ORIGINAL STUDY

acta orthopaedica belgica, 2023, 89, 507-514

doi.org/10.52628/89.3.11999

Which parameters predict correction of the intermetatarsal angle after first metatarsophalangeal fusion?

L. DE COCK[1], S. WUITE[2], W.-J. VLEUGELS[3], A. BURSSENS[4], G.A. MATRICALI[2]

[1]Department of Orthopaedics, AZ Sint-Blasius Hospital, Dendermonde, Belgium; [2]Department of Orthopaedics, Foot and Ankle Unit, University Hospitals Leuven, Leuven, Belgium. Department of Development and Regeneration, KU Leuven-University of Leuven, Leuven, Belgium. Institute of Orthopaedic Research and Training, KU Leuven-University of Leuven, Leuven, Belgium; [3]Department of Orthopaedics, University Hospitals Leuven, Leuven, Belgium; [4]Department of Orthopaedics, Ghent University Hospital, Ghent, Belgium.

Correspondence at: De Cock Laurens, MD, Orthopaedic Surgeon, Department of Orthopaedic Surgery, AZ Sint-Blasius, Dendermonde, Belgium, Phone: +32 474 46 54 82, Email: laurens.decock@gmail.com

Fusion of the first metatarsophalangeal joint (MTPJ) is a commonly performed surgical procedure. Although the effect of first MTPJ fusion on reduction of Intermetatarsal angle (IMA) is well described, contributing factors remain unclear. The aim of this study was to identity predictive parameters for IMA reduction. Fifty-one patients (68 feet) who underwent a first MTPJ fusion and had an IMA greater than fourteen degrees were assessed retrospectively. The average age was 68 (31.4-79.3) years. Sixteen demographic and radiographic variables were evaluated using a multivariate regression analysis for association with change in IMA after surgery. The mean preoperative IMA was 16.11 (range, 14.0-22.5) degrees with a mean reduction of 4.95 (range, 0-17) degrees after surgery. Multivariate regression analysis revealed three significant independent predictors of the change in IMA. Increased preoperative IMA (β = .663, CI = .419, .908, *P* <.001), increased preoperative translation at base of MT1 (β = .490, CI = 0.005, .974, *P* = 0.039), and less postoperative translation in the fusion (β= -0.693, CI= -1.054, -.331, P= 0.002) significantly increased the amount of IMA reduction. Pre-operative IMA and translation at the base of the first metatarsal were positive predictors for correction of IMA after first MTPJ fusion. Translation at the level of the MTP I fusion was a negative predictor for the amount of IMA correction. Based on these findings, we recommend minimizing the lateral translation of the proximal phalanx relative to the metatarsal head to optimize IMA correction after MTPJ fusion.

Key words: mtp i arthrodesis, radiographic analysis, forefoot alignment, intermetatarsal angle, weightbearing radiographs, and hallux valgus.

INTRODUCTION

First metatarsophalangeal joint (MTPJ) fusion is a commonly performed technique for a variety of first ray deformities. In cases with severe hallux valgus deformity, correction of the intermetatarsal angle (IMA) and reduction of the width of the foot is expected after surgery[5,16,18]. Failure to reduce the IMA, might reduce patient reported outcomes by causing pain over the medial prominence[6]. Therefore, some authors advocate the use of an additional basal osteotomy, to help correct the IMA in those cases with a larger preoperative IMA[17]. Others have claimed that this extra osteotomy is unnecessary, because even in cases with IMA greater than 15 degrees, a desirable correction has been shown after first MTPJ fusion alone[13]. However, the reduction of IMA is not as well understood and it remains unclear which factors influence the amount of IMA reduction. The aim of this study was to explore whether different factors could be identified, that are predictive for the amount of IMA correction after first MTPJ fusion. Our hypothesis was that IMA correction observed postoperatively could be predicted by different clinical or radiological variables.

