Original article

Investigation of the optimal location of the metatarsal pad in the standing position

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Abstract

The location of the metatarsal pads was quantitated in 16 healthy men (32 feet) using plantar pressure measurement and numeric rating scale (NRS) systems. Plantar pressure measurement system (F-Scan, Nitta co. Japan) was used to measure plantar pressure in subjects standing still under 5 different placement conditions of metatarsal pads (thickness, 8 mm). Measurement was also performed with no pads (control, 0 mm). After plantar pressure measurement under each condition, subjects rated pain caused by the height of the pads using NRS. The results showed that the placement was optimum when the apex of the pad was located 2 cm proximal and 5 mm lateral to the proximal end of the second metatarsal head along the longitudinal axis of feet.

Introduction

Metatarsalgia and pain in the heads of plantar metatarsi are frequently encountered in clinical practice. According to Fann, pressure on the metatarsal heads is increased by external and external biomechanical factors during weight bearing, occasionally causing metatarsalgia [1]. When this happens, metatarsal pads are prescribed to direct pressure to the diaphysis of the metatarsus where soft tissue are relatively abundant, thus reducing pressure on the metatarsal heads [2-5]. Previous studies occasionally reported on the shape, location, and materials of metatarsal pads, but only a few provided numerical values, with the absence of unified views. Consequently, the clinical application of metatarsal pads requires the experience and skills of prosthetists. We therefore previously evaluated the height of pads to quantitatively analyze metatarsal pads in subjects standing still [6]. However, information remains insufficient for proper quantification. From the perspective of foot care in diabetic patients, Zou et al. investigated pressure distribution on the plantar surface and showed a high correlation between peak pressure and maximum shear stress that damages the plantar skin [7]. In addition, Goske et al. reported that the most important variable was the conformity of the insole, not the selection of insole materials [8]. In this study, we therefore investigated the location of metatarsal pads that has a large impact on insole conformity. The optimal location of metatarsal pads was determined by comparing the sensory evaluation of pain by subjects and the reduction of plantar pressure in the metatarsal heads by the metatarsal pads.

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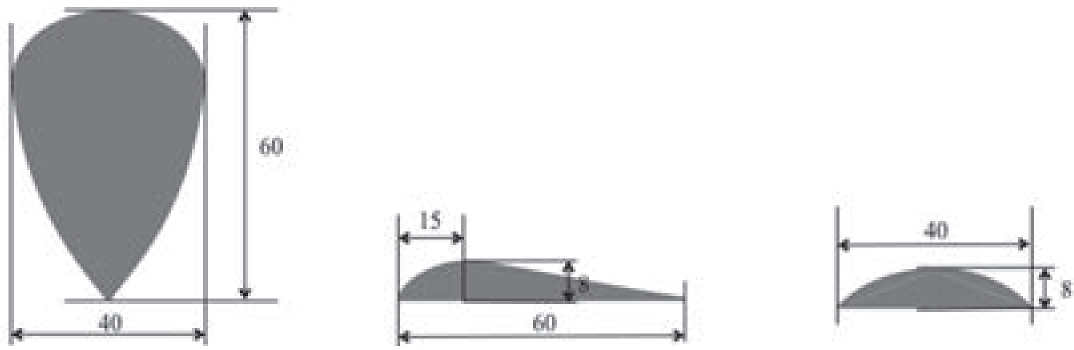

Figure 1. Dimensions of the metatarsal pad (unit: mm)

Materials and Methods

1. Subjects

Thirty-two feet (feet length, 253.2 ± 8.6 mm; feet wise, 101.6 ± 4.0 mm) of 16 healthy men (age, 21.1 ± 3.5 years; height, 174 ± 8.7 cm; and weight, 62.0 ± 17.1 kg) were examined. They were fully informed orally and in writing of the details of the study before submitting consent. This study was approved by the Institutional Review Board of Niigata University of Health and Welfare (No. 17310-120216).

2. Conditions of pads

Teardrop-shaped metatarsal pads, which are the most common today, were used in this study. To prevent deformation of the pads by pressure, ethylene vinyl acetate (hardness 70; rubber hardness tester type C, Japanese Industrial Standard K7312) was used to produce pads. The shape of the pad was tears type, 40mm in width, 60mm in length and 8mm in height (Figure 1).

