

Osteosynthesis of small fragments in multisplintered fractures of the distal humerus metaepiphysis

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The **purpose** of this study was to improve the treatment results of multicomminuted fractures of the distal humerus metaepiphysis through the development of a compression device that provides stable osteosynthesis of small fragments. **Materials and methods** Clinical testing of the device developed for osteosynthesis of small fragments in multicomminuted fractures of the distal humerus metaepiphysis (patent of Ukraine for useful model #12560) was conducted. Treatment sample included 104 persons with multicomminuted fractures of the distal humerus metaepiphysis admitted to the Donetsk national medical university and national trauma center of Donetsk. **Results** Osteosynthesis of small fragments in multicomminuted metaepiphyseal fractures of the distal humerus with the help of the developed by us compression device enabled to reduce and stabilize small bone fragments, provided the possibility of early movements in the joint and resulted in good outcomes. **Conclusions** Osteosynthesis of small fragments with application of the developed by us compression device in patients with multicomminuted fractures of the distal humerus metaepiphysis showed high efficiency. The mean score was 82.67 ± 5.59 points, which corresponds to good results of treatment.

Keywords: osteosynthesis, small fragments, fracture, distal humerus

INTRODUCTION

Searching for new options in the management of fractures of the distal humeral metaepiphysis is clinically relevant as their incidence and severity is high. Moreover, the rate of disability after such injuries is also high. Among intraarticular fractures, injuries of the elbow joint make 79.5–89 % [1]. According to the literature, fractures of the humeral condyle comprise 0.5–2 % in the total of the injuries of the musculoskeletal system, 6.5–15 % of fractures of the humerus are, and 30 % of the injuries in the elbow joint area [1–4]. One of the frequent complications of intraarticular fractures is contractures of the elbow joint (85 %), which are caused by its prolonged immobilization [5–11].

The negative effect of prolonged immobilization on the function of the joint was proven by a number of studies conducted since the early 60s of the last century [12, 13]. In particular, the complexity of the anatomical structure of the elbow joint, features of its biomechanics as well as a limited capability of the hyaline cartilage to regenerate determine the main problems in the rehabilitation treatment of patients with multifragmental fractures of the distal metaepiphysis of the humerus. Intraarticular injuries of the elbow joint area are accompanied by destruction of the articular cartilage. As a result, degenerative manifestations develop rapidly and osteoarthritis

becomes inevitable. The characteristic morphology of the paraarticular tissue and neurovascular formations in the capsulo-ligamentous apparatus of the elbow joint is close to the structure of the periosteum. Therefore, if immobilization of the joint is prolonged, fracture healing resembles diaphyseal periosteal osteogenesis, and regeneration of the hyaline cartilage ceases in the phase of non-differentiated fibrous tissue. Therefore, passive movements should start in the early stages after injury in order to restore the locomotor function of the elbow joint in intraarticular fractures [13].

Preservation of movements determines the priority of the treatment methods that enable early rehabilitation of the affected joint in multifragmental fractures of the distal metaepiphysis of the humerus. Complications due to the restriction of the joint function will thus be avoided [13].

The device developed and proposed by us provides reduction and osteosynthesis with wires with a reserve of stability for starting to train movements in the injured elbow joint immediately after surgery and, as a result, reduces the risk of developing postoperative contractures in the elbow joint.

Multicomminuted injuries of the distal metaepiphysis of the humerus with the presence of small fragments are the most challenging. These fractures result in the highest percentage of negative

outcomes due to the fact that stable fixation of small fragments of the joint is often impossible to achieve using the standard methods of internal osteosynthesis.

Therefore, the only way to keep the fragments of the articular surface of the distal humerus after reduction is to fix these small fragments with wires. The positive facts of this type of fixation are possibility

of stabilization of small bone fragments, no need for a complete separation of fragments and the possibility of introducing the wires in various directions (including the introduction of wires percutaneously). The only, but a very significant shortcoming of such osteosynthesis is unstable fixation of bone fragments. The construct designed by us is deprived of this shortcoming.