METHODS

This retrospective cohort study reviewed all patients in the foot and ankle registry of the XXX hospitals, who underwent first MTPJ fusion between January 2008 and November 2015 by two experienced orthopedic foot and ankle surgeons. The study protocol was reviewed and approved by the investigator's institutional review board and informed consent was waived (IRB number: S61496). The inclusion criteria for this study were all patients with a first MTPJ fusion and a pre-operative

IMA of 14 degrees or more. Presence of a preoperative as well as postoperative, weightbearing AP radiographs of the foot at a minimum of 48 weeks after surgery. This minimum time was chosen to allow patients to comfortably walk and we could take upright, full weightbearing x-rays[2]. The exclusion criteria consisted of patients with a non-union and those with neuromuscular imbalance, e.g., cerebral palsy. Patients who underwent concomitant procedures on the metatarsals, midfoot, or hindfoot during the same anesthesia were also excluded.

The initial review of the registry data identified a total of 61 patients (79 feet) who had undergone a first MTPJ fusion on at least one foot with an IMA angle greater than 14 degrees. Four patients who did not have follow-up radiographs, three patients with cerebral palsy and three patients whose arthrodesis did not fuse were excluded.

A total of 51 patients (68 feet) were included for final analysis. In the final cohort, the mean age was 63.4 (range, 24 to 80) years at the time of surgery. Final radiographs were obtained at a mean of 1 year (range, 48 to 65 weeks). Three patients had radiographs less than 1 year after surgery.

The cohort consisted of eight men and 43 women. Thirty-six fusions were performed on the right and 32 were performed on the left side. Thirty-six fusions were performed using IOFIX (an Intra-Osseous FIXation device, Extremity medical, New Jersey, USA), 25 fusions were performed using cross screws and in the other seven cases plate/lag screws were used. Most fusions (44/68, 64.7%) were performed for moderate to severe hallux valgus (with a hallux valgus angle [HVA] > 30 degrees), whereas the remaining fusions were performed for hallux rigidus (14/68, 20.6%), previous failed hallux valgus correction (6/68, 8.8%), and degenerative hallux valgus deformity (4/68, 5.9%). Eleven feet (16%) had had a prior procedure on the first MTP joint, including cheilectomy (5), chevron osteotomy (4) and scarf osteotomy (2).

Radiographic analysis was performed using the digital picture archiving and communication system (PACS) (Agfa-Gevaert, BE). All radiographs contained autocalibration in order to maintain the same measurement distance when enlarging the images. Radiographic analysis was performed based on weightbearing images obtained during our standard radiographic routine, which included an anteroposterior (AP) and lateral image of the foot. Measurements were performed on preoperative weightbearing radiographs and postoperative weightbearing radiographs at the last follow-up visit at least 48 weeks after surgery.

Figure 1 — Anteroposterior radiograph of the foot depicting in detail the base of the first metatarsal. The translation at the base of MT1 was determined by the distance between the most lateral edge of the MT1 and the most lateral edge of the medial cuneiform.

On preoperative and postoperative standing radiographs, the following measurements were performed: hallux valgus angle (HVA), intermetatarsal angle (IMA), length of first ray relative to the second metatarsal (MT2), first metatarsocuneiform angle (MCA) and first metatarsocuneiform slope angle (MCSA), sesamoids position and length of the first metatarsal relative to the second metatarsal. The HVA was measured between the line drawn down the first metatarsal and a second line down the center of the proximal phalanx shaft. The IMA was obtained by the angle between the mid-axis lines of the first and second metatarsal. The length of first ray was determined by the sum of the length of the mid-axis lines for the proximal phalanx and the first metatarsal[3] The first metatarsocuneiform angle is the measured angle between the longitudinal axis of the first metatarsal and the longitudinal axis of the medial cuneiform[8]. The first metatarsocuneiform slope angle is the measured angle between a line drawn at the base of the first metatarsal and a line perpendicular to the longitudinal axis of the medial cuneiform[8]. Position of the sesamoids was determined using Hardy and Clapham's tibial sesamoid seven position system in an anteroposterior view[11]. We also measured the dorsiflexion angle of the first MTPJ on postoperative radiographs[3]. We evaluated whether there was osteoarthritis of the first cuneo-metatarsal joint using a previous described method, using a radiographic atlas, were scoring of the osteophytes and joint space narrowing was performed. Radiographic osteoarthritis was considered to be present if a score of 2 or more is documented for either osteophytes or

