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Footprint as an alternative to X-ray in hallux valgus angle measurement

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Abstract

Background: X- ray images provide accurate and reliable data in different foot pathologies. However, the accompanied complications will limit its use for epidemiological studies and research purposes, especially in children. Therefore, simple, accessible, and cost- effective methods such as footprint, with a good correlation with x-ray images, are needed to help diagnose different foot pathologies. In the present study, the accuracy of footprint technique in assessing hallux valgus angle (HVA) was evaluated based on x-ray images through measuring the angle between the medial border protrusion of the foot and the hallux.

Methods: In this cross-sectional study, 42 participants with symptomatic hallux valgus were recruited. HVA was measured by both x-ray imaging and footprint. The differences between the two approaches were identified by applying correlation-coefficient test and reliability, which was assessed using interclass correlation (ICC).

Results: A significant correlation was found between the HVA measured by x-ray and HVA by footprints ($p < 0.001$), and the ICC was upper than 90%.

Conclusion: Foot print is a reliable method for measuring HVA, as it was highly correlated with the HVAs obtained by x-ray imaging.

Keywords: Hallux valgus angle, X-ray, Foot print

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Introduction

Hallux valgus (HV) or bunion is the medial deviation of the first metatarsal head and the lateral deviation of the great toe (1-4). It is a common foot deformity with prevalence of 23% in adults and 35.7% in older adults (5, 6). The underlying cause of HV is not well known; however, several factors are reported as the cause of HV including genetic predisposition (5-8), heredity, female gender (8-11), old age (11, 12), pes planus and structural factors (9, 13, 14), trauma, type of footwear, and poor shoes fitness (13, 14). Progression of HV leads to foot pain, osteoarthritis of the first metatarsophalangeal joint, impaired gait pattern, poor stability, increased risk of falling in older adults, and foot surgery (14-17). Thereby, accurate and on time diagnosis of this deformity appears to be crucial (17-19). X-ray images are used as an accurate and common tool in diagnosing and identifying the severity of HV (19, 20) by measuring hallux valgus angle (HVA). The relative position of hallux and first metatarsal bone or angle between the first and second met atarsal bones defines the HVA (7-9). As this angle quantitatively reflects the severity of deformity, it has been widely applied in the clinical and scientific studies (8, 9, 21). However, the application of x-ray images in measuring HVA, especially in children, is restricted by fear of being exposed to unnecessary radiation (8, 9). Some other clinical measures, which are only moderately correlated with the radiographic approaches (8), have been used in epidemiological studies (22). The most developed tools are the Manchester scale described by Garrow, et al. in 2001 (23, 24) and a line drawing tool described by Roddy in 2007 (24-26). However, the lack of

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↑*What is "already known" in this topic:*
The hallux valgus angle of the margo medialis pedis was introduced as a conceptual alternative measurement of the metatarsophalangeal hallux valgus angle.

→*What this article adds:*
New foot print angle altered the x-ray as an invasive measurement to x-ray in hallux valgus angle measurement.

Table 1. Mean (Standard Deviation) of Gender-wise HVA in Footprint and X-ray

Gender	FPR*	FPL*	RR*	RL*	Weight**	BMI***	Age****
Male	12.52 (0.59)	12.68 (0.60)	12.54 (0.65)	12.65 (0.61)	66.40 (7.74)	20.20 (1.65)	51.40 (11.10)
Female	12.55 (0.78)	12.92 (0.76)	12.54 (0.75)	12.85 (0.75)	68.25 (7.90)	19.50 (1.54)	53.05 (13.33)
Total	12.54 (0.69)	12.82 (0.69)	12.54 (0.70)	12.76 (0.69)	67.46 (7.77)	19.80 (1.60)	52.34 (12.28)

*: Degree, **: Kg, *** (Kg)/M2, ****: Year
FPR =foot print right
FPL =foot print left
RR= X-ray image of right foot
RL= X-ray image of left foot

Table 2. Regression between Foot Print and X-ray Images

	Right Foot		p	Left Foot		p
	HVA in foot print	HVA in X-ray		HVA in foot print	HVA in X-ray	
Mean (SD) (Degree)	12.53 (0.69)	12.54 (0.70)		12.82 (0.70)	12.76 (0.69)	
Correlation coefficient	0.997		0.0001*	0.974		0.0001*
Regression constant	0.419		0.481	0.274		0.443

