Original article
https://doi.org/10.18019/1028-4427-2024-30-6-889-896

Original first metatarsophalangeal hemiarthroplasty and installation technique in treatment of grade 3–4 hallux rigidus

V.V. Skrebtsov[1]✉, V.G. Protsko[1,2], A.V. Skrebtsov[1], S.K. Tamoev[1], V.K. Nikitina[1]

[1] Yudin City Clinical Hospital, Moscow, Russian Federation
[2] Peoples' Friendship University of Russia named after Patrice Lumumba, Moscow, Russian Federation

Corresponding author: Vladimir V. Skrebtsov, Skrebtsov@mail.ru

Abstract

Introduction Arthrodesis is the "gold standard" for the treatment of stage 3–4 osteoarthritis of the first metatarsophalangeal (MTP) joint. However, restricted movements in the joint can lead to changes in the biomechanics of the foot overloading the adjacent joints and are accompanied by decreased activity which is important for younger patients. The available implants of the first MTP joint have some disadvantages and an original hemiarthroplasty of the first MTP joint was developed.

The **objective** was to demonstrate an original technique of hemiarthroplasty of the first MTP joint and installation to treat stage 3–4 hallux rigidus.

Material and methods The hemiendoprosthesis is made of zirconium ceramics. The head of the hemiendoprosthesis is made with a low profile. The cross-section of the stem has a four-bladed shape to ensure rotational stability of the implant. The hemiendoprosthesis can be placed using specially designed instruments. A case of a 74-year-old patient diagnosed with stage 3 osteoarthritis of the first MTP joint is reported.

Results AOFAS Hallux scored 28 and 95, VAS scored 9 and 0 and FFI scored 112 and 6 preoperatively and at 24 months, respectively. The range of motion in the joint (extension/flexion) measured 0°–0°–5° preoperatively and 60°–0°–15° at 24 months. The dynamic pedobarography indicated to the physiological distribution of pressure in the foot being restored postoperatively.

Discussion The first implants offered to replace first MTP joint were made of silicone and metal alloys and total joint arthroplasty was associated with significant resection of bone tissue; cases of endoprosthetic instability were reported. Hemiarthroplasty appeared to be a sparing technique. However, implants made of metal alloys could have an aggressive effect on the opposite articular surface. Hemiarthroplasty of the first MTP joint using a zirconium ceramic implant could minimize the risk of the complications.

Conclusion Hemiarthroplasty of the first MTP joint using an original zirconium ceramic implant was shown to be effective for patients with stage 3–4 hallux rigidus. The technique reported can be a good alternative to arthrodesis of MTP joint.

Keywords: osteoarthritis, rigid finger, hemiarthroplasty, zirconium ceramics

For citation: Skrebtsov VV, Protsko VG, Skrebtsov AV, Tamoev SK, Nikitina VK. Original first metatarsophalangeal hemiarthroplasty and installation technique in treatment of grade 3–4 hallux rigidus. *Genij Ortopedii*. 2024;30(6):889-896. doi: 10.18019/1028-4427-2024-30-6-889-896

INTRODUCTION

Hallux rigidus is a condition that is characterized by degenerative changes in the first metatarsophalangeal (MTP) joint, pain and limited range of motion (ROM) in the joint. Joint-saving techniques are used for surgical treatment of patients grade 1–2 osteoarthritis to ensure good results. Fusion of the first metatarsophalangeal joint is the best option for cases of advanced osteoarthritis [1]. Despite its widespread use and low cost, the treatment can be associated with progressive overload osteoarthritis of adjacent joints including the interphalangeal joint, poor outcomes in younger patients, some limited activities. Surgical interventions aimed at preserving movements in the joint are essential to avoid the adverse events. Original hemiarthroplasty of the first MTP joint using a ceramic implant was developed [2].

The **objective** was to demonstrate an original technique of hemiarthroplasty of the first MTP joint and installation to treat stage 3–4 hallux rigidus.

MATERIAL AND METHODS

Description of the hemiendoprosthetic implant

The hemiendoprosthesis is made of yttrium-stabilized zirconium ceramics. This material has the best coefficient of friction and wetting, is characterized by high strength and crack resistance, is the most gentle to the articular cartilage, bioinert and has the property of osseointegration [3–6].

