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Experimental topographic and anatomical substantiation of hybrid osteosynthesis of the fibula in patients with ankle fractures

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Abstract

Introduction Ankle fractures are one of the common injuries treated by orthopaedic surgeons. The lack of a standard medical care can be associated with poor outcomes, high disability rates with conservative treatments. Reported outcomes following operative fixation vary widely in the literature and infectious complications can complicate the rehabilitation process.

The **objective** was to show a clinical possibility, safety and feasibility of a new method of fibula fixation in ankle fractures using necropsy material and to reduce negative consequences after surgical treatment.

Material and methods Major vessels and nerves were isolated in the lower third of tibia in 11 biomannequins, AO 44C1 and 44C2 fractures obtained mechanically and fibula fixed using the technique offered. Forces were applied to the injury site through mechanical stress tests.

Results The fixation method did not lead to a conflict between fixing screws and major vessels and nerves. No visible changes in the fibula position were noted in the biomannequins with the foot brought to extreme positions of plantar and dorsal flexion, with stress tests causing valgus and varus deformities.

Discussion As opposed to conventional surgical treatments of ankle fractures, no large incisions are required with the technique to place implants. There is no need to use plates, and the fracture can be fixed using the paired bone of the injured segment instead. Fixation screws can be inserted transcutaneously through soft tissue punctures. The new method is associated with less trauma, less quantity of metal needed and reduced probability of infectious complications. It can be used for AO 44C1 and 44C2 fractures in medical institutions with different availability of equipment.

Conclusions Ankle fractures can be repaired with the technique offered causing no damage to the major vessels and nerves at the surgical site. Stress tests showed stable fibula fixation achieved in all cases avoiding mobility at the fracture site. The new technique can facilitate normal reparative osteogenesis in clinical practice.

Keywords: osteosynthesis, ankle fracture, trauma

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INTRODUCTION

Ankle fractures are often considered a routine pathology [1–4] and are still commonly underestimated and overlooked. Inadequate strategies for treating ankle fractures can lead to poor outcomes [5–12]. The best treatment for ankle fractures remains a topic of debate and depends on the specific fracture and patient factors. Conservative (non-surgical) treatment of ankle fractures, particularly those that are unstable or displaced, can lead to poor outcomes and ankle fracture surgery comes with a risk of fracture-related infection [13–16].

In recent years, a progress has been made in the treatment of patients with diaphyseal fractures of the limbs, and significantly less so when the fracture is localized in the metaepiphysis or is intra-articular. Besides simple fracture entities resulting from low energy trauma, there are comminuted ankle fractures associated with significant soft tissue damage and bone displacement [17]. Ankle fractures, including pilon and malleolus fractures, are prioritized based on their severity and stability [18, 19].

Early application of conventional methods of osteosynthesis with metal constructs can lead to poor outcomes. Open reduction and internal fixation (ORIF) for ankle fractures, while often effective, can present several disadvantages and potential complications [20]. Early intervention and rehabilitation after an ankle fracture can significantly improve outcomes and functional recovery [21]. Minimally invasive osteosynthesis has been reported to be superior to open reduction and internal fixation in the treatment of different long bone fractures. All of the above served as a reason for developing a method of fracture fixation, which, in contrast to traditional approaches, is less traumatic and metal-intensive, and allows for reliable bone fixation that would result in complete fusion.

The **objective** was to show a clinical possibility, safety and feasibility of a new method of fibula fixation in ankle fractures using necropsy material and to reduce negative consequences after surgical treatment.

MATERIAL AND METHODS

The study was performed using 11 lower limbs of biomanikins to be used for the method of osteosynthesis proposed. The intact tibia of the traumatized bone was used for the fibular fixation instead of extra-osseous or intraosseous implant (Patent “Method to repair tibial and forearm fractures”) [22, 23].