MATERIAL AND METHODS

Clinical trials of the device developed by us for osteosynthesis of small fragments in multicomminuted fractures of the distal metaepiphysis of the humerus (Ukrainian patent for useful model No. 12560) were performed in 104 patients. All the injured were treated at the Donetsk M. Gorky National Medical University and the Republican trauma center of the city of Donetsk. There were four times more men than women, 77.9 (81) and 22.1 % (23) respectively. Injuries sustained at industrial sites were 55.8 % (58 subjects). Domestic injuries were diagnosed in 34.6 % (36 injured persons), transport injuries in 5.8 % (6) and sports injuries in 3.8 % (4 patients). In 86.54 % of cases, the mechanism of injury was indirect. All patients included in the study had multicomminuted fractures of the distal metaepiphysis of the humerus with small fragments that required reduction and fixation. Small fragments, as we define, ranged in size from 0.5 to 2.0 cm and which are of fundamental importance for the congruence of the joint and the integrity of the cartilage tissue, perform the bearing and sliding functions of the joint.

Thirty-five patients (33.6 %) had distal humerus fracture type A3; 58 (55.8 %) patients had type B2, the rest 11 (10.6 %) patients had type C2 and C3, six (5.8 %) and five (4.8 %) cases, respectively.

All patients underwent clinical and radiographic examinations. Spiral computed tomography of the elbow joint was performed in order to clarify the displacement of fragments and preoperative planning. The studies were conducted using a computed tomography system Philips Mx8000, multislice MRI was performed on a Hitachi Aperto 04 T device. DICOM images were processed on E-film 4.1 and OsiriX 8.0.1 software products.

Statistical analysis methods were chosen on the basis of the Shapiro-Wilk zero hypothesis, which is based on the assumption that the analyzed data do not obey the law of normal distribution. The statistical significance of the Shapiro-Wilk's test more than 0.05 rejects this assumption, therefore, proves the normal distribution. The results obtained, selected for

statistical analysis, had normal distribution, therefore parametric analysis methods were used.

Using descriptive statistics, we determined the mean value of the quantities (M), the error of the mean (m), the confidence interval (σ), the minimum and maximum values of the parameter. When analyzing the differences between two indicators, a T-test for independent samples was used; when comparing samples with one indicator (norm), a T-test for one sample was used; the Duncan a posteriori test was used for the analysis of several samples to reveal significant differences between several rows of findings.

Average term from the injury to surgery was 12.7 days.

Surgical interventions were performed under conduction anesthesia of the brachial plexus in all the patients and provided for a complete revision of the elbow joint. Posterior approach was used. In 70 (67.3 %) patients, the olecranon process osteotomy was used as access to the joint (i.e., trans-olecranon access). In 34 (32.7 %) patients, tangential osteotomy of the apex of the olecranon and mobilization of the tendon of the triceps of the humerus laterally (a modification of the Bryan-Morrey access) were applied.

Osteotomy of the olecranon enabled to expose the posterior surface of the distal epimetaphysis of the humerus, perform a low traumatic revision of both posterior and anterior compartments of the articular surface of the humerus and allowed reconstitution of the articular surface without any skeletonizing and isolation of bone fragment (**Fig. 1**).

After provisional fixation of the distal articular surface of the humerus, stable osteosynthesis of the humerus was performed with wires. In this case, we used a compression device developed by us. The proposed device is a wire with a stopper pad. The cutting end of the wire is supplied with a thread, and a stop tube shaped as a hollow screw with an external thread for fixation in bone tissue and an internal thread corresponding to the thread on the wire. The device allows compression of small bone fragments due to the screwing of the wire into the thread of the hollow screw.

