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A tactical algorithm for minimally invasive reduction of talar fracture-dislocations

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Abstract

Introduction Poor outcomes in the treatment of fracture-dislocations of the talus lead to revision surgeries and disability. There is no standardized algorithm for their minimally invasive reduction.

Purpose Analysis of treatment outcomes in patients with fracture-dislocations of the talus using the developed minimally invasive reduction.

Materials and Methods Data from 46 patients were analyzed. Group A (n = 21) underwent algorithmic reduction, while Group B (n = 25) served as controls. The groups were matched by sex, age, and injury severity. Medical records, CT scans, radiographs, SF-36, and Foot and Ankle Outcome Score (FAOS) questionnaires were assessed and evaluated.

Results In Group A, reduction followed a stepwise approach: Type 1 injuries received instrumental and manual reduction; complex types 2–3 were converted to type 1; multifragmentary fractures (type 4) underwent open reduction. The Ilizarov fixator with ankle hinges was used in Group A. Minimally invasive reduction success rate was three times higher in Group A: 13 cases (62 %) versus 5 (20 %) in Group B. Avascular necrosis occurred in 1 patient (5 %) in Group A versus 9 (36 %) in Group B, 7.2 times less. SF-36 and FAOS scores were significantly higher in Group A. Joint arthrodesis was required 6.7 times more frequently in Group B.

Discussion We achieved low rates of aseptic necrosis and the need for subsequent arthrodesis, as well as good evaluation grading results for minimally invasive reduction techniques in Group A, which is consistent with the authors' opinions using hardware-based reduction and osteosynthesis techniques. A differentiated approach to reduction and patient management depending on the type of talar fracture-dislocation is a distinctive feature of the proposed algorithm.

Conclusions The minimally invasive reduction algorithm is reproducible and triples success rate. The algorithm reduces the complication rate of avascular necrosis and infection rate. The algorithm technique results were superior in functional outcomes (SF-36, FAOS) and therefore reduced arthrodesis necessity. The hinged Ilizarov fixator is crucial for preventing talar collapse and arthritis.

Keywords: talus fracture, minimally invasive reduction, algorithm, Ilizarov fixator

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INTRODUCTION

Fractures and fracture-dislocations of the talus are rare, accounting for 0.5–1.0 % of all injuries and 20 % of all foot fractures [1, 2, 3, 4]. Most patients are of working age [5]. The low incidence of this injury complicates the accumulation and generalization of experience in its surgical treatment [6]. Talus fractures mostly result from high-energy trauma, while the mechanism of injury has not been fully studied [7]. Most of the talus (60–73 %) is covered with cartilage and is deprived of blood circulation through penetrating blood vessels [6, 8, 9]. Anatomical features are the main cause of critical circulatory impairment in fracture-dislocations of the talus and determine high rates of avascular necrosis (from 10 % to 100 %) [2, 3, 7, 9]. It has been noted that avascular necrosis most frequently develops in fracture-dislocations of the neck and body of the talus [10, 11, 12]. The main mechanisms of talus fracture are splitting and impression, with the latter being more common [13]. Avascular necrosis and subsequent degenerative changes in the ankle, subtalar and talonavicular joints lead to a high rate of poor results and the need for repeated surgeries such as arthrodesis of the ankle and/or subtalar joint [14, 15]. Treatment of patients with this injury requires: bone grafting or 3D printing of a custom implant [16], sanation arthroscopies for minor defects of the articular surface and osteochondroplasty [17, 18], and ankle arthroplasty or talus replacement [19]. High rates of avascular necrosis and degenerative changes result in disability of the third and second grades, the frequency of which can reach 15–30 % [1, 14, 15].

The diagnosis of fractures and dislocations of the talus is based not only on multi-position radiographs, but also computed tomography (CT), magnetic resonance imaging (MRI) to obtain complete information about the position of the fragments for correct preoperative planning [20, 21, 22].

Current studies confirm the relevance of minimally invasive reduction and low-trauma osteosynthesis, but lacks uniform, practical tactical algorithms. Developing such an algorithm and analyzing its effectiveness is a pressing and important goal.

Purpose of the work was analysis of treatment outcomes in patients with fracture-dislocations of the talus using the developed minimally invasive reduction and alignment.

Working hypotheses

— The developed algorithm for minimally invasive reduction and alingment of fracture-dislocations of the talus is reproducible in clinical practice and increases the success of reduction;

— The treatment result depends on the trauma of the reduction method.

