

## Long-term functional results of first metatarsophalangeal joint arthrodesis for hallux rigidus

D.V. Ichenko<sup>1</sup>, A.V. Korolev<sup>1,2</sup>, A.A. Kardanov<sup>1,2</sup>

<sup>1</sup>European Clinic of Sports Traumatology and Orthopaedics (ECSTO), Moscow, Russian Federation,

<sup>2</sup>Peoples' Friendship University of Russia, Moscow, Russian Federation

**Introduction** First metatarsophalangeal joint (MTPJ) osteoarthritis hallux rigidus (HR) is the most common arthritic condition in the foot and occurs in 2.5–7.8 % of the population over 50 years. First MTPJ arthrodesis is currently considered to be the gold standard for the treatment of end-stage HR. When treating the advanced stage of HR, arthrodesis has long been established as an effective surgical procedure providing very predictable and satisfying results. Although the surgical authors prefer joint-sparing procedures first MTPJ fusion when required is the joint destructive procedure of choice in severe HR to eliminate or minimize pain, stabilize the first MTPJ and allow the hallux to bear weight. Functional outcomes achieved with fusion are also consistent with those from other surgical procedures. **The purpose** of this study is to evaluate long-term functional outcomes of first MTPJ arthrodesis. **Material and methods** Clinical and functional outcomes of MTPJ arthrodesis performed for 19 patients (25 feet) with grade 3 or 4 HR using the Coughlin and Shurnas Classification System between September 2010 and December 2017 were reviewed. The patients' mean age was 60 years (range, 35 to 86 years). The median interval between surgery and the last follow-up was 5 years (interquartile range, 1.5 to 8 years). Ultimately, outcome assessment relied on patient satisfaction, radiographic examination, visual analogue scale (VAS), the American Orthopaedic Foot & Ankle Society (AOFAS) and the Foot and Ankle Ability Measure (FAAM) scores. **Results** AOFAS score was rated as good in 92 % of the cases (23/25), as fair in 8 % (2/25) with neither excellent nor poor results recorded. The median AOFAS score increased from preoperative 43.0 to postoperative 85.0 that was statistically significant ( $p < 0.05$ ). Postoperative median FAAM Activities of Daily Living (ADL) was 99 %, median subjective ADL was 90 %, median FAAM sport was 84 %, and median subjective sport was 80 %. Patient subjective assessment was scored as "excellent" in 36 % of cases (9/25), "good" in 56 % (14/25), "fair" in 8 % (2/25) with no "poor" results recorded. The median VAS pain score decreased from 6 at baseline to 1 point postsurgery ( $p < 0.05$ ). **Conclusion** First MTPJ arthrodesis was shown to be a very effective, reliable and lasting primary procedure for severe HR that provided 92% of good outcomes in our series. The procedure can be advocated as a predictable and excellent option for Coughlin and Shurnas grades 3 and 4 HR facilitating high success rates in pain relief and restoration of function.

**Keywords:** hallux rigidus, first metatarsophalangeal joint osteoarthritis, osteotomy, arthrodesis

### INTRODUCTION

Deforming osteoarthritis (OA) is a degenerative long-lasting joint disease affecting articular cartilage and periarticular tissues with alternating acute episodes of exacerbation and periods of remission. Deforming OA is the most common joint disorder. First metatarsophalangeal joint (MTPJ) osteoarthritis hallux rigidus is the most common arthritic condition in the foot. Of all patients aged over 50 years, 2.5–7.8 % report degenerative arthritis of the first MTPJ, termed 'hallux rigidus' (HR) [1, 2]. It is characterised by pain, a progressive decrease in range of motion, primarily with dorsiflexion, periarticular osteophyte formation and cartilage degeneration. The disease initially affects the dorsal portion of the joint and progresses resulting in articular cartilage loss, debilitating pain and limited functional activity [3]. Although HR was first described in the orthopaedic

literature towards the end of the nineteenth century, a search for more effective treatment options is still being conducted [4].

