shapiro – Wilk test; equality of variance in the compared groups was examined using the Fisher test. Most of the distributions were found to be abnormal and heteroscedastic, and therefore comparisons were made using the nonparametric Mann – Whitney U-test. The pseudo-median (PM) of the differences in values and the standardised difference in mean (SDM) were calculated to assess the magnitude of the difference between the groups. Continuous indices were described as median [first quartile; third quartile]



а *б*

FIG. 3.

*Positioning of a non-free graft downwards from the small humerus tuberosity (**a**); insertion of the graft with the withdrawal of guide ligatures on the greater tuberosity (**b**)*

(M [Q1; Q3]), mean ± standard deviation (M ± SD), minimum and maximum values (min–max).

Binary consolidation and elevation indices were described as number of events and incidence (*n*, %) with construction of 95 % confidence interval (95% CI) using Wilson's formula. Risk difference (RD) and odds ratio (OR) with 95% CI were calculated to assess the difference between groups. The number of patients and frequency (degree – *n* (%)) were calculated for the degrees of HHAN categorical indicators. Binary and categorical indicators were compared by two-tailed Fisher's exact test. Correction of multiple comparison error by the Benjamini – Hochberg criterion was performed during the comparison of degrees in categorical indices (Table 1).

The statistical hypotheses were tested at a critical significance level of $p = 0.05$, i. e., differences were considered statistically significant at $p < 0.05$.

All statistical calculations were performed in the Rstudio software (version 2022.07.2 + 576, 2022-09-06, USA) in the R language (version 4.1.3, Austria). The results of statistical calculations are summarized in Table 1.

The distribution of HHAN degrees in the comparison and study groups differed statistically significantly ($p = 0.010$), namely, for the 0th degree (absence) – in 12 (48 %) and 20 (87 %) patients, respectively ($p = 0.018$); for the 4th degree – in 10 (40 %) and 2 (8.7 %) patients, respectively ($p = 0.028$). There were no differences in the 3rd HHAN degree ($p = 0.610$) (Fig. 4).

PS in the comparison and study groups was within 45 [35; 50] and 45 [45; 50] units, respectively, with a statistically significantly higher ($p = 0.024$) average of 5 points in the study group (Fig. 5).

The range of active motion in the comparison and study groups was within comparable limits: in the comparison group, it was lower on average by 5–10 units (degrees) ($p = 0.483$–0.532) (Fig. 6).

The ADL and total ASES score indices in the comparison and study groups were within comparable limits, but the minimum score in the study group was statistically significantly greater ($p = 0.877$ and $p = 0.535$, respectively), by an average of 7 (ADL) and 12 units (ASES total score).

Consequently, the manifestations of posttraumatic aseptic necrosis of the humerus proximal epiphysis of the 4th degree were reduced 4-fold. A single application of the osteosynthesis technique with a non-free osteomuscular graft (osteomyocutaneous graft) from the clavicular process of the scapula in a case of an unconsolidated intra-articular fracture of the humeral head more than 6 weeks old did not lead to a positive result, con-

TABLE 1

COMPARATIVE TREATMENT RESULTS OF PATIENTS IN THE CONTROL GROUP AND THE STUDY GROUP

Indicators	Comparison group (*n* = 25)	Study group (*n* = 23)	Difference assessment	*p*
Age, M [Q1; Q3] (min–max)	67 [55; 70] (33–77)	65 [62; 76] (46–81)	PM: 4 [–3; 9] SMD: 0.43	0.296
Postoperative examination, M [Q1; Q3] (min–max)	48 [24; 48] (12–68)	18 [11; 24] (6–36)	PM: 24 [12; 36] SMD: 1.52	< 0.001*
Consolidation, *n* (%) [95%CI]	23 (92 %) [75 %; 98 %]	23 (100 %) [86 %; 100 %]	RD: 8 % [3 %; 19 %]	0.491
HHAN, degree	0th degree – 12 (48 %) 3rd degree – 3 (12 %) 4th degree – 10 (40 %)	0th degree – 20 (87 %) 3rd degree – 1 (4.3 %) 4th degree – 2 (8.7 %)		Overall comparison *p* = 0.010* Category: *p*; correction *p* 0th: 0.006*; 0.018* 3rd: 0.610; 0.610 4th: 0.019*; 0.028*
PS, M [Q1; Q3] (min–max)	45 [35; 50] (5–50)	45 [45; 50] (35–50)	PM: 5 [0; 10] SMD: 0.83	0.017*
ADL, M [Q1; Q3] (min–max)	37 [22; 45] (12–50)	33 [29.5; 42] (22–50)	PM: 0 [–6; 10] SMD: 0.18	0.877
ASES total, M [Q1; Q3] (min–max)	80 [62; 88] (27–100)	80 [77; 88.5] (68–95)	PM: 4 [–5; 16] SMD: 0.54	0.535

