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Original Article

The correlation between deformity and metatarsus projection area and the ratios of projection to all metatarsi in direct radiographs in hallux valgus cases

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Abstract

Aim: Hallux valgus (HV) is a common deformity where the hallux deviates laterally in the metatarsophalangeal joint. Although various radiographic measurements have been developed to assess HV, not all are considered universally necessary and the correlations between these methods were not determined. The present study aimed to investigate the correlation between the metatarsus (MT) projection area and the projection rates to all MTs and deformity observed in direct radiographs in HV cases.

Material and Methods: We retrospectively analyzed foot radiographs of 100 female cases (20-60 years old). The cases were divided into two groups of 50 HV and 50 non-HV based on HV angles (HVA). HVA>15˚ was accepted as HV. The MT projection areas and the projection rates to all MTs, HVA, and intermetatarsal angle (IMA) were measured in HV cases. Paired t-tests were used to compare continuous numeric variables (Significance: $p \leq 0.05$).

Results: HVA was higher in HV cases (mean, 22.2˚) when compared to the non-HV group (mean, 7.4˚) ($p = 0.000$). There was no difference between the mean MT projection areas in HV and non-HV groups. While there was no significant difference between the ratios of the projection area in MT I, II, III and IV to total MT area in HV and non-HV groups, the ratio of the projection area of MT V to the total MT area was lower in HV cases when compared to that of the non-HV group ($p = 0.027$).

Conclusion: Although it was observed that HV did not affect the projection area of each MT, when the total MT area was considered, it was observed that the projection area of MT V was lower. This finding supported that HV is a condition that affects the whole foot.

Keywords: Hallux valgus; metatarsus area; radiography

INTRODUCTION

Hallux valgus (HV) is induced by the lateral deviation of the hallux and the medial deviation of the first metatarsal (1). HV is the most common pathology that affects the toe in 28% of the general population and 74% of the elderly population (1, 2). In recent years, it was determined that HV does not entail only hallux deformity but also the deformation of the foot as a whole (3). Several studies were conducted to investigate HV pathogenesis. It was suggested that the shape of the first metatarsal (MT I) head was probably associated with the development of HV (3, 4). In a study conducted by Okuda et al. on dorsoplantar radiographs, it was reported that there was a significant correlation between the roundness of the MT I head and HV (5). It was demonstrated that wearing narrow shoes was an extrinsic factor in HV development and it was reported that those who wear narrow shoes exhibited a 15 times higher HV prevalence when compared to others (1). Similarly, in Japan, Kato and Watanabe emphasized that the prevalence of HV among women increased after the World War II with the dramatic increase in high-heeled shoe use (6).

HV severity is defined by angular deformity and the severity plays a key role in the selection of an adequate treatment. Measurement of angles in anterior foot X-rays is an important instrument in determination of HV deformity treatment (7). The significant angles reported in the literature included the HV angle (HVA), the intermetatarsal angle (IMA) between the MT I and MT II longitudinal axes, and the distal metatarsal articular angle (DMAA) (8-11).

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These angles have traditionally been measured manually on hard copy radiographs; however, digital radiography became popular since the early 21st century. It was reported that inter- and intra-observer agreement in radiographic measurement of HVA and IMA were good with both conventional and digital techniques. However, it was reported that both techniques were unreliable in DMAA measurement (12-14).

The literature review conducted by the authors demonstrated that the correlation between the MT projection areas and deformity was not investigated in HV cases. Thus, the present study aimed to investigate the correlation between the MT projection areas and the projection rates to all MTs in deformity in HV cases using foot radiographs.

MATERIAL and METHODS

In this retrospective study, images of the 20-60 years old patients, who underwent foot radiography on suspicion of fracture in the emergency department between March 2018 and February 2019, were scanned. Among these images, 100 female cases were categorized as 50 HV and 50 non-HV cases based on the HVA by an experienced radiologist. HVA>15˚ was accepted as HV. Exclusion criteria included previous foot surgery, previous fracture in the foot, and rheumatoid arthritis. All radiographs were taken with a digital monocular X-ray machine (Jumong, SG Healthcare, Korea). A personal workstation (ImageJ software) was used for angle and area measurements (Figs. 1 and 2). The present study was approved by the Non-Interventional Ethics Committee (Decision no: 3/20 - 28.02.2018).

