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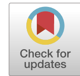

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ABSTRACT

Background: To evaluate the radiological outcome, especially undercorrection of hallux valgus deformity correction with first metatarsal osteotomy.
Patients and methods: 439 1st metatarsal osteotomies including 241 distal (55 %), 175 midshaft (40 %), and 23 proximal (5 %) were available for analysis with median follow-up time was 48 days (range 27–990 days).
Results: The postoperative HVA was normal in 237 (54 %), mild in 110 (25 %), moderate in 87 (20 %), and severe in 5 (1 %) of the cases. BMI ($p = 0.0127$), sex ($p = 0.0004$), preoperative HVA ($p = 0.0028$), and surgeons experience ($p < 0.0001$) were associated with radiological outcome, whereas age, hospital, and type of osteotomy had no effect. Foot and ankle surgeons achieved normal postoperative HVA in 76 %, general orthopedic surgeons in 41 %, and residents in 47 % of the operations.
Conclusion: Radiological undercorrection was common. As foot and ankle surgeons achieved best radiological correction, hallux valgus deformity should be operated by specialists.
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1. Introduction

Hallux valgus is a common forefoot deformity affecting both foot function as well as quality of life [1–4]. Due to its high incidence, surgery is often required, and successful surgical treatment has been shown to improve the quality of life of hallux valgus patients [5]. Operative techniques to correct hallux valgus deformity include various osteotomies of the first metatarsal, arthrodesis of the first metatarsophalangeal joint (MTPJ) and the first tarsometatarsal joint (TMTJ) (modified Lapidus procedure). The choice of a procedure depends on the severity of the deformity, the condition of related joints, and potential associated deformities along with on surgeon's preference. However, evidence provided by the current literature to support one method over another in long term is still inadequate [2,6]. Although the use of modified Lapidus procedure and minimally invasive techniques is increasing, the open first metatarsal osteotomy is still the most common primary operative procedure for hallux valgus deformity [3,7,8].

In a recent review including 229 studies one of the most common complications after hallux valgus deformity correction was recurrence of the deformity (5 %) [9]. Increased preoperative hallux valgus angle and undercorrection has been shown to increase the risk for the recurrence of hallux valgus [9–11]. Undercorrection is also associated with decreased patient satisfaction [11]. Long-term studies with follow-up time up to 14 years have shown 30 % rates of radiological recurrence [12], the risk being highest among older patients [13]. As the radiological correction is evidently associated with the outcome of the hallux valgus surgery, we wanted to investigate factors associated with undercorrection in a large heterogenic patient population.

The aim of this study was first, to evaluate the radiological correction of hallux valgus deformity treated with first metatarsal osteotomy, and second, to analyse the factors associated with the outcome of correction in a large University Hospital cohort.

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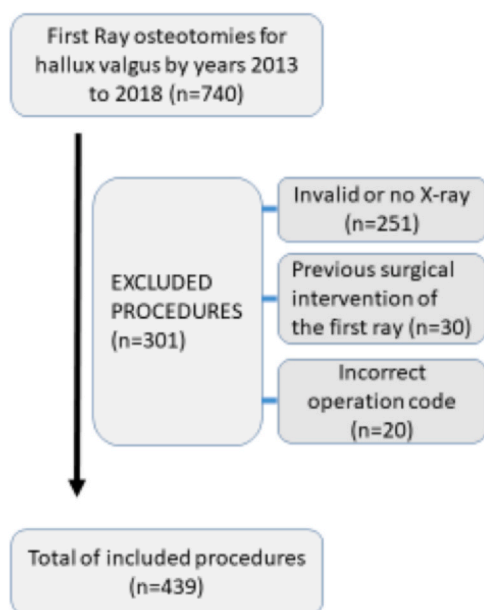

Fig. 1. Flowchart for the selection of patients.

