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A Comparison of Self-Designed Scanner Device and AutoCAD Image Calibration Method with Gold Standard Classical Ink Foot Print Method: An Analysis of Arches of Foot

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Abstract

Objective: The purpose of this study was to evaluate the accuracy and the intrarater reliability of arch angle (AA), Staheli Index (SI), and Chippaux-Smirak Index (CSI) and Arch Index (AI) by comparing footprints obtained from ink footprint and self-designed scanner device.

Methods: Measurements of AA, SI, CSI and AI were obtained from ink footprints and self-designed scanner footprints in 400 healthy participants (aged 21 to 50 years). Intrarater reliability was calculated for all parameters obtained using the 2 methods. Standard error of measurement and minimal detectable change were also calculated.

Results: The statistical analysis were undertaken using the SPSS Statistical software (version 16.0) and executed at 95% confidence interval. Mean and standard deviations (SD) were observed by descriptive analysis. Intraclass correlation (IC) and 95% confidence intervals (CIs) were used to analyze the intrarater reliability of ink footprints and scanner footprints. Reliability of the method was interpreted as follows: excellent (≥0.75), moderate (0.4-0.74) and poor (0-0.39).

Conclusion: Our study revealed that AA, CSI, SI and AI obtained from the ink foot prints and scanner foot prints had high intrarater reliability and reproducible. The device was designed in a portable manner so it can be carried easily by a single person to any places that allows to diagnose or to collect data in rural and under-served areas without any cost.

Keywords: Arches of foot, self-designed scanner, flat foot, high arch foot

Introduction

The evolution of human bipedalism began about four million years ago [7]. The foot functions as a rigid structure during weight bearing and it can also function as a flexible structure to adapt to uneven surfaces [28]. The arches of foot acts as a spring, bearing the body weight and absorb the shock produced during

locomotion. Knowledge of foot morphology and morphometric analysis plays a vital role in several domains [10]. Morphology and clinical measurements of the arches of foot were developed to quantify the geometry as well as the purpose of diagnosis of certain ailments [12], [13], [14]. Anthropometric, foot print indices and radiographic methods are classical methods in analyzing the integrity of the arches of foot [25], [36]. Conventional footprints were acquired from ink and graphite powder method in a paper, for establishing the contact between the plantar surface of the foot and supporting surface [1], [4]. Clarkes angle, Staheli index, Chippaux-Smirak Index, Arch index and Truncated arch index are the most reliable methods in assessing the footprints [24], [32]. Pita-Fern 2015 analyzed footprint indices of 1,002 subjects 505 aged 40–64 years, and 497 aged ≥65 years and revealed that footprint indices are the Gold standard method in diagnosing flatfoot [23], [37]. The standard ink footprints method is a simple, but time-consuming, messy and laborious, digitalizing the footprint is an easier way to solve and overcome the problems of obtaining ink footprints [6], [19]. Robinette KM 2006 described that in recent days, usage of 3D foot scanning with advanced optoelectronic technology were used for footwear customization in footwear industries [15], [26]. The disadvantages of 3D foot scanners as, it is too expensive; the devices are too large for homes and basic clinical setup; and the equipment needs an expertise to collect the relevant foot print indices [2]. However, most of the clinician's and researchers had implemented either the standard ink footprint or expensive 3D foot scanning methods for obtaining the foot print indices. Since 3D foot scanning is expensive, and not affordable for primary health centers, rural areas and in minor clinics. Therefore, the present study attempts to compare the reliability of Gold standard footprints obtained from ink and paper method, with the footprints obtained from self-designed foot scanning device in an effort to produce consistent and compatible standards for future work. Hence, the present study aims to develop a reliable technique for measuring the footprint parameters, using a low cost and portable self-designed scanner device comparing it with Gold standard ink foot print method.

Material and Methods

Participants and study area

This is a comparison study in which a total number of 400 healthy participants (200 males and 200 females) between the age group of 21 to 50 were included. Participants with recent surgery (within six months) or any open wounds in the lower extremity and neurological disorders were excluded. Ethical approval was obtained from the Institutional Ethics Committee (IEC) of Sri Ramachandra Medical College and Research Institute, Tamilnadu, Chennai. Written consent was obtained from the patients after detailed explanation of the study, their role, risks & benefits involved and their rights.