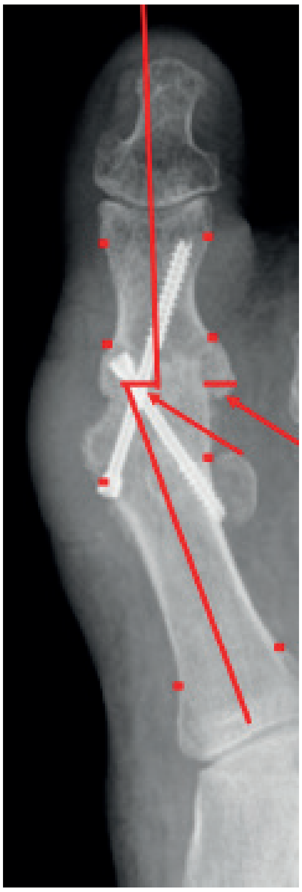

Figure 2 — Anteroposterior radiograph of the first ray, demonstrating the measurement of the translation in the fusion by the average of two measurements: one between the longitudinal axis of the first metatarsal and the proximal phalanx and one on the lateral side between the cortex of the first metatarsal and that of the proximal phalanx.

joint space narrowing from either the AP or lateral view[14]. IMA correction was determined by subtraction of postoperative IMA from preoperative IMA.

Furthermore, we performed two new measurements, the translation at the base of the first metatarsal (MT1) and the translation in the fusion. The translation at the base of MT1 was determined by the distance between the most lateral edge of the MT1 and the most lateral edge of the medial cuneiform at the level of the first tarsometatarsal joint (Figure 1). The translation in the fusion was determined by the average of two measurements: one between the longitudinal axis of the first metatarsal and the proximal phalanx and one on the lateral side between the cortex of the first metatarsal and that of the proximal phalanx (Figure 2). Those two measurements were performed perpendicular to the axis of the second row.

After removal of all identifying information from each radiograph, each subfolder was randomly assigned a unique identifying code so that the pre- and postoperative radiographs of the same patient could not be identified by the reviewers. All radiographs were analyzed by two independent reviewers at different levels of training (Author 1 and Author 3). At the completion of the review process, the identifying code was broken, and all recorded measurements were transferred to a master spreadsheet.

Sixteen variables were included in our analysis to determine predictors of correction in IMA angle after surgery. Numerical variables included age, preoperative HVA, postoperative HVA, the difference between preoperative and postoperative HVA (HVA correction), preoperative IMA, first MCA, first MCSA, translation in the fusion, translation at the base of MT1, the shortening of the first ray relative to the second metatarsal and the dorsiflexion angle. Categorical variables included gender, fixation type, preoperative indication for surgery, position of the sesamoids and osteoarthritis of the first cuneo-metatarsal joint.

Pearson correlation coefficient was used to investigate associations between each of the numerical variables and the change in IMA angle. For the categorical variables with two groups a Wilcoxon rank-sum test and for categorical variables with three or more groups a Kruskal-Wallis test was used to compare change in IMA between patients in each group. With those three tests, *P* values less than or equal to .05 were considered statistically significant. To account for possible interactions among predictor variables, however, all variables that were found to have *P* values less than .10 in univariate analysis were subsequently included in our initial multivariate linear regression model[2]. In order to identify independent predictors associated with IMA reduction, a backward selection procedure was applied retaining variables with *P* values less than or equal to .05, using a linear regression model with IMA reduction as continuous outcome variable. For evaluation of the interrater reliability of the measurement of the translation in the fusion and translation at the base of MT1, intraclass correlation coefficients (ICCs) were calculated for both measurements. All statistical analyses were performed using SPSS software (version 21; SPSS; Chicago, IL).

A statistical power analysis using G*Power (Version 3.1.9.2, Dusseldorf University, Dusseldorf, Germany) was performed for sample size estimation, based on previously reported data regarding the primary outcome: intermetatarsal angle (IMA) [4].

