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Original Guide for Minimally Invasive Distal Osteotomy of the First Metatarsal Bone in the Treatment of Hallux Valgus

Aleksei V. Oleinik [1], Igor G. Belenkiy [1,2], Gennadii D. Sergeev [1,2], Aleksandr Yu. Kochish [3], Kseniya V. Razumova [1], Artur E. Binazarov [1], Boris A. Maiorov [1,2]

[1] *St. Petersburg I.I. Dzhanelidze Research Institute of Emergency Medicine, St. Petersburg, Russia*

[2] *St. Petersburg State University, St. Petersburg, Russia*

[3] *Vreden National Medical Research Center of Traumatology and Orthopedics, St. Petersburg, Russian Federation*

Abstract

Background. Minimally invasive surgical interventions are widely used in trauma and orthopedic surgery. Both the surgical technique and the instruments applied are being improved, which contributes to better functional results of patients' treatment.

Aim of the study — to present a new guide tool for minimally invasive surgical correction of acquired hallux valgus.

Guide description. A guide tool intended to be used in minimally invasive surgical interventions for hallux valgus (HV) correction has been developed. It consists of several interconnecting components: the distal bar, the intramedullary guide, the proximal bar, and the wire guide. These components are fixed to each other. At the same time, the distal bar, the proximal bar, and the wire guide are connected with the possibility of adjusting their mutual positioning. The design of the proposed device enables to guide the first guiding wire and to place the cannulated screw in an optimal position. The presented clinical case illustrates the successful application of the described device. The patient underwent minimally invasive distal corrective osteotomy for hallux valgus of medium severity. According to the preoperative X-rays, the first intermetatarsal angle and the first toe deviation angle were 13.5° and 25°, respectively. Six months after the surgery, they were 3° and 7°, respectively. The result of the corrective surgery was considered excellent.

Conclusion. Application of the proposed guide tool decreases surgery duration, reduces soft tissue damage and minimizes radiation exposure of the surgeon and the patient.

Keywords: minimally invasive surgery, valgus deformity of the first toe, hallux valgus, correcting osteotomy, guide tool.

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Igor G. Belenkiy; e-mail: belenkiy.trauma@mail.ru

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Оригинальный направитель для малоинвазивной дистальной остеотомии первой плюсневой кости при лечении вальгусной деформации первого пальца стопы

А.В. Олейник [1], И.Г. Беленький [1,2], Г.Д. Сергеев [1,2], А.Ю. Кочиш [3], К.В. Разумова [1], А.Е. Биназаров [1], Б.А. Майоров [1,2]

[1] *ГБУ «Санкт-Петербургский научно-исследовательский институт скорой помощи им. И.И. Джанелидзе», г. Санкт-Петербург, Россия*

[2] *ФГБОУ ВО «Санкт-Петербургский государственный университет», г. Санкт-Петербург, Россия*

[3] *ФГБУ «Национальный медицинский исследовательский центр травматологии и ортопедии им. Р.Р. Вредена» Минздрава России, г. Санкт-Петербург, Россия*

Реферат

Малоинвазивные хирургические вмешательства широко применяются в травматологии и ортопедии. Совершенствуется как техника операций, так и применяемые инструменты, что способствует улучшению функциональных результатов лечения пациентов.

Цель исследования: представить новый инструмент — направитель для малоинвазивной хирургической коррекции приобретенной вальгусной деформации первого пальца стопы.

Описание инструмента. Разработан направитель, предназначенный для использования при выполнении малоинвазивных оперативных вмешательств для коррекции hallux valgus (HV). Он состоит из нескольких соединяющихся между собой компонентов: дистальная планка, интрамедуллярный направитель, проксимальная планка, шаблон для спицы. Эти детали фиксируются друг с другом. При этом дистальная планка, проксимальная планка и шаблон для спицы соединяются с возможностью регулировки взаимного их расположения. Конструкция предложенного устройства позволяет провести первую направляющую спицу для установки канюлированного винта в оптимальном положении. Представленный клинический случай, иллюстрирует успешное применение описанного устройства. Пациентке выполнена малоинвазивная дистальная корригирующая остеотомия по поводу вальгусного отклонения первого пальца средней степени тяжести. По данным дооперационных рентгенограмм первый межплюсневый угол и угол отклонения первого пальца были равны 13,5° и 25° соответственно, через 6 мес. после операции — 3° и 7°, соответственно. Результат корригирующей операции был признан отличным.