Note. * – statistically significant differences.

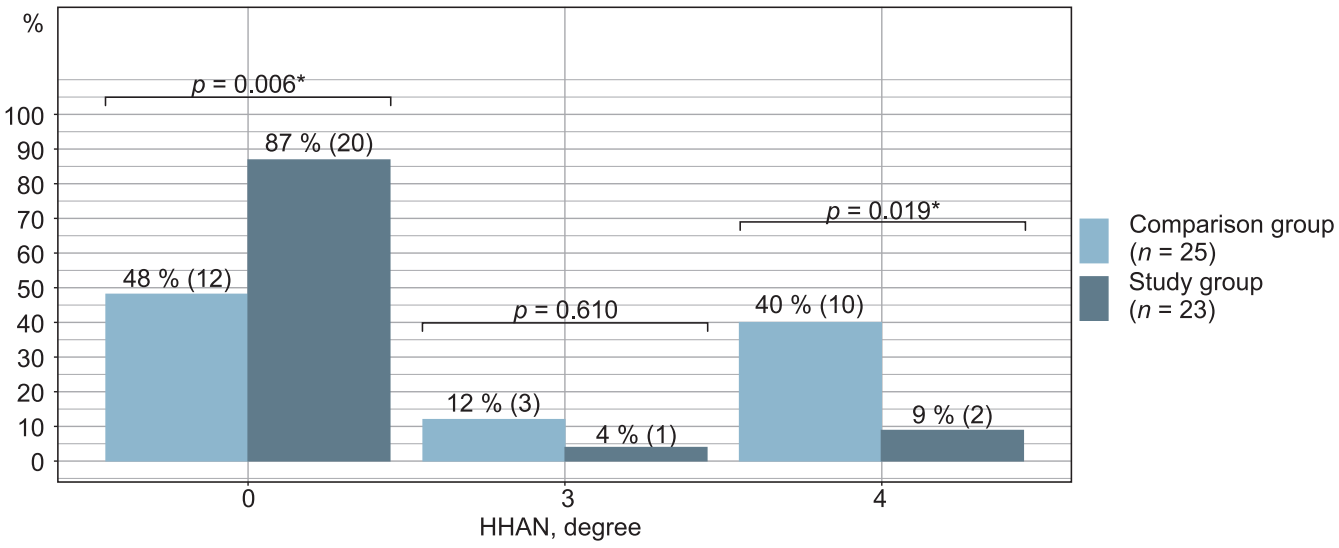


FIG. 4.

