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Results of Surgical Treatment of Ankle and Posterior Malleolus Fractures Using Different Surgical Techniques

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Abstract

Background. Almost half of the patients with ankle fractures have fracture of the posterior malleolus. Conclusions of the existing studies are contradictory and do not provide a decisive answer to the question of the need for fixation of the posterior tibial fragment.

Aim of the study — to compare the radiologic and functional outcomes of osteosynthesis of the posterior tibial fragment in unstable ankle fractures using closed reduction and minimally invasive technique and direct open reduction using posterolateral and posteromedial surgical approaches.

Methods. Prospective multicenter study enrolled 132 patients with complex ankle and posterior malleolus fractures. They were divided into three groups depending on the technique of fixation of posterior tibia. Functional and radiologic results of treatment were assessed at 12, 24, and 48 weeks after osteosynthesis. The AOFAS and Neer scales were used.

Results. Bone union occurred in all patients at an average of 8.3±0.8 weeks after surgery. Analysis of postoperative CT scans showed that the use of posterior approaches provided statistically significantly more precise reduction of the fragments of posterior tibia. Functional results of patients of the second (posterolateral approach) and third (posteromedial approach) groups at 24 and 48 weeks of follow-up were statistically significantly superior to those of the first group. The median AOFAS score at 48 weeks of follow-up was 86 for group 2 patients and 90 for group 3. The median scores on the Neer scale were 88 and 94 points respectively.

Conclusions. Posterior approaches in the surgical treatment of patients with complex ankle and posterior malleolus fractures allow for more precise fragment open reduction compared to closed one. These patients also show better mid-term functional outcomes.

Keywords: ankle fracture, posterior malleolus fracture, tibia fracture, posteromedial approach, posterolateral approach.

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Результаты лечения пациентов с переломами лодыжек и заднего края большеберцовой кости с использованием различных вариантов хирургической техники

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Реферат

Актуальность. Почти у половины пациентов перелом лодыжек сопровождается повреждением заднего края большеберцовой кости (ББК). Результаты проведенных исследований противоречивы и не дают однозначного ответа на вопрос о необходимости фиксации заднего фрагмента ББК.

Цель исследования — сравнить рентгенологические и функциональные результаты различных вариантов остеосинтеза фрагмента заднего края большеберцовой кости при нестабильных переломах лодыжек с использованием заднелатерального и заднемедиального хирургических доступов.

Материал и методы. В проспективное с ретроспективной группой сравнения многоцентровое исследование включены 132 пациента со сложными переломами лодыжек и заднего отдела ББК, которые были разделены на три группы в зависимости от методики фиксации заднего края. В первой группе (70 пациентов) репозиция фрагмента заднего края ББК выполнялась закрытым способом, а его остеосинтез был выполнен малоинвазивно стягивающими винтами, проведенными в направлении спереди назад. Во второй группе (33 пациента) выполняли открытую репозицию и внутреннюю фиксацию фрагмента заднего края ББК из заднелатерального хирургического доступа. В третьей группе (29 пациентов) были выполнены открытая репозиция и остеосинтез заднего края ББК через заднемедиальный или модифицированный заднемедиальный доступ. Оценка функциональных и рентгенологических результатов лечения производилась в сроки 12, 24 и 48 нед. после операции остеосинтеза по шкалам AOFAS и Neer.

Результаты. Консолидация перелома у всех пациентов наступила в среднем через 8,3±0,8 нед. Анализ срезов послеоперационной СКТ показал, что применение задних доступов обеспечило статистически значимо более точную репозицию фрагментов заднего края ББК. Функциональные результаты пациентов второй (заднелатеральный доступ) и третьей (заднемедиальный доступ) групп на сроках наблюдения 24 и 48 нед. статистически значимо превосходили показатели первой группы. По шкале AOFAS на сроке 48 нед. после операции медиана значений у пациентов второй группы составила 86 баллов, у пациентов третьей — 90 баллов, по шкале Neer — 88 и 94 баллов соответственно.

Заключение. Применение задних доступов при хирургическом лечении пациентов со сложными переломами лодыжек и заднего края большеберцовой кости позволяет добиться более точной открытой репозиции отломков по сравнению с закрытой. Эти пациенты демонстрируют более высокие среднесрочные функциональные результаты.