Заключение. Применение предложенного направителя сокращает время операции, уменьшает ее травматичность и минимизирует лучевую нагрузку на хирурга и пациента.

Ключевые слова: минимально инвазивная хирургия, вальгусная деформация первого пальца стопы, *hallux valgus*, корригирующая остеотомия, направляющее устройство.

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Беленький Игорь Григорьевич; e-mail: belenkiy.trauma@mail.ru

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BACKGROUND

The problem of surgical treatment of hallux valgus (HV) has been a topic of interest to surgeons for almost two centuries [1]. This can be explained not only by the high incidence of this disease, but also by the complexity of its etiopathogenesis [2, 3, 4]. Surgeons' attempts to deal with various pathogenetic factors of HV have resulted in more than 130 variants of surgical interventions described to date [1, 5]. The most modern methods of treatment are minimally invasive corrective osteotomies, which are widely used for mild and moderate HV deformities [6, 7].

In publications dedicated to the surgical treatment of HV, the authors mention three generations of minimally invasive interventions [6, 8]. The first generation includes the Reverdin-Isham procedure, which is a wedge-shaped closed-angle osteotomy at the level of the head of the first metatarsal bone performed via mini-approaches. The second generation is the minimally invasive Bosch osteotomy. It consists of percutaneous transverse distal osteotomy of the first metatarsal bone with fixation of bone fragments with a Kirschner wire. These two generations of HV surgical treatment methods have been criticized in the scientific literature due to the insufficient evidence base for their widespread clinical use and high complication rates [8]. Nowadays, the most popular is the third generation of surgical procedures which is the minimally invasive distal chevron osteotomy of the first metatarsal bone combined with the Akin osteotomy (MICA - minimally invasive chevron Akin), where the bone fragments are fixed using cannulated compression screws [7, 9].

Results of studies published in the previous decade indicate that the functional outcomes of minimally invasive and open corrective surgeries for HV are similar. [10, 11, 12]. However, a meta-analysis of the most recent publications on this topic says for minimally invasive interventions [6]. Advantages of minimally invasive surgeries over open ones include gentler attitude to soft tissues, shorter duration of intervention, shorter rehabilitation time, and more pronounced cosmetic effect [13]. However, there are also some disadvantages. Minimally invasive corrective osteotomies require mandatory intraoperative X-ray imaging at the surgical stages [14]. Closed technique of fragment fixation using cannulated screws leads to greater operating time of the image intensifier and, consequently, increases the radiation exposure of both the patient and the surgeon. Duration of this surgical stage also depends on the surgeon's experience. Incorrect final screw positioning can lead to failure of fixation, pain syndrome in the postoperative period, and patient dissatisfaction with the treatment as a whole. In order to solve these problems, we have developed a universal guide device for insertion of guide wires for cannulated compression screws. This device simplifies the stage of fixation of osteotomized fragments of the first metatarsal bone and minimizes the risk of incorrect placement of screws.

Aim of the study — to present a new guide tool for minimally invasive surgical correction of acquired hallux valgus.

Guide description

The device has been invented at the St. Petersburg I.I. Dzhanelidze Research Institute of Emergency Medicine. This device is designed to be used in minimally invasive surgical interventions for HV correction. It consists of several interconnecting components: the distal bar, the intramedullary guide, the proximal bar, and the wire guide. These parts are fixed to each other, whereby the distal bar, the proximal bar and the wire guide are connected with the possibility of adjusting their mutual positioning (Fig. 1).

The distal and proximal bars are the main parts of the device to which the intramedullary guide and the wire guide are attached, respectively. All parts of the device are assembled using thread locks.