All the participants underwent both assessment, the scanning method and ink foot print method. As preliminary procedure the entire participant's foot was cleansed with mild soap water and wiped thoroughly with a towel, for both digitalized plantar scan method and ink footprint method.

A. Instrumentation and procedure

Device and acquisition of digitalized plantar scan images (DPSI)

The device for the present study was self-designed made with wood, toughened glass and a HP branded document scanning machine. The device can withstand up to 200kgs when the subject stands over the

equipment. Each subject was requested to stand erect, facing forwards, on the scanning device; after a few trials of familiarization with the scanner, the digitalized plantar scan images were obtained.

Calibration of images

The images of the scanned plantar surface were transferred to the computer. Calibration of images was carried out in AutoCAD software by placing the calibration marks on two points that are a known distance apart, and entering the actual distance spanned by the points in centimeters. AutoCAD software was used as a planimetric tool to measure angle, length and area on digital foot print images.

B. Acquisition of ink footprint

The subjects are instructed to stand in the tray containing non-irritant blue ink pad, then advised to stamp their foot print by standing erect and looking straight ahead on the 600 cm length x 57cm breadth of paper. Three sets of foot prints were taken from each subject. The better impregnated foot prints in the paper were selected and the parameters were observed. Draft scale and transparent graph sheet was used for measuring the ink foot prints.

Parameters

Arch angle (AA) is the angle between the medial line of the footprint (a) and the line connecting the most medial aspect of the metatarsus and the most lateral point of the medial foot (b) [3], [17], [18].

Staheli Index (SI) obtained by dividing the minimal width of the midfoot (d) by the widest width of the (e) rearfoot region [5], [11], [20], [33].

Chippaux-Smirak Index (CSI) is obtained by dividing the minimal distance of the (d) midfoot by the maximal distance of the (c) forefoot [30], [27], [31]

Arch index (AI) The length of the footprint excluding the toes (L) is divided into equal thirds. The AI is then calculated as the area of the middle third of the footprint divided by the entire footprint area (AI = B/A + B + C) [16], [21], [34], [35], [29].

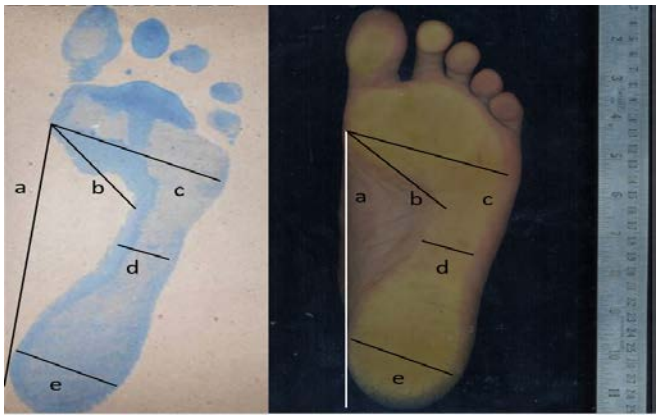

Fig: 1 shows the measurement of AA, SI and CSI in normal arch foot with both ink foot print and scanner method

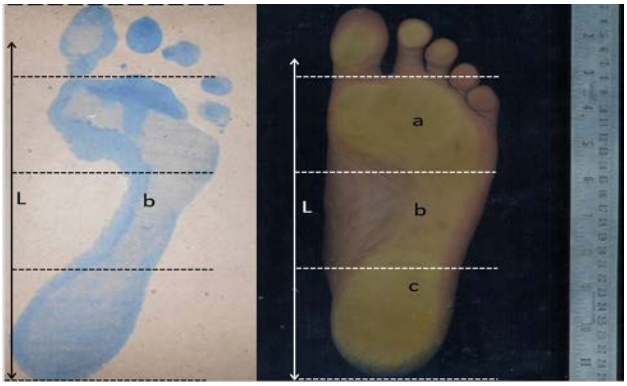

Fig: 2 shows measurement of AI, in normal arch foot with both ink foot print and scanner method

