Radiographic morphological characteristics of bunionette deformity

Abstract

Background: Bunionette deformity is characterized as head hypertrophy, lateral bowing, or splaying of the fifth metatarsal, or a combination of these deformities. Most previous studies have focused on the fourth and fifth metatarsals; few have analyzed the radiographic morphological characteristics of the entire foot. The morphological characteristics of the entire foot in cases of symptomatic bunionette deformity were analyzed with a radiographic image-mapping system.

Methods: The system was used for the morphological analysis of 112 feet with symptomatic deformity and 123 asymptomatic control feet. The mapping system includes two-dimensional coordinates. We compared morphologies of both groups on the basis of simple models prepared from x and y coordinates of each reference point, calculated by using the mapping system and various angle measurements. We set cutoff values and categorized cases according to Fallat's system. We evaluated the characteristics of each type and a new deformity type (type V) wherein no measurement exceeded the cutoff values.

Results: The heads of the third, fourth, and fifth metatarsals were more laterally displaced and the angles between the metatarsal axes were larger in the deformity group. Comparison of deformity types showed that the morphology of the fifth metatarsal might be only one cause of deformity. The intermetatarsal angles between the second and third metatarsals and between the third and fourth metatarsals were larger in deformity type II and type V feet than in control feet. Additionally, the intermetatarsal angles between the third and fourth metatarsals and between the fourth and fifth metatarsals were larger in deformity type III and type IV feet than in control feet.

Conclusion: It is necessary to not only focus on the fourth and fifth metatarsals, but also assess the morphological characteristics of the entire foot in patients, including splaying of all the metatarsals and the forefoot width, when planning surgery.

Level of Evidence: Level III, retrospective comparative study

Keywords: Bunionette deformity, Radiographic analysis, Mapping system, Morphological characteristics, Fallat's classification

Introduction

Bunionette deformity or "tailor's bunion," is a disorder in which the fifth metatarsal head is prominent laterally and the fifth toe is supinated at the metatarsophalangeal (MTP) joint, and the disorder is frequently associated with painful keratosis on the lateral or plantar aspect of the fifth metatarsal head.[1,4] Although constricting footwear can cause its symptoms, several anatomical factors have been suggested to contribute to its development, including an enlargement of the fifth metatarsal head and lateral bowing in the diaphysis of the fifth metatarsal,[16] as well as an increased intermetatarsal angle between the fourth and fifth metatarsals.[1,4,13]

Initially, conservative management involving instructions to choose the appropriate shoes or to use insoles should be considered[9]; however, if conservative management is ineffective, surgical management is indicated. Various surgical procedures have been reported for bunionette deformity with good results.[1,3,5,6,9] Furthermore, the selection of the correct surgical procedure on the basis of preoperative morphology on radiography has been recommended[1,2,5,9,10]; therefore, the assessment of the radiographic morphological characteristics of bunionette deformity is important.

Most previous studies have focused on the fourth and fifth metatarsals, and few studies have analyzed the radiographic morphological characteristics of the entire foot in detail. Therefore, in the present study, the morphological characteristics of the entire foot in cases of symptomatic bunionette deformity were analyzed using a system for mapping radiographic images.[12,14,15]

Materials and Methods

The present study was approved by the ethics committee of our university. We retrospectively investigated the radiographic images of 112 feet from 74 patients with symptomatic bunionette deformity, who were treated at our hospital consecutively between 1992 and 2012. Of the 112 feet, 5 were from 3 men and 107 were from 71 women. The mean age of the patients was 59 years (range, 14–80 years). Both feet were affected in 38 patients, the right foot was affected in 13, and the left foot was affected in 23.

We also investigated 123 feet of the opposite side in 73 patients with minor injuries, soft tissue tumors, or ligament injuries, without any history of discomfort as a control group. Of the 123 feet in the control group, 5 were from 3 men and 118 were from 70 women. The mean age of the patients in the control group was 57 years (range, 14–82 years). There was no significant difference in age or sex between the bunionette deformity group and the control group.

The mean body mass index values of 52 patients whose physical description was available were 22.5 kg/m^2 in the bunionette deformity group and 23.8 kg/m^2 in the control group.