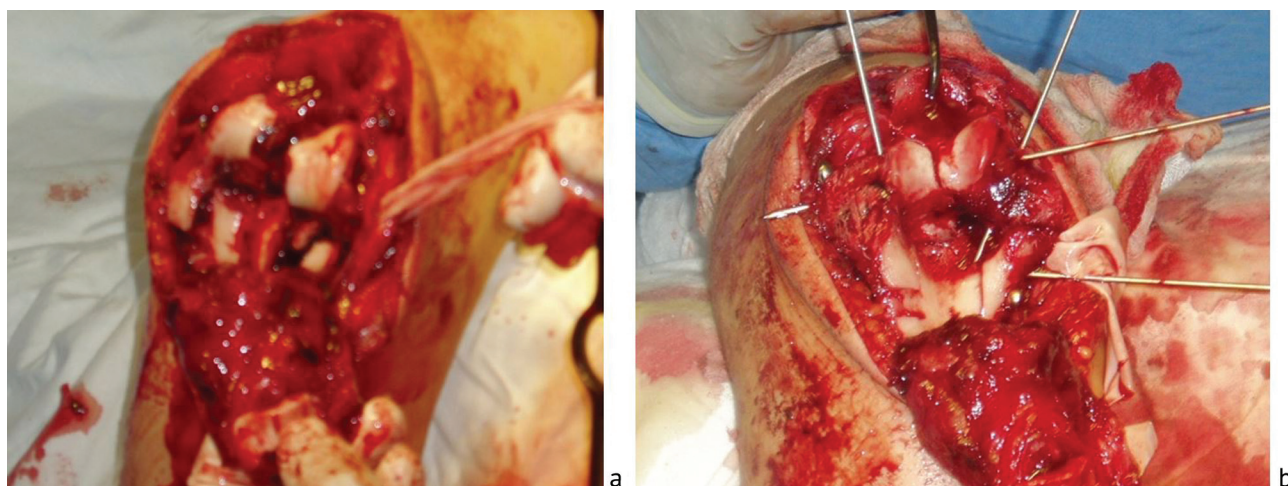


Fig. 1 Photos of surgical wound. Revision of the injured zone of the distal metaepiphysis of the humerus after the osteotomy of the olecranon. The ulnar nerve is isolated and clipped with a holder (a). Provisional fixation of the distal articular end of the humerus with the wires without isolating bone fragments and skeletonizing them (b)

This device was used by us as an additional means of stabilization combined with other types of osteosynthesis or as the main means of osteosynthesis.

Combined osteosynthesis was performed in patients with type C injuries. Stable internal osteosynthesis with standard fixation means (plates and (or) screws) was used in this category of patients along with the device developed by us as an additional means of stabilizing separate small bone fragments that could not be fixed by standard osteosynthesis. In six (5.8 %) patients with type C2 fractures, plates were used as the main type of stabilization, which were located along the medial or lateral crest of the distal metaepiphysis of the humerus, depending on the fracture. The compression device developed by us was used as an additional means of stabilizing small bone fragments.

In fragmentary fractures of the articular surface, it was rarely possible to use two plates to stabilize the

fragments, placing them along both crests of the distal metaepiphysis, since the screws do not fix the bone fragments, but, on the contrary, displace small fragments due to the complex relief and curve of the distal humerus and different orientation of fracture planes. In such cases, the plate was positioned closer to the posterior surface of the humerus. Separate bone fragments were fixed by the proposed compression device for osteosynthesis (**Fig. 2**).

It was not possible to use plates in five (4.8 %) patients with type C3 fractures due to the nature of the fracture of the distal humerus. For osteosynthesis, screws and a compression device developed by us were applied. The direction of screws insertion and of the proposed device for osteosynthesis was dictated by the size of bone fragments, orientation of the fracture planes and anatomy of the distal humerus.

We demonstrate the use of the compression device developed in management of patients with type C fractures.