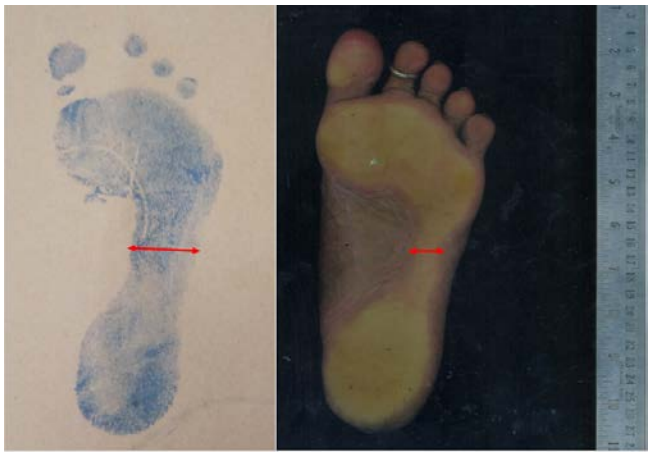

Fig: 3 shows high arch foot with reduced medial longitudinal arch exactly seen in scanner image when compared with ink foot print.

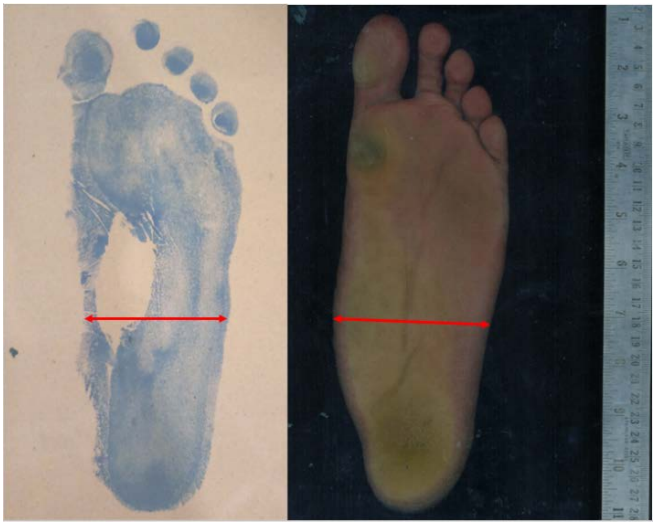

Fig: 4 shows flat arch foot with complete collapse of MLA and TA with prominence medial protuberance clearly seen in scanner image when compared with ink foot print.

Results

The statistical analyses were undertaken using the SPSS Statistical software (version 16.0) and executed at 95% confidence interval. Means and standard deviations (SD) were observed by descriptive analysis. Intraclass correlation (IC) and 95% confidence intervals (CIs) were used to analyse the intrarater reliability of ink footprints and scanner footprints. Reliability of the method was interpreted as follows: excellent (≥0.75), moderate (0.4-0.74) and poor (0-0.39). Standard errors (SE) of measurement were also calculated as shown in table 3. Sensitivity, specificity, positive and negative predicted value as well as the prevalence of different types of arches of the foot was expressed as percentages in table 5. Clopper-Pearson confidence intervals were used for sensitivity, specificity and accuracy. Standard logit confidence intervals were used for the confidence intervals of positive and negative predicted values based on Mercaldo et al.2007 [22].

Gender	Age Mean±SD	Height Mean±SD	Weight Mean±SD
Males	32.6 ± 9.2	176±3.4	78.4±10.6
Females	27.4±7.8	161±4.2	66.2±8.4

Table 1: The characteristics of subjects (Mean±SD)

Variables	Ink footprint method		Scanner method	
	M	F	M	F
Normal Arch	62.0%	55.5%	56.0%	54.5%
High Arch	17.0%	16.5%	20.5%	17.5%
Flat Arch	21.0%	28.0%	23.5%	28.0%

Table 2: Distribution of different types of arches of foot determined using both ink footprint method and scanner device method.

Parameters	Ink foot print			Scanner foot print			95% C.I
	Mean ±SD	SE	IC	Mean ±SD	SE	IC	
AA	40.3± 4.3	0.871	0.97	43.1± 3.9	1.83	0.97	0.69-0.78
CI	31.8± 2.1	0.01	0.99	32.2± 4.1	1.31	0.98	0.68-0.86
SI	0.6±0.06	0.61	0.98	0.73± 0.05	1.21	0.97	0.54-0.58
AI	0.23± 0.11	0.11	0.95	0.25± 0.18	1.01	0.96	0.78-0.96

Table 3: SD-Standard deviation, SE-Standard error, IC-Intraclass correlation, p-values for IC >0.01.