In the intramedullary guide, the part inserted into the medullary canal of the first metatarsal bone with a 2 mm wide slit for the wire guide should be highlighted. A guiding hole is located in the wire guide. The axis of the hole intersects the axis of the intramedullary guide and lies in the same plane as its slit. The position of the wire guide is adjusted along two mutually perpendicular axes due to the mobility of the wire guide and the distal bar. Adjustment accuracy is achieved by the scales on the proximal bar. The scale on the short arm of the proximal bar has a scale division value of 1 mm, on the long arm — 5 mm. The angle of inclination of the axis of the guiding hole of the wire guide is 102° with 18-20° of deviation of the distal osteotomized part of the first metacarpal bone from the axis of the proximal part of the bone. The angular values as well as the division values of the scales were calculated empirically using computer modeling method. Due to such design of the guide, the guide wire exits the lateral cortical layer of the first metatarsal bone 10 mm proximal to the osteotomy site. This distance is optimal for further fixation. One of the purposes of the developed device is the ability to keep this point unchanged with different anthropometric data of patients.

The guide is positioned in the medullary canal of the first metatarsal bone so that a wire inserted through the wire guide passes through the medial and lateral cortical layers of the first metatarsal bone. A cannulated screw for fixation of fragments of the first metatarsal bone is inserted using the installed wire as a guide.

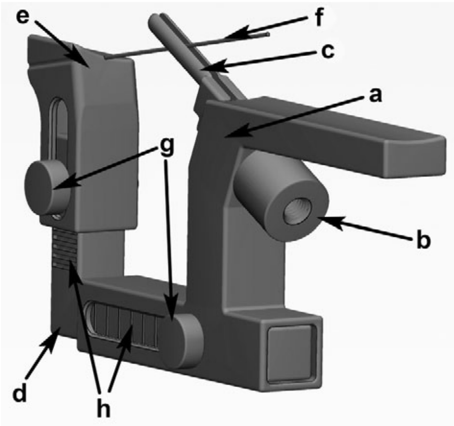

Fig. 1. Guide view (oblique view):
a — distal bar; b — fixator;
c — intramedullary guide; d — proximal bar;
e — wire guide; f — wire;
g — adjusting screws fixing proximal and distal bars;
h — adjusting scales

Surgical technique

The patient is placed on the operating table in a supine position. The surgical field is treated with antiseptic solutions and delimited with sterile drape from the tips of toes of the operated foot to the upper third of the lower leg. Using a scalpel, the surgeon makes a 3-4 mm skin incision along the inner surface of the forefoot in the projection of the distal 1/4 of the diaphysis of the first metatarsal bone right up to the bone. The level of the osteotomy is located at a distance of approximately 2.0-2.5 cm from the radiological projection of the articular gap of the first metatarsophalangeal joint. Transverse osteotomy of the diaphysis of the first metatarsal bone is performed with a 2.2-2.9 mm burr. The head of the first metatarsal bone is displaced laterally. The intramedullary guide of the developed device is inserted into the medullary canal of the proximal fragment of the first metatarsal bone through the incision made earlier for osteotomy. The base of the guide is placed against the head of the first metatarsal bone, displacing it laterally and holding it in this position. The degree of outward displacement of the head is determined by the design of the guide and is not adjusted additionally. Depending on the individual features of the foot, the surgeon adjusts the position of the wire guide.

After setting up the device, a guide wire is inserted with a medical drill percutaneously and transosseously through the hole in the wire guide. The wire passes through the proximal fragment of the first metatarsal bone and then enters the metatarsal head. Position of the wire is assessed using intraoperative X-rays. The drill is detached from the wire. The guide tool is removed from the surgical wound.

To reduce soft tissue damage, 2 mm incisions are made to the sides of the points where the wires enter the skin. Cannulated 2.7 mm drill bit forms a channel for the cannulated screw along the guide wire. Using a cannulated screwdriver, a 3.5 mm cannulated screw is inserted to fix the fragments of the first metatarsal bone. The wire is removed. The second wire is inserted using the free-hand method parallel to the already inserted screw. Then, after the cannulated drill bit has formed a channel along the wire, the second cannulated screw is inserted.

The surgeon controls the stability of fixation of fragments of the first metatarsal bone clinically and radiologically. Next, a burr is used to resect excess bone tissue of the medial part of the proximal and, if necessary, distal fragments of the first metatarsal bone. Surgical wounds are washed with antiseptic solutions and sutured after control of hemostasis.