Ключевые слова: перелом лодыжек, перелом большеберцовой кости, заднемедиальныйй доступ, заднелатеральный доступ, остеосинтез лодыжек.

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BACKGROUND

Ankle fractures account for 4-9% of all bone fractures, with 46% of these injuries associated with the damage to the posterior malleolus [1, 2].

Although trauma surgeons have extensive experience in treating patients with comminuted ankle fractures, the need for osteosynthesis of the posterior edge of the tibia is still under discussion. The previously accepted tactics of refraining from fixation if the fragment's size is less than 25-33% of the articular surface is now giving way to the approach that all damaged structures of the ankle should be restored [3]. The results of various studies have demonstrated that the presence of a fracture of the posterior tibial edge, regardless of the size of the fragment, negatively affects treatment outcomes [3, 4].

The attempt to systematize approaches to the surgical treatment of posterior malleolus fractures has led to the creation of relatively new classifications of these injuries based on the multislice spiral computed tomography (MSCT) data. N. Haraguchi et al. proposed to divide the posterior tibial edge fractures into three types depending on the size of the fragment [5]. J. Bartoníček et al. divided these injuries into four types depending on the degree of involvement of the fibular notch in the fracture [6]. Both authors believe that all fractures of the posterior malleolus that can technically be fixed should be fixed. Only the so-called shell-shaped fractures according to the classification of N. Haraguchi or extraincisural fractures according to the classification of J. Bartoníček require fixation of the distal tibiofibular syndesmosis with a positional screw due to the lack of technical possibility to perform osteosynthesis of the posterior malleolus [5, 6].

Technically, osteosynthesis of the posterior tibial fracture can be performed using closed reduction with the anterior-posterior insertion of screws or open reduction with their posterior-anterior insertion. In the scientific literature, there is no common opinion regarding the functional results of surgical treatment of such patients depending on the applied method of fixation. K. Pilskog et al. report similar results in assessing ankle joint function when using traditional and posterior approaches [1]. On the other hand, S. Erinç and N. Cam, when evaluating the functional results using the SF-36 and FAOS scales, obtained data in favor of using posterior approaches [7].

The existence of such contradictions determined the relevance of our comparative study.

Aim of the study is to compare the radiologic and functional outcomes of osteosynthesis of the posterior tibial fragment in unstable ankle fractures using closed reduction and minimally invasive technique and direct open reduction using posterolateral and posteromedial surgical approaches.

METHODS

Study design

Type of the study: multicenter cohort prospective study with retrospective comparison group.

The study was performed on the basis of St. Petersburg I.I. Dzhanelidze Research Institute of Emergency Medicine and Interdistrict Clinical Hospital of Vsevolozhsk. The study enrolled 132 patients, including 31 men and 101 women, who were admitted as inpatients from January 2021 to December 2022 inclusive. Patients' mean age was 52.0±14.1 years.

Inclusion criteria:

– patient age older than 18 years;

– isolated closed injury with 44B3 and 44C1.3, C2.3 and C3.3 types of fractures according to the AO/ASIF classification;

– no chronic diseases in the stage of sub- and decompensation, oncologic pathology and constant therapy with steroids;

– no more than 30 days since the injury;

– osteosynthesis of the posterior edge of the tibia, lateral and/or medial malleoli;

– possibility to evaluate short- and mid-term functional results.

Exclusion criteria:

– age under 18 years;

– ankle fractures without damage to the posterior edge of the tibia, or as part of polytrauma or multiple fractures;

– chronic diseases in the stage of sub- and decompensation, oncologic pathology or constant therapy with steroids;

– old injury;

– performed conservative treatment of the ankle fracture;

– inability to assess short- and mid-term functional results.

All patients underwent osteosynthesis of the malleoli and the posterior edge of the tibia. The groups were divided depending on the method of reduction of the fragment of the posterior edge of the tibia and the surgical approach used for fixation. On admission to the hospital, all patients underwent conventional X-ray examination in two views and multislice spiral computed tomography (MSCT) to clarify the fracture pattern and to determine the degree of involvement of the posterior tibial edge.