MATERIAL AND METHODS

Study design: controlled open retrospective cohort multicenter randomized study.

Inclusion criteria: fracture-dislocation of the talus, surgical treatment, complete radiographic archive, follow-up.

Exclusion criteria: absent treatment outcome due to patient death, refusal to participate in the study, or lack of contact with the patient.

Study framework: analysis of medical records, radiographs, CT scans, outpatient cards, data from patient follow-up examinations, and questionnaire results was performed.

A set of data including the VAS (visual analogue scale), SF36, and FAOS (Foot and Ankle Outcome Score) scales and questionnaires was collected. The quality and method of reduction, signs of aseptic necrosis with bone collapse, and infectious complications were assessed. Poor reduction was defined as visual deformity of the talus and displacement of one of the articular surfaces by 3 mm or more. Signs of secondary displacement were defined as the dynamic appearance of the same signs on radiographs and/or CT.

The authors of this study developed an algorithm for minimally invasive reduction and alignment of talus fractures and dislocations. The algorithm classifies all talus fractures and dislocations into four types based on minimally invasive reduction techniques and the anatomical variations of the lesion to the capsular-ligamentous apparatus of the hindfoot (Fig. 1):

Type I: large fragments are located in the ankle joint, the displacement is predominantly rotational; there is no dislocation in the subtalar joint. This type of fracture-dislocation is characterized by preservation or minor damage to the capsular-ligamentous apparatus of the ankle joint;

Type II: a large fragment(s) is dislocated from the ankle joint; there is no dislocation in the subtalar joint. This type is characterized by partial damage to the capsular-ligamentous apparatus; reduction of the dislocated fragment(s) is difficult due to interposition of the ankle joint capsule that is changed in the shape;

Type III: part of the talus retains its original position in the ankle joint, while the rest of the talus is dislocated along with the foot; the deformity is similar to a subtalar dislocation of the foot. This type of fracture, as in a subtalar dislocation of the foot, features injury to the ligaments of the subtalar and ankle joints;

Type IV: multiple fragments are located in the ankle joint; there is no dislocation of the subtalar joint. This type is characterized by an impression fracture of the talus.

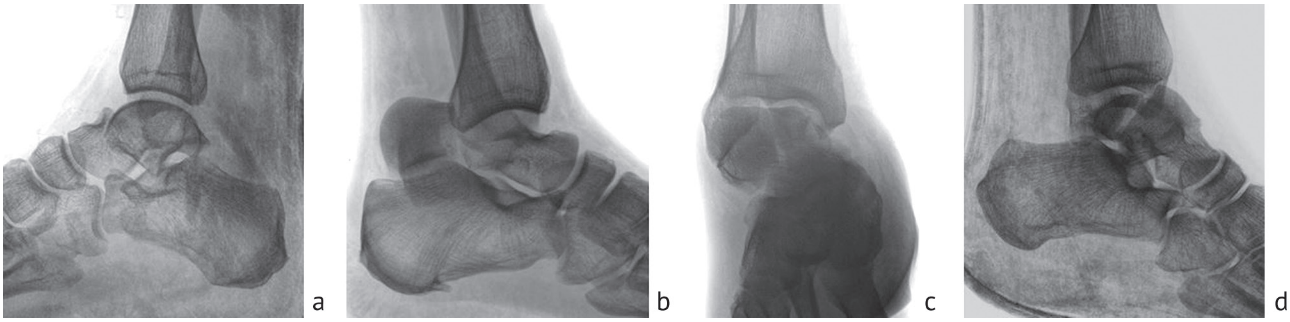


Fig. 1 Types of fractures and fracture-dislocations of the talus according to the anatomical variants of damage to the capsular-ligamentous apparatus of the hindfoot: (a) Type I; (b) Type II; (c) Type III; (d) Type IV

The AO/OTA classification describes fracture anatomy but does not describe the fracture-dislocation types we identified. It only partially addresses fracture-dislocations of the talar neck, but does not specify displacement patterns for fracture-dislocations of the talar body. Accordingly, the AO/OTA classification cannot be used to explain the logical sequence of the algorithm for minimally invasive reduction of talar fracture-dislocations. This circumstance led us to distinguish four types of fracture-dislocations. The AO/OTA classification focuses on the choice of surgical approach and osteosynthesis. The algorithm we developed is designed for minimally invasive reduction of talar fracture-dislocations, i.e., it pursues different goals.