Nonsurgical techniques can often be used to successfully treat patients at early stages of degeneration whereas surgical treatment is associated with greater risk of complications or lower rate of satisfactory outcomes. Cheilectomy and arthrodesis of the first MTPJ remain first-line surgical treatments tested in clinical trials [5, 6, 7]. Premeditated ankylosis of the first MTP joint was described by Wyeth (1887) and later by Clutton (1894) who contended that ankylosis in an ideal position would produce a permanent and very satisfactory result. Glissan and McKeever are generally associated with the modern era of first MTP joint arthrodesis and they described unintentional ankylosis in a patient who

suffered stiffness after bunion surgery and found that the 'complication' made the foot function better. It is from these observations that led to the orthopedic community to embrace first MTPJ arthrodesis in the mid-20th century. There are multiple surgical techniques for arthrodesis of the first MTPJ utilizing different ways to prepare the bone surfaces and a wide variety of techniques of internal and external fixation, all of which may have their place in various instances [5]. Dorsal plate and lag screw fixation provides reliable biomechanical stability for the fusion [8, 9, 10]. The reported rate of bone healing and consolidation of the fusion site ranges between 77 % and 100 % with the mean of 90 % [11, 12, 13]. Optimal position of the first MTP joint is with neutral rotation R1, 5° to 15° of valgus and 20° to 25° relative to the first metatarsal M1 [11, 14]. Different types of arthroplasty and arthrodesis of the first MTPJ can be the method of choice in degenerative joint surgery. Many replacement procedures are associated with a higher complication rate due to bone loss, loosening or fragmentation of implant components and

transfer metatarsalgia [15]. Traditionally, first MTPJ arthrodesis can be applied to primary degenerative arthritis and revision of prior failed surgery to this joint with iatrogenic changes [16, 17]. However, revisionary surgery of the first MTP joint has been shown to result in inferior clinical and functional outcomes and greater complications [15]. Primary arthrodesis of the first MTP appears to be a safe and efficient method for surgical treatment of severe arthritis. The procedure can facilitate bone healing that removes pain, regains range of movement, maintains the medial column and toe length, achieves stability of the first ray sacrificing motion in the MTPJ. Furthermore, fusion sacrifices motion which may lead to patient dissatisfaction and a decrease in first-ray mobility results in a significant change in the postoperative gait pattern, characterized by a shorter step length and a reduction in ankle power at push-off. Clinical results indicate effective pain relief and a high activity level in patients with symptomatic HR.

**The purpose** of this study was to evaluate long-term functional outcomes of first MTPJ arthrodesis.

#### MATERIAL AND METHODS

We performed a retrospective study of 19 patients (25 feet) who had undergone a surgical treatment for deforming OA of the first MTP joint between September 2010 and December 2017 at the European Clinic of Sports Traumatology and Orthopaedics of the European Medical Center. The mean patients' age was 60 years (range, 35 to 86 years). There were 1 male and 18 female patients. Preoperative radiological examination included the weightbearing dorsiplantar and lateral foot films. HR grade 4 (n = 14) and HR grade 3 (n = 11) using the Coughlin and Shurnas Classification System were diagnosed using clinical and radiological findings [11] (Fig. 1).



**Fig. 1** Severe deforming OA of the first MTP joint Coughlin и Shurnas grade 4

Preoperative planning included measurements of the metatarsal index and interphalangeal valgus and evaluation of degenerative changes on weightbearing radiographs. Isolated arthrodesis of the first MTPJ was performed for 18 patients, and the Chevron osteotomy was added in one case with M1R1  $\leq 30^\circ$  and M1M2  $\leq 12^\circ$  (Fig. 2), and the distal minimally invasive osteotomy R1 supplemented 6 operative interventions to correct hallux valgus interphalangeus with the bone fixed with screws.

All patients were examined preoperatively and at a long-term follow-up. The median interval between surgery and the last follow-up was 5 years (interquartile range, 1.5 to 8 years). Patients were requested to complete the American Orthopaedic Foot & Ankle Society (AOFAS) questionnaire preoperatively and at a long-term follow-up to assess the forefoot (Table 1), and the Foot and Ankle Ability Measure (FAAM) to assess postoperative physical functioning [18].

Outcome assessment also relied on subjective patient satisfaction after surgical treatment rated as 'excellent', 'good', 'fair' and 'poor' and preoperative and postoperative visual analogue scale (VAS) score.



**Fig. 2** Preoperative (a, c) and postoperative (b, d) radiographs of the right foot showing the foot bones before and after first MTPJ arthrodesis combined with the Chevron osteotomy of M1

**Table 1**

Interpretation of AOFAS scores

Rating	Scores
Excellent	95–100
Good	75–94
Fair	51–74
Poor	0–50

### Statistical analysis

Statistical analysis was performed with computer software (IBM SPSS Statistics 23.0.0.0). The Shapiro-Wilk test was used to determine normality of distribution in the groups. The data obtained were summarized as means  $\pm$  standard deviations with maximal and minimal values in normal distribution; numerical data were presented with median and interquartile range when distribution was different from the norm. Quantitative data were presented in box plots. The Wilcoxon signed-rank test was used to analyze data in two related paired samples. The Mann-Whitney U test was used to compare differences between two independent groups. For calculations, a significance level of 5 % ( $p \leq 0.05$ ) was adopted.