Clinical case

A case of a 48-year-old female patient with acquired deformity of the left forefoot is presented. At the time of preoperative examination, she complained of pain in the area of deformity. Complaints persisted for a year before the treatment. Load X-rays of the foot were performed (Fig. 2). To assess the degree of deformity correction, the first intermetatarsal angle and the first toe deviation angle were measured and resulted 13.5° and 25°, respectively.

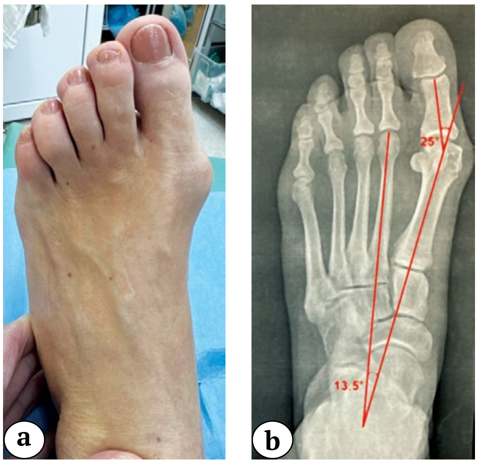

Fig. 2. Foot before surgery:
a — general view;
b — stress X-ray in AP view

The diagnosis was made: combined flat foot; acquired deformity of the left forefoot; moderate hallux valgus deformity of the left foot.

Conservative methods of treatment (shoe fitting and individual orthotic insoles) were ineffective. It was decided to perform surgical treatment. The patient underwent minimally invasive surgical correction of HV deformity of the left foot with the use of the designed guide device according to the technique described above (Fig. 3).

In the X-rays performed on the first day after the surgery, the first intermetatarsal angle was 3°, the valgus deviation angle of the first toe was 4°. The postoperative period was uneventful.

Control examinations with X-rays at 4 and 8 weeks revealed no complications. Signs of bone callus formation were noted in the X-rays performed at 8 weeks.

According to the load X-rays performed 6 months after the surgery, the bone callus is fully formed. The first intermetatarsal angle was 3°, and the valgus deviation angle of the first toe was 7° (Fig. 4). The patient returned to her usual way of life.

Fig. 3. Intramedullary guide inserted into the medullary canal of the first metatarsal bone

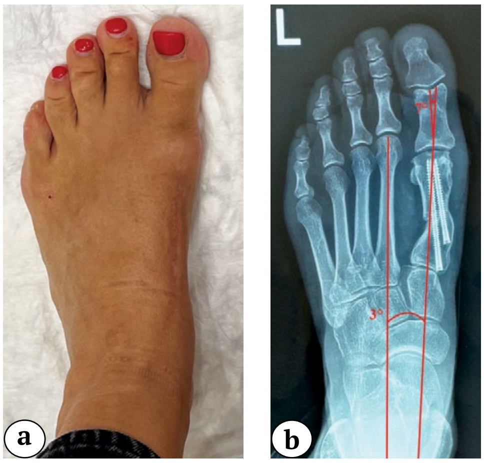

Fig. 4. Six months after surgery:
a — general view of the foot;
b — stress X-ray in AP view: completed bone callus formation

DISCUSSION

Minimally invasive surgery is one of the most advanced areas of traumatology and orthopedics. Many authors have discussed the issues of minimizing traumatic effects of surgeries for acquired forefoot deformities [7, 8, 9]. Minimally invasive corrective osteotomies are technically more complicated compared to open ones, but they have a number of advantages. Due to this reason, orthopedic surgeons all over the world have been using various variants of these minimally traumatic surgical interventions in their clinical practice for more than 30 years [1].

Minimally invasive corrective interventions of the third generation imply fixation of fragments of the first metatarsal bone with screws [7, 9]. Basing on our own experience of surgical treatment of patients with HV, we believe that such fixation allows us to start active rehabilitation from the first day after the surgery. However, in the future we are planning to perform comparative studies to evaluate the effect of the rehabilitation protocol we use on the functional results and patient satisfaction with treatment.