Logical sequence of the algorithm

Type I Elimination of rotational displacement of fragments in the ankle joint with joystick, lever, and reduction with the aid of bone forceps (Fig. 2 a, b).

Type II Inferior and posterior traction on the calcaneus using a wire tensioned in a clamp or the Ilizarov apparatus arch; foot inclination at an angle open to the dislocated fragment; pressure with a finger on the dislocated fragment; conversion of the fracture from type II to type I (Fig. 2 c). If the bone fragment is interlocked with other bones in a "Russian lock" pattern, it must be unlocked with an awl.

Type III Axial traction on the calcaneus using a clamp with a tensioned clamp or in the Ilizarov apparatus arch and manual reduction of the fracture-dislocation similar as in the reduction of a subtalar dislocation of the foot; conversion of the fracture from type II to type I (Fig. 2 d)

Type IV Open reduction followed by final fixation with the Ilizarov apparatus or the Ilizarov apparatus and cannulated screws (Fig. 2 e).

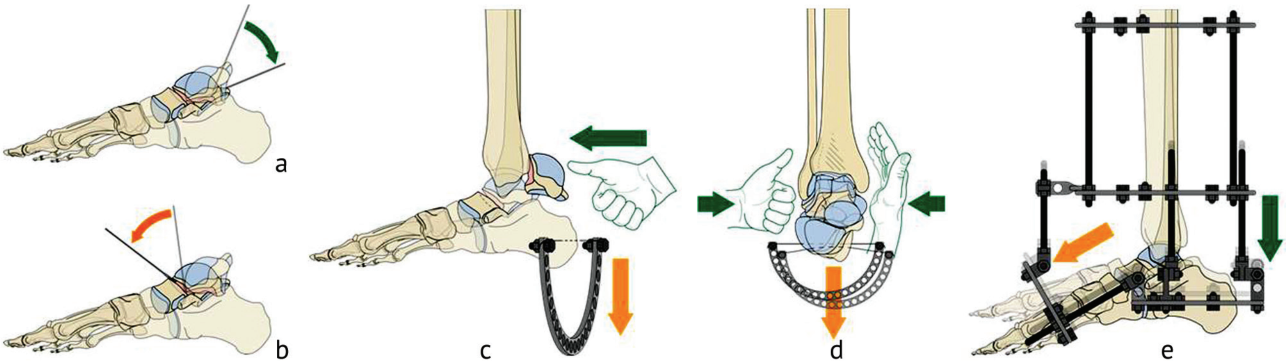


Fig. 2 Reduction techniques sequentially used in surgical treatment of fracture-dislocations of the talus according to the proposed algorithm: (a) "joystick" method; (b) "lever" method; (c) traction and finger pressure; (d) traction and palmar counterstop; € combined distraction in the Ilizarov apparatus

All patients were divided into two groups:

— Group A: study group (n = 21) in which the developed algorithm was used;

— Group B: control group (n = 25), in which the algorithm developed by the authors was not used.

The patients were treated from 2015 throughout 2024 at the Traumatology and Orthopedic Department No. 1 of the G.A. Ilizarov National Medical Research Center of Traumatology and Orthopedics (Kurgan), the traumatology departments of the City Clinical Hospital No. 6 (Chelyabinsk), City Clinical Hospital No. 1 (Chelyabinsk), City Clinical Hospital No. 9 (Chelyabinsk), Chelyabinsk Regional Clinical Hospital, Chelyabinsk Regional Clinical Hospital No. 3, and City Clinical Hospital No. 3 (Magnitogorsk).

Surgeries in the study group were performed by the authors of the article and five orthopedic surgeons from Chelyabinsk City Clinical Hospital No. 6, trained in the algorithm for minimally invasive reduction and reduction of talus fractures and dislocations. All patients in Group A underwent surgery within 48 hours since injury.

The surgeons who treated the patients in the control group were unaware of and did not use the developed algorithm. The study in Group B was conducted retrospectively; surgical interventions in the group were performed within the period from 48 hours to five days after injury.

Then analysis of surgical treatment outcomes of 46 talus fractures and dislocations in 46 patients was conducted. Males predominated among the patients (n = 39, 85 %), which is associated with the more common occupational injuries, as the service areas of most Chelyabinsk medical institutions include metallurgical plants and other enterprises. Eighteen (46 %) of the occupational injuries were sustained in males.