The first group (retrospective comparison group) included 70 patients who underwent closed reduction of the posterior edge fragment and minimally invasive osteosynthesis with anterior-posterior lag screws. This clinical group was represented by 20 (29%) males and 50 (71%) females. The mean age of the patients was 52.0±14.0 years. Ankle fracture type 44B3 according to the AO/ASIF classification was diagnosed in 56 (80%) patients, type 44C1.3 in 4 (6%) patients, type 44C2.3 in 2 (3%) patients, and type 44C3.3 in 8 (11%) patients. According to the classification of J. Bartoníček, the patients were distributed as follows: 38 (54%) patients had a type 2 fracture, 20 (29%) had a type 3 fracture, and 12 (17%) had a type 4 fracture.

The second group consisted of 33 patients, including 6 (18%) men and 27 (82%) women. In this group, open reduction and internal fixation of the fragment of the posterior edge of the tibia from the posterolateral surgical approach were performed. The mean age of the patients was 52.8±14.4 years. Type 44B3 fracture according to the AO/ASIF classification was diagnosed in 27 (82%) patients, type 44C3 fracture — in 6 (18%) patients. Type 2 fracture according to the classification of J. Bartoníček in this group of patients was observed in 18 (55%) cases, type 3 — in 9 (27%) and type 4 — in 6 (18%) cases.

The third group was represented by 29 patients, 5 (17%) males and 24 (83%) females. Patients in this group underwent open reduction and osteosynthesis of the posterior malleolus via the posteromedial or modified posteromedial approach. It was beyond the scope of this study to investigate the feasibility of these two posteromedial approaches for specific types of posterior edge fracture. Therefore, the patients were included in one clinical group. Of 29 patients, 17 (59%) were treated for AO/ASIF type 44B3 ankle fracture, 3 (10%) patients were diagnosed with type 44C1, 5 (17%) with type 44C2, and 4 (14%) with type 44C3 ankle fracture. Three (10%) patients had Bartoníček type 2 fracture, 16 (55%) patients had type 3 fracture and 10 (34%) patients had a type 4 fracture according to MSCT data.

The choice of surgical approach for fixation of the posterior fragment of the tibia in patients of the second and third groups was made taking into account the MSCT images.

Surgical technique

Patients in the first group underwent surgery in the supine position. First of all, they underwent fixation of the fibula via the lateral approach with a 1/3 tubular plate and 3.5 mm screws. Then via the medial or anteromedial approach two partially threaded 4.0 mm cancellous screws were introduced to fix the medial malleolus. Closed reduction of the fragment of the posterior edge of the tibia was performed under intraoperative X-ray control. Its fixation was carried out with anterior-posterior 3.5 mm lag screws. At the final stage of the surgery, the stability of the distal tibiofibular syndesmosis was assessed by performing the intraoperative stress tests and X-rays. If necessary, a positional screw was placed.

The surgical technique applied in patients of the second and third groups is described in details in our previous works [8, 9]. We should note that the patients in the second group were placed on the operating table in the supine position for convenient posterolateral approach and fixation of the fragments of the posterior edge of the tibia and the lateral malleolus. Osteosynthesis of the posterior malleolus was performed with either 3.5 mm lag screws or a 1/3 tubular plate and 3.5 mm screws. Osteosynthesis of the medial malleolus was performed in the same patient position from the traditional medial approach with partially threaded 4.0 mm cancellous screws.

Patients of the third group were operated on in the supine position. The injured lower extremity was abducted in the hip joint and flexed in the knee joint. In this position, a posteromedial approach was performed, and the posterior and medial malleoli were fixed. After that, the injured lower limb was extended, and osteosynthesis of the lateral malleolus was carried out via traditional lateral approach. In this group, the implants were similar to those used in the patients of the second group. Intraoperative stress tests and X-ray

examination were also performed to check the condition of the distal tibiofibular syndesmosis in patients of the second and third groups, and the results were taken into account to decide whether a positional screw should be inserted.

Postoperative management

In the postoperative period, all patients were allowed to walk with additional support on crutches. During the first 6 weeks, it was recommended to limit the axial load on the operated limb, only touching the floor with the foot. From the 7th week until the fracture healing, partial weight bearing with additional support on crutches was allowed. Removal of the positional screw was performed 10-12 weeks after the osteosynthesis.

Assessment of outcomes

Control X-rays in AP and lateral views were performed 4, 8, and 10 weeks after osteosynthesis to assess the bone union. Criteria for the fibular fracture were bone callus formation and disappearance of the fracture line (bone union under conditions of relative stability) or disappearance of the fracture line (bone union under conditions of absolute stability). The criterion for the medial and posterior malleoli fractures was the disappearance of the fracture line in control X-rays.