Degree distribution of humeral head aseptic necrosis development by groups

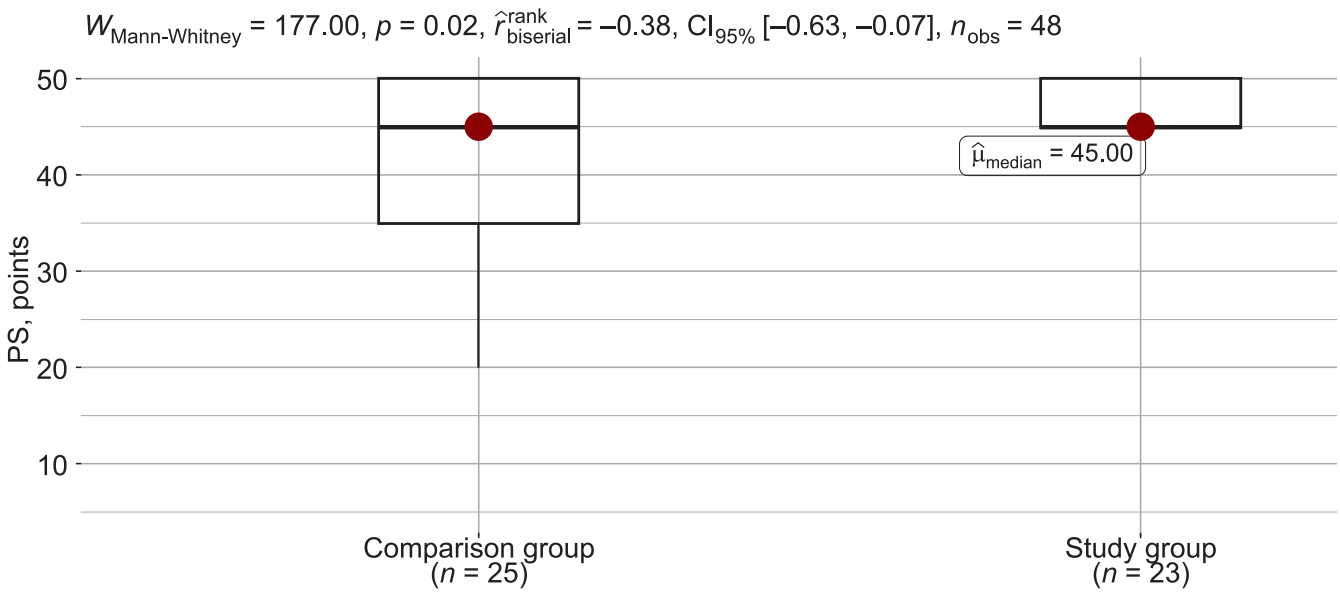


FIG. 5.
Distribution of degrees of pain syndrome (PS index) severity by groups

solidation was not obtained. An assessment of the pain syndrome in the rehabilitation period (6–12 months after surgical treatment) and in the long-term period (more than 1 year) reveals a decrease in the intensity of postoperative pain, mainly as a result of good consolidation of the fracture and a decrease in post-ischaemic bone tissue impairment.

Following the end of the rehabilitation period and restoration of the range of motion in the shoulder joint, in addition to the reduction of pain syndrome, the patients in the study group also experienced a significant reduction or disappearance of pain at night.

Based on the results of the study, a patent for invention "Method of treatment of intra-articular fractures of the proximal humerus" (No. 2740851; priority of invention from June 30, 2020) was obtained.

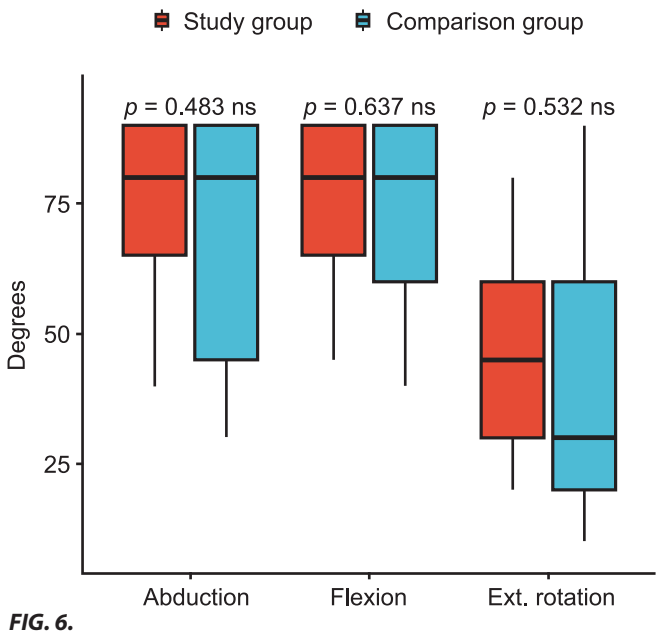


FIG. 6.
Ratio of the active shoulder joint motion volume in the study group and the comparison group

Clinical case No. 1

Patient G., 57 years old, underwent surgery in February 2020 (Fig. 7a, b). The intra-articular nature of the fracture was confirmed intraoperatively, and coracoid transposition was performed (Fig. 7c). At examination after 7.5 months – full range of motion, no pain syndrome, household and partly sports activities without difficulties. Bone structure of the humeral head is radiographically without signs of ischaemia (Fig. 7d). The treatment outcome is excellent.