The implant consists of a head and a stem. The hemiendoprosthetic head is made as a sphere and is close to the anatomical shape of the head of the first metatarsal. The articulating surface is smooth with roughness of Ra ~ 0.02 μm corresponding to the roughness class 13 and provides optimal characteristics of the ceramic-cartilage friction pair and high functionality over a long period of time. The low profile of the hemiendoprosthetic head allows for minimal resection of the affected portion of the head of the first metatarsal to ensure implant stability and preserve bone mass for revision interventions in case of a complication. There are longitudinal and transverse grooves on the back side of the implant head designed to increase the contact area and accelerate osseointegration.

The implant stem has a four-blade shape to ensure stable fixation of the hemiendoprosthesis in the metaphysis of the first metatarsal due to the press-fit and an increased contact area at the implant-bone interface. The stem roughness is Ra ~ 1.5–2.5 μm to promote optimal ingrowth, a strong and reliable connection between the implant and body tissues. The shape of the hemiendoprosthetic stem allows for maximum rotational stability of the implant and minimizes the bone defect with a canal forming in the metaphysis of the metatarsal. The size range of the hemiendoprosthesis is presented in four options, allowing surgical intervention to be performed with different diameters of the plane of the bone sawing of the head.

Surgical procedure

The patient is in supine position. The surgical field is treated with antiseptic solutions three times. An arthrotomy of the first MTP joint is performed using a medial approach. An oscillatory saw is used to resect osteochondral exostoses and perform soft tissue release of the first MTP joint and sesamoid hammock. The affected area of the articular surface of the head of the first metatarsal is resected with an original sawing block (Fig. 1).