In the early postoperative period, the patients underwent control CT on a GE Revolution CT ES 512 (General Electric, USA) to determine the accuracy of reduction and correct position of the implants. The size of the posterior edge fragment was measured using the RadiAnt DICOM Viewer software (Medixant, Poland).

During the study, we performed a comparative analysis of the following parameters: size of the posterior tibial fragment, determined in sagittal slices of MSCT; duration of surgery; duration of hospital stay; residual displacement of the posterior tibial fragment according to sagittal slices of the control MSCT; range of motions and joint function according to the AOFAS [10] and Neer [11] scales at 12, 24 and 48 weeks after the surgery.

Statistical analysis

Statistical analysis was performed using Statistica 8.0 software (StatSoft Inc., USA).

Populations of variables of each of the studied parameters were tested for compliance with the law of normal distribution. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used for this purpose. The distribution in the sample of the duration of surgical intervention values corresponded to the normal distribution. Therefore, the obtained results are presented as mean value with standard deviation ($M \pm \sigma$). In the samples of all other parameters the distribution differed from normal, therefore they are presented as median with lower and upper quartiles — Me (Q1; Q3). In the comparative analysis, the parameters of the second and third groups were alternately compared with the similar parameters of the first group. The parametric Student's t-test was used for variables with normal distribution. For variables with a distribution other than normal, the nonparametric Mann-Whitney U-test was used. Relative values are presented as percentages. Differences between samples were considered statistically significant at $p<0.05$.

RESULTS

The numerical values of the studied parameters as well as the calculated p values are presented in Tables 1 and 2.

The duration of hospital stay and the duration of surgery were not statistically significantly different in all three groups of patients. However, it can be noted that the surgery with the use of posteromedial approach lasted on average 12-13 minutes more than the other two variants of intervention, but this difference is statistically insignificant ($p = 0.0533$).

According to MSCT data, the patients of the first group were diagnosed with statistically significantly larger fragments of the posterior edge of the tibia -1.34 cm (1.1; 1.73).

After osteosynthesis, the residual displacement of the posterior tibial fragment in the patients of the first group was statistically significantly greater than in the patients of the second and third groups ($p = 0.0009$ and $p=0.0004$, respectively). Radiologically detectable displacement of the posterior tibial fragment in patients of the second and third groups did not exceed 0.5 mm on average, while in case of closed reduction the average displacement amounted to 0.91 mm. It should be noted that the residual displacement exceeded 2 mm in 10 (14%) patients of the first group, while in the second group such displacement was observed in 1 (3%) patient. No patient in the third group had signs of displacement.

Table 1

Studied parameters in all groups of patients with the level of statistical significance

Parameter	Group 1	Group 2		Group 3	
		Value	p	Value	p
Duration of hospital stay, days	14.7 (10; 17)	14 (12; 20)	0.146397	13 (12; 15)	0.871732
Duration of surgery, min.	82.5±33.1	83.9±21.7	0.823438	95.5±20.2	0.053277
Size of the posterior tibial fragment, cm	1.34 (1.10; 1.73)	1.1 (0.9; 1.6)	**0.014867**	1.0 (0.7; 1.5)	**0.000549**
Residual displacement of the posterior tibial fragment after surgery, mm	0.91 (0.6; 1.5)	0.45 (0; 1.05)	**0.000944**	0.5 (0.2; 0.85)	**0.000416**

Values are presented as Me (Q1; Q3) for variables with non-normal distribution and as M±σ for variables with normal distribution. Statistically significant values are highlighted in bold.

Table 2

Functional results of patients of all groups over time, Me (Q1; Q3)