### Surgical technique

Different types of fixation and techniques for preparation of the articular surfaces are employed for first MTPJ arthrodesis. We applied two different techniques depending on a ratio between M1 and M2 lengths. The start-up surgical phase was identical for the cases with medial approach followed by dissection of the articular capsule. R1 and M1 articular ends were resected with M1 length being greater or equal to M2 length to regain metatarsal index and fixation provided either with two crossed compression screws or a dorsal plate and a lag screw. The latter was shown to be a more stable and more expensive option.

Fixation was ensured with screws only ( $n = 21$ ) and a plate and a screw ( $n = 4$ ). Position of metal constructs was evaluated radiologically in all cases (Fig. 3). Milling of the articular ends was produced with M1 length not exceeding M2 length thoroughly observing volume of resection to avoid excessive shortening of M1 and development of transfer metatarsalgia. Excised bone fragments were removed at the stage and conjugated ends adapted to ensure a tight M1 and R1 contact. Compression screws were used for bone fixation. Optimal positioning of R1 relative to M1 is very important. A supporting foot plate was used to ensure ankle dorsiflexion at  $90^\circ$  and neutral rotation R1,  $5^\circ$  to  $15^\circ$  of valgus and  $20^\circ$  to  $25^\circ$  relative to the first metatarsal M1 (Fig. 4). In our series, successful arthrodesis occurred in all cases after operative treatment of HR and bone healing was radiologically visualized at 3 to 4 months postsurgery.



**Fig. 3** Position of metal construct identified with intraoperative radiograph



**Fig. 4** Supporting foot plate used to secure intraoperative position of the foot. A R1 to M1 angle is supposed to measure  $20^\circ$ – $25^\circ$

## RESULTS

AOFAS scores showed 92 % of good results (23 operative interventions) and 8 % of fair (2 surgeries) results. Neither excellent nor poor outcomes were observed. Absence of excellent results to be rated on AOFAS scale was associated with considerable limitations in ROM in the first MTPJ because of fusion with the resultant score lacking 10 points and being rated as a good result. The median AOFAS score was 43.0 (interquartile range, from 25.0 to 47.0) that increased postsurgery to 85.0 (interquartile range, from 82.0 to 87.0) and was statistically significant ( $p < 0.05$ ). Preoperative and postoperative AOFAS scores are presented in Figure 5. Subjective patient satisfaction was rated as 'excellent' in 36 % of the cases (9 surgical interventions), 'good' in 56 % (14 surgical interventions) and 'fair' in 8 %

(2 surgical interventions). No 'poor' subjective scores were recorded. The median postoperative FAAM score on activities of daily living subscale was 99 % (interquartile range, from 98 to 100 %) and on subjective form of activities of daily living subscale was 90 % (interquartile range, from 80 to 100 %) (Fig. 6). The FAAM sports subscale was scored only in 7 cases of first MTPJ arthrodesis. The median postoperative FAAM score on sports subscale was 84 % (interquartile range, from 78 to 90 %) and on subjective sports form was 80 % (interquartile range, from 70 to 80 %) (Fig. 7). The median VAS score was 6 (interquartile range, from 4 to 7) preoperatively and improved to 1 point postoperatively (interquartile range, from 1 to 1) that was statistically significant ( $p < 0.05$ ) (Fig. 8).