Two pairs of Kirschner wires were placed transcutaneously in the distal tibia and fibula lateral-to-medial. The wires were placed in cutting planes with an arbitrary divergence from 6° to 30° in-between them and passed through the cortices of the fibula and tibia of the simulated injured segment of the limb at a distance of (4.2 ± 0.3) cm from the tip of the lateral malleolus to the distal wires (the first distally located wire) and (9.1 ± 0.3) cm from the tip of the lateral malleolus to the proximal wires (the fourth proximal wire). In this way, fixation of the fibula to the tibia was simulated that could replace the plate or another implant (Fig. 1).

Then the skin-fascial flap was removed, tissue preparation was performed to isolate the anterior tibial vascular bundle and the peroneal nerve. Position of the wires in relation to the vascular-nerve formations was visually determined, and distances from them to the apex of the lateral malleolus were measured in the frontal and parasagittal planes(Fig. 2). The fibula was osteotomized between the pairs of wires at a distance of (6.2 ± 0.2) cm from the apex of the lateral malleolus using the Gigli saw (Fig. 3). The pins were removed and fibula fracture was temporarily fixed with a bone holder (Fig. 4). The next stage included osteosynthesis using the proposed method with screws placed in the channels formed by the wires in such a way that they also passed through the fibula and tibia cortices (Fig. 5).

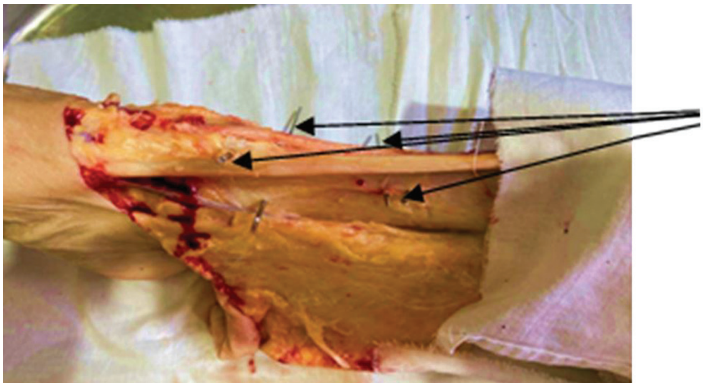

Fig. 1 Kirschner wires placed in the tibia and fibula

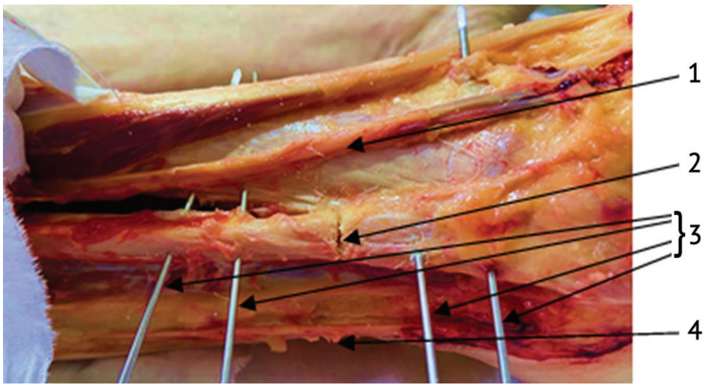

Fig. 2 Wires positioned relative to the vascular-nerve bundles: (1) anterior tibial artery; (2) Kirschner wires; (3) peroneal nerve

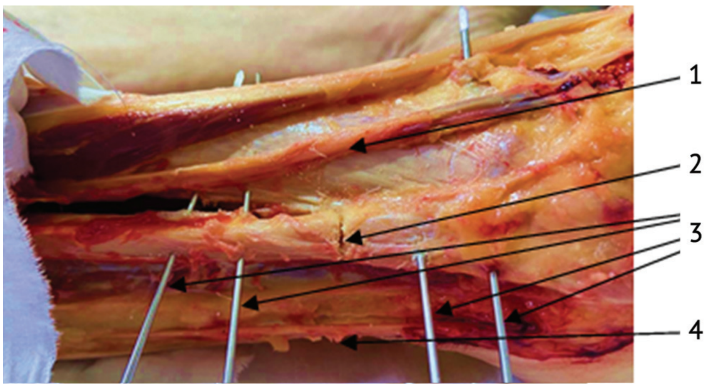

Fig. 3 Condition after fibular osteotomy: (1) anterior tibial artery; (2) line of the fibula fracture formed; (3) Kirschner wires; (4) peroneal nerve