The age of all patients at the time of injury ranged from 22 to 64 years (average age 40.5 years): the average age of patients in group A was 41.86 years, group B — 39.36 years, t_{Emp} = 0.7, thus both groups consisted of patients of working age.

All fractures were classified according to AO/OTA (Table 1). The predominant injury pattern was fractures of the talar neck with dislocation of the trochlea. Thus, in terms of age distribution and the nature of talar fracture-dislocation, Group A and Group B are comparable.

Table 1

Distribution of patients in groups according to the AO/OTA classification

AO classification	Group A (*n* = 21)		Group B (*n* = 25)	
	Number	%	Number	%
81.1. A2	0		1	4.0
81.1. A3	1	4.8	1	4.0
81.2. B	1	4.8	4	16.0
81.2. C	3	14.3	6	24.0
81.2. D	2	9.5	1	4.0
81.1. C1	5	23.8	3	12.0
81.1. C2	5	23.8	6	24.0
81.1. C3	4	19.0	3	12.0

The severity of soft tissue injuries was retrospectively assessed using case records: severe soft tissue injuries of Gustilio-Andersen type 3, or Tscherne O 3–4, or Tscherne C 2–3 were more common in Group A (n = 11) than in Group B (n = 5), $p = 0.017$ (< 0.05). Severe soft tissue injuries were also more common in Group A. Groups A and Group B were comparable in injury severity.

Statistical data processing was performed in MS Excel 16.16.27 (2012) with the AtteStat 12.0.5 add-in. The following statistical methods were used in the comparative analysis: mean value, median, Student's t-test or nonparametric Mann – Whitney U-test, Fisher's exact test, χ^2 test, and odds ratio.

The studies were approved by the Ethics Committee of the South Ural State Medical University of the Russian Ministry of Health (protocols No. 1 of 06.01.2019 and No. 2 of 15.02.2023), the Ethics Committees of the State Autonomous Healthcare Institution City Clinical Hospital No. 3 of Magnitogorsk, the State Autonomous Healthcare Institution City Clinical Hospital No. 6 of Chelyabinsk, and the Ilizarov National Medical Research Center for Traumatology and Orthopedics of the Russian Ministry of Health.

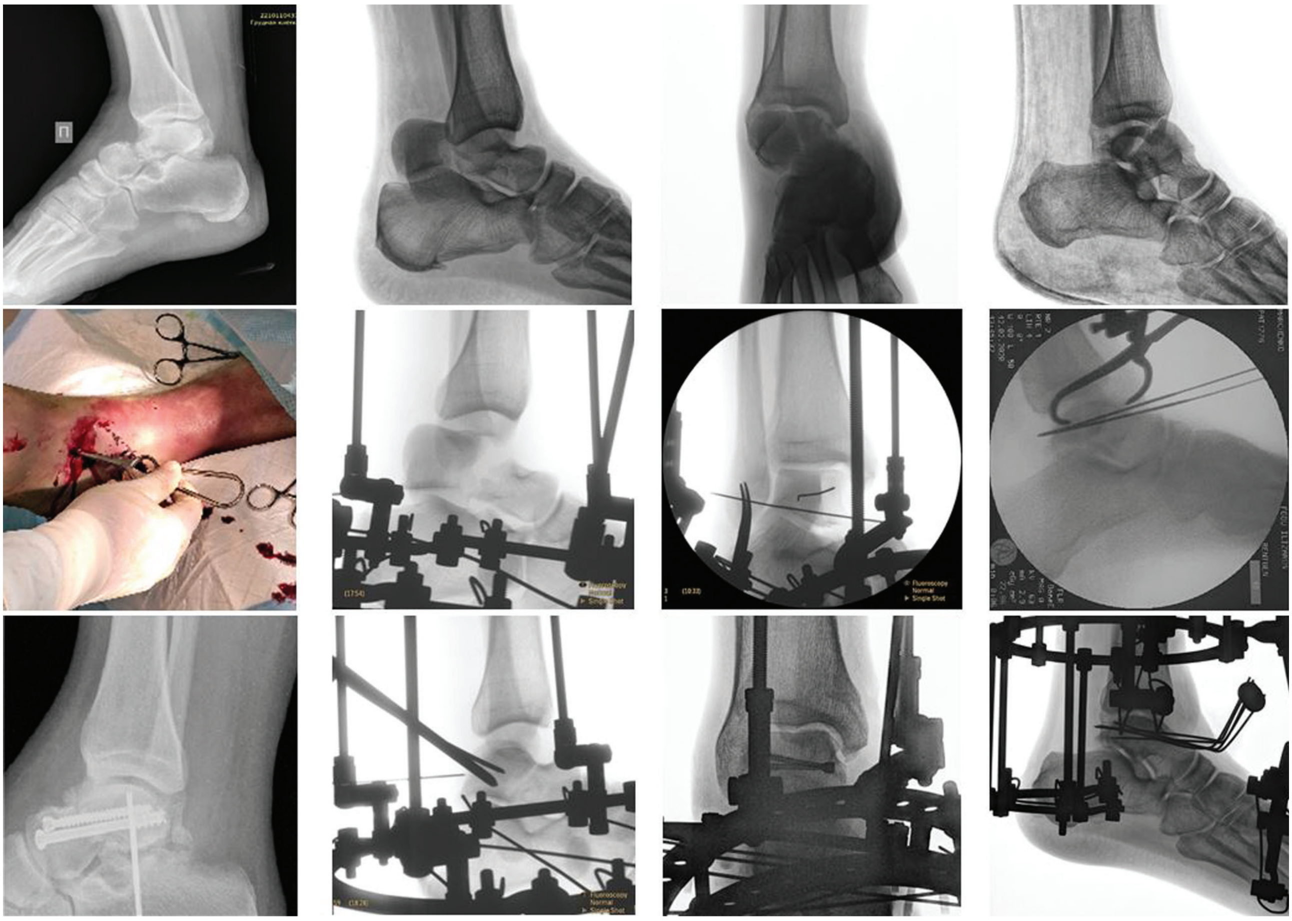
All patients signed consent to participate in the study and publication of its results.