2. Patients and methods

2.1. Patients

Consecutive patients operated with first metatarsal osteotomy to correct hallux valgus deformity in one University Hospital region of half million inhabitants including five different hospitals in 2013 – 2018 were reviewed. The data was searched from healthcare patient database with a diagnosis code for hallux valgus (ICD-10 classification M20.1) with an operative code for first metatarsal osteotomy (NHK30 by NOMESCO classification of surgical procedures). During 2013 – 2018 there were altogether 740 procedures for 659 patients. 251 procedures were excluded due to nonweightbearing or missing postoperative radiographs. 30 operations were revisions for recurrent hallux valgus deformity and 20 procedures had an incorrect operative code. Total number for excluded procedures was 301 leaving 439 procedures for analysis (Fig. 1). Median age was 55 (range 16–82) years, 388 (88 %) of the patients were female, and median BMI was 26 (n = 422; range 15–43). The median follow-up time was 48 days (range 27–990 days) calculated from the day of the operation to the last control visit with a weightbearing radiograph of the foot. All first metatarsal osteotomies were included and divided into distal (n = 241, 55 %), midshaft (n = 175, 40 %), and proximal (n = 23, 5 %). Distal group included 233 Chevron osteotomies and 8 Mitchel osteotomies. Midshaft group were all Scarf osteotomies, and proximal group medial open wedge osteotomies. Surgeon's experience was classified into three groups by consensus as follows: The first group included orthopedic residents with orthopedic surgeon as an assistant (n = 45, 10 %), the second group general orthopedic surgeons (n = 241, 55 %), and the last group orthopedic surgeons with years of experience in and practising only foot and ankle surgery (n = 153, 35 %). None of the authors were among the groups of orthopedic surgeons. 357 surgeries (81 %) were performed in Central University hospital and 82 (19 %) in district hospitals. Demographic data is shown in the Table 1.

2.2. Radiological analysis

Hallux valgus (HVA) and intermetarsal (IMA) angles were measured pre- and postoperatively from weightbearing dorso-plantar radiographs of the foot by two orthopedic surgeons with at least two years of experience in orthopedic surgery. HVA was measured by two longitudinal bisections of the shafts of the first metatarsal and the proximal phalanx of hallux and classified into normal (< 15°), mild (15° to < 20°), moderate (20° to < 40°) and severe (≥40°). IMA was measured by two longitudinal bisections of the shafts of the first and the second metatarsal and classified into normal (< 9°), mild (9° to < 12°), moderate (12° to < 18°) and severe (≥18°). A postoperative HVA > 15° was defined as radiological undercorrection.

Table 1
Demographic data of and correction to normal defined by HVA. N = number of first ray osteotomies.

	All operations[a]	Correction to normal HVA (< 15°) postoperative[b]
All	439	237 (54 %)
Female N (%)	388 (88 %)	218 (56 %)
Male N (%)	51 (12 %)	19 (37 %)
Median age years (range)	55 (16–82)	
Median BMI (range)	26 (15–43)	
Type of osteotomy N (%)		
Distal	241 (55 %)	133 (55 %)
Shaft	175 (40 %)	97 (55 %)
Proximal	23 (5 %)	7 (30 %)
Preoperative hallux valgus (HVA) groups N (%)		
Normal (< 15°)	7 (< 2 %)	6 (86 %)
Mild (15° to < 20°)	29 (7 %)	25 (86 %)
Moderate (20° to < 40°)	355 (81 %)	199 (56 %)
Severe (≥40°)	48 (11 %)	7 (15 %)
Experience of operating physician N (%)		
Resident	45 (10 %)	21 (47 %)
General Orthopedic Surgeon	241 (55 %)	99 (41 %)
Foot and Ankle Surgeon	153 (35 %)	117 (76 %)
Hospital N (%)		
Central (1 hospital)	357 (81 %)	196 (55 %)
District (4 hospitals)	82 (19 %)	41 (50 %)

[a] Percentage of all operations;
[b] Percentage of the group presented in the previous column

2.3. Statistical analysis

HVA and IMA were summarized with descriptive statistics. For analysis HVA was categorized in groups (normal, mild, moderate, severe). Associations between categorical HVA and variables (sex, age, BMI, preoperative HVA, surgeons experience, hospital, type of osteotomy) were summarized with descriptive statistics and studied one by one with Kruskal-Wallis test and chi-square test (for categorical variables). Final the association between HVA and explanatory variables were studied with multinomial regression model. Model was including all explanatory variables.