Figure 1. Hallux valgus angle measurement on AP radiograph.

Figure 2. Os metatarsus I area measurement on AP radiograph

Statistical data analysis was conducted with Minitab statistics software (v. 17.3.1, Minitab Inc., State College, PA, USA). Anderson-Darling test was used to determine the normality of the study data distribution. Since all data exhibited normal distribution, paired t-test was used to compare continuous numeric variables. Statistical significance was accepted as 5% ($p < 0.05$).

RESULTS

The mean age of the cases included in the study sample was 44.6 for the HV group and 42.4 for the non-HV group ($p = 0.348$) (Table 1).

Table 1. Comparison of ag between HV cases and non-HV group

	Mean±SD	Range	p value
HV	44.6±9.63	22-60	0.348
non-HV	42.4±12.33	21-60	

HV: Hallux valgus, SD: Standard deviation.

HVA ranged between 16˚ and 35˚ in HV cases and between 1˚ and 15˚ in the non-HV group. The mean HVA was 22.2˚ in HV cases and was higher when compared to the non-HV group (7.4˚) ($p = 0.000$) (Table 2).

Table 2. Comparison of HVA between HV cases and non-HV group

	Mean±SD	Range	p value
HV	22.2±4.54	16-35	0.000*
non-HV	7.4±3.88	1-15	

HV: Hallux valgus, SD: Standard deviation.

IMA varied between 10˚ and 18˚ in HV cases, and the mean was 13.5±2.04˚. The mean MT I, II, III, IV, and V projection areas were 1086.8 mm², 703.9 mm², 617.2 mm², 629 mm² and 747.2 mm² in HV cases, respectively, and the same figures were 1084 mm², 680.3 mm², 615.8 mm², 622.4 mm² and 782.8 mm² in the non-HV group, respectively ($p > 0.05$) (Table 3).

Table 3. Comparison of ossa metatarsi areas in HV and non-HV groups

	Mean±SD (mm²)		p value
	HV	non-HV	
MT I	1086.8±169.5	1084.0±147.8	0.931
MT II	703.9±114	680.3±114	0.356
MT III	617.2±94.9	615.8±108.2	0.949
MT IV	629.0±100.2	622.4±116.4	0.772
MT V	747.2±109.7	782.8±129.9	0.153

MT: Metatarsus, HV: Hallux valgus, SD: Standard deviation.

The ratios of MT I, II, III, IV and V areas to all MT areas were 28.75%, 18.58%, 16.28%, 16.59% and 19.77% in HV cases, respectively. The same ratios were 28.67%, 17.99%, 16.23%, 16.38% and 20.71% in the non-HV group (Table 4). Thus, it was determined that the ratio of the MT V projection area to the total MT area was lower in HV cases when compared to the non-HV group (p = 0.027).

Table 4. Comparison of HV and non-HV groups based on the ratio of each os metatarsus area to the total ossa metatarsi area

	Mean±SD (%)		p value
	HV	non-HV	
MT I/All MT	28.75 ± 0.02	28.67 ± 0.02	0.875
MT II/All MT	18.58 ± 0.01	17.99 ± 0.01	0.109
MT III/All MT	16.28 ± 0.01	16.23 ± 0.01	0.839
MT IV/All MT	16.59 ± 0.01	16.38 ± 0.01	0.494
MT V/All MT	19.77 ± 0.01	20.71 ± 0.02	0.027*

HV: Hallux valgus, MT:Metatarsus, SD: Standart deviation.

DISCUSSION

HV is the most common anterior foot deformity encountered by foot and ankle surgeons. It is characterized by the lateral deviation of hallux and medial deviation of the first MT (15) and often leads to foot pain and severe functional restraints (2). HV deformity could be caused by several exogenous and endogenous factors such as wearing tight and high-heeled shoes or genetic predisposition (16-19).