RESULTS

In Group A, the reduction techniques and tactics were chosen according to the algorithm for minimally invasive reduction and realignment of talus fractures and dislocations. Clinical examples of the algorithm application are presented in Figure 3.

The rate of successful minimally invasive reduction and alignment of talus fracture-dislocation was assessed in both groups (Table 2).

In Group A, minimally invasive reduction of fracture-dislocations was achieved in 13 of 21 cases (62 %), while in Group B, minimally invasive reduction was successful in only five of 25 cases (20 %). There was a significant difference in the success rate of minimally invasive reduction in the groups, $p = 0.012$ (< 0.05). In Group A, minimally invasive reduction was not indicated in four cases (19 %), as these fracture-dislocations were type IV. In four cases, closed reduction of the fracture-dislocation was not possible due to irreversible soft tissue interposition; in those cases, the tissue interposition was eliminated openly.



a b c d

Fig. 3 Use of reduction techniques based on the type of fracture-dislocation of the talus: (a) type I; (b) type II; (c) type III; (d) type IV

Table 2

The reduction methods used by doctors depending on the type of fracture according to the authors' classification

Type of fracture dislocation	Group A						Group B					
	Total (*n* = 21)		Low traumatic (*n* = 13)		Open (*n* = 8)		Total (*n* = 25)		Low traumatic (*n* = 5)		Open (*n* = 20)	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Тип I	38.1	7	53.8	1	12.5	7	28.0	2	40.0	5	25.0	25,0
Тип II	14.3	2	15.4	1	12.5	3	12.0	0		3	15.0	15,0
Тип III	28.6	4	30.8	2	25.0	10	40.0	3	60.0	7	35.0	35,0
Тип IV	19.0	0		4	50.0	5	20.0	0		5	25.0	25,0

In Group A, minimally invasive reduction was performed exclusively according to the algorithm developed by the authors. Manual reduction, the joystick method, the lever principle, and traction with the Ilizarov apparatus were used for minimally invasive reduction. In all 13 cases, consistent adherence to the algorithm resulted in fracture-dislocation reduction and subsequent talus reduction. Reduction control was performed intraoperatively on a C-arm using lateral and AP views of the ankle joint, axial views of the talus, and the Canale and Broden views. In open fractures, we performed reduction using the same principles, without increasing the size of the surgical wound. In Type IV fracture-dislocation, open reduction was used for better restoration of the anatomy of the talus with osteosynthesis using screws or preliminary fixation with wires of fragments axially or from the calcaneus to fragments of the talus according to the "fan" principle and subsequent Ilizarov osteosynthesis.

In Group B, lateral approaches with osteotomies of the lateral or medial malleolus were used for reduction. After osteosynthesis, the malleoli were fixed with screws or a one-third tubular plate. The minimally invasive reduction techniques used in the control group were not described in detail in the surgical protocols.