The normality of variables was evaluated visually and tested with the Shapiro-Wilk test. Due to the non-normality of the continuous variables, nonparametric methods were used. All tests were performed as two-sided with a significance level set at 0.05. The analyses were carried out using the SAS system, version 9.4 for Windows (SAS Institute Inc., Cary, NC, USA).

3. Results

Most of the procedures were done for moderate hallux valgus (355 feet; 81 %). Severe deformity was operated in 48 feet (11 %), and mild in 29 (7 %) of the cases. The older the patients were the more severe was preoperative HVA. The postoperative HVA was classified as normal in 237 (54 %), mild in 110 (25 %), moderate in 87 (20 %), and severe in 5 (1 %) of the cases. The postoperative IMA was

Table 2
The chosen operative techniques and the median amount of correction achieved according to preoperative deformity severity groups defined by preoperative HVA.

Preoperative HVA group	Operative technique			Median correction (degrees)	
	Distal	Midshaft	Proximal	HVA	IMA
Normal (< 15°) (n = 7;1 %)	7 (100 %)	0	0	3.0	4.0
Mild (15° to < 20°) (n = 29;7 %)	21 (72 %)	8 (28 %)	0	9.0	5.0
Moderate (20° to < 40°) (n = 355;81 %)	195 (55 %)	145 (41 %)	15 (4 %)	15.0	7.0
Severe (≥40°) (n = 48;11 %)	18 (38 %)	22 (46 %)	8 (17 %)	22.5	8.0
Total (n = 439)	241	175	23	14.0	7.0

Table 3
The median amount of correction achieved by different types of osteotomies in different preoperative deformity severity groups defined by preoperative HVA.

Type of osteotomy	Median amount of correction achieved by different techniques (degrees)		
	Preoperative group (defined by preoperative HVA)	HVA	IMA
Distal	Normal	3.0	4.0
	Mild	8.0	4.0
	Moderate	13.0	6.0
	Severe	22.5	7.5
Midshaft	Mild	12.5	6.5
	Moderate	17.0	8.0
	Severe	21.5	8.0
Proximal	Moderate	12.0	8.0
	Severe	29.5	12.0

classified as normal in 221 (50 %), mild in 141 (32 %), moderate in 69 (16 %), and severe in 8 (2%) of the cases. The chosen operative techniques and the mean amount of correction by different types of osteotomies are shown in Tables 2, and 3, and Fig. 2.

3.1. Factors associated with radiological outcome in univariate analysis

In univariate analysis BMI, sex, preoperative HVA, and surgeons experience were associated with radiological correction. Lower BMI was associated with better correction (p = 0.0127). Male patients had higher risk for worse correction (p = 0.0004). A normal postoperative angle was achieved in 56 % in females compared to 37 % in males. Higher preoperative HV group was associated with worse correction (p < 0.0028). A normal postoperative HVA was achieved in 86 % of cases with mild deformity, 56 % in moderate, and 15 % in severe. Surgeon's experience was associated with better correction (p < 0.0001). Foot and ankle surgeons achieved normal postoperative HVA in 117 cases (76 %), mild in 25 (16 %), and moderate in 11 (7 %); none were left severe. General orthopedic surgeons achieved normal postoperative HVA in 99 (41 %) cases, mild in 75 (31 %), moderate in 62 (26 %), and severe in 5 (2 %). Residents achieved normal postoperative HVA in 21 cases (47 %), mild in 10 (22 %), and moderate in 14 (31 %); none were left severe (Fig. 3). Age of patient, hospital type, and type of osteotomy had no effect on postoperative correction of the first metatarsal (all p > 0.05).

3.2. Factors associated with radiological outcome in multivariate analysis

In multivariate analysis sex (p = 0.0265), preoperative HVA (p = 0.0028), and surgeons´ experience (p = 0.0001) were similarly associated with radiological correction as in the univariate analysis, but the effect of BMI was not anymore statistically significant (p = 0.6481).

4. Discussion

We found relatively high number of radiological undercorrection after hallux valgus deformity surgery with first metatarsal osteotomies. The male sex, higher BMI, and higher preoperative HVA were statistically significantly associated with worse correction. Foot and ankle surgeons were able to achieve better radiological correction compared to general orthopedic surgeons or residents.