A minimal sample size of 18 patients needed to be enrolled with a calculated effect size (f= 1.71), a power level of 0.8 and level of significance set at 0.05.

RESULTS

Patient cohort characteristics are shown in Table I. The average reduction in IMA angle from preoperative to postoperative values was 4.95 degrees (range, 0 to 17). In 7/68 cases (10.2%) the postoperative IMA was greater than 14 degrees. Among the numerical variables analyzed in the univariate analysis, preoperative HVA (P = .013), HVA correction (P = .03), preoperative IMA (P = .001), first MCSA (P = .07), translation in fusion (P = .003) and translation at base MT1 (P = .036) were significantly correlated with IMA reduction. Age, postoperative HVA, first MCA, change in length of the first ray and postoperative DFA did not show a significant association with IMA reduction (Table II). For the categorical variables, the fixation type was significantly correlated with IMA reduction (P = .005). Gender, osteoarthritis of first CM joint, position of sesamoids and preoperative indication did not show a significant association with IMA correction. (Table III).

Seven variables were found to have P values less than .10 on univariate analysis and were included in the initial multivariate linear regression model. Stepwise regression using a backward selection procedure was performed retaining only variables with $P < .05$: preoperative HVA, first MCSA, fixation method and HVA correction were sequentially removed from the model. The final linear regression model demonstrated three independent predictors for IMA reduction: Increased preoperative IMA (β = .663, CI = .419, .908, P <.001), increased pre-operative translation at base of MT1 (β = .490, CI = 0.005, .974, P = .039), and less translation at the fusion site (β= -0.693, CI= -1.054, -.331 ,P= .002) significantly increased the IMA reduction (Table IV).

Interrater reliability was excellent for the translation at the base of MT1 and translation at the level of the MTP I fusion site in this study. The ICC value was 0.95 (95% confidence interval [CI], 0.93 to 0.97) for translation at the base of MT1 and 0.92 (95% CI, 0.88 to 0.96) for translation at the fusion site.

DISCUSSION

Previous studies focused on the effectiveness of first MTPJ fusion in reducing the IMA angle, both in feet with a moderate[10,15] and high preoperative IMA[1]. However, it remains unclear whether there are predictive factors

Table I. — Patient cohort characteristics

	Patients (feet)	Mean ± SD	Range
Demographics			
Age (y)	(68)	63.4 ± 10.9	31.4 to 79.3
Male/ female	8/43		
Left/ right	32/36		
Preoperative radiographs			
HVA (degrees)	(68)	43.6 ± 11.5	18.4 to 71.4
IMA (degrees)	(68)	16.11 ± 2.4	14.0 to 22.5
Length of MT1 vs MT2 (%)	(68)	124.0 ± 9.0	87.8 to 147.5
First MCA (degrees)	(68)	28.4 ± 7.1	14 to 54
First MCSA (degrees)	(68)	62.7 ± 8.7	32.8 to 79.7
Translation at base MT1 (mm)	(68)	1.0 ± 1.4	0 to 4.5
Postoperative radiographs			
HVA (degrees)	(68)	16.8 ± 7.7	1 to 31
IMA (degrees)	(68)	11.3 ± 2.7	6 to 19
Length of MT1 vs MT2 (%)	(68)	116.1 ± 6.1	101.5 to 134.0
Translation in the fusion (mm)	(68)	0.8 ± 1.6	0 to 6.5
Dorsiflexion angle (degrees)	(68)	27.6 ± 6.7	11.2 to 52.4

Abbreviations: HVA, hallux valgus angle; IMA, intermetatarsal angle; MT1, first metatarsal; MT2, second metatarsal; N/A, non-applicable; SD, standard deviation; MCA, metatarsocuneiform angle; MCSA, metatarsocuneiform slope angle