The HVA in footprint of the right foot equals to 0.967 * HVA in x-ray.
The HVA in footprint of the left foot equals to 0.974 * HVA in x-ray.
In the current regression model, the amount of footprint in both left and right foot considered as an independent value and x- ray as a dependent value*, showed a significant value of p.
HVA FP = hallux valgus angle in foot print
HVA x-ray = hallux valgus angle in x-ray

precision in HVA measurements compared with x-ray measurement restricted their widespread use (27-30). In addition, standardized digital photography is reported as a more advanced tool for measuring HVA; however, determining the reference points on the photos may be difficult. Kilmartin and Bishop (15) used a finger goniometer to measure the HVA, which had only a medium correlation with x-ray images. According to the literature, an acceptable correlation with the x-ray images was obtained by measuring the protrusions of the head and base of the first metatarsal bone and the hallux by footprint and foot outline (9). Therefore, the accuracy of footprint, as a potential method for screening purposes, compared to x-ray imaging, was used in diagnosing HV in this study. The HVA was defined as the angle between the medial border of the protrusion of the foot and hallux based on the same feet positions in both approaches (8, 9).

Methods

In this cross- sectional study, 42 patients (31 females and 11 males) with unilateral or bilateral symptomatic HV (63 feet), who referred to Adabian rehabilitation center of Kermanshah (Iran) to receive the orthotic treatment for HV, were included. The inclusion criteria were bilateral or unilateral HV with HVA above 20 degrees. Patients with previous foot surgery, metabolic disorders, neuromuscular disorders, and flat foot were excluded. A radiological image of the involved foot, which had previously been taken for physician diagnosis, was used. Therefore, no image was taken for the purposes of the current study. Each participant provided an informed consent for participation in this study. Research committee of the affiliated university provided approval for this study.

Equipment: A static footprint with a scanning area of 398×312×191 mm was used. The sampling rate of scans was 50/60 Hz, with speed of 30 mm/s and the error of 1-2 mm in plane.

Protocol: Participants were instructed to stand on the footprint with barefoot, with their arms hanging relaxed at their sides. A static footprint was obtained. The x-rays were taken in upright standing posture. Then, the Corel-Draw software (Version 12.0) was used to analyze the x-rays. The marked foot two dimensional model scans were analyzed with home written Mat lab code. The footprint was defined as the first frame of the foot model in X-Y plane. To calculate the HVA, a straight line was drawn from the medial border of the heel, tangentially to the ball of the great toe, which was titled as hind-fore foot line. Then, another line was drawn from the ball of the great toe to the medial border of the soft tissue of the great toe, which was called forefoot-hallux line. Then, HVA was calculated between the straight extension of the hind-fore foot line and the forefoot-hallux line. HVA was obtained from both the footprint and the x-ray images. The accuracy of the measurement angle was about 0.7 degrees.

Statistical Analysis

Normal distribution of data was confirmed using Kolmogrov-Smirnov test (p> 0.05), then, student t test was used to compare the means of numeric variables between genders. Linear regression model was used to predict the equation for HVA in x-ray images and new footprint. In addition, the Pearson correlation coefficient (r) and intraclass correlation were performed to examine the association between HVA and its reliability, using x-ray images and footprint. P-value less than 0.05 was considered as significant.

Results

In this study, 42 adults, with the mean age of 52.39 (SD=10.3) yrs. (age range: 27-75 yrs.) participated. A total of 42 feet were measured including 35 (83%) right and 28 (66%) left unilateral deformity feet and in 18 bilateral participants. The apparent cause of hallux valgus in 20 patients was constricting footwear and it were rheumatoid arthritis, osteoarthritis, and pronated foot in 22 patients.

Demographic characteristics of the participants are demonstrated in Table 1. In female participants, the mean of HVA in footprint and x-ray images was 12.55 (SD=0.78) degrees for the right foot and 12.92 (SD= 0.76) degrees for the left foot. In the male participants, the mean of HVA in footprint was 12.52 (SD= 0.56) for the right foot and 12.68 (SD= 0.60) for the left foot. In female participants, the mean of HVA in x-ray was 12.54 (SD=0.65) for the right foot and 12.82 (SD= 0.75) for the left foot; and in the male participants, the mean of HVA in foot print was 12.54 (SD= 0.75) for the right foot and 12.76 (SD= 0.69) for the left foot (Table 1). The results of the t test revealed no significant difference between male and female participants in HVA mean in foot print and x-ray ($p > 0.05$). The mean (SD) of BMI was 19.50 (1.54) in females and 20.20 (1.64) in males, respectively. A significant difference for BMI was observed across genders in severe cases ($p = 0.02$).