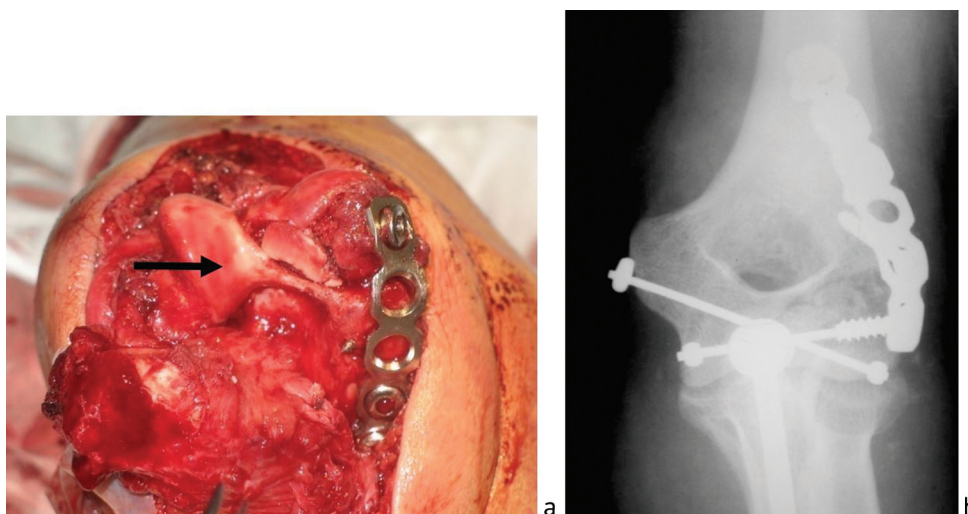


Fig. 2 Photo of surgical wound (a) and a radiograph of the elbow joint after osteosynthesis with a support plate (b). As an additional means of fixation of bone fragments, a compression device developed was used (arrow)

Patient E., 69 years old, had a fall on the street on the left arm which bent in the elbow joint. She was transported urgently to the RTC of Donetsk, where, after a clinical and X-ray examination, a closed C2 type comminuted fracture of the distal epimetaphysis of the left humerus with displacement according to the classification of AO/ASIF was diagnosed (**Fig. 3**).

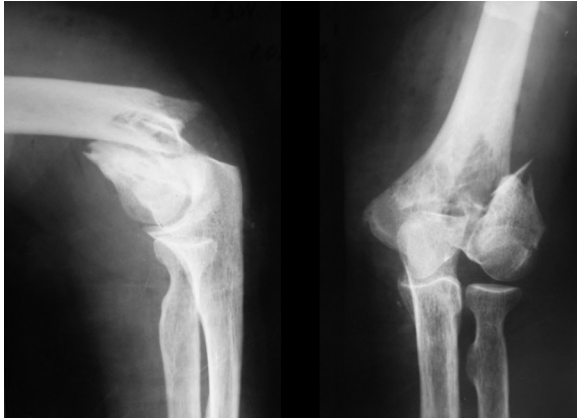


Fig. 3 Radiographs of the elbow joint after injury in patient E., 69 years old, frontal and lateral views

On the 3rd day after the injury, an intervention was performed: open reduction, stable osteosynthesis of the fragments of the lateral condyle with screws and a compression device developed by us. The operation was performed from the posterior approach with the osteotomy of the olecranon, which provided a good overview of the affected area and reduction and fixation of bone fragments of the lateral condyle without any additional skeletization or fragment isolation (**Fig. 4**).

With the help of a long malleolar screw, the fragment of the lateral condyle was fixed to its anatomic bed in the correct position (head with a part of the humerus). The medial fragment of the condyle was fixed with two cortical screws. The intermediate fragment with a part of the articular surface was fixed with the compression device developed by us. Osteosynthesis was stable.

The synthesis of the olecranon was made with the help of a screw for spongy bone and a wire loop (**Fig. 5**). The postoperative period was uneventful. Motions in the elbow joint started from the second day after the operation.

When performing osteosynthesis, our device has significantly simplified the synthesis of fragments. Anatomical reduction of fragments and their stable fixation was achieved with a minimum number of metal implants. All patients followed the standard rehabilitation program. Functioning of the elbow joint was restored. The bone fragments of the humeral condyle of the humerus united in the generally accepted terms (**Fig. 6**).

Functional outcome was rated as good (**Fig. 7**).

The total flexion in the elbow joint reached 80°, which is 16 points; pronation-supination movements were not limited. The patient did not feel either a decrease in muscle strength or pain. The left elbow joint is stable. The total score on the Broberg-Morrey scale is 89 points, which corresponds to a good result. The method of Casselbaum also evaluated the treatment outcome as good. There was no difference in the assessment of outcome.