Table II. — Numerical variables on univariate analysis

Pearson correlation coefficients		
	IMA reduction	**P**
Age (y)	0.16	.19
Preoperative HVA (degrees)	0.30	.013[a]
Postoperative HVA (degrees)	0.05	.67
HVA correction (degrees)	0.26	.03[a]
Preoperative IMA (degrees)	0.38	.001[a]
First MCA (degrees)	-0,12	.34
First MCSA (degrees)	-0,22	.07[a]
Translation in fusion (mm)	-0,54	.003[a]
Translation at base MT1 (mm)	0.26	.036[a]
Change in length first ray (%)	0.11	.37
Postoperative DFA (degrees)	0.20	.11

Abbreviations: DFA, dorsiflexion angle; HVA, hallux valgus angle; IMA, intermetatarsal angle; MCA, metatarsocuneiform angle; MT1, first metatarsal; MCSA, metatarsocuneiform slope angle. [a]*P* values <0.1 were included for initial multivariate analysis.

Table III. — Categorical variables on univariate analysis

		Mean Reduction of IMA ± SD	
	Feet (n)	IMA reduction (degrees)	*P*
Gender			
Male	12	4.55 ± 2.77	.87
Female	56	4.61 ± 3.11	
Osteoarthritis first CM			
Yes	12	4.50 ± 4.81	.39
No	56	4.63 ± 2.58	

Abbreviations: CM, cuneiform-metatarsal joint; IMA, inter-metatarsal angle; SD, standard deviation.

for IMA correction after MTPJ I fusion. Therefore, we assed different clinical and radiological parameters associated with MTPJ 1 fusions into a multivariate analysis with a backward selection procedure.

Table IV. — Categorical variables on multivariate analysis

		Mean Reduction of IMA ± SD
Group	Feet (n)	IMA reduction (degrees)
Fixation Type		
IOFIX	36	5.03 ± 2.49
Crossed screws	25	4.88 ± 3.59
Plate/lag screws	7	1.43 ± 1.61
Sesamoid position		
5	8	3.63 ± 1.60
6	18	3.89 ± 2.52
7	42	5.10 ± 3.38
Preoperative indication		
Severe hallux valgus	44	3.40 ± 2.07
Hallux rigidus	13	4.67 ± 2.16
Relaps Hallux valgus	6	4.38 ± 2.75
Hallux valgus rigidus	5	4.80 ± 3.34

Abbreviations: IMA, intermetatarsal angle; SD, standard .deviation; aP values <0.1 were included for initial multivariate analysis..

Our principal finding could identify three independent predictors of IMA reduction occurring after first MTPJ fusion. A higher preoperative IMA and translation at the base of MT1 predict a higher IMA correction after surgery. On the contrary, translation at the fusion site decreases the possibility of IMA reduction after surgery.

In 2009, Pydah et al.[16] reported on a retrospective case series of 69 first MTPJ fusion for hallux valgus. Their results showed a mean IMA reduction of 4.5 degrees. That study demonstrated similar results to those from the study by Sung et al.[18], where a mean IMA reduction of 4.7 degrees was achieved in a retrospective study on first MTPJ fusion on 58 feet. These findings are consistent with our results, demonstrating an IMA reduction of 4.95 degrees.

However, failure to reduce IMA after surgery lead to reduced patient reported outcomes and functionality[6]. Therefore some authors have suggested to perform a

Table V. — Multivariate linear regression model.[a]

	Parameter estimate	Standard error	*P* value	95% confidence interval for parameter estimate	
				lower	Upper
Preoperative IMA	0.663	0.124	<.001[b]	0.419	0.908
Translation in the fusion	-0.693	0.184	.002[b]	-1.054	-0.331
Translation at base MT1	0.490	0.247	.039[b]	0.005	0.974

Abbreviations: IMA, intermetatarsal angle; MT1, first metatarsal. [a]Model information: n= 68, R^2 = 0.408, adjusted R^2 = 0.389. [b]Only P values < .05 were considered significant.