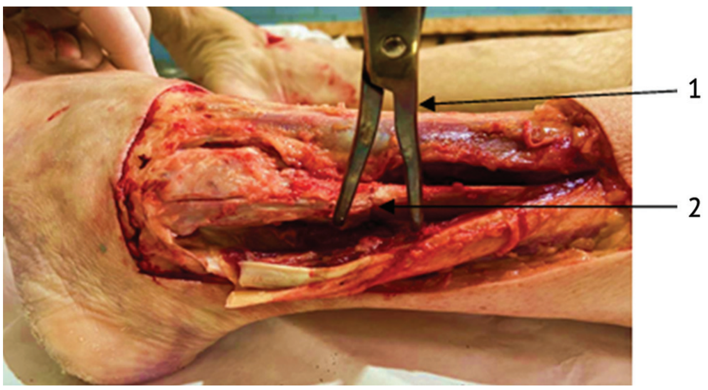

Fig. 4 Temporary bone fixation: (1) bone holder; (2) line of the fibula fracture

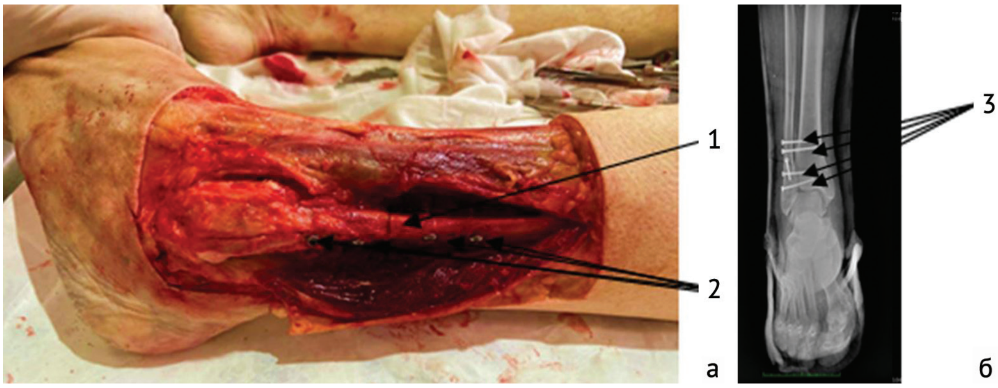

Fig. 5 Osteosynthesis of the fracture using the method proposed (a) and an X-ray of the injured segment after osteosynthesis using the scheme proposed (b): (1) line of the fibular fracture; (2) screw heads after the insertion; (3) cortical screws

Visual assessment of fracture fixation was performed using stress tests aimed at maximum medialization and lateralization of the foot, and using the extreme positions of plantar and dorsal flexion.

RESULTS

The measurements are presented in Table 1.