Term	Parameter	Group 1	Group 2		Group 3	
			Value	p	Value	p
12 weeks	Range of motions, deg.	40 (35; 45)	45 (40; 50)	**0.000213**	40 (35; 45)	0.282958
	AOFAS, points	69 (65; 72)	70 (65; 76)	0.171804	67 (64; 70)	0.102455
	Neer scale, points	69 (68; 72)	70 (68; 74)	0.692336	68 (64; 70)	0.342917
24 weeks	Range of motions, deg.	65 (60; 70)	75 (65; 80)	**0.000379**	65 (60; 70)	0.398068
	AOFAS, points	80 (76; 82)	84 (80; 85)	**0.000956**	86 (82; 90)	**0.000001**
	Neer scale, points	78 (76; 80)	84 (80; 86)	**0.000007**	88 (84; 92)	**0.000000**
48 weeks	Range of motions, deg.	75 (70; 80)	80 (75; 85)	**0.009953**	80 (75; 85)	**0.025007**
	AOFAS, points	86 (82; 88)	86 (85; 90,5)	**0.037621**	90 (86; 95)	**0.000155**
	Neer scale, points	85 (83; 88)	88 (86; 92)	**0.000050**	94 (94; 96)	**0.000000**

Values are presented as Me (Q1; Q3) for variables with non-normal distribution and as M±σ for variables with normal distribution. Statistically significant values are highlighted in bold.

Bone union was achieved in all patients at an average of 8.3±0.8 weeks after osteosynthesis.

Functional assessment of the treatment results was performed at 12, 24 and 48 weeks. At 12 weeks after surgery, only patients of the second group showed statistically significantly ($p = 0.0002$) greater range of motion in the ankle. On average, this parameter was 45° (40; 50). No significant differences between the groups at this follow-up were observed according to the AOFAS and Neer scales.

Twenty-four weeks after osteosynthesis, the range of motion in the ankle in the second group was 75° (65; 80) and was statistically significantly ($p=0.0004$) greater than in the first and third groups. When analyzing the individual questionnaires based on the AOFAS and Neer scales, we found that the scores of patients in the second group were statistically significantly ($p = 0.001$ and $p<0.001$, respectively) higher than those in the first group. The third group also had better functional results than the first group. This difference was statistically significant ($p<0.001$ for both scales).

The final examination with evaluation of the function of the operated ankle was performed 48 weeks after the surgery. At this time, the average range of motion in the second and third groups

was 80° (75; 85) and was statistically significantly (p = 0.001 and p = 0.025, respectively) greater than that of the first group patients - 75° (70; 80). When assessed by the AOFAS and Neer scales, the ankle function of patients in the second and third groups was statistically significantly better than in the first group. It should be noted that at 48 weeks, the medians of the samples of scores of the first and second groups were close (AOFAS - 86 and 86 points respectively at p = 0.04, Neer - 85 and 88 points respectively at p<0.001). However, the analysis of the lower and upper quartile values indicates that in the second group, a greater proportion of patients demonstrated better functional outcomes.

Complications

There were no cases of infection, failure of fixation and other complications in the first group.

One patient (3%) from the second group developed a deep surgical site infection at 2 weeks, which affected the functional outcome. The patient underwent several revision surgeries and the course of etiotropic antibiotic therapy. It was decided to leave the implants until the bone union. Eighteen weeks after the osteosynthesis, the hardware was removed, and the infectious process was resolved. At 48 weeks, the range of motion in the ankle joint of the patient was 40°, and the functional scores were 52 and 46 according to the AOFAS and Neer scales, respectively.

In the third group, failure of fixation of the medial malleolus fragment and secondary displacement of the fragments were found in control X-rays of one (3%) patient 6 weeks after the surgery. However, the patient refused to undergo the second operation. On the follow-up 48 weeks after the osteosynthesis, the range of motion in the ankle joint was 60°, the AOFAS score was 56 points, and the Neer score was 50 points, which corresponds to an unsatisfactory result.

DISCUSSIONS

In the surgical treatment of ankle fractures complicated by the damage to the posterior edge of the tibia, it was conventionally considered that the posterior tibial fragment, which size is 25-33% of the articular surface, did not need fixation [1, 12, 13]. This approach was supported by biomechanical studies. Their results indicated that the posterior part of the articular surface of the tibia did not play any role in the axial load on the ankle joint by the body weight. In this regard, its damage does not lead to biomechanical disorders in joint motions [14, 15].

The opposite point of view is confirmed by the results of other studies, which are systematized in the publication of S. Odak et al. Based on the studied publications, the authors make the following conclusion: despite the fact that the posterior tibial edge does not bear a pronounced functional load, its fracture leads to an abnormal redistribution of this load and the development of instability in the ankle joint. This may be a predisposing factor for the development of posttraumatic osteoarthritis [2]. Because of this, surgeons began to aim for full restoration of the structural integrity of the ankle joint during surgical treatment of ankle fractures with damage to the posterior malleolus [12, 16]. This approach is fully consistent with the principles of surgical treatment of intraarticular fractures [13].