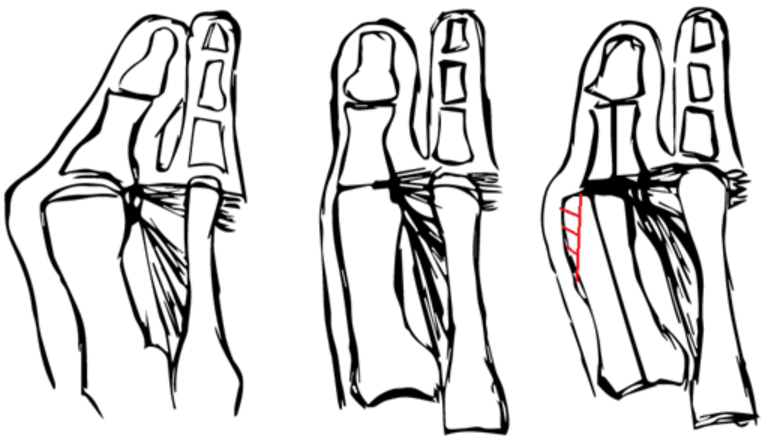

Figure 3 — Schematic depiction of the adductor tendon used as an IMA correcting force after first MTPJ fusion (middle) and case where translation in the fusion might lead to less pull of the adductor tendon (right).

more proximal osteotomy in addition to the first MTPJ fusion to assure a reduced IMA after surgery[17]. This was contradicted by others researchers, who have claimed that this additional osteotomy is unnecessary, because even in cases of IMA greater than 15 degrees, a desirable correction was obtained after first MTPJ fusion alone[13]. In our cohort only 10.2% of all feet ended up with an IMA of more than 14 degrees, indicating that an associated proximal osteotomy is not required in the majority of cases.

The mechanism of metatarsus varus correction after first MTPJ fusion is unclear and few authors provided an explanation. A possible explanation might be that during correction and fusion of the MTPJ, the adductor of the hallux acts through the conjoint tendon of the lateral sesamoid on the proximal phalanx and the first metatarsal as one unit following fixation[5]. This force, combined with a mobile TMT1 joint, reduces the IMA[16]. Others propose that the IMA correction is caused by the spontaneous reduction of the first metatarsal after relief of retrograde force from the hallux pushing the first metatarsal medially[9]. This explanation is supported by the visible correction immediately postoperatively and appears to be maintained consistently on postoperative clinical and radiographic examination.

Despite these suggestions, the relation between possible explaining variables and IMA reduction has to our knowledge not been explored.

In our study, seven variables were positively correlated with IMA reduction on initial univariate analysis. When these variables were combined into a multivariate analysis with a backward selection procedure, only preoperative IMA, translation at the fusion site and preoperative translation at the base of MT1 were found to independently predict reduction of IMA. These three predicting factors could have potentially important clinical applications in helping to estimate in which feet a higher IMA reduction can be expected.

First, the higher the preoperative IMA the higher the IMA reduction that can be expected. This has also been demonstrated in a study performed by Mann et al.[12], where change in the IMA was directly proportional to the preoperative IMA. Sung et al.[18], also noted a proportionate improvement of the IMA according to the severity of the deformity. These data further clarified that it is unnecessary to routinely perform a proximal procedure, even in cases of large IMA.

Secondly, how larger the translation at the base of the first metatarsal (figure 2) the bigger the IMA reduction that can be expected. This translation at the base of the first metatarsal can be a sign of its mobility and allows for IMA reduction to happen. This conforms the assumption of Pydah et al.[16], that a mobile first metatarsal is needed to allow IMA reduction. In a case series of Dalat et al.[6], there were two cases without IMA reduction after surgery in which vast osteoarthritis of TMT1 was observed, causing a loss of mobility in that joint.

Thirdly, a larger postoperative lateral translation of the proximal phalanx relative to the metatarsal head leads to less reduction of IMA. This might be explained by the reduced pull of the adductor of the hallux on the proximal phalanx and the first metatarsal as one unit following fixation (figure 3). This novel finding is of importance, as surgeons should pay attention during surgery to position the proximal phalanx maximally medial relative to the metatarsal head to allow for maximal IMA reduction.