A linear regression model was used for x-ray and new footprint. The Pearson correlation coefficient (r) was used to report the association between the HVA in footprint as a dependent variable, and HVA in x-ray as an independent variable. A significant difference was obtained between HVA in footprint and HVA in x-ray in the right foot of the patients ($p \leq 0.001$). Linear correlation coefficient between HVA footprint and HVA x-ray demonstrated the highest correlation between them ($r = 0.936$). In addition, significant differences were observed between new foot print and x-ray HVA in the left foot of the patients ($p < 0.001$). Linear correlation coefficient between HVA footprint and HVA x-ray demonstrated the highest correlation with HVA obtained by x-ray ($r = 0.987$). The relationship between x-ray and HVA footprint is demonstrated in Table 2. According to our study, both right and left foot prints could be used as a single best predictor for severity of hallux valgus and as a substitution for x- ray.

Discussion

The first aim of the current study was to introduce a creative and intellectual approach to compare, evaluate, and utilize the hallux valgus angle using footprint and x-ray picture, which showed that our foot print HVA has a high linear correlation with the radiographic measurement.

As mentioned in this study, The HVA was the angle between the medial border of the protrusion of the hallux and the first metatarsal bone. The first objective of this study was to evaluate the correlation between the hallux valgus angle from the radiographic and footprint approaches based on medial border protrusions of the hallux and the first metatarsal of the foot. This method may be used as an alternative to the customary metatarsophalangeal hallux valgus angle and foot print and could be derived from any other non-radiographic method, which provides a clear picture of the foot without any distortion.

A number of different methods for measuring the metatarsophalangeal angle based on medial protrusion of the hallux have been reported (9, 13). For the first time, Spooner, et al. reported the protrusion of medial border of the foot as a landmark although the application of this landmark was not reported for HVA measurement (2). Kilmartin used hand-made goniometer as an anthropometric method to measure HVA, with a moderate linear correlation, and compared it with the x-ray method.

In another study, using footprint and x-ray images, Park evaluated HVA by observing the protrusion on the first and second metatarsophalangeal angle of healthy participants aged 15 and 70. He found an acceptable correlation between the 2 methods (4, 15). However, the angle they chose as HVA and their method was different from ours, and the relationship between x-ray and footprint methods was confirmed in this study.

Bandicoot and Hardy declared an assumption of existence of systematic bias in hallux valgus measurement based on traditional method on the first and second metarsophalangeal joint, which is due to the anatomical varus position of the first metatarsale with respect to the cuneiforme and navicular. This bias has a direct impact on the metatarsophalangeal angle report. Because of selecting a different angle as a hallux valgus angle in our method, this bias did not affect our measurement (27-29).

Another main objective of this study was to assess the possibility of using this hallux valgus angle as an alternative to the metatarsophalangeal hallux angle. In our study, the result of correlation between HVA foot print and the x-ray was improved, where significant differences were observed between them; this was confirmed by a study conducted by Zho et al. who found an acceptable correlation between HVA footprint and HVA x-ray. Furthermore, they confirmed that using this angle to measure HVA, the angle between first metatarsal and hallux, has a priority to foot print method. However, their study had some limitations such as small sample size and absence of female population (4, 9, 29).

This study found that the pattern and severity of hallux valgus in the left and right foot were significantly different in the x-ray images and footprints, $p = 0.01$. Therefore, we can use separate regression models for every foot. This aspect of our study, as a unique part of our study, was not considered in other research studies.

Conclusion

The method designed in this study included the principles of radiography and footprint, and an optimal result in the HVA measurement was obtained. Overall, this method is effective and can be easily, directly, and quickly used as an alternative traditional approach in routine hallux valgus evaluation. There were several limitations to our study. First, our study did not collect any data on structural factors, which might have been due to the severity of hallux valgus including metatarsal length, head shape, and lack of pronation in hind-foot. The second limitation was that most of our participants were middle age females who suffered from hallux valgus. Thus, future studies with larger sample size of middle age female and male participants should be conducted to determine the effectiveness of foot print method in diagnosing hallux valgus. In future studies, it is better to focus more on the biomechanical and plantar pressure changes in the foot in hallux valgus over time.

Conflict of Interests

The authors declare that they have no competing interests.

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