Table 1

Measurements

Measurements		№ preparation											Average values
		1	2	3	4	5	6	7	8	9	10	11	
Distance from the wires at the fracture level at the tibiofibular syndesmosis, drawn perpendicular to the long axis of the tibiofibular joint, cm													
to the anterior tibial artery		1.2	1.1	1.3	1.0	1.3	1.2	1.0	1.1	1.3	1.2	1.0	1.1 ± 0.2
to the peroneal nerve		1.9	2.1	2.0	1.8	2.3	2.1	1.7	1.8	1.9	2.2	1.8	1.9 ± 0.4
Length of the fibula from the head to the top of the lateral malleolus, cm		41.5	40.2	42.4	41.0	41.2	42.0	41.3	41.9	40.3	42.1	41.7	41.4 ± 0.5
Distance from the top of the lateral malleolus, cm													
to the fracture site formed, cm		6.3	6.2	6.4	6.0	6.3	6.5	6.1	6.3	6.2	6.0	6.4	6.2 ± 0.2
to the distal wires (1st DW)		4.5	4.1	4.4	4.2	4.0	4.2	4.3	4.4	4.0	4.5	4.1	4.2 ± 0.3
to the proximal wires (4th PW)		9.4	9.0	9.1	8.9	8.7	9.0	9,.2	9.1	9.3	9.1	9.3	9.1 ± 0.3
Distance from the wires at the level of a line drawn perpendicular to the long tibial axis, cm													
to the anterior tibial artery at the level of the exit of the bundle of wires	1st distal wire	4.8	5.0	4.9	4.7	5.1	5.0	4.9	4.7	4.8	5.1	4.9	4.9 ± 0.2
	4th proximal wire	4.7	4.8	4.6	4.6	4.9	5.1	4.8	4.8	4.6	5.0	4.6	4.7 ± 0.4
to the peroneal nerve at the level of the entry of the bundle of wires	1st distal wire	2.6	2.4	2.5	2.4	2.3	2.5	2.6	2.2	2.4	2.5	2.3	2.3 ± 0.3
	4th proximal wire	2.2	2.5	2.1	2.5	2.2	2.6	2.3	2.4	2.5	2.3	2.5	2.3 ± 0.3

The objective data obtained confirmed the results of visual control. It can be suggested that the method proposed does not cause a conflict of wires, which are located at a significant distance from major vascular-nerve formations.

DISCUSSION

Literature review showed that the method of treating ankle fractures depends on the type of injury. If the ankle joint remains stable after the injury, the conservative treatment methods provide excellent results. However, J.D. Michelson reported non-displaced syndesmosis injuries requiring fixation after stress testing [24]. Immobilization of fracture dislocations in the ankle joint using various conservative means can lead to a loss of reduction and complications with soft tissues. The risks can be reduced by surgical treatment with use of external fixation devices [25, 26]. Unstable ankle joint are repaired with surgical methods. Fixation plates are reliable for comminuted fracture [27]. Intramedullary osteosynthesis can be used for fixation of unstable distal fibula fractures [28]. This is supported by an experimental study that has proven the advantage of the fixation method compared to conventional plating [29].

Injuries of the tibiofibular syndesmosis can be repaired with dynamic fixation using metal buttons combined with a thread as reported by Lazko [30]. Gafurov considers this method a good alternative to traditional static fixation using a positional screw [31]. With the advantages of dynamic fixation, the technique can be expensive and static methods remain an important trauma and orthopedic tool [30, 31]. Murphy does not see a significant difference between the methods, although the latter may cause postoperative complications and a greater rate of re-operations [32].

The hybrid method of fibula osteosynthesis is chareacterized by the entry and exit points of the screws being located in the area of the anterior tibial artery and peroneal nerve. The study was aimed at demonstrating the safety of the method offered and some advantages compared to the traditional method of osteosynthesis of the lower fibula third.

Therefore, the method of osteosynthesis can be used to repair ankle fractures AO 44C1, 44C2 in clinical practice. The new method is associated with less trauma, less quantity of metal needed and can be offered for medical care provided for patients in institutions with varying levels of equipment, reducing financial costs for the treatment of the cohort of patients.

CONCLUSION

Предложенный Ankle fractures can be repaired with the technique offered causing no damage to the major vessels and nerves at the surgical site. Stress tests showed stable fibula fixation achieved in all cases avoiding mobility at the fracture site. The method of hybrid osteosynthesis of the fibula provides stable bone fixation at the fracture site in patients with ankle fractures and is safe and technically feasible in clinical scenarios. The findings allow us to recommend the method for use in clinical practice.