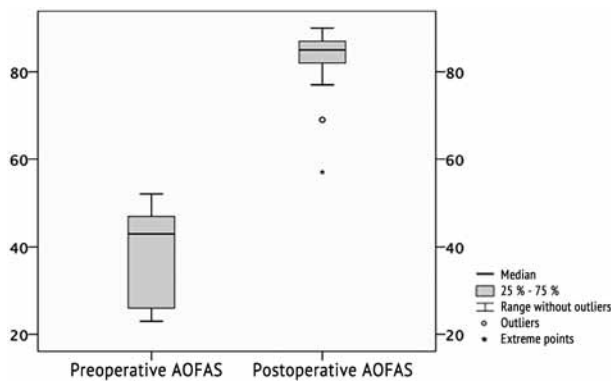


Fig. 5 Preoperative and postoperative AOFAS scores

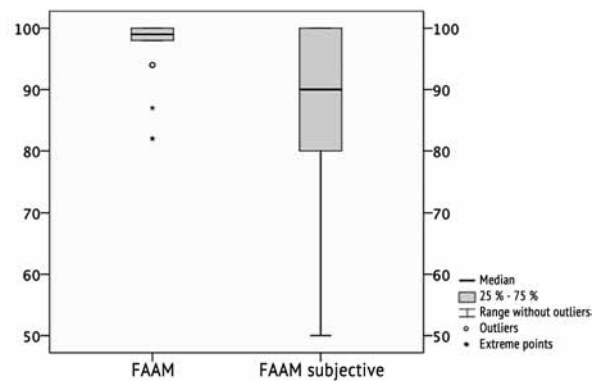


Fig. 6 FAAM scores on ADL subscale

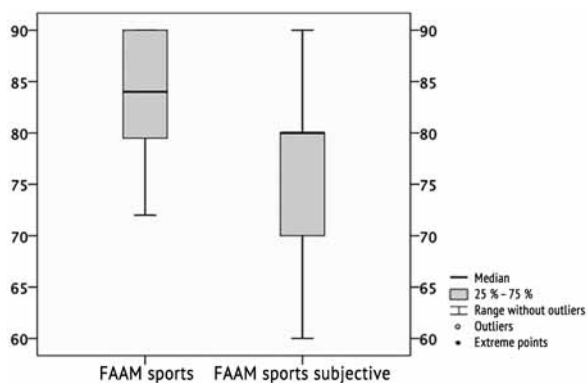


Fig. 7 FAAM scores on sports subscale

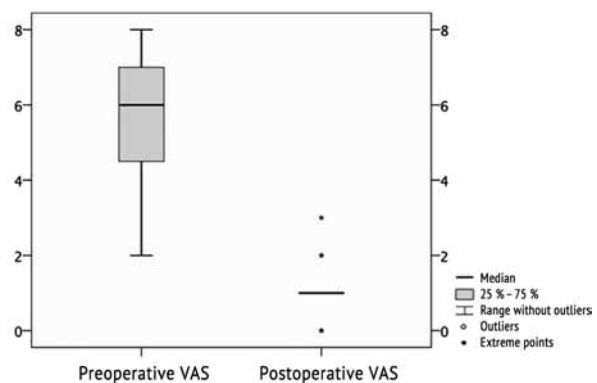


Fig. 8 Preoperative and postoperative VAS scores

## DISCUSSION

Severe OA of the first MTPJ remains difficult to treat. First MTPJ arthrodesis is a well-documented, reliable and reproducible procedure that results in excellent pain relief and improved functionality, however, loss of motion can lead to limited activities of daily living or sports. However, patients may experience shoe-

wearing limitation after the procedure. There are still debates regarding arthrodesis and arthroplasty aimed at preservation of motion in the first MTPJ and, subsequently, biomechanics of the gait. Implant arthroplasty of the first MTPJ has a high complication rate due to greater loss of osseous tissues, loosening

and tear and wear of prosthetic components as well as absence of outcome prediction and limited number of clinical trials.

In our series, first MTPJ arthrodesis has been shown to be a very effective and reliable procedure for HR providing excellent clinical and functional results. Our findings were comparable to those reported in foreign studies. Raikin et al. reported 82 % good results and 4 % poor outcomes in 27 cases of first MTPJ arthrodesis at a 30-month follow-up with VAS score decreased to 0.7 points and AOFAS score increased to 83.8 points [19]. Gibson and Thomson reported 95.5 % good results in 22 patients (38 feet) following first MTPJ arthrodesis at a 24-month follow-up with VAS score decreased to 1.1 points and all arthrodeses united [20]. Stevens et al. presented systematic review of the literature including thirty-three studies, describing a total of 741 arthrodeses and 555 total joint replacements. Six different prostheses were used for total joint replacement, and various fixation techniques were used for arthrodesis. Pooled results showed superiority of arthrodesis compared with total joint replacement for improving clinical outcome (by 43.8 versus 37.7 points on the AOFAS-HMI score) and reducing pain (a decrease of 6.56 versus 4.65 points on the VAS pain score). Fewer intervention-related complications (23.1 % versus 26.3 %) and revisions (3.9 % versus 11 %) were reported after arthrodesis as compared with total joint replacement [21]. Coughlin and Shurnas reported 100 % positive outcomes in 30 patients with Grade-3 HR and Grade-4 HR treated with first MTPJ arthrodesis, with AOFAS scores averaged 88.9 at an average follow-up of 80 months [11]. Chraim et al. performed a retrospective review of 60 patients (61 feet) who underwent arthrodesis of the first MTPJ with average follow-up of 47.3 months. The AOFAS increased postoperatively from 40.9 to 79.3. Concerning the postoperative satisfaction, 71.7 % of the patients were very satisfied and 18.3 % were satisfied. Complications included 6.7 % of the cases who ended up with a painless pseudarthrosis and required no additional surgery [22]. Successful consolidation were reported in 98 % of primary first MTPJ arthrodesis [23, 24, 25]. Wanivenhaus et al. retrospectively reviewed 39 patients (41 feet) who underwent first MTPJ fusion using a compressive locking plate that was successful in