The standard location (C) of the pad anterior edge, which was 5mm proximal to the head of the second metatarsus, was determined based on the morphology of the feet of each subject. The center axis of metatarsal pads was placed parallel to the base line through between the center of second metatarsus head and the center of behind the heel (ptemion) (Figure 2). Location C was used as the base to determine the other locations: location A, 5 mm distal to C along the base line;

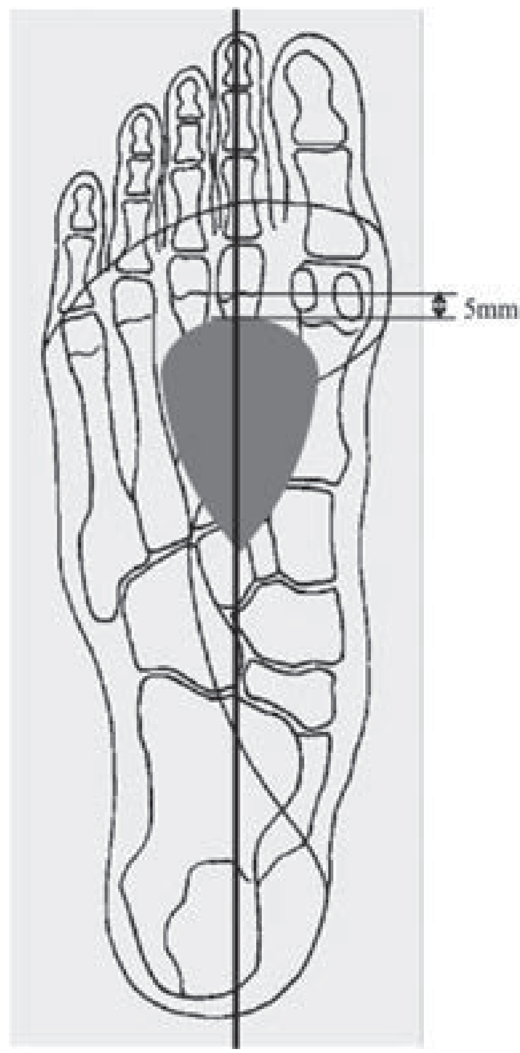

Figure 2. Control location of metatarsal pads

location P, 5 mm proximal to C along the base line; location M, 5 mm medial to C along the transverse axis of the base line, and location L, 5 mm lateral to C along the transverse axis of the base line [9,10].

3. Measurement procedure

Barefoot static stance pressure measurement was performed simultaneously in both feet. Subjects stepped on pads that were placed on a transparency plastic flat sheet (50 × 50cm, t = 10 mm) of pedscope on the floor and were covered by a pressure distribution sensor sheet. Metatarsal pad was attached to an adjustable alignment fixture fabricated out of thin plastic sheeting configured with a sliding scale. The metatarsal pad alignment fixture was adhered to the plastic flat sheet with double-sided surgical tape. To ensure that foot position was maintained during the different test conditions, an L-shaped alignment fixture was utilized. Performed it in reference to the method of Brodtkorb et al. [10]. Then, a peak contact pressure between the head of the metatarsus and the pad was measured using plantar pressure measurement system (F-Scan, Nitta co. Osaka, Japan) twice for 30 sec that started a measurement three seconds after posture was stable. Each subjects staring a target 2 m ahead and standing still with 10cm spacing between the feet. The data was adopted mean. Measurement was also performed with no pads as a control (N), and the location of pads was selected randomly. Confirmed steady states that load depended on equally for both foot from a screen at F-scan. These measurements performed by proficient Prosthetist and Orthotist.

4. Numeric rating scale

After the measurement of plantar pressure under each condition, subjects rated pain caused by the pad using a 11-point numeric rating scale (NRS) with no pain as 0 and maximum pain as 10.

5. Statistical analysis

Statistical analysis was performed using the Friedman's $\chi 2$ r-test followed by Wilcoxon signed-rank test with Bonferroni correction by software for statistical analysis (y-stat 2008, Igakutosho-shuppan Ltd., Tokyo, Japan). This analysis was conducted for each plantar pressure of the regions of the pads and NRS. Statistical significance was set at 5% level.