In a recent review including 229 studies common complications after hallux valgus deformity correction were dissatisfaction (10.6 %), metatarsalgia (6.3 %), recurrence of the deformity (4.9 %), nerve injuries (3 %), infection (2.6 %), overcorrection to varus (1.83 %), residual pain (1.5 %) and non-union (0.04 %) [9]. Increased preoperative hallux valgus angle and undercorrection have been shown to increase the risk for the recurrence of hallux valgus [10,14,15]. As the terms recurrence and undercorrection are somewhat overlapping and inconsistent, we decided to use undercorrection as the follow-up time of this study was not long enough to investigate true recurrence. The classification of the severity of

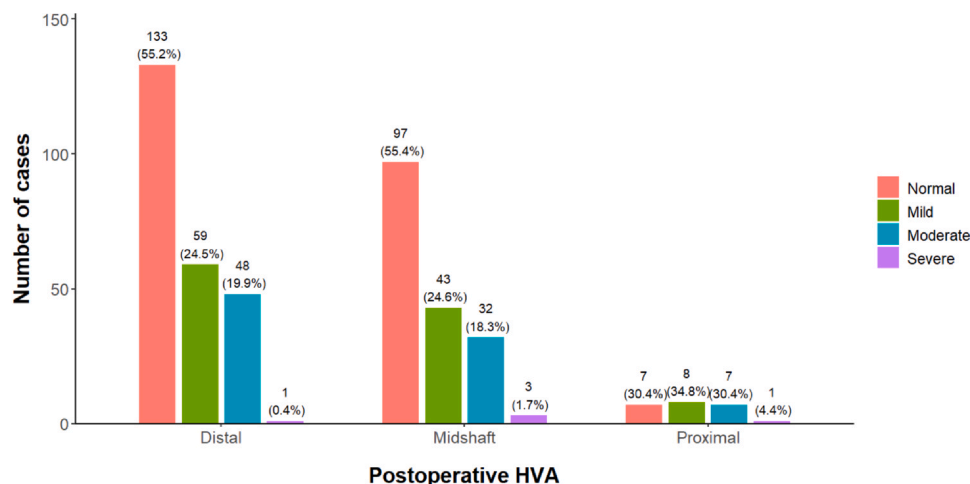

Fig. 2. Radiological outcome determined by postoperative HVA after different operative techniques.

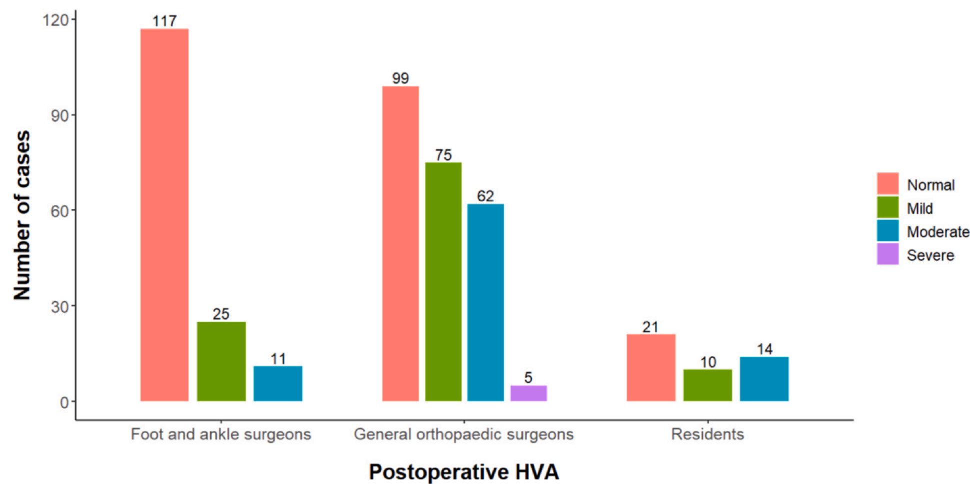

Fig. 3. Postoperative results by operating surgeon.

hallux valgus defined by angles is also variable. We decided to use 15° as a cut-off point for normal HVA, but in some studies also 20° has been used [11,13]. Even lower limits have been used, as in a study of 117 feet an immediate postoperative HVA of ≥ 8° was significantly associated with recurrence, however, measurements were drawn from nonweightbearing radiographs [15]. Our results showing a statistically significant association between preoperative HVA and radiological undercorrection are coherent with previous findings.