In Group A, multiprojection radiography and CT in the operating room and postoperative period showed that it was possible to restore the anatomy of the talus in 100 % of patients ($n = 21$). In Group B, anatomical reduction was not achieved in 12 patients (48 %).

Various methods of osteosynthesis of the talus after its reduction were used.

In Group A, internal and external fixators were used. For fracture-dislocation types I, II, and III with comminuted fractures and significant soft tissue damage, a load-shunting approach was used to unload the talus during fixation. Ankle joint motion was maintained by installing single-plane hinges along the ankle joint axis, with orientation on the malleolus tips. Treatment with the apparatus for type IV allowed the patient to ambulate with weight-bearing motion until the tibia modules were removed. In two patients with type IV talus fractures, unloading with the Ilizarov apparatus was not performed according to the developed algorithm, but vertical loading was limited to four months. For type III fracture-dislocations, talus fixation was performed with the Ilizarov apparatus or transarticular wire from the calcaneus to the talus without penetrating the ankle joint. In the latter option, fixation with orthoses was used. For type I, II, and III fracture-dislocations with large fragments, fixation was performed using cannulated screws with preliminary bone reaming along a guide wire and countersinking adjacent to the screw head. Headless, cannulated, self-tapping, fully threaded FootDoctor XFL screws with diameters of 5.5 mm and 4.3 mm were used in 90 % of cases. No implant migration or loss of reduction was observed during the healing phase. In one case, a combination of cannulated screw osteosynthesis and the Ilizarov apparatus was used for a grade 81.1 C3 fracture according to the AO/OTA classification.

In group B, osteosynthesis was performed using screws, including non-cannulated ones, since osteosynthesis was open.

Table 3 shows the methods of osteosynthesis of the talus depending on the AO/OTA classification and the type of fracture according to the algorithm developed by the authors.

Table 3

Distribution of osteosynthesis methods according to AO/OTA classifications and the authors'

Fracture classification		Group A (n = 21)						Group B (n = 25)					
		Screws (n = 11)		TCDO (n = 9)		Screws + TCDO (n = 1)		Screws (n = 16)		TCDO (n = 8)		Screws + TCDO (n = 1)	
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
AO/OTA	81.1. A	0		1	11.1	0		2	12.5	0		0	
	81.2.	4	36.4	2	22.2	0		6	37.5	5	62.5	1	100.0
	81.1. B & C	7	63.6	6	66.7	1	100.0	8	50.0	3	37.5	0	
Authors' classification	Type I	3	27.3	5	55.6	0		5	31.3	2	25.0	0	
	Type II	3	27.3	0		0		2	12.5	1	12.5	0	
	Type III	3	27.3	3	33.3	0		6	37.5	4	50.0	1	100.0
	Type IV	2	18.2	1	11.1	1	100.0	3	18.8	1	12.5	0	

In Group A, the Ilizarov apparatus was used for comminuted fractures of the talus body. For screw-assisted osteosynthesis of type 81.2, B, and C fractures or type IV fractures, the Ilizarov apparatus was the definitive fixation method, ensuring stability of the osteosynthesis, unloading the talus to prevent collapse, and provided early mobilization of the ankle joint in the hinged module. No complications related to skin inflammation in the wire/pin insertion sites that impacted treatment outcome were observed.

No secondary displacement was observed in the study group; nine cases of displacement (36 %) were recorded in the control group.

To assess the treatment results, the SF36 and FAOS questionnaires were used (Table 4).

Table 4

Main indicators of the SF36 and FAOS questionnaires in the mid- and long-term since the injury