The present study aimed to investigate the correlation between the MT projection areas and the projection ratios of those areas to all MTs and deformity based on direct radiographs in HV cases. It was found that HVA was higher in HV cases when compared to healthy subjects. No significant difference was determined between HV patients and healthy individuals based on the MT projection areas. The review of the ratio of MT area to all MT projection areas demonstrated that the ratios of MT V projection area to all MT projection areas were lower in HV cases when compared to healthy individuals. This finding supported the view that HV is not only a hallux deformity but also entails the deformation of the whole foot. Literature review revealed no studies on MT projection areas and the ratio of the MT projection areas to all MT projection areas in HV cases. The present study findings suggested that the study could contribute to future studies with respect to a different parameter on the topic.

The global HV prevalence defined in the international literature is 23% in 18-65 years old patients and 35% in elderly individuals older than 65 (2). Coughlin et al. (11) reported a median age of 31 for HV deformity, and in the same study, the onset of deformity peaked in the third decade of life. The mean age of females with HV deformity, who were included in the present study, was 44.6. The youngest patient was 22 years old with an HVA of 21˚. The HVAs of the two 60 years old patients were 18˚ and 24˚.

It was reported that the deformity was more prevalent among females when compared to males and female/male ratios of up to 15:1 have been reported (20, 21). In the present retrospective study, it was found that most patient radiographs that revealed HV deformity were those of the female patients. Thus, we included only female individuals in the present study.

The reliability of general anterior foot geometry measurement and especially HVA, IMA and DMAA measurements have been discussed in several studies in the literature (14,15,22). HVA is widely used in the evaluation of deformity and to determine the treatment method. Several studies were conducted on HVA in the literature. Hardy et al. (23) reported that an HVA greater than 15 degrees should be considered non-normal. Coughlin and Mann (24) reported a classification conducted with HVA and analyzed HV deformity in three stages. An HVA lower than 20˚ and an IMA lower than 11˚ were classified as mild HV deformity, an HVA between 21˚-40˚ was classified as moderate HV deformity, and an HVA greater than 40˚ was classified as severe HV deformity. Based on this classification, 15 (30%) HV cases had mild deformity and 35 (70%) had a moderate deformity in the present study. There were no cases with an HVA of 40˚ or above in the current study. Mean HVA was 22.2˚ and IMA figures ranged between 10˚ and 18˚ in all HV cases.

Radiographic methods are prominent in the assessment of HV deformity, determination of the suitable surgical method and evaluation of postoperative results. Several radiographic methods focus on the angular assessment of HV deformity. Previous studies reported the reliability of various radiographic measurements in HV deformity assessment (22), and weighted AP radiographs were considered as the gold standard (19,25). In the present study, the measurements were conducted with AP radiographs in the assessment of the deformity. The projection areas of MTs were measured on AP radiographs to obtain the current study findings. The present study findings were consistent with the findings in the literature in the sense that radiographic methods were effective in

the evaluation and classification of HV deformity.

In a prospective study conducted with 103 patients, Coughlin reported that 84% of the cases were bilateral (26). In 50 patients with HV deformity included in the present study, it was determined that HV deformity was bilateral in 66% of the cases during the analyses conducted with AP foot radiographs. In unilateral HV cases (34%), HV deformity was more pronounced in the left foot.

Limitations of our study include the fact that the number of HV cases was limited, the exclusion of the male cases and the lack of clinical information.

CONCLUSION

Although it was observed that HV, which develops due to the lateral deviation of hallux and medial deviation of the MT I, did not affect the projection area of each MT in the present study, it was considered that the projection area of MT V could be a factor that contributes to the reduction of the ratio of its projection area to the total MT areas. The process that entails the decision on the selection of the procedure for a patient with HV requires careful preoperative physical and radiographic assessments to identify the pathological factors. Surgically, all deformation factors, including increased HVA, increased IMA, pronation of the hallux, increased distal MTF articular angle, increased medial superiority, and subluxation of the sesamoids should be corrected.

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