L. Ji et al. concluded in their meta-analysis performed in 2022 that minimally invasive interventions in the treatment of HV were more effective than open interventions. This is evidenced by better clinical and radiologic (degree of correction of the first intermetatarsal angle and valgus deviation angle of the first toe) results of minimally invasive surgeries. The authors also note that the duration of minimally invasive interventions is statistically significantly shorter than that of open surgeries, while the cosmetic effect is more pronounced, the postoperative rehabilitation time is shorter, and the patient's satisfaction with the treatment is higher. It is worth adding that the meta-analysis included publications from 2021. [6]. These findings confirm the fact of successful continuous development of minimally invasive techniques for the treatment of HV.

In addition to improving surgical techniques, surgeons and researchers have focused on developing instruments that simplify minimally invasive corrective interventions and reduce their duration. Mostly, wires, screws, or cannulated screws are used to fix the fragments of the first metatarsal bone after osteotomy [7]. Given the minimally invasive technique of surgical intervention, their insertion without auxiliary guide devices is technically challenging.

Among the proposed instruments there are devices that minimize the possibility of a surgeon's error when performing minimally invasive corrective osteotomies for HV [15, 16, 17]. The use of our guide also enables to reduce the probability of incorrect positioning of fixation screws by simplifying the insertion of guide wires. As a consequence, this reduces surgery duration. In addition, the use of the guide decreases traumatic effects of intervention by reducing the number of attempts for correct insertion of guide wires. This minimizes radiation exposure of the patient and the surgeon, as the operating time of image intensifier is also reduced.

CONCLUSION

Application of the proposed guide tool for minimally invasive surgical interventions for HV deformity enables precise positioning of the guide wire for the cannulated screw and makes it possible to achieve reliable fixation of the fragments of the first metatarsal bone in the position of correction.

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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Disclosure competing interests. The authors declare that they have no competing interests.

Ethics approval. Clinical application of the proposed guide tool has been approved by the local Ethics Review Committee of St. Petersburg I.I. Dzhanelidze Research Institute of Emergency Medicine, protocol No. 12-3, 13.12.2022.

Consent for publication. Written consent was obtained from the patient for publication of relevant medical information and all of accompanying images within the manuscript.