Patients with diseases that could influence bones or joints, such as rheumatoid arthritis and other systemic inflammatory diseases, were not included in the bunionette deformity and control groups.

Radiographic technique

Patients underwent standardized dorsoplantar radiography of their feet in the standing position with one foot on a film cassette. The patients were instructed to hold a rail on the radiographic table for support in order to maintain the lower limb vertical to the cassette. An X-ray beam was inclined 15° from the vertical source at a distance of 100 cm. To ensure precision, the direction of the beam was fixed parallel to the axis of the foot and centered on the second tarsometatarsal joint.

Mapping system

The mapping system includes a two-dimensional coordinate system.[12,14,15] In this system, the axis of the shaft of the second metatarsal is the x-axis, the intersection of the x-axis with the proximal end of the second metatarsal is the point of origin, and the axis perpendicular to the x-axis that passes through the point of origin is the y-axis. Additionally, the regions distal and medial to the point of origin are positive in relation to the x-axis and y-axis, respectively. The distal ends of the distal phalanxes of the first through fifth toes were marked as D1–D5, respectively. The points of intersection of the axes of the metatarsals with the distal ends of the metatarsals were marked as MH1–MH5, respectively, and the points of intersection of the axes with the proximal ends were marked as MB1–MB5, respectively. The midpoint of the joint space on the medial margin of the navicular-first cuneiform joint and the midpoint of the talonavicular joint were marked as NC and TN, respectively. The midpoint of the joint space on the lateral margin of the calcaneocuboid joint was marked as CC (Figure 1). Each point was marked with the computer. The x and y coordinates of each point were obtained with a resolution of 0.1 mm. The values were expressed as a percentage of the length of the second metatarsal (the distance from the origin to MH2) to standardize the measurements, despite differences in foot size. The coordinates for MB2 were always (0,0) and for MH2 were always (100,0). The reproducibility of the measurements using this mapping system has been validated.[14]

Angular measurements

We measured the hallux valgus angle, the fifth MTP angle (the angle between the axis of the fifth proximal phalange and the fifth metatarsal), and the intermetatarsal angles between the axes of the metatarsals (M1/2, M2/3, M3/4, and M4/5). The metatarsal axis was defined as the line connecting the midpoints of the distal and proximal ends of its diaphysis, and the proximal phalangeal axis was the line connecting the most concave points of its proximal and distal articular surfaces. We further measured the fifth metatarsal head width and the lateral deviation angle of the fifth metatarsal. The width of the metatarsal head was defined as the greatest distance between the medial and lateral borders of the metatarsal head perpendicular to the fifth metatarsal axis, and the lateral deviation angle was defined as the angle between a line along the proximal medial margin of the shaft of the fifth metatarsal and a line connecting the midpoint of the width of the fifth metatarsal head and the midpoint of the fifth metatarsal neck (Figure 2). The transverse diameter of the fifth metatarsal neck was defined as a line perpendicular to the axis of the fifth metatarsal at the narrowest point of the distal part of the shaft.

In the previous literature that used this evaluation system, ten radiographs were randomly chosen and measured by two observers twice on different days. The standard deviations of the measurements on the 10 radiographs were within 1° for all angles. The standard deviations of the values of both the x and y coordinates were within 1% at all points measured. The absolute value of the coefficient of variation was within 5%. Based on these results, the measurement method demonstrated sufficient accuracy.[14]

We compared the morphology of the foot between the bunionette deformity and control groups on the basis of simple morphological models of the entire foot prepared from the x and y coordinates of each reference point, calculated by using the mapping system and various angle measurements.

Fallat's classification system

We categorized the cases of bunionette deformity according to Fallat's classification system[5] (Figure 3) and discussed the characteristics of each type of bunionette deformity. The cutoff value of each parameter was decided as follows. Each value of the bunionette deformity group was arranged in descending order from the largest to the smallest. Subgroups included cases with the largest value, and smaller values were added individually. Each subgroup was compared with the control group, and the smallest mean value of the subgroup that was significantly different ($p<0.01$) from the mean value of the control group was considered the cutoff value. Type I bunionette deformity was defined as a metatarsal head width ≥13 mm, lateral deviation angle <3.9°, and M4/5 angle <10° ; type II as a metatarsal head width <13 mm, lateral deviation angle ≥3.9°, and M4/5 angle <10°; type III as a metatarsal head width <13 mm, lateral deviation angle <3.9°, and M4/5 angle ≥10°; and type IV as a metatarsal head width ≥13 mm and lateral deviation angle ≥3.9° or a lateral deviation angle ≥3.9° and M4/5 angle ≥10°. We had diagnosed bunionette deformity on the basis of clinical symptoms such as thickening of the capsule on the lateral or plantar aspect of the fifth MTP joint or presence of pain, and the patients were treated accordingly. Several cases could not be classified into any of the previously reported groups because they did not have a wide metatarsal head of 13 mm, large lateral deviation angle of 3.9°, or large M4/5 angle of 10°. We defined these deformities as type V (Figure 4).