Test Outcome	Abnormal Arches	Normal Arches	Results
Abnormal Arches	TP (165)	FP (14)	179
Normal Arches	FN (0)	TP (221)	221
Total	165	235	400

Table 4: Comparative analysis of the sensitivity and specificity of foot print indices using ink foot print method and Scanner foot prints method.

(TP-True Positive, FP-False Positive, FN-False Negative, TN-True Negative)

Statistics	**Values**	**Confidence Interval 95% CI**
Sensitivity	100%	97.34% - 100%
Specificity	94.68%	91.23% - 97.06%
PPV	90.73%	85.46% - 94.22%
NPV	100%	100%
Accuracy	96.50%	94.20% - 98.07%
Prevalence	34.25%	29.61% - 39.13%

Table 5: shows the results of sensitivity, specificity, PPV, NPV, accuracy and prevalence tested among 400 participants. (PPV-Positive predicted value, NPV-Negative predicted value).

Discussion

In this study among 400 participants normal arch, flat arch and high arch foot have been identified. The flat and high arch foot are categorized as abnormal arches and the normal arched foot remains the same as shown in table 2. The goal of the present study was to examine the ability of the self-designed scanner device to assess the foot print indices compared with the Gold standard ink foot print method. The most interesting finding was that the images obtained from the scanner device are very clear and took short span for the procurement and also for observation of parameters, when compared with Gold standard method as shown in figure 1,2,3and 4.

All variables showed intra-class correlation coefficient >0.9 which revealed excellent intrarater reliability with 95% confidence interval. Literature on reliability has reported similar results, but the comparison of methodology varies. Queen et al studied the reliability of AA, CSI, and SI using the mirrored foot photo box among 30 healthy individuals [24]. All parameters showed good interrater, and intrarater reliability, SI (ICC = 0.963), CSI (ICC = 0.961) and AA (ICC = 0.957). When compared our study results with Queen et al study, the intrarater reliability were similar but the difference is a self-designed scanner method was used in the present study. Fascione J observed the CSI and SI intrarater reliability by examining 10 adults in dynamic conditions using an ink mat and the results showed an ICC of 0.99 for both [9]. Similarly in the present study the intrarater correlation value for (CSI = 0.992) and (SI = 0.988) the difference is that we obtained the ink foot prints in static condition. The present study showed the excellent reliability similar to the results of Queen et al and Fascione et al but the contrast is that these authors examined fewer participants, whereas 400 participants were analysed in the present study and results were obtained.

Zuil-Escobar et al., 2016 studied the reliability of ink foot print method and pressure platform among 40 subjects revealed that AA, SI, and CSI the results obtained from both the methods similar [38]. When compared the results of Zuil-Escobar et al study with the present study AA, CSI, SI and AI also were analysed and the results showed an excellent reliability and validity obtained from both ink foot print method and self-designed scanner method.

In addition, the present study also revealed the distribution of normal arched, flat arched and high arched foot. Regarding the accuracy of ink footprint and self-designed scanner foot parameters, the ICs obtained in comparison of the 2 methods showed excellent value (0.75).

Examining the sensitivity and specificity of the scanner device revealed a positive result. Hoffman revealed that "a test with a sensitivity and specificity of around 90% would be considered to have good diagnostic performance [8]. In the present study comparison of scanning method with the Gold standard ink foot print method showed sensitivity 100% and specificity 94.68% with very low ranges of both FP (14), FN (0), 90.73% of PPV and 94.22% NPV values as shown in table 4. According to the literature and our results, the parameters evaluated (AA, SI, CSI and AI) using ink foot print and self-designed scanner method are similar, statistically having a high IC value with excellent reliability and are reproducible.

Conclusion

This study reported that AA, CSI, SI and AI obtained from the ink foot prints and scanner foot prints had high intrarater reliability and reproducible. The images obtained from the self-designed scanner device are very clear and took very less time for the assessment when compared to the Gold standard method. According to our knowledge, this is the first study to evaluate the foot print indices using the AutoCAD software with image calibration technique. The device was designed in a portable manner so it can be carried easily by a single person to any places that allow to diagnose or to collect data in rural and under-served areas without any cost.

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