Anatomical reduction of the articular surface fragments in most cases involves their manipulation under direct vision. Posteromedial, modified posteromedial and posterolateral approaches provide the best visualization with the least number of complications [17, 18]. We compared the radiologic and functional results of the surgical treatment of patients with comminuted ankle fractures using posterior approaches with the results of patients after minimally invasive osteosynthesis of the posterior malleolus and lateral and medial malleoli fractures fixed via conventional approaches. In our opinion, a comparative analysis of the values of the second and third groups is of no scientific significance. This is confirmed by the study of S. Zhong et al. where the authors demonstrated that the choice of approach should have been made on the basis of MRI data and the surgeon's clinical experience. Similar functional and radiologic results were obtained using both posteromedial and posterolateral approaches [19].

The problem of choice of the best approach for osteosynthesis in case of fractures of the posterior malleolus remains unsolved. The posteromedial approach is more convenient, as it is performed in the conventional supine position of the patient and provides visualization of 64% of the posterior surface of the tibia. The modified posteromedial approach increases this percentage up to 91. Moreover, it is convenient to perform reduction and fixation of the medial malleolus fracture

via this approach. Posterolateral approach is performed with patient in prone or decubitus position, which is less convenient. Only 40% of the posterior surface of the tibia is visualized via this approach, which is slightly less than that of posteromedial one [20]. The advantage is that the posterolateral surgical approach can also be used for osteosynthesis of a lateral malleolus fracture if the level of the fracture allows for this procedure. Thus, it seems reasonable to use the posteromedial approach when the fracture of the posterior tibia is associated with the fracture of the medial malleolus, and posterolateral approach when fracture of the posterior tibia is accompanied by the fracture of the lateral malleolus at the same level. In addition, posteromedial surgical approach is preferable when the anterolateral approach is necessary (e.g., for revision of the anterior portion of the distal tibiofibular syndesmosis), as well as in high fractures of the fibula when the posterolateral fixation is not possible. There are several posterior tibial fractures in which both posterolateral and posteromedial surgical approaches can be used for osteosynthesis. In this case, in our opinion, the choice should depend on the surgeon's preference. The main thing is that the surgery should result in the most accurate reduction of the fragment of the posterior malleolus and its stable fixation.

During the study, we found that the duration of hospital stay, as well as the duration of surgery, did not depend on the chosen surgical approach for the reduction and fixation of the posterior malleolus.

Residual displacement of the posterior tibial fragment after osteosynthesis was assessed using sagittal CT slices. A common sign of unsatisfactory reduction is the presence of a "step" of more than 2 mm between the fragments of the articular surface visualized in X-rays [8, 9, 21]. The first group of patients is characterized not only by a statistically significantly larger average residual displacement of the posterior tibial fragment after closed reduction, but also by a greater proportion of patients in whom this displacement exceeds the threshold of 2 mm. This indicates that open reduction provides better restoration of the articular surface of the ankle joint.

According to the data of foreign authors, traditional closed reduction and fixation of the posterior tibial fragment with anterior-posterior lag screws is associated with a high frequency of unsatisfactory posterior fragment reduction [22, 23]. C. Drijfhout van Hooff et al. report that 42% of patients operated on using the conventional technique had unsatisfactory posterior fragment reduction [22]. In the study by D. Vidović et al. the results of a randomized comparative study of closed and open reduction of the posterior malleolus are presented. According to their data, discongruence of the articular surface was observed in 23% of cases with minimally invasive fixation and only in 4% of cases with reduction and osteosynthesis under direct vision [23]. E. Fernández-Rojas et al. in their study also conclude that posteromedial and posterolateral approaches are preferable for osteosynthesis of the posterior edge of the tibia [21].

Congruence of the distal articular surface of the tibia along with such factors as the initial fracture dislocation and residual subluxation of the talus after osteosynthesis is associated with a higher risk of posttraumatic osteoarthritis. According to a systematic literature review, the overall incidence of degenerative changes in the ankle joint is 33.5%. However, some authors note that the size of the posterior edge fragment does not affect the development of posttraumatic osteoarthritis [2].