Parameters		Mid-term follow-up (0–4 years)			Long-term follow-up (5–10 years)		
		Group A (n = 2)	Group B (n = 11)	p-value	Group A (n = 9)	Group B (n = 13)	p-value
SF36	Physical function, points	*N* 76.03 [min 30; max 100] *M* 88.77	*N* 61.82 [min 25; max 95] *M* 55.00	$p = 0.048$ < 0.05	*N* 86.34 [min 65; max 100] *M* 88.77	*N* 53.93 [min 10; max 100] *M* 88.77	$p = 0.0007$ < 0.001
	Pain severity, points	*N* 75.83 [min 42; max 100] *M* 81.00	*N* 58.18 [min 35; max 90] *M* 55.00	$p = 0.019$ < 0.05	*N* 75.67 [min 45; max 100] *M* 77.00	*N* 53.92 [min 22; max 100] *M* 45.00	$p = 0.012$ < 0.05
FAOS	FS (Foot and Ankle Core Scale: Standardized Mean), points	*N* 81.67 [min 48; max 100] *M* 82.00	*N* 61.82 [min 58; max 95] *M* 75.45	$p = 0.374$	*N* 91.22 [min 86; max 96] *M* 91.00	*N* 70.08 [min 33; max 99] *M* 76.00	$p = 0.003$ < 0.005
	SS (Shoe Comfort Scale: Standardized Mean), points	*N* 87.01 [min 39; max 100] *M* 90.00	*N* 64.5 [min 20; max 100] *M* 60.00	$p = 0.032$ < 0.05	*N* 97.30 [min 80; max 100] *M* 100.00	*N* 53.8 [min 0; max 100] *M* 40.00	$p = 0.0009$ < 0.05

Notes: *N* — mean; *M* — median; min — minimal; max — maximal

In terms of the "physical functioning" the SF36 scale, Group A demonstrated better results in both the mid-term and long-term periods (a difference of 14.21 points and 32.41 points, respectively). Patients in Group A reported lower pain intensity by 17.65 points lower in the mid-term and 21.75 points in the long-term periods compared to patients in Group B.

The best FAOS results were also obtained in Group A: no significant differences were found for the FS indicator in the medium term, but the average FS value in the long term was 21.14 points higher. For the SS indicator, the average value was 22.6 points higher in the early stages and 43.5 points higher in the long term. Significantly positive dynamics were observed in Group A for the SF36 and FAOS scales in the long term compared to the results recorded in the medium term.

Avascular necrosis of the talus with deformity or destruction was observed in one case (4.8 % of patients) in Group A. This same patient developed stage 3 ankle osteoarthritis within one year, necessitating arthrodesis. Patients in Group A with type IV fracture-dislocation underwent open reduction and talus unloading using an external fixator (Fig. 2 e), which prevented talus collapse. The proportion of patients in Group A without avascular necrosis was 95.2 %.

In group B, avascular necrosis of the talus was observed in nine (36 %) cases, leading to deformity of the talus and the development of arthrosis or nonunion of the fracture.

Eight patients (32 %) in Group B underwent ankle or subtalar joint arthrodesis; one patient underwent arthroscopic osteophyte resection and synovectomy for stage 3 arthrosis. In Group A, arthrodesis was performed in one patient (4.8 %). Thus, arthrodesis of the foot joints was performed 6.7 times more frequently in Group B than in Group A.

In Group A, no infectious complications were observed. One patient developed osteomyelitis of the calcaneus of the contralateral limb, and one patient developed trauma-related skin necrosis of the calcaneus of the contralateral limb. In Group B, four cases of talar osteomyelitis and one case of non-cannulated screw migration were recorded.

DISCUSSION

In our study, minimally invasive reduction of talar fractures and dislocations was successfully performed not only by the authors of the article, but also by five orthopedic traumatologists trained in the algorithm. The successful reduction rate of talar fractures and dislocations reflects the reproducibility of the algorithm proposed by the authors.

Screw osteosynthesis prevailed in both groups. TCDO was also used in a significant number of fracture-dislocations (nine cases in each group), with a tendency to use TCDO for more complex 81B and 81C fractures, as well as for open fractures and compromised soft tissues. We used the Ilizarov apparatus in six cases of closed fractures to unload the talus, three cases of 81.1C fractures, two cases of 81.2 fractures, and one case of 81A3 fracture due to its comminuted nature.

In group A, secondary fracture displacement was observed three times less frequently than in group B, which is due to stronger fixation with the Ilizarov apparatus.

In group B, joint arthrodesis was performed 6.7 times more often than in group A, which is associated with the predominance of open surgeries in the conditions of circulatory disorders.

In Group A, aseptic necrosis of the talus and its deformity developed 7.5 times less frequently than in Group B. The proportion of patients without it in Group A was 95.2 % versus 60.0 % in Group B ($p = 0.004$). We attribute the lower incidence of aseptic necrosis in patients in the study group to the preservation of blood circulation due to minimally invasive reduction of fractures and dislocations, as well as to early rehabilitation using the Ilizarov apparatus with a hinge at the ankle joint. The treatment in the fixator relieves the talus in severe fractures and simultaneously allows for early mobilization of the joint, which is an important factor in restoring synovial fluid circulation and, consequently, improving talar nutrition.