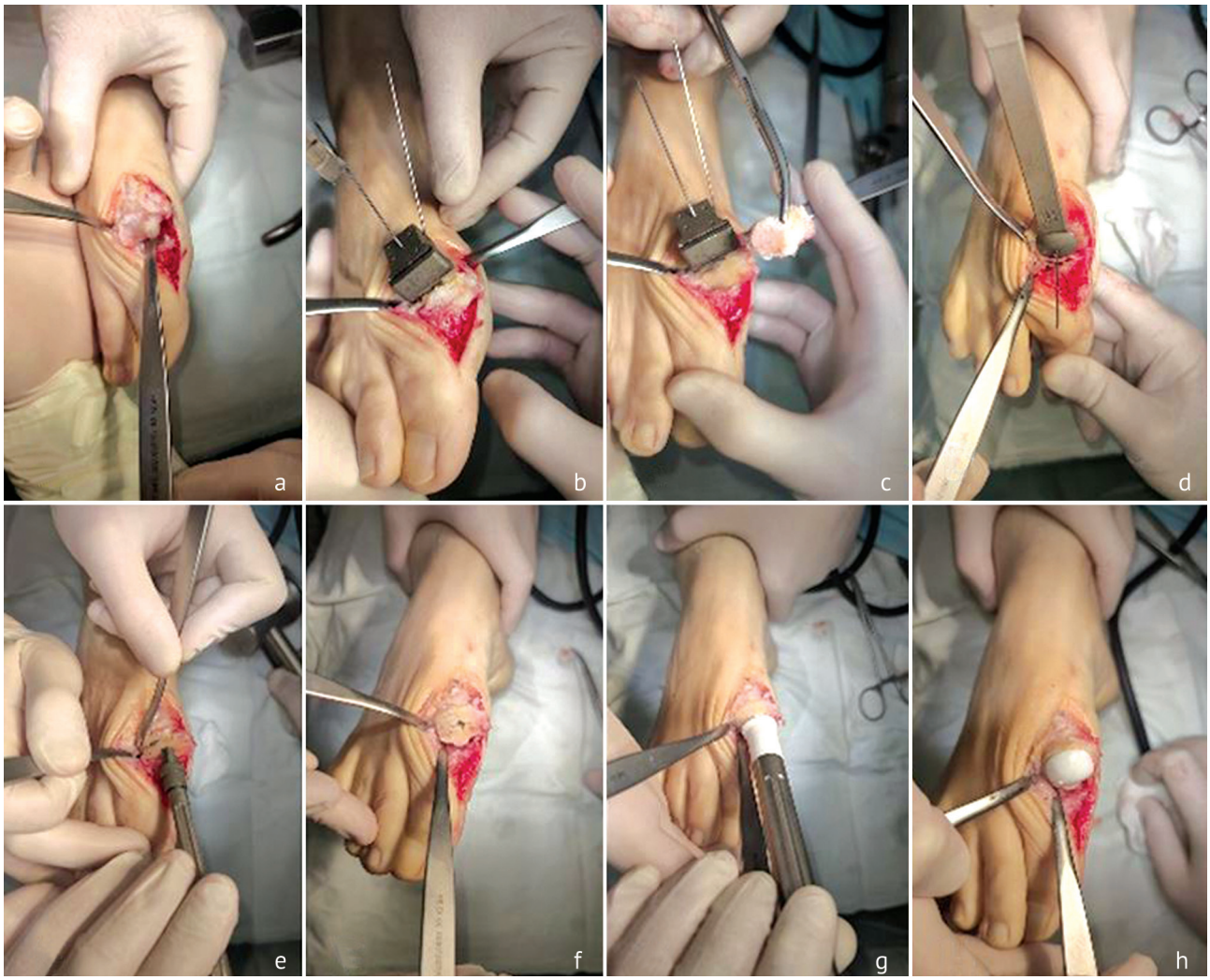

Fig. 1 Intraoperative photos showing (a) intraoperative assessment of the articular cartilage, (b) use of a sawing template, (c) resection of the articular surface, (d) determination of the implant size using a test template, (e, f) preparation of the canal with a compactor, (g) installation of a hemiendoprosthesis, (h) hemiendoprosthesis placed

Amount of the head resected is essential. Based on experience with the surgical procedures, resection to the cancellous bone tissue supplied with blood can be recommended. Installation of a hemiendoprosthesis into the sclerotic head of the first metatarsal can result in cracking during the formation of the channel for the stem and worse osseointegration of the implant.

A test template of the original model is placed on the osteotomy plane of the metatarsal to assess the required size of the hemiendoprosthesis, the expected ROM in the joint and the adequate metatarsal shortening.

If greater shortening of the metatarsal bone is necessary, the sawing block is moved proximally and additional resection of bone tissue is produced to achieve the ROM as required. The intraoperative ROM is deemed as a sufficient ROM in the MPT joint with extension/flexion measuring 60°–0°–15°. Then a guide pin is passed through the guide in the test template. The canal for the hemiendoprosthetic stem is prepared along using compactors of two sizes (starting and finishing). The implant is placed press-fit using the original impactor and the ROM in the joint is re-assessed. The wound is treated with antiseptic solutions and sutured in layers, and an aseptic bandage applied.

Clinical instance

A 74-year-old patient reported pain in the projection of the first MTP joint of the right foot, which intensified during physical activity, and limited ROM in the joint. The patient considered himself sick for many years, reported negative dynamics in his condition. he complained of constant pain for the last two years. He denied any history of injuries to the right foot. Previously, the patient had undergone courses of conservative anti-inflammatory therapy and used custom orthopaedic insoles with no improvement noted.

A physical examination revealed pronounced hard tissue formations in the projection of the first MTP joint of the right foot. Palpation of the joint was painful. He had severely limited and painful movements in the MTP joint. Preoperative ROM in the first MTP joint measured extension/flexion of 0°–0°–5°. AP view of both feet showed pronounced osteochondral exostoses in the projection of the joint, a significantly narrowed joint space and subchondral sclerosis.

Fig 2 Preoperative photograph and radiography of the right foot showing pronounced osteochondral exostoses in the projection of the first MTP joint; narrowing and distorted joint space, subchondral sclerosis seen radiographically

Preoperative AOFAS Hallux scored 28, VAS scored 9, and Foot Function Index (FFI) scored 112 points.

Dynamic pedobarography indicated a pathological distribution of pressure at the gait and a decrease in maximum pressure and force in the hindfoot. A significant increase in the maximum pressure and force in the forefoot, high values of the maximum pressure under the heads of the 4th and 5th metatarsals were recorded (Fig. 3).

The patient was diagnosed with stage 3 osteoarthritis of the first MTP joint of the right foot.