Clinical case No. 2

Patient D., 74 years old, underwent surgery in early August 2020. Fracture consolidation occurred after 2 months; after 7 months – full range of motion, household activities of the hand do not cause pain and discomfort. No signs of aseptic necrosis were radiologically observed (Fig. 8). The treatment outcome is excellent.

Clinical case No. 3

Patient S., 72 years old. Primary osteosynthesis was performed in September 2019, and secondary displacement of the fragments was observed 2 months later (Fig. 9a). Revision in early December 2019 revealed aseptic necrosis of the head with massive lysis, intraoperatively the remaining part of the head up to 1.5 cm

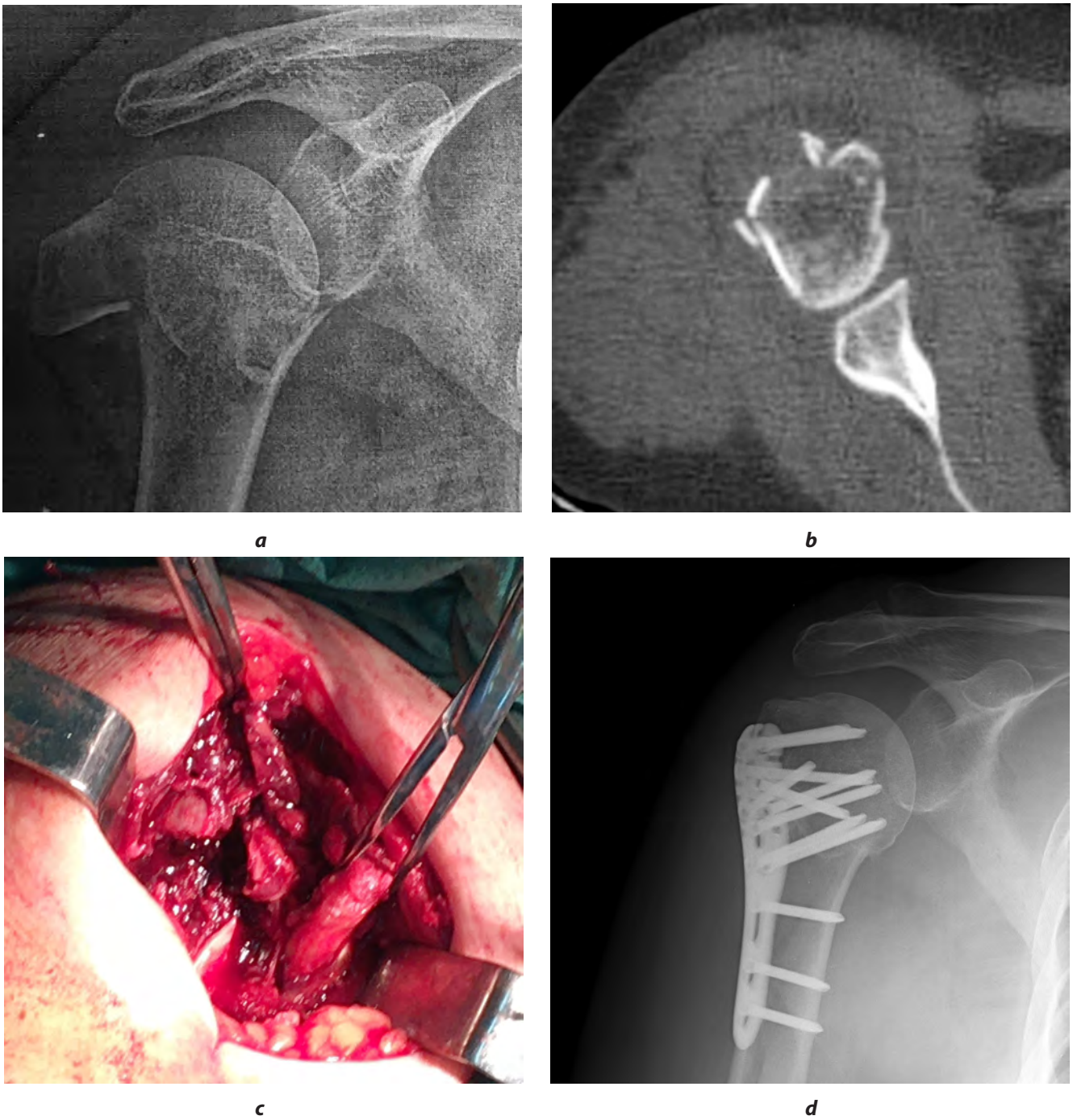


FIG. 7.