Patients diagnosed with type A3 fractures underwent osteosynthesis using only a compression device developed by us. After osteosynthesis, the surgical wound was carefully sutured and drained. Drainage was removed after 2–3 days. Immobilization with a plaster splint was performed to removal of sutures, and only in one patient with a multifragmental fracture of type C3, immobilization continued 4 weeks. After the sutures were removed, the joint was freed and the patient started training the movements in the joints of the limb under the supervision of an exercise therapist following a gradual increase in the number of exercises and the range of the forearm motion.

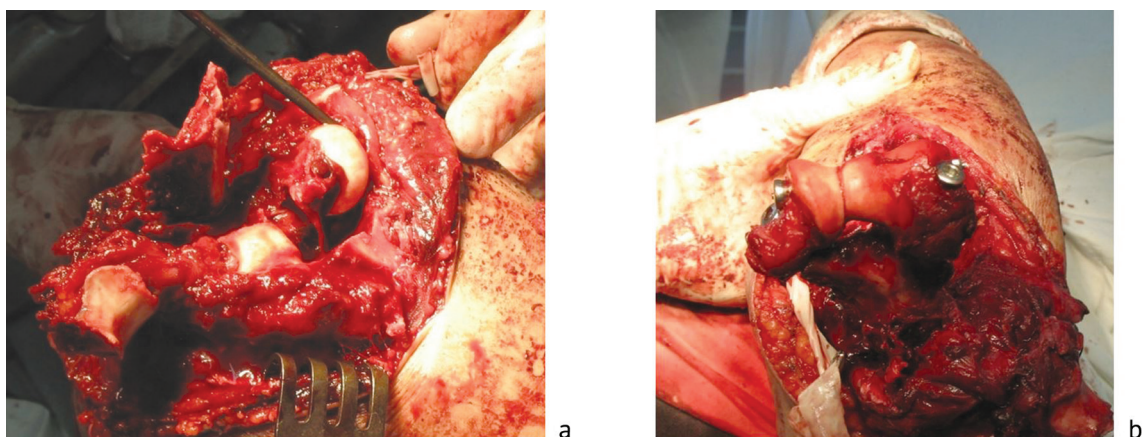


Fig. 4 Photo of surgical wound in patient E., 69 years old. View of the comminuted fracture zone of the distal metaepiphysis of the humerus after arthrotomy (a); distal articular end of the humerus fixed with metal constructs (b)



Fig. 5 Radiographs of the elbow joint of patient E., 69 years old, after surgery, in two projections (a, b). Satisfactory reduction of fragments fixed with screws and a compression device



Fig. 6 Radiographs of the elbow joint of patient E., 69 years old, two months after surgery (a, b). Union of fragments without complete reorganization. Partial migration of the fixation screw and associated slight secondary displacement of the fragment along the medial surface