The odds ratio of success is 13.33, indicating a significant advantage for the method used in Group A.

Statistically significant improvements were observed in Group A for physical functioning (by 14.21 points in the midterm and 32.41 points in the long-term) and pain (17.65 points lower in the midterm and 21.75 points lower in the long-term, $p < 0.05$). Patients in Group A rated their condition better in the SF36 questionnaires, even in the long-term, due to greater preservation of the ankle and foot joints.

Similar patterns were also found in the analysis of the FAOS questionnaire. Up to four years, limb function scores were comparable in both groups; after four years, significantly better results were noted in Group A for the FS score (21.14 points higher). For the SS score, which reflects shoe use, Group A showed better results across all follow-ups (22.6 points higher in the mid-term period and 43.5 points higher in the long term), which is associated with smaller scars, fewer arthrodeses, and restoration of normal anatomy in the study group.

The lower number of infectious complications in group A is associated with less tissue trauma during minimally invasive reduction.

It was interesting to compare the obtained results with the opinions of other researchers. Various tactical and technological approaches exist for minimally invasive reduction and osteosynthesis of talar fractures and dislocations. A review of the literature reveals two opposing opinions:

1. Inappropriateness of minimally invasive reduction of talus fragments; preference is given to open reduction and internal osteosynthesis [1, 4–6, 8, 11, 12, 23–30]. The authors substantiate their opinion with the following statements:
   - osteosynthesis of fracture-dislocations of the talus is technically complex, traumatic and fails frequently;
   - dissection of the fascial sheaths surrounding the injured area may reduce the pressure on it during post-traumatic edema.

2. Minimally invasive reduction and low-traumatic osteosynthesis are preferred [2, 7, 31, 32]. The authors note the preservation of the remaining blood circulation of the talus, a reduction in circulatory disorders at the edges of the wound due to the absence of wide approaches.

All authors agree that the less traumatic is the approach, the better. The first group of authors reports a high failure rate with minimally invasive methods of reduction and alignment of fractures and dislocations. Authors using minimally invasive methods of reduction report a lower incidence of aseptic necrosis with bone collapse, 10 % to 40 % [2, 7, 31, 32]. In this regard, minimally invasive methods of reduction are attractive for use. Analyzing the literature, we did not find a detailed description of the tactics of minimally invasive reduction of fractures and dislocations of the talus. The authors report that reduction was successful in a small number of patients, without explaining the procedure, or recommend reduction after traction and bringing the foot to the equinus position in the Ilizarov apparatus [2, 7]. Satake et al. share the results of successful reduction of a fracture of the posterior process of the talus under arthroscopic control [32]. For intraoperative monitoring, all the authors listed in the article use multiprojection radiography in the direct, lateral, axial projections, the Canale projection and, in complex cases, the Broden projection.

Our data indicate that the best results were indeed recorded in the group of minimally invasive methods of fracture reduction and alignment. However, for type IV fractures, minimally invasive reduction methods are not practical and require talus unloading with an external fixator. Therefore, we select a tactical approach based on our algorithm, which depends on the type of talus fracture.

We obtained low rates of aseptic necrosis, low need for subsequent arthrodesis, and good results on assessment scales with minimally invasive reduction methods, which is consistent with the opinion of authors using hardware methods of reduction and osteosynthesis [2, 7, 31, 32]. Our use of open reduction methods for type IV fracture-dislocation with prolonged talar unloading or load bypass in the Ilizarov apparatus was a combination of approaches proposed by the authors of all the analyzed articles. Open reduction for this type of fracture-dislocation resulted in a high rate of successful reduction in the group using minimally invasive methods of reduction and alingment of fracture-dislocations. We believe that it was the lack of an algorithm in other studies that led to a lower rate of reduction with reduction in the fixator [2, 7].

A differentiated approach to methods of reduction, realignment and patient care based on the type of fracture-dislocation of the talus is a distinctive feature of the algorithm we proposed.

CONCLUSION

The minimally invasive reduction algorithm is reproducible, increases procedure success, reduces the incidence of aseptic necrosis, decreases infection rates, leads to improved functional outcomes (SF-36, FAOS), and reduces the need for arthrodesis. The use of the Ilizarov frame with an articulated module is important for the prevention of talar collapse and arthritis.

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Informed consent *All patients of the study voluntarily signed informed consent for the publication of their personal medical information in anonymous form.*

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