95 % of the cases with the forefoot AOFAS score improved significantly from  $50 \pm 13$  preoperatively to  $80 \pm 7$  at > 1 year of follow-up ( $p = 0.001$ ) [26]. Korim et al. performed a qualitative synthesis of the current literature to determine the union frequencies for first MTPJ arthrodesis as well as the influence of pathology, joint preparation and fixation methods on union. The systematic review included 26 studies with 2059 feet. The mean age was 60 years (range 18–84) and the mean follow-up was 32.6 months (range 1.5–156). The union frequency was 93.5 % (1923/2059). The union frequencies were significantly higher when low velocity joint preparation methods were used ( $p < 0.0001$ ) and the pathology was HR ( $p = 0.002$ ) [27].

Our findings have been found to be in line with those reported in the literature. Patients with Coughlin and Shurnas Grade 3 and Grade 4 HR in our series showed lower VAS values, higher AOFAS scores and levels of activities of daily living and sports as well as higher patient satisfaction at a long-term follow-up. Brodsky et al. examined the effects of first MTP joint arthrodesis on activities of daily living and recreational activities in 53 patients (60 feet). The mean follow-up was 44 months. The authors found that patients were able to return to hiking 92 % of the time, golf 80 % of the time, tennis 75 % of the time and jogging 75 % of the time [28]. Similar results were obtained by Da Cunha et al. who assessed sports and physical activities in 50 patients following first MTPJ arthrodesis identified by review of a prospective registry with follow-up at a mean of 5.1 years with a mean age at surgery of 49.7 years. The most common sports and physical activities patients participated in were walking, biking, weightlifting, swimming, running, and golf. Compared to preoperatively, patients rated 27.4 % of activities as less difficult, 51.2 % as the same, and 21.4 % as more difficult. Ninety-six percent of patients (48/50) were satisfied with the procedure regarding return to sports and physical activities [29]. In our series, we could evaluate sports and physical activities in 7 patients following surgical treatment of HR with the FAAM and patient satisfaction levels dropped down to 84 % and 80 %, respectively.

Our study had several limitations. First, this was a retrospective case series with a small number of participants. Second, clinical signs of overloading

or OA in adjacent joints of the first ray or joints of the foot might have played a role in postoperative AOFAS and FAAM scores in presence of limited mobility in the first MTPJ following arthrodesis. Third, a further thorough functional analysis is needed to be performed with findings from pedobarography and preoperative and postoperative

gait analysis as far as objective AOFAS and FAAM scores have not been confirmed by trials and cannot be used for informative conclusions. We can also suggest that a more continuous observation of surgically treated patients would be practical for comprehensive assessment of clinical and radiological findings.

## CONCLUSION

First MTPJ arthrodesis was shown to be a very effective, reliable and lasting primary procedure for severe HR that provided 92 % of good outcomes in our series. The procedure can

be advocated as a predictable and excellent option for Coughlin and Shurnas grades 3 and 4 HR facilitating high success rates in pain relief and restoration of function.

**Competing interests.** The authors have declared that no competing interest exists.

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Received: 24.05.2019

#### **Information about the authors:**

1. Denis V. Ilchenko, M.D.,  
European Clinic of Sports Traumatology and Orthopaedics (ECSTO), Moscow, Russian Federation,  
Email: dilchenko@emcmos.ru
2. Andrey V. Korolev, M.D., Ph.D.,  
European Clinic of Sports Traumatology and Orthopaedics (ECSTO), Moscow, Russian Federation,  
Peoples' Friendship University of Russia, Moscow, Russian Federation,  
European Medical Center (EMC), Moscow, Russian Federation
3. Andrey A. Kardanov, Ph.D., Professor,  
Peoples' Friendship University of Russia, Moscow, Russian Federation,  
European Clinic of Sports Traumatology and Orthopaedics (ECSTO), Moscow, Russian Federation,  
Email: akardanov@emcmos.ru