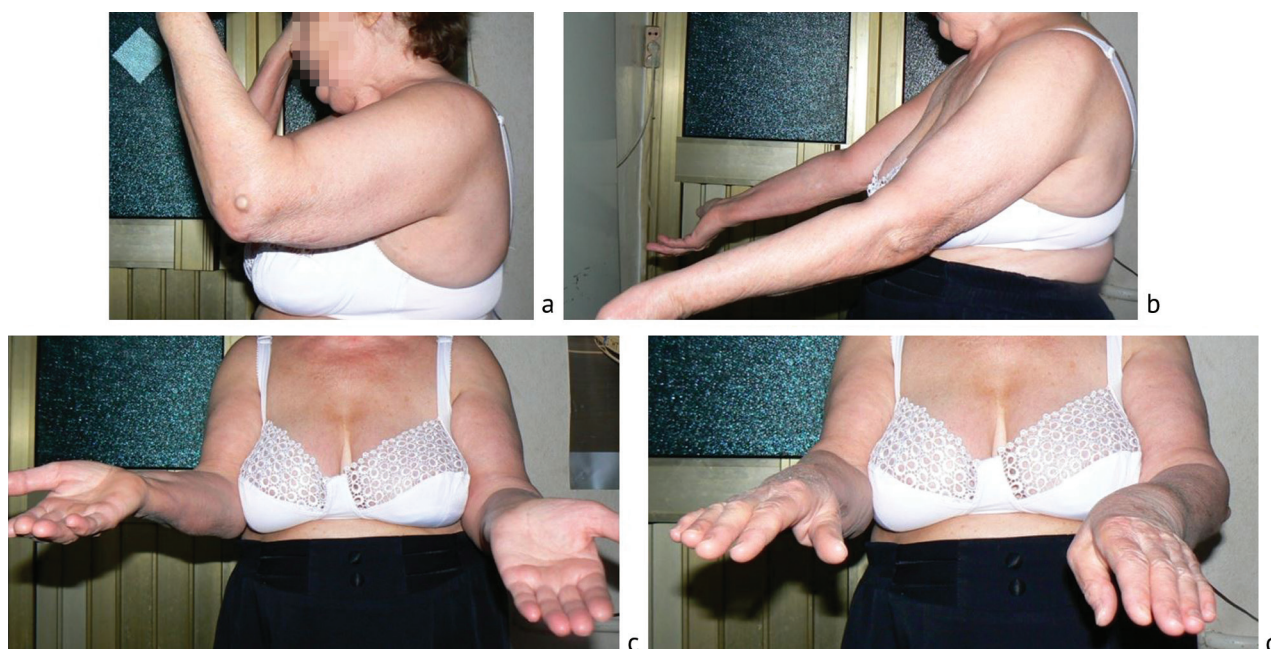


Fig. 7 Function of the elbow joint of patient E., 69 years old, two years after the operation. There is good flexion (a) and extension (b) and almost full pronation and supination (c, d)

We present a clinical example to illustrate the use of the developed device in the treatment of patients with fractures of type A3 (**Fig. 8**).

Patient Sh., 35 years old, was injured when falling on a slippery road and fell on the arm bent in the elbow. When admitted to the RTC and after a clinical X-ray examination, a closed comminuted fracture of the distal metaepiphysis of the left humerus was diagnosed. As a result of the treatment, the range of movements in the elbow joint was fully restored: extension – flexion 0/0/130°; supination – pronation in full range (**Fig. 9**).

When recording the outcome of treatment, it was revealed that the total amplitude of flexion was 130°,

which corresponds to 29 points. Pronation-supination movements were not restricted, which corresponds to an excellent outcome both on the Broberg-Morrey scale and on the Casselbaum rating scale. The patient had neither a decrease in muscle strength nor pain. The left elbow joint was stable. The total score on the Broberg-Morrey scale is 99 points, which corresponds to an excellent result. Evaluation of the result according to the method of Casselbaum also rated the outcome of treatment as excellent.

Analyzing the result of treatment in this patient, it should be noted that the use of a stable internal osteosynthesis using the device proposed could

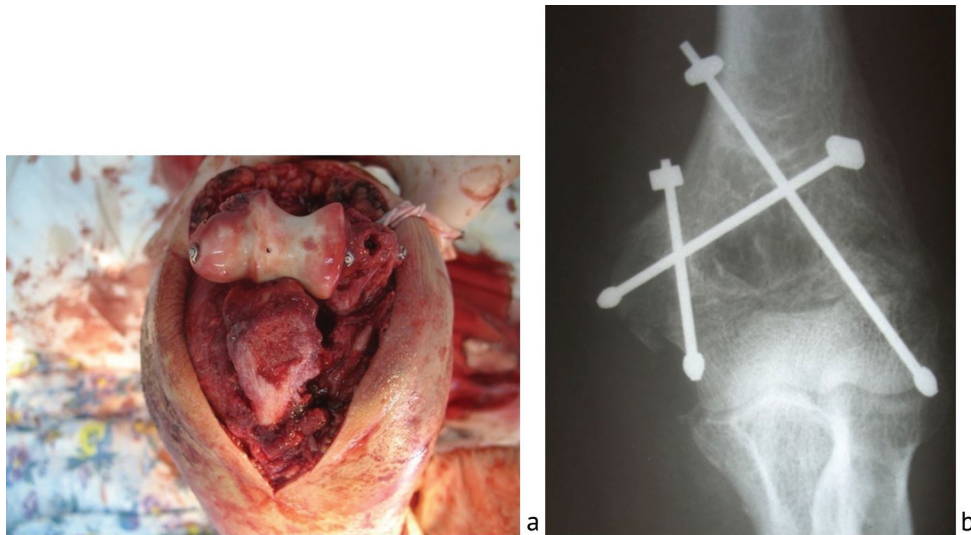


Fig. 8 Photo of the surgical wound (a) and radiograph of the elbow joint of the patient Sh., 35 years old, frontal view (b) after osteosynthesis with a developed compression device