Male patients had a higher risk of worse correction than female, contrary to a previous study investigating specifically sex-related differences in the outcome of hallux valgus surgery concluding no significant differences between male and female patients [16]. The distribution of males and females was similar than in a previous study addressing the incidence of hallux valgus operations in Finland [7]. Although the preoperative angles were more severe in older patients age itself had no statistically significant effect on the radiological outcome as has also been found previously [13]. The worsening of the deformity with age is consistent with previous findings showing hallux valgus being a progressive deformity [17], although older patients in general might request surgical treatment only with more severe deformity. BMI does not seem to play a role in the development of hallux valgus at least in women [4,18], but in this series it was associated with the radiological outcome of deformity correction as being a risk for radiological undercorrection. However, the association was not found in the multivariate analysis.

There are several studies comparing clinical and radiological outcome of different types of first metatarsal osteotomies with varying results [6,8]. In this series there were no differences between the outcome of distal and midshaft osteotomies, like in a recent review comparing the clinical and radiological outcome of Chevron and Scarf osteotomies in the management of mild to moderate HV deformity [19]. However, the radiological correction achieved by proximal osteotomies was slightly inferior compared to midshaft or distal osteotomies, although the difference was not statistically significant. Potential explanations might include the small proportion of proximal osteotomies, a more demanding technique, and probably the use of proximal osteotomy in more severe cases in general. Interestingly, seven cases had a normal preoperative HVA. This is probably explained by the three-dimensional nature of the deformity which cannot be solely determined by radiographs. All these cases had mild to moderate IMA which was corrected acceptably in all cases.

The experience level of the operating surgeon was strongly associated with the radiological correction of hallux valgus deformity regardless of other associated factors, whereas the size of a hospital was not significant. The correction of hallux valgus was clearly not easy to achieve even in the hands of an expert, as almost one fourth of procedures had suboptimal correction also in the group of foot and ankle surgeons. Lowering the aimed level of correction by setting the optimal cut-off point of HVA to 20°, an acceptable result was achieved in 79 % of all the procedures. However, the foot and ankle surgeons did still reach acceptable correction best, in 93% of the cases, whereas general orthopedic surgeons reach that in only 72 %, and residents in 69 % of the cases. Being a very common forefoot deformity, hallux valgus is still often one of the first operations for orthopedic surgeons in training. Comprehensive understanding of the multidimensional pathology of hallux valgus deformity is a key to successful treatment, especially as it has been shown that the undercorrection of the hallux valgus deformity is associated with both lower patient satisfaction and recurrence [9–11,14]. The trained foot and ankle surgeons are likely most familiar with the suitable methods for correction and using additional procedures like Akin´s osteotomy and lateral release to achieve the best possible outcome for each case. Therefore, it is reasonable to recommend that the surgical correction of hallux valgus should be centralized to hands of surgeons specialized to foot and ankle surgery. Achieving a good and lasting outcome with primary surgical operation and therefore avoiding revision procedures is presumable also cost-effective.

Limitations of this study includes high proportion of procedures excluded due to missing or nonweightbearing radiographs, although weightbearing radiographs should nowadays be standard in all foot and ankle surgery [20]. The radiological outcome was determined solely on radiographs with two measured angles, although the rotation of the first metatarsal seems to play a potential role in the hallux valgus deformity [21,22]. This is reliably measured by weightbearing computed tomography (WBCT) [22–24], which was not available and yet rarely in routine use. The effect of a common additional procedure, Akin osteotomy of the proximal phalanx of hallux, would have been an interesting to determine, but it was not reliably retrieved from the data. The strength of the study is that it represents true life involving different hospitals, mixed patient material and surgeons of every level.

5. Conclusion

In this large cohort, radiological undercorrection after hallux valgus deformity surgery with first metatarsal osteotomies was common as the HVA was not corrected to normal in nearly half of the operations. As foot and ankle surgeons achieved statistically significantly better radiological correction compared to general

orthopedic surgeons or residents, hallux valgus surgery should be centralized to specialists.

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Declaration of Competing Interest

The authors declare that this manuscript is original, has not been published before, and is not currently being considered for publication.

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