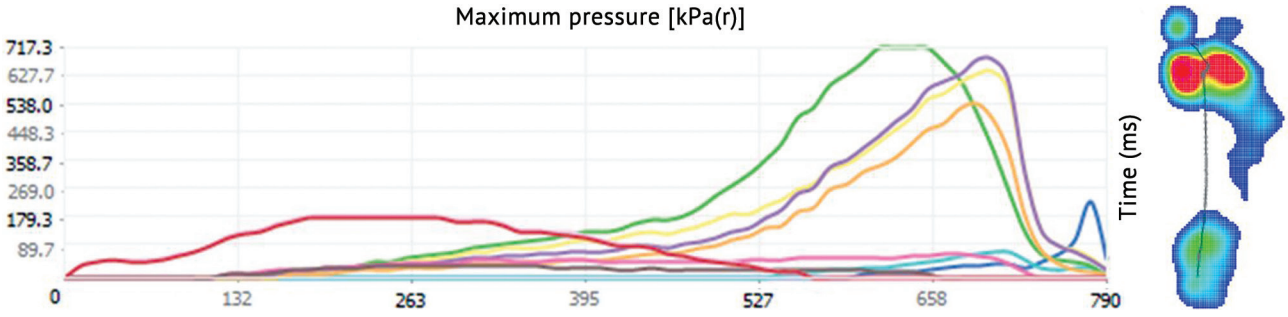

Fig. 3 Preoperative dynamic pedobarography showing a significant increase in maximum pressure in the forefoot. Green indexing — first metatarsal — 714 kPa, yellow indexing — second metatarsal — 586 kPa, purple indexing — third metatarsal — 617 kPa, orange indexing — fourth metatarsal — 499 kPa

RESULTS

The treatment options including arthrodesis of the first MTP joint were discussed with the patient. However, the patient chose the treatment aimed at preserving the motion in the affected joint.

Surgical intervention included hemiarthroplasty of the first MTP joint of the right foot using the technique described above. The patient was encouraged to ambulate early after the surgery and exercise the operated MTP joint the next postoperative day. He was allowed to walk using a Barock shoe for 1 month. The postoperative period was uneventful. The patient had no complaints at the time of a follow-up examination at 24 months.

Postoperative scars showed no signs of inflammation (Fig. 4). Palpation in the projection of the joint was painless. The ROM in the first MTP joint measured extension/flexion of 60°–0°–15° (Fig. 5). The AOFAS Hallux scored 95, the VAS scored 0 and the FFI scored 6.

Fig. 4 Photograph and radiograph of the foot at 24 months showing the realigned first toe; no radiological signs of implant instability seen

Fig. 5 The ROM in the first MTP joint at 24 months measured extension/flexion 60°–0°–15°

Dynamic pedobarography produced at 24 months showed changes in the patient's gait as compared to the baseline. There was an increase in maximum pressure and force in the hindfoot and a decrease in contact time and maximum pressure in the midfoot. The RMI index allowed us to conclude that the physiological distribution of pressure in the foot restored in the postoperative period [7] (Fig. 6).

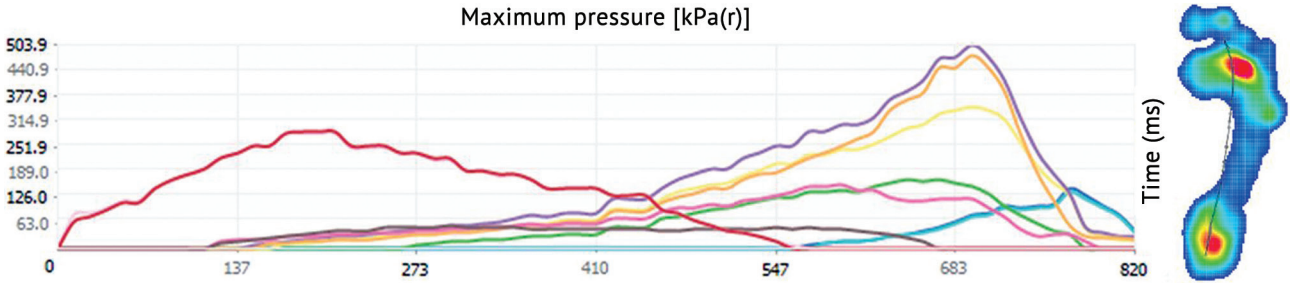

Fig. 6 Dynamic pedobarography performed at 24 months indicated an increase in maximum pressure in the hindfoot and a decrease in maximum pressure in the forefoot. Green Indexing — First Metatarsal — 184 kPa, Yellow Indexing — Second Metatarsal — 356 kPa, Purple Indexing — Third Metatarsal — 503 kPa, Orange Indexing — Fourth Metatarsal — 477 kPa