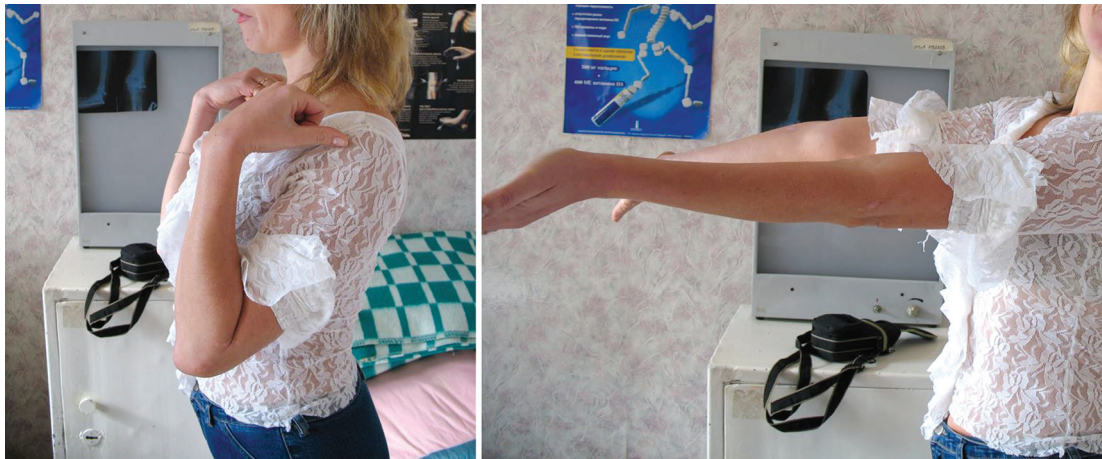


Fig. 9 Range of motion in the elbow joint in patient Sh., 35 years old. There is no limitation of movements in the sagittal plane

provide an accurate reduction of fragments of the condyles of the humerus and stable fixation of fragments, and, therefore, the conditions for restoring the function of the elbow joint.

We used the following protocol of exercise therapy in all the patients with the above injuries:

- Days 2–5: 10–20 passive movements in the elbow joint (flexion-extension, pronation-supination) once a day; active movements of the hand and shoulder joints.
- From the 6th–8th day, actively and passive movements in the elbow joint were done, focusing on the patient's sensations, 20–30 movements 2–3 times a day (flexion-extension, pronation-supination). Active movements of the hand and shoulder joint.
- From the 10th to the 12th day, active movements in the elbow joint of the operated limb, increasing the frequency and duration of training were recommended. Doing them, the patient assisted with a healthy hand by movements in the operated elbow joint.
- From week 3–4, the load was increased to an

active “counteraction” to the emerging sensation of an obstacle at the end points of the movement, focusing on the patient's sensations.

In our opinion, the most important period in the training of movements in the elbow joint is the first 6–8 weeks after surgery. During this period, the stereotype of movements is restored, muscular activity is achieved and the maximum increase in the range of movements is achieved. The growth of the range of motion reduces sharply. It is important not to stop rehabilitation treatment during this period, but to continue it, which will contribute to a further increase in the range of movements in the elbow joint.

The studies were approved by the ethics committee of the Donetsk Gorky National Medical University and were conducted in accordance with the ethical standards set forth by the Helsinki Declaration of the World Medical Association “Ethical principles of scientific medical research involving humans” (2000).