We evaluated the functional results of patients in all three groups over time. The most significant difference in the AOFAS and Neer scores was observed at 24 weeks after the surgery. The median scores of patients in the second and third groups were significantly higher than in the first group. This indicates a more favorable course of the rehabilitation process in patients who underwent open reduction of the posterior tibial fragment. This statement is confirmed by the functional results of the patients of the second and third groups of our study, observed at 48 weeks postoperatively. A statistically significant superiority over the first group was observed for all corresponding functional parameters. In addition, the values of the upper quartiles of the statistics population of scores at 48 weeks postoperatively indicate that a greater proportion of the patients of the second and third groups compared to the first group showed excellent functional results (their AOFAS and Neer scores exceeded 90 points).

Foreign researchers studying the efficacy of surgical treatment of patients with malleoli and posterior tibial fractures via posterior approaches

also obtained the values similar to those of our study according to the AOFAS scale. Thus, S. Zhong et al. reported that at the follow-up period of 12 months the mean values in patients who underwent surgery via posteromedial approach were 92.5 points. In the posterolateral approach group at the same period of time, the mean score was 91.4 points [19]. L. Yang et al. evaluated the functional outcome in patients with comminuted ankle fractures after fixation of the posterior edge of the tibia via the posterolateral approach. The mean AOFAS score was 81.35±6.15 at 6 months and 90.56±4.98 at the final examination. The authors did not specify the time of the final examination, but based on the content of the publication, it was more than 2 years after surgery [3].

Limitations

Distribution of patients by groups was not randomized. Osteosynthesis in patients of the same study group was performed by different surgeons. The choice of surgical approach for fixation of the posterior edge of the tibia was determined by the operating surgeon on the basis of his/her skills, clinical experience, and radiologic picture. Insufficiently long follow-up period does not allow us to assess the signs of development of posttraumatic osteoarthritis.

CONCLUSIONS

The application of posterolateral or posteromedial approach for open reduction and osteosynthesis in the surgical treatment of patients with comminuted fractures of the ankle and posterior edge of the tibia allows for more accurate alignment of the fragments of the articular surface compared to closed reduction. In addition, patients who underwent surgery using posterior approaches demonstrate better mid-term functional results.

DISCLAIMERS

Author contribution

All authors made equal contributions to the study and the publication.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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REFERENCES

1. Pilskog K., Gote T.B., Odland H.E.J., Fjeldsgaard K.A., Dale H., Inderhaug E. et al. Traditional Approach vs Posterior Approach for Ankle Fractures Involving the Posterior Malleolus. *Foot Ankle Int.* 2021;42(4):389-399. doi: 10.1177/1071100720969431.
2. Odak S., Ahluwalia R., Unnikrishnan P., Hennessy M., Platt S. Management of Posterior Malleolar Fractures: A Systematic Review. *J Foot Ankle Surg.* 2016;55(1):140-145. doi: 10.1053/j.jfas.2015.04.001.
3. Yang L., Yin G., Zhu J., Liu H., Zhao X., Xue L. et al. Posterolateral approach for posterior malleolus fixation in ankle fractures: functional and radiological outcome based on Bartonicek classification. *Arch Orthop Trauma Surg.* 2023;143(7):4099-4109. doi: 10.1007/s00402-022-04620-0.
4. Neumann A.P., Rammelt S. Ankle fractures involving the posterior malleolus: patient characteristics and 7-year results in 100 cases. *Arch Orthop Trauma Surg.* 2022;142(8):1823-1834. doi: 10.1007/s00402-021-03875-3.
5. Haraguchi N., Haruyama H., Toga H., Kato F. Pathoanatomy of posterior malleolar fractures of the ankle. *J Bone Joint Surg Am.* 2006;88(5):1085-1092. doi: 10.2106/JBJS.E.00856.
6. Bartoníček J., Rammelt S., Tuček M. Posterior Malleolar Fractures: Changing Concepts and Recent Developments. *Foot Ankle Clin.* 2017;22(1):125-145. doi: 10.1016/j.fcl.2016.09.009.
7. Erinç S., Cam N. Does it matter the fixation method of the posterior malleolar fragment in trimalleolar fractures? *Acta Chir Orthop Traumatol Cech.* 2021;88(3):204-210. (In English).
8. Belen'kii I.G., Maiorov B.A., Kochish A.Y., Sergeev G.D,. Refitskii Y.V., Savello V.E. et al. Posteromedial Approach in Fracture Fixation of Malleoli and Posterior Edge of Tibia. *Traumatology and Orthopedics of Russia.* 2022;28(3):16-28. (In Russian). doi: 10.17816/2311-2905-1800.
9. Belen'kii I.G., Maiorov B.A., Kochish A.Y., Sergeev G.D., Savello V.E., Tul'chinskii A.E. et al. Unstable Fractures Osteosynthesis of Malleoli and Posterior Edge of the Tibia Using Posterolateral Surgical Approach. *Traumatology and Orthopedics of Russia.* 2021;27(3):29-42. (In Russian). doi: 10.21823/2311-2905-2021-27-3-29-42.