DISCUSSION

There is a wide range of implants on the market that differ in philosophy, assembly and structure [8]. The total arthroplasty of the first MTP joint is a conventional and one of the first options offered for joint replacement [8]. The first and second generations of the total arthroplasty include silicone implants that provide satisfactory long-term results despite a fairly high complication rate [9]. Implants of later generations are made of metal alloys and other materials [10]. The MTP1 joint replacement using the *ToeFit Plus* system is one of the treatment alternatives. The prosthesis is composed of a tapered, threaded, conical titanium core, which avoids any need for cement. On the metatarsal side, a cobalt chrome metatarsal head is tapped into the titanium core and to accommodate the proximal phalanx, a polyethylene phalangeal plate is clipped to the core. Short-term and long-term results show the effectiveness of the system [11, 12].The ceramic toe implant made of zirconium oxide can be used for MTP1 joint replacement. The ceramic prosthesis offers less reliable outcomes than the "gold standard" arthrodesis and caution is advised regarding its use for osteoarthritis of the first MTP joint. More studies including larger number of patients with longer follow-up are needed to evaluate the long-term results of the ceramic prosthesis for MPJ replacements [13].

Total arthroplasty of the first MTP joint is associated with resection of a significant amount of bone tissue. With unstable proximal component of the prosthesis, this may necessitate complex osteoplastic surgical interventions aimed at replacing the bone defect of the first metatarsal bone. A high incidence of instability of the distal component of the implant is reported [11]. The complication can occur with hemi-prostheses used at the base of the proximal phalanx of the first toe. A significant injury to the articular cartilage on the metatarsal head can result in a poor outcome with this type of hemi-prosthesis [14].

Hemiarthroplasty of the metatarsal head is another treatment option for hallux rigidus. The treatment is more pathogenetically substantiated with the articular surface of the metatarsal head being degenerative in osteoarthritis of the first metatarsophalangeal joint [15]. Another advantage of articular surface replacement is the ability to perform decompression in the joint due to gradual shortening of the metatarsal head bone which is used in other surgical techniques [16, 17]. HemiCAP is a common implant of this type and is available in several generations. The results with the implant are described in the literature [18].

The aggressive effect of titanium on the opposite articular surface is a disadvantage with the implant. Galambor et al. reported the results of histological studies performed during two revision surgeries after hemiarthroplasty of the main phalanx of the first toe using titanium implants due to instability [19]. The authors reported metallosis which indicated destruction of the implant.

There is also evidence in the literature about pronounced changes in the opposite articular surface due to wear caused by the aggressive effect of the metal implant on the cartilage [14]. We have been performing hemiarthroplasty of the first MTP joint with a ceramic implant since 2021. During this period, more than 40 surgical interventions were performed for patients with stage 3–4 hallux rigidus. An invention patent was received for this technology [2].

Preoperative dynamic pedobarography indicated antalgic gait and aimed at reduction of the ROM including extension in the first MTP joint in the sagittal plane. Restricted extension in the first MTP joint causes an increase in maximum forefoot pressure under the first metatarsal head and the heads of the lesser rays. These changes correspond to a “low-gear” roll, which occurs through the oblique axis connecting the second and fifth metatarsals [20]. According to the author, the roll is more energy-consuming, since the winch mechanism is not activated. Postoperative dynamic pedobarography performed at the time of examination at 24 months show an increase in maximum pressure in the hindfoot and a decrease in this parameter in the forefoot.

Restoration of the foot kinematics during the treatment of advanced hallux rigidus is still an unresolved issue. Cheilectomy is recommended for early disease to restore the natural roll of the foot [21]. The physiological roll of the foot cannot be restore in advanced stages of the disease. The main goal is to reduce resistance in the first metatarsal joint during forefoot roll. In this case, the maximum pressure under the head of the first metatarsal decreases, a relatively high load on the minor rays remains, and the load vector of the foot lateralizes. These changes are observed regardless of the treatment method, are compensated by the body and do not cause discomfort or pain in the postoperative period [22, 23, 24].