RESULTS AND DISCUSSION

The duration of follow-up ranged from two to 5 years. The results of the treatment were analyzed using 1) the method described by Broberg and Morrey [14]; 2) the technique described by Casselbaum modified Jupiter J.B. et al. [15]. These evaluation techniques take into account such parameters as a pain; range of motion (bending, pronation, supination); muscle strength of the limb operated; stability of the elbow joint. According to the Broberg and Morrey rating scale, the pain factor has the greatest value (maximum 35 points), the muscle strength can be as high as 20 points and the stability of the joint as 5 points maximum. When estimating the range of motion, the points for the range of motion are calculated as follows: for bending - the amount of bending in degrees is multiplied by a factor of 0.2; pronation - pronation in degrees is multiplied by a factor of 0.1; supination - supination in degrees is multiplied by a factor of 0.1; then the points are summed up. The maximum amount of flexion is considered 135° (27 points), pronation is 60° (6 points), and supination is 70° (7 points). Thus, the maximum number of

points that estimate the amount of movement is 40 points. A detailed description of the evaluation of the functional results of the treatment of fractures of the distal metaepiphysis of the humerus according to the Broberg and Morrey scale is given in Table 1.

The maximum possible number of points that a patient can score is 100. Therefore, the functional outcome was evaluated in relative terms. Assessment of the quality of recovery of the function of the elbow joint in points is given in table 2.

The system for evaluating the results of treating patients with fractures of the distal articular end of the humerus, described by Casselbaum as modified by Jupiter J.B. et al. (1985), is simpler to use in clinical practice, but more subjective. It evaluates only three parameters: range of motion in the elbow joint, pain severity and ability to fulfill household activities (Table 3).

We used both rating scales in order, first, to increase the objectivity of the results obtained and, second, to compare the results of the scales. We did not reveal any case of discrepancies in the results of treatment, evaluated with these score systems.

Table 1

Functional evaluation of fractures of the distal humeral metaepiphysis according to Broberg and Morrey (points)

Parameter	Description	Points
Strength	Normal	20
	Mild loss (appreciable but not limiting; strength 80 % that of contralateral side)	13
	Moderate loss (limits some activity; strength 50 % that of contralateral side)	5
	Severe loss (limits everyday tasks, disabling)	0
Stability	Normal	5
	Mild loss (perceived by patient, no limitation)	4
	Moderate loss (limits some activity)	2
	Severe loss (limits everyday tasks)	0
Pain	None	35
	Mild (with activity, no medication)	28
	Moderate (with or after activity)	15
	Severe (at rest, constant medication, disabling)	0
Range of Motion	maximum	40

Table 2

Evaluation of treatment outcomes of fractures of the distal humeral metaepiphysis according to Broberg and Morrey

Points	Outcome
95-100	Excellent
80-94	Good
60-79	Insufficient
0-59	Poor

Table 3

Evaluation of treatment results of fractures of the distal humerus according to Casselbaum scale

	Outcome	Pain	Range of motion	Activity limitation
4	Excellent	none	115° and more	none
3	Good	Occasionally	90-115°	Minimal
2	Fair	By motion	50-100°	moderate
1	Poor	At rest	Less than 50°	Marked

These characteristics made enabled to evaluate the results of treatment of patients with multicomminuted fractures of the distal metaepiphysis of the humerus with the presence of small fragments. Using the Broberg – Morrey functional index, as well as the Casselbaum treatment outcome evaluation system modified by Jupiter J.B. et al. (1985), we assessed

the results of treatment in all groups of patients as a whole. This approach to evaluating the results of treatment, in our opinion, was more indicative. Thus, excellent treatment outcomes were achieved in 62 (59.6 %) patients, good results in 36 (34.6 %) patients, and in six (5.8 %) patients, the result was evaluated as fair.

CONCLUSION

Thus, osteosynthesis using the compression device developed by us reduces and stabilizes small bone fragments, enables the implementation of early movements in the elbow joint, and provides good treatment results.

Osteosynthesis of small fragments using the compression device developed showed high efficiency in patients with multicomminuted fractures of the distal metaepiphysis of the humerus. The mean score was 82.67 ± 5.59 points, which corresponds to a good treatment outcome.

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