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Ethical review *The study is exempt from the need for evaluation by an ethics committee.*

REFERENCES

1. Li X, Moskaliov VP. Review of treatment modalities of malleolar fractures. *The Scientific Notes of the Pavlov University*. 2015;22(3):6-10. (In Russ.) doi: 10.24884/1607-4181-2015-22-3-6-10.
2. Slastinin VV, Klyukvin IYu, Filippov OP, Bogolyubsky YuA. Intra-articular fractures of the distal tibia: evolving of views on surgical treatment. *Russian Sklifosovsky Journal "Emergency Medical Care"*. 2015;(3):23-29. (In Russ.)
3. Lehtonen H, Järvinen TL, Honkonen S, et al. Use of a cast compared with a functional ankle brace after operative treatment of an ankle fracture. A prospective, randomized study. *J Bone Joint Surg Am*. 2003;85(2):205-211. doi: 10.2106/00004623-200302000-00004.
4. Court-Brown CM, Caesar B. Epidemiology of adult fractures: A review. *Injury*. 2006;37(8):691-697. doi: 10.1016/j.injury.2006.04.130.
5. Franke J, von Recum J, Suda AJ, et al. Intraoperative three-dimensional imaging in the treatment of acute unstable syndesmotic injuries. *J Bone Joint Surg Am*. 2012;94(15):1386-1390. doi: 10.2106/JBJS.K.01122.
6. Omelchenko TN. Ankle fractures and rapidly progressive osteoarthrosis of the ankle: prevention and treatment. *Orthopedics, traumatology and prosthetics*. 2013;(4):35-40. (In Russ.)
7. Yaremenko DA, Shevchenko EG, Tarshis VB. Intra-articular injuries of the lower extremities as causes of persistent loss of working capacity. *Orthopedics, traumatology and prosthetics*. 1994;(Supplement):46-47. (In Russ.)
8. Rolik OV, Zasadnyuk IA. Failure of long bones to grow (analysis, risk factors, therapeutic tactics). Orthopedics, traumatology and prosthetics. 2005;(2):61-65. (In Ukr.)
9. Thomas RH, Daniels TR. Ankle arthritis. *J Bone Joint Surg Am*. 2003;85(5):923-936. doi: 10.2106/00004623-200305000-00026.
10. Valderrabano V, Hintermann B, Horisberger M, Fung TS. Ligamentous posttraumatic ankle osteoarthritis. *Am J Sports Med*. 2006;34(4):612-620. doi: 10.1177/0363546505281813.
11. Elsoe R, Ostgaard SE, Larsen P. Population-based epidemiology of 9767 ankle fractures. *Foot Ankle Surg*. 2018;24(1):34-39. doi: 10.1016/j.fas.2016.11.002.
12. Martijn HA, Lambers KTA, Dahmen J, et al. High incidence of (osteo)chondral lesions in ankle fractures. *Knee Surg Sports Traumatol Arthrosc*. 2021;29(5):1523-1534. doi: 10.1007/s00167-020-06187-y.
13. Leontaritis N, Hinojosa L, Panchbhavi VK. Arthroscopically detected intra-articular lesions associated with acute ankle fractures. *J. Bone Joint. Surg. Am*. 2009;91(2):333-339. doi: 10.2106/JBJS.H.00584.
14. Assal M, Ray A, Stern R. Strategies for surgical approaches in open reduction internal fixation of pilon fractures. *J Orthop Trauma*. 2015;29(2):69-79. doi: 10.1097/BOT.0000000000000218.
15. McFerran MA, Smith SW, Boulas HJ, Schwartz HS. Complications encountered in the treatment of pilon fractures. *J Orthop Trauma*. 1992;6(2):195-200. doi: 10.1097/00005131-199206000-00011.
16. Teeny SM, Wiss DA. Open reduction and internal fixation of tibial plafond fractures. Variables contributing to poor results and complications. *Clin Orthop Relat Res*. 1993;(292):108-117.
17. Toleukhanov BO, Dolgov AA, Abilmazhinov MT, et al. On the guestion of compound ankle fractures. *Astana Medical Journal*. 2019;3(101):259-264. (In Russ.)