A succession of correction of the concomitant forefoot deformity and hemiarthroplasty of the head of the first metatarsal bone is important. In our opinion, the best results can be achieved in stages: anatomical realignment and deformity correction are to be produced first, and the affected articular surface can be replaced as the second step. This is justified by different approaches to postoperative rehabilitation. A protective regime for the forefoot is to be observed in the case of osteotomies. Isolated hemiarthroplasty allows for early ambulation and early exercising. The practice described allows you to achieve the best clinical results.

CONCLUSION

Hemiarthroplasty of the first metatarsophalangeal joint using a ceramic implant of an original design was shown to be an effective and reproducible surgical treatment of patients with stage 3–4 hallux rigidus. The functional results indicated the technique as a good alternative to arthrodesis of the first MTP joint.

Conflict of interest: *The authors declare that there is no conflict of interest.*

Funding: *The authors received no specific funding for this work.*

REFERENCES

1. Hoveidaei AH, Roshanshad A, Vosoughi AR. Clinical and radiological outcomes after arthrodesis of the first metatarsophalangeal joint. *Int Orthop*. 2021;45(3):711-719. doi: 10.1007/s00264-020-04807-3
2. Karlov AV, Skrebtsov VV, Protsko VG. *Hemiendoprosthesis of the first metatarsophalangeal joint*. Patent RF, no. 211915. 2022. Available at: https://www.fips.ru/cdfi/fips.dll/ru?ty=29&docid=211915&ki=PM. Accessed Jul 05, 2024.
3. Chen YW, Moussi J, Drury JL, Wataha JC. Zirconia in biomedical applications. *Expert Rev Med Devices*. 2016;13(10):945-963. doi: 10.1080/17434440.2016.1230017
4. Vanlommel J, De Corte R, Luyckx JP, et al. Articulation of Native Cartilage Against Different Femoral Component Materials. Oxidized Zirconium Damages Cartilage Less Than Cobalt-Chrome. *J Arthroplasty*. 2017;32(1):256-262. doi: 10.1016/j.arth.2016.06.024
5. Rezaei NM, Hasegawa M, Ishijima M, et al. Biological and osseointegration capabilities of hierarchically (meso-/micro-/nano-scale) roughened zirconia. *Int J Nanomedicine*. 2018;13:3381-3395. doi: 10.2147/IJN.S159955
6. Wimmer MA, Pacione C, Yuh C, et al. Articulation of an alumina-zirconia composite ceramic against living cartilage - An in vitro wear test. *J Mech Behav Biomed Mater*. 2020;103:103531. doi: 10.1016/j.jmbbm.2019.103531