Patient G. ***a*** *– X-ray of the shoulder joint before the surgery;* ***b*** *– multi-layer spiral CT before the surgery;* ***c*** *– intraoperative photo of mobilization of a non-free autograft;* ***d*** *– control X-ray of the shoulder joint 7.5 months after the surgery*

of subchondral bone (Fig. 9b). An extramedullary re-osteosynthesis with LCP plate and non-free bone grafting with a graft from the coracoid process was performed. At the follow-up examination 3 months after revision intervention, no fusion was noted (Fig. 9c). At 6 months after removal of the constructs, intraoperative signs of a false joint and ongoing lysis of the head. Intraoperative biopsy confirmed aseptic necrosis of the humeral head.

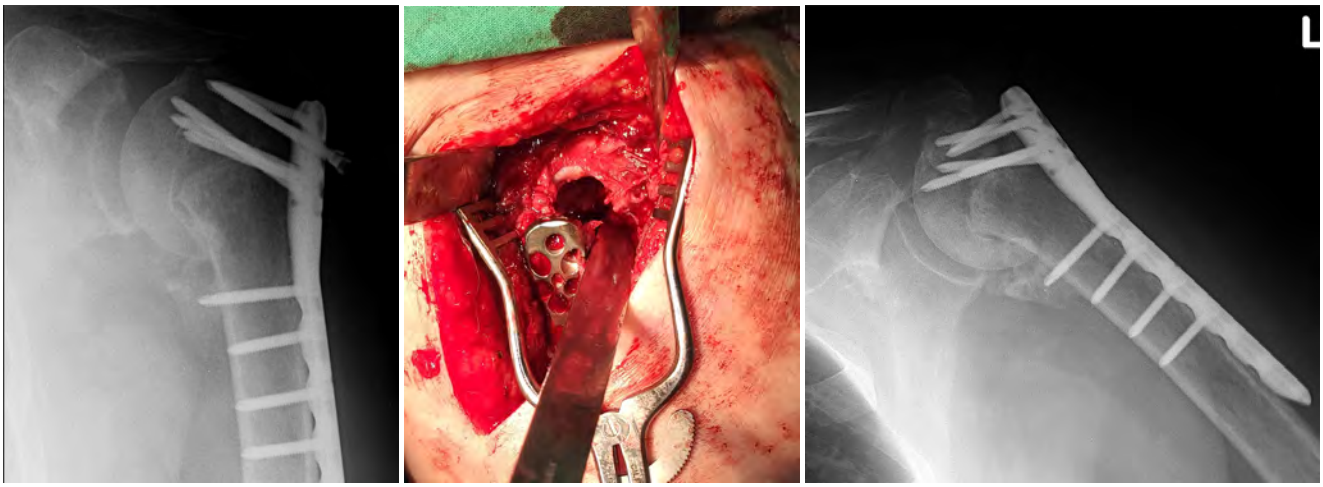
CONCLUSION

The use of autoplasty with a non-free osteomuscular graft (osteocutaneous graft) from the clavicular process of the scapula in the treatment of "fresh" intra-articular fractures of the proximal humerus reduces the risk of posttraumatic aseptic necrosis of the humeral head, provides predominantly excellent and good results with primary stable osteosynthesis.

а *б* *в*

FIG. 8.

Patient D. ***a*** *– X-ray before the surgery;* ***b*** *– 3D reconstruction of the fracture zone according to multi-layer spiral CT;* ***c*** *– control X-ray of the consolidated fracture 7 months after the surgery y*



а *б* *в*

FIG. 9.

Patient S. ***a*** *– control X-ray 8 weeks after primary osteosynthesis;* ***b*** *– intraoperative photograph of the humeral head lysis;* ***c*** *– control X-ray of an unconsolidated fracture 6 months after re-osteosynthesis*

Conflict of interest

The authors of this article declare no conflicts of interest.

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