18. Telicin PN, Zhila NG. Tactics of treatment of ankle joint fractures and fracture-dislocations. *Far East Medical Journal*. 2016;(3):31-35. (In Russ.).
19. Gorbatov RO, Pavlov DV, Malyshev EE. Modern Operative Treatment of Malleolar Fractures and Associated Consequences (Review). *Modern technologies in medicine*. 2015;7(2):153-167. doi: 10.17691/stm2015.7.2.20.
20. Ruedy TP, Buckley RE, Moran CG. *AO — Principles of fracture treatment*. Second revised and supplemented edition. Vassa Media; 2007;2:870-896. (In Russ.).
21. Marazzi C, Wittauer M, Hirschmann MT, Testa EA. Minimally invasive plate osteosynthesis (MIPO) versus open reduction and internal fixation (ORIF) in the treatment of distal fibula Danis-Weber types B and C fractures. *J Orthop Surg Res*. 2020;15(1):491. doi: 10.1186/s13018-020-02018-5.
22. Kashansky YuB, Kondratyev IP, Kucheev IO, et al. Mathematical justification of transosseous osteosynthesis with short wires with open external supports. *Medline.ru*. 2019;20:373-384. (In Russ.).
23. 23. Tsapenko VO, Kashansky YuB, Kondratiev IP, et al. *Method for treating fractures of the shin and forearm bones*. Patent RF, no. 2691015. 2019. Available at: https://patentimages.storage.googleapis.com/dc/a8/8c/183f543c027b09/RU2302835C1.pdf. Accessed May 06, 2025. (In Russ.).
24. Michelson JD, Wright M, Blankstein M. Syndesmotic Ankle Fractures. *J Orthop Trauma*. 2018;32(1):10-14. doi: 10.1097/BOT.0000000000000937.
25. Buyukkuscu MO, Basilgan S, Mollaomeroglu A, et al. Splinting vs temporary external fixation in the initial treatment of ankle fracture-dislocations. *Foot Ankle Surg*. 2022;28(2):235-239. doi: 10.1016/j.fas.2021.03.018.
26. Sanders DW, Tieszer C, Corbett B; Canadian Orthopedic Trauma Society. Operative versus nonoperative treatment of unstable lateral malleolar fractures: a randomized multicenter trial. *J Orthop Trauma*. 2012;26(3):129-134. doi: 10.1097/BOT.0b013e3182460837.
27. Aiyer AA, Zachwieja EC, Lawrie CM, Kaplan JRM. Management of Isolated Lateral Malleolus Fractures. *J Am Acad Orthop Surg*. 2019;27(2):50-59. doi: 10.5435/JAAOS-D-17-00417.
28. Jain S, Haughton BA, Brew C. Intramedullary fixation of distal fibular fractures: a systematic review of clinical and functional outcomes. *J Orthop Traumatol*. 2014;15(4):245-254. doi: 10.1007/s10195-014-0320-0.
29. Smith G, Mackenzie SP, Wallace RJ, et al. Biomechanical Comparison of Intramedullary Fibular Nail Versus Plate and Screw Fixation. *Foot Ankle Int*. 2017;38(12):1394-1399. doi: 10.1177/1071100717731757.

30. Lazko FL, Zahorodnii NV, Semenov AYu, et al. Operative therapy of malleolar fracture with distal tibiofibular articulation damage. Static and dynamic fixation of tibiofibular syndesmosis, comparison of results. *Surgical practice (Russia)*. 2018;(2):15-21. (In Russ.) doi: 10.17238/issn2223-2427.2018.2.15-21.
31. Gafurov FA, Khodzhanov IYu, Mansurov DSh, Eranov ShN. Intramedullary osteosynthesis for ankle fractures and distal tibiofibular syndesmotic disruption. *Genij Ortopedii*. 2024;30(1):142-152. doi: 10.18019/1028-4427-2024-30-1-142-152.
32. Murphy SC, Murphy B, O'Loughlin P. Syndesmotic injury with ankle fracture: A systematic review of screw vs dynamic fixation. *Ir J Med Sci*. 2024;193(3):1323-1330. doi: 10.1007/s11845-024-03619-3.

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