7. Arno F, Roman F, Martin W, et al. Facilitating the interpretation of pedobarography: the relative midfoot index as marker for pathologic gait in ankle osteoarthritic and contralateral feet. *J Foot Ankle Res*. 2016;9:47. doi: 10.1186/s13047-016-0177-y
8. Butterworth ML, Ugrinich M. First Metatarsophalangeal Joint Implant Options. *Clin Podiatr Med Surg*. 2019;36(4):577-596. doi: 10.1016/j.cpm.2019.07.003
9. Sung W, Weil L Jr, Weil LS Sr, Stark T. Total first metatarsophalangeal joint implant arthroplasty: a 30-year retrospective. *Clin Podiatr Med Surg*. 2011;28(4):755-761. doi: 10.1016/j.cpm.2011.08.005
10. Gupta S, Mallya N. TOEFIT-PLUSTM replacement of the first metatarsophalangeal joint of the first toe: A short-term follow-up study. *The Foot*. 2008;18(1):20-24. doi: 10.1016/j.foot.2007.07.001
11. Gupta S, Masud S. Long term results of the Toefit-Plus replacement for first metatarsophalangeal joint arthritis. *The Foot*. 2017;31:67-71. doi: 10.1016/j.foot.2017.04.006
12. Erkocak OF, Senaran H, Altan E, et al. Short-term functional outcomes of first metatarsophalangeal total joint replacement for hallux rigidus. *Foot Ankle Int*. 2013;34(11):1569-1579. doi: 10.1177/1071100713496770
13. Nagy MT, Walker CR, Sirikonda SP. Second-Generation Ceramic First Metatarsophalangeal Joint Replacement for Hallux Rigidus. *Foot Ankle Int*. 2014;35(7):690-698. doi: 10.1177/1071100714536539
14. Raikin SM, Ahmad J, Pour AE, Abidi N. Comparison of arthrodesis and metallic hemiarthroplasty of the hallux metatarsophalangeal joint. *J Bone Joint Surg Am*. 2007;89(9):1979-1985. doi: 10.2106/JBJS.F.01385
15. Kline AJ, Hasselman CT. Resurfacing of the Metatarsal Head to Treat Advanced Hallux Rigidus. *Foot Ankle Clin*. 2015;20(3):451-463. doi: 10.1016/j.fcl.2015.04.007
16. Colò G, Samaila EM, Magnan B, Felli L. Valenti resection arthroplasty for hallux rigidus: A systematic review. *Foot Ankle Surg*. 2020;26(8):838-844. doi: 10.1016/j.fas.2019.11.009
17. Mackey RB, Johnson JE. Modified Oblique Keller Capsular Interposition Arthroplasty for Hallux Rigidus. *JBJS Essent Surg Tech*. 2012;2(1):e3. doi: 10.2106/JBJS.ST.K.00030
18. Jørsboe PH, Pedersen MS, Benyahia M, et al. Mid-Term Functionality and Survival of 116 HemiCAP® Implants for Hallux Rigidus. *J Foot Ankle Surg*. 2021;60(2):322-327. doi: 10.1053/j.jfas.2020.10.010
19. Ghalambor N, Cho DR, Goldring SR, et al. Microscopic metallic wear and tissue response in failed titanium hallux metatarsophalangeal implants: two cases. *Foot Ankle Int*. 2002;23(2):158-162. doi: 10.1177/107110070202300214
20. Bojsen-Møller F. Calcaneocuboid joint and stability of the longitudinal arch of the foot at high and low gear push off. *J Anat*. 1979;129(Pt 1):165-176.
21. Nawoczenski DA, Ketz J, Baumhauer JF. Dynamic kinematic and plantar pressure changes following cheilectomy for hallux rigidus: a mid-term followup. *Foot Ankle Int*. 2008;29(3):265-272. doi: 10.3113/FAI.2008.0265
22. Jørsboe PH, Speedtsberg MB, Kallemose T, et al. Plantar forces mid-term after hemiarthroplasty with HemiCAP for hallux rigidus. *Foot Ankle Surg*. 2020;26(4):432-438. doi: 10.1016/j.fas.2019.05.012
23. Alentorn-Geli E, Gil S, Bascuas I, et al. Correlation of dorsiflexion angle and plantar pressure following arthrodesis of the first metatarsophalangeal joint. *Foot Ankle Int*. 2013;34(4):504-511. doi: 10.1177/1071100713477386
24. Stevens J, Meijer K, Bijnens W, et al. Gait Analysis of Foot Compensation After Arthrodesis of the First Metatarsophalangeal Joint. *Foot Ankle Int*. 2017;38(2):181-191. doi: 10.1177/1071100716674310

The article was submitted 28.05.2024; approved after reviewing 01.07.2024; accepted for publication 21.10.2024.

Information about the authors:

Vladimir V. Skrebtsov — Candidate of Medical Sciences, orthopaedic surgeon, Skrebtsov@mail.ru, https://orcid.org/0000-0003-0833-6628;

Victor G. Protsko — Doctor of Medical Sciences, Associate Professor of the Department, orthopaedic surgeon, 89035586679@mail.ru, https://orcid.org/0000-0002-5077-2186;

Alexander V. Skrebtsov — orthopaedic surgeon, Skrebtsovalex@mail.ru, https://orcid.org/0000-0002-1418-3368;

Sargon K. Tamoev — Candidate of Medical Sciences, Head of the department, orthopaedic surgeon, Sargonik@mail.ru, https://orcid.org/0000-0001-8748-0059;

Victoria K. Nikitina — orthopaedic surgeon, vcnikitina@gmail.com, https://orcid.org/ 0000-0002-0064-3175.