Although there was a significant correlation considering the previous described three variables, no significant associations were found with other variables and IMA reduction in the final model. Reduction of length of the first ray was expected to play a role in IMA reduction, as this shortening could lead to relieve of retrograde force from the hallux pushing the first metatarsal medially [9], but it was not an independent predictor.

Furthermore, reduction of HVA by first MTPJ fusion was expected to play a role in IMA reduction, as putting the hallux into a more varus position leads to IMA reduction[7,19], but it was not an independent predictor.

The current study has several limitations. First, although a power analysis was performed regarding the primary outcome IMA, a larger sample size might be required to achieve additional power to decrease the probability of a Type II error for variables that did not reach significance. Second, we used two new measurements: Although translation in the fusion and translation at the base of MT1 are new measures, interrater ICC values from our measurements in the study demonstrated excellent reliability. These data suggest that the two new distances can be reliably measured and support the use of this radiographic parameters in future research. Third, this is a retrospective study and did not investigate clinical outcomes in association with the reduction in IMA. It is essential that future prospective studies be performed to verify our findings and to evaluate its efficacy in optimizing patient outcomes.

CONCLUSION

Pre-operative IMA and translation at the base of the first metatarsal were positive predictors for correction of IMA after first MTPJ fusion. Translation at the level of the MTP I fusion was a negative predictor for IMA correction. Based on these findings, we recommended to limit the lateral translation of the proximal phalanx relative to the metatarsal head to optimize IMA correction after MTPJ fusion. A possible explanation for the observed IMA correction after MTPJ I fusion can be attributed to the pull of the adductor muscle on both the proximal phalanx and first metatarsal, which act as a single unit after fusion. Future prospective studies with large cohorts including both clinical and radiological parameters are required to further improve our understanding of IMA correction mechanism after MTPJ 1 fusion.

*Conflict of interest: T*he authors declare no conflict of interest or acceptance of external funding. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Besse JL, Chouteau J, Laptoiu D. Arthrodesis of the first metatarsophalangeal joint with ball and cup reamers and osteosynthesis with pure titanium staples Radiological evaluation of a continuous series of 54 cases. *Foot Ankle Surg*. 2010;16(1):32-7, doi:http://dx.doi.org/10.1016/j.fas.2009.03.008.
2. Chan JY, Greenfield ST, Soukup DS, Do HT, Deland JT, Ellis SJ. Contribution of Lateral Column Lengthening to Correction of Forefoot Abduction in Stage IIb Adult Acquired Flatfoot Deformity Reconstruction. *Foot Ankle Int.* 2015;36(12):1400-11, doi:http://dx.doi.org/10.1177/1071100715596607.
3. Coughlin MJ, Grebing BR, Jones CP. Arthrodesis of the first metatarsophalangeal joint for idiopathic hallux valgus: intermediate results. *Foot Ankle Int.* 2005;26(10):783-92, doi:http://dx.doi.org/10.1177/107110070502601001.
4. Crevoisier X, Mouhsine E, Ortolano V, Udin B, Dutoit M. The scarf osteotomy for the treatment of hallux valgus deformity: a review of 84 cases. *Foot Ankle Int.* 2001;22(12):970-6, doi:http://dx.doi.org/10.1177/107110070102201208.
5. Cronin JJ, Limbers JP, Kutty S, Stephens MM. Intermetatarsal angle after first metatarsophalangeal joint arthrodesis for hallux valgus. *Foot Ankle Int*. 2006;27(2):104-9, doi:http://dx.doi.org/10.1177/107110070602700206.
6. Dalat F, Cottalorda F, Fessy MH, Besse JL. Does arthrodesis of the first metatarsophalangeal joint correct the intermetatarsal M1M2 angle? Analysis of a continuous series of 208 arthrodeses fixed with plates. *Orthop Traumatol Surg Res*. 2015;101(6):709-14, doi:http://dx.doi.org/10.1016/j.otsr.2015.06.021.
7. Dayton P, Feilmeier M, Kauwe M, Holmes C, McArdle A, Coleman N. Observed changes in radiographic measurements of the first ray after frontal and transverse plane rotation of the hallux: does the hallux drive the metatarsal in a bunion deformity? *J Foot Ankle Surg.* 2014;53(5):584-7, doi:http://dx.doi.org/10.1053/j.jfas.2014.02.003.
8. Erduran M, Acar N, Demirkiran ND, Atalay K. The im-pact of medial cuneiform bone variant measures on the severity of hallux valgus: A radiological study. *J Orthop Surg.* 2017;25(3):2309499017727921, doi:http://dx.doi.org/10.1177/2309499017727921.
9. Feilmeier M, Dayton P, Wienke JC, Jr. Reduction of intermetatarsal angle after first metatarsophalangeal joint arthrodesis in patients with hallux valgus. J *Foot Ankle Surg.* 2014;53(1):29-31, doi:http://dx.doi.org/10.1053/j.jfas.2013.09.012.
10. Goucher NR, Coughlin MJ. Hallux metatarsophalangeal joint arthrodesis using dome-shaped reamers and dorsal plate fixation: a prospective study. *Foot Ankle Int.* 2006;27(11):869-76, doi:http://dx.doi.org/10.1177/107110070602701101.
11. Hardy RH, Clapham JC. Observations on hallux valgus; based on a controlled series. *J Bone Joint Surg Br*. 1951;33-B(3):376-91, doi:http://dx.doi.org/10.1302/0301-620X.33B3.376.
12. Mann RA, Katcherian DA. Relationship of Metatarsophalangeal Joint Fusion on the Intermetatarsal Angle. *Foot Ankle Int.* 1989;10(1):8-11, doi:http://dx.doi.org/10.1177/107110078901000102.
13. McKean RM, Bergin PF, Watson G, Mehta SK, Tarquinio TA. Radiographic Evaluation of Intermetatarsal Angle Correction Following First MTP Joint Arthrodesis for Severe Hallux Valgus. *Foot Ankle Int*. 2016;37(11):1183-1186, doi:http://dx.doi.org/10.1177/1071100716656442.
14. Menz HB, Munteanu SE, Landorf KB, Zammit GV, Cicuttini FM. Radiographic classification of osteoarthritis