REFERENCES

1. Jeyaseelan L., Malagelada F. Minimally Invasive Hallux Valgus Surgery - A Systematic Review and Assessment of State of the Art. *Foot Ankle Clin.* 2020;25(3):345-359. doi: 10.1016/j.fcl.2020.05.001.
2. Smyth N.A., Aiyer A.A. Introduction: Why Are There so Many Different Surgeries for Hallux Valgus? *Foot Ankle Clin*. 2018;23(2):171-182. doi: 10.1016/j.fcl.2018.01.001.
3. Belenkiy I.G., Sergeev G.D., Oleynik A.V., Mayorov B.A. Modern Views on Surgical Treatment of Hallux Valgus. *Modern Problems of Science and Education*. 2021;(6):180. doi: 10.17513/spno.31199. Available from: https://science-education.ru/ru/article/view?id=31199.
4. Mursalov A.K., Dzyuba A.M., Shaikevich A.V., Esedov G.I. First metatarsal pronation in hallux valgus deformity: literature review. Department of Traumatology and Orthopedics. 2022;1(47):76-80. doi: 10.17238/2226-2016-2022-1-76-80.
5. Usoltsev I.V., Leonova S.N. Problems of Diagnostics and Surgical Treatment of Hallux Valgus (literature review). *Acta Biomedica Scientifica*. 2017;6(118):69-75. doi: 10.12737/article_5a0a869e6b7f52.08755802.
6. Ji L., Wang K., Ding S., Sun C., Sun S., Zhang M. Minimally Invasive vs. Open Surgery for Hallux Valgus: A Meta-Analysis. Front. Surg. 2022;9:843410. doi: 10.3389/fsurg.2022.843410.
7. Singh M.S., Khurana A., Kapoor D., Katekar S., Kumar A., Vishwakarma G. Minimally invasive vs open distal metatarsal osteotomy for hallux valgus - A systematic review and meta-analysis. *J Clin Orthop Trauma*. 2020;11(3):348-356. doi: 10.1016/j.jcot.2020.04.016.
8. Bia A., Guerra-Pinto F., Pereira B.S., Corte-Real N., Oliva X.M. Percutaneous Osteotomies in Hallux Valgus: A Systematic Review. *J Foot Ankle Surg.* 2018;57(1):123-130. doi: 10.1053/j.jfas.2017.06.027.
9. Holme T.J., Sivaloganathan S.S., Patel B., Kunasingam K. Third-Generation Minimally Invasive Chevron Akin Osteotomy for Hallux Valgus. *Foot Ankle Int.* 2020;41(1):50-56. doi: 10.1177/1071100719874360.
10. Lu J., Zhao H., Liang X., Ma Q. Comparison of Minimally Invasive and Traditionally Open Surgeries in Correction of Hallux Valgus: A Meta-Analysis. *J Foot Ankle Surg.* 2020;59(4):801-806. doi: 10.1053/j.jfas.2019.03.021.
11. Radwan Y.A., Mansour A.M. Percutaneous Distal Metatarsal Osteotomy Versus Distal Chevron Osteotomy for Correction of Mild-To-Moderate Hallux Valgus Deformity. *Arch Orthop Trauma Surg.* 2012;132(11):1539-1546. doi: 10.1007/s00402-012-1585-5.
12. Kaufmann G., Dammerer D., Heyenbrock F., Braito M., Moertlbauer L., Liebensteiner M. Minimally Invasive Versus Open Chevron Osteotomy for Hallux Valgus Correction: A Randomized Controlled Trial. *Int Orthop.* 2019;43(2):343-350. doi: 10.1007/s00264-018-4006-8.
13. Malagelada F., Sahirad C., Dalmau-Pastor M., Vega J., Bhumbra R., Manzanares-Céspedes M.C. et al. Minimally Invasive Surgery for Hallux Valgus: A Systematic Review of Current Surgical Techniques. *Int Orthop.* 2019;43(3):625-637. doi: 10.1007/s00264-018-4138-x.
14. Galois L. History of Surgical Treatments for Hallux Valgus. *Eur J Orthop Surg Traumatol*. 2018;28(8): 1633-1639. doi: 10.1007/s00590-018-2235-6.
15. Korman Z., White J., inventors; Wright Medical Technology, Inc., assignee. Targeting Guide and Associated Method. International Patent WO 2021/201916 A1. Publication Date 07.10.2021. Available from: https://patents.justia.com/patent/20230055767.
16. Marinozzi A., Martinelli N., Ronconi P., Cancilleri F., Papalia R., Denaro V. A New Device for Performing Triplanar Distal Osteotomy for Hallux Valgus. *J Am Podiatr Med Assoc.* 2009;99(6):536-540. doi: 10.7547/0990536.
17. Savintsev A.M., Boiko A.A., inventors; LVM AT MEDITSINA, assignee. Device for personalized treatment of valgus deformity of the first toe and method of its use. Patent 2741198 C1 RU. Publication Date 22.01.2021.

Authors' information

✉ *Igor G. Belenkiy* — Dr. Sci. (Med.)
Address: 3, Budapeshtskaya str., St. Petersburg, 192242, Russia
https://orcid.org/0000-0001-9951-5183
e-mail: belenkiy.trauma@mail.ru

Aleksei V. Oleinik
https://orcid.org/0000-0003-2748-0588
e-mail: oleynik77@gmail.com

Gennadii D. Sergeev — Cand. Sci. (Med.)
https://orcid.org/0000-0002-8898-503X
e-mail: gdsergeev@gmail.com

Aleksandr Yu. Kochish — Dr. Sci. (Med.), Professor
https://orcid.org/0000-0002-2466-7120
e-mail: auk1959@mail.ru

Kseniya V. Razumova
https://orcid.org/0009-0004-4436-4356
e-mail: ksukeks@yandex.ru

Artur E. Binazarov
https://orcid.org/0009-0006-3690-672X
e-mail: crazytrain.90@mail.ru

Boris A. Maiorov — Cand. Sci. (Med.)
https://orcid.org/0000-0003-1559-1571
e-mail: bmayorov@mail.ru -