Results

Mean peak pressure at the metatarsal head were significantly increased in the no pads as a control (N) compared with all other locations. There were non- significant difference between the location L and M, and the location P was significantly increased than the location A (Table 1). Mean peak pressure at the pad was significantly decreased in the location P compared

Table 1. Mean peak pressure at the metatarsal head under each condition (kgf/cm^2)

	Mean(SD)	C	L	M	A	P
N	1.48(0.41)	**	**	**	**	**
C	1.08(0.35)		ns	ns	**	ns
L	1.07(0.42)			ns	ns	*
M	1.11(0.44)				**	ns
A	0.95(0.35)					**
P	1.16(0.43)					

**: p<0.01 *: p<0.05 ns: no significant (n=32) with all other locations. The location M was significantly lower than the location L, and the location P were significantly lower than the location A (Table 2).

Results of NRS evaluation (points) and statistical analysis were shown in Table 3. The location L was significantly lower than the location M, and the location A was significantly lower than the location P.

Discussion

1. Peak pressure

Locations proximal to the head of the metatarsus are the most popular locations for metatarsal pads in clinical practice. Proximal locations are also recommended by Hayda et al. [9] and Hsi et al. [10]. In our present study, location A had the highest pressure-lowering effect compared with locations C and P, with no difference between the two locations, which supports the findings in the previous studies by Hayda et al. [9] and Hsi et al. [11].

On the other hand, Brodtkorba et al. [10] used 5- and 10-mm-thick metatarsal pads to investigate the effect of different locations on the longitudinal axis in subjects standing still on one foot. The results showed no significant difference between locations 5–25 mm proximal to the head of the second metatarsus, contradicting the findings in previous studies. We think this disparity arose because Brodtkorba et al. [10] used were of the triangular shape with rounded corners, 50 mm in width and 55 mm in length, hardness 55 whereas the present study and the studies conducted by Hayda et al. [9] and Hsi et al. [11] used shape of the pad in tears type and harder material.

In the present study, no significant difference was observed in the movement along the transverse axis (M-C-L), suggesting no change pressure-lowering effects at the metatarsal head (Table 1).

The comparison of all conditions revealed that pressure of the metatarsal head was reduced most effectively in locations A and L (Table 1). The A

Table 2. Mean peak pressure at the pad under each condition (kgf/cm^2)

	Mean(SD)	L	M	A	P
C	3.70(1.07)	**	**	**	**
L	4.05(1.11)		**	*	**
M	3.25(0.98)			**	*
A	4.33(1.22)				**
P	2.98(0.84)				

**: p<0.01 *: p<0.05 (n=32)

Table 3. Results of NRS evaluation (points)

	Mean(SD)	L	M	A	P
C	3.31(1.81)	**	**	**	ns
L	4.11(2.38)		ns	ns	**
M	3.94(1.81)			**	**
A	4.50(2.13)				**
P	2.89(1.90)				

**: p<0.01 ns: no significant (n=32)

is close to metatarsal head and the L is located in the center of the transverse arch. This is because the maintenance of the transversal arches formed by the rows of the metatarsal bones is easily affected at these two locations, greatly reducing pressure on the sole.

Although there was no difference in pressure to the metatarsal heads between locations A and L, pressure against the pad was lower at location L than at location A. This suggests that location L is more useful because of less stress on the foot despite no difference in the pressure-lowing effects.

2. NRS

The relations were obtained in the measurements of peak pressure decreases when sensory evaluation increases (Table 2,3). Subjects perceived less pain in location L than in location A even though the largest pressure-lowering effect was observed in the metatarsal head at both locations.

According to Ferrari [12], discomfort caused by metatarsal pads is temporary and disappears after using the pads for a certain period of time. However, the pads are accepted more readily by patients feeling less pain, making the application more effective and appropriate.

3. Summary

The findings in this study showed that the optimal location of the five conditions of metatarsal pad is 5 mm proximal to the head of the second metatarsus and 5 mm lateral to the transverse axis of the base line.

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