in commonly affected joints of the foot. *Osteoarthritis Cartilage.* 2007;15(11):1333-8, doi:http://dx.doi.org/10.1016/j.joca.2007.05.007.

15. Nicholas C, Silhanek AD, Connolly FG, Lombardi CM. The effect of first metatarsophalangeal arthrodesis on transverse plane deviation of the second toe: a retrospective radiographic study. *J Foot Ankle Surg.* 2005;44(5):365-76, doi:http://dx.doi.org/10.1053/j.jfas.2005.07.007.
16. Pydah SK, Toh EM, Sirikonda SP, Walker CR. Intermetatarsal angular change following fusion of the first metatarsophalangeal joint. *Foot Ankle Int*. 2009;30(5):415-8, doi:http://dx.doi.org/10.3113/fai.2009.041510.3113/fai-2009-0415.
17. Rippstein PF, Park YU, Naal FD. Combination of first metatarsophalangeal joint arthrodesis and proximal correction for severe hallux valgus deformity. *Foot Ankle Int.* 2012;33(5):400-5, doi:http://dx.doi.org/10.3113/fai.2012.0400.
18. Sung W, Kluesner AJ, Irrgang J, Burns P, Wukich DK. Radiographic outcomes following primary arthrodesis of the first metatarsophalangeal joint in hallux abductovalgus deformity. J *Foot Ankle Surg.* 2010;49(5):446-51, doi:http://dx.doi.org/10.1053/j.jfas.2010.06.007.
19. Scheele CB, Kinast C, Lenze F, Wimmer J, Beischl S, Harrasser N. Radiographic Evaluation of First Tarsometatarsal Joint Arthrodesis for Hallux Valgus Deformity Does the Fusion of the First to the Second Metatarsal Base Reduce the Radiological Recurrence Rate? *Foot Ankle Spec.* 2023: 6; 19386400231164209, doi: 10.1177/19386400231164209.