10. Kitaoka H.B., Alexander I.J., Adelaar R.S., Nunley J.A., Myerson M.S., Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int.* 1994;15(7):349-353. doi: 10.1177/107110079401500701.
11. Neer C.S. 2nd, Grantham S.A., Shelton M.L. Supracondylar fracture of the adult femur. A study of one hundred and ten cases. *J Bone Joint Surg Am.* 1967;49(4):591-613.
12. Tenenbaum S., Shazar N., Bruck N., Bariteau J. Posterior Malleolus Fractures. *Orthop Clin North Am*. 2017;48(1):81-89. doi: 10.1016/j.ocl.2016.08.004.
13. Buckley R.E., Moran C.G., Apivatthakakul Th. AO principles of fracture management. Stuttgart: Thieme; 2018. 1120 p.
14. Vrahas M., Fu F., Veenis B. Intraarticular contact stresses with simulated ankle malunions. *J Orthop Trauma*. 1994;8(2):159-166. doi: 10.1097/00005131-199404000-00014.
15. Papachristou G., Efstathopoulos N., Levidiotis C., Chronopoulos E. Early weight bearing after posterior malleolar fractures: an experimental and prospective clinical study. *J Foot Ankle Surg.* 2003;42(2):99-104. doi: 10.1016/s1067-2516(03)70009-x.
16. Voronkevich I.A., Kulik V.I., Lavrentyev A.V. Ergonomics of osteosynthesis of "trimalleolar" fracture. *Traumatology and Orthopedics of Russia*. 2002;(1):44-46. (In Russian).
17. Wang Y., Wang J., Luo C.F. Modified posteromedial approach for treatment of posterior pilon variant fracture. *BMC Musculoskelet Disord.* 2016;17:328. doi: 10.1186/s12891-016-1182-9.
18. Arrondo G.M., Joannas G. Complex Ankle Fractures: Practical Approach for Surgical Treatment. *Foot Ankle Clin.* 2020;25(4):587-595. doi: 10.1016/j.fcl.2020.08.002.
19. Zhong S., Shen L., Zhao J.G.., Chen J., Xie J.F., Shi Q. et al. Comparison of Posteromedial Versus Posterolateral Approach for Posterior Malleolus Fixation in Trimalleolar Ankle Fractures. *Orthop Surg.* 2017;9(1):69-76. doi: 10.1111/os.12308.
20. Assal M., Dalmau-Pastor M., Ray A., Stern R. How to Get to the Distal Posterior Tibial Malleolus? A Cadaveric Anatomic Study Defining the Access Corridors Through 3 Different Approaches. *J Orthop Trauma.* 2017;31(4): e127-e129. doi: 10.1097/BOT.0000000000000774.
21. Fernández-Rojas E., Herrera-Pérez M., Vilá-Rico J. Posterior malleolar fractures: Indications and surgical approaches. *Rev Esp Cir Ortop Traumatol*. 2023;67(2):160-169. doi: 10.1016/j.recot.2022.10.019.
22. Drijfhout van Hooff C.C., Verhage S.M., Hoogendoorn J.M. Influence of fragment size and postoperative joint congruency on long-term outcome of posterior malleolar fractures. *Foot Ankle Int.* 2015;36(6):673-678. doi: 10.1177/1071100715570895.
23. Vidović D., Elabjer E., Muškardin I.V.A., Milosevic M., Bekic M., Bakota B. Posterior fragment in ankle fractures: anteroposterior vs posteroanterior fixation. *Injury*. 2017;48(5):S65-S69. doi: 10.1016/S0020-1383(17)30743-X.

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