Statistical analysis

In the comparison of the x and y coordinates of each point or each measurement angle between the bunionette deformity and control groups, we used Student's t-test for equivalent dispersions and the Welch's t-test for non-equivalent dispersions.

Results

Angular measurements

The hallux valgus angle ($p < 0.001$); fifth MTP angle ($p < 0.001$); and M1/2 ($p < 0.001$), M2/3 ($p < 0.001$), M3/4 ($p < 0.05$), and M4/5 angles ($p < 0.001$) were significantly larger in the bunionette deformity group than in the control group. There was no difference between the two groups in terms of the fifth metatarsal head width or the lateral deviation angle (Table 1).

Comparison of the bunionette deformity model with the control model

Mapping showed that at D1 and D2, both the x and y coordinates were smaller in the bunionette deformity model than in the control model; at D3, the x coordinate was smaller in the bunionette deformity model than in the control model, while the y coordinate was equivalent; and at D4 and D5, the x coordinate was smaller and the y coordinate was larger in the bunionette deformity model than in the control model. Additionally, at MH1, the y coordinate was larger in the bunionette deformity model than in the control model, while the x coordinate was equivalent. Moreover, at MB1 and TN, both the x and y coordinates were larger in the bunionette deformity model than in the control model, and at NC, both the x and y coordinates were equivalent between the models. Furthermore, at MH3, MH4, MH5, MB3, MB4, MB5, and CC, both the x and y coordinates were smaller in the bunionette deformity model than in the control model (Figure 5).

Comparison of the bunionette deformity types in Fallat's classification

Of the 112 feet of patients with bunionette deformity, 10 (9%) were classified as type I, 18 (16%) as type II, 31 (28%) as type III, 37 (33%) as type IV, and 16 (14%) as type V. In type I feet, the fifth metatarsal head width was greater in the bunionette deformity group than in the control feet; however, the M4/5 angle and lateral deviation angle were smaller than in the control feet, suggesting that the enlargement of the fifth metatarsal head was responsible for the deformity. Although the M1/2, M2/3, and M3/4 angles were larger in type II feet, the M4/5 angle and fifth metatarsal head width were smaller in type II feet than in the control feet. Both the hallux valgus angle and fifth MTP angle were large in type III feet. Although the M1/2 and M1/5 angles were extremely large in all of the bunionette deformity types, the fifth metatarsal head width and the lateral deviation angle were smaller in type III feet than in the control feet. Therefore, the cause of type III bunionette deformity was considered to be lateral displacement of the metatarsals. All the measured values except for the M3/4 angle were larger in type IV feet than in the control feet. The M2/3 and M3/4 angles were larger and the M4/5 angle and fifth metatarsal head width were smaller in type V feet than in the control feet. The M2/3 and M3/4 angles were extremely large in all of the bunionette deformity types (Table 2).

Discussion

The present study determined the morphological characteristics of the entire foot in cases of symptomatic bunionette deformity.

Since Fallat[5] categorized bunionette deformity into types I–IV in 1990, this condition has been characterized by hypertrophy of the fifth metatarsal head, lateral bowing of the fifth metatarsal, or splaying of the fifth metatarsal. Although Nestor et al.[11] measured the forefoot width and identified spreading of the foot, numerous other studies have focused solely on the morphology of the fifth metatarsal and the increase in the angle between the fourth and fifth metatarsals in patients with bunionette deformity. However, a detailed study of the entire foot in patients with bunionette deformity has not yet been reported.

In the present study, we found that the angle between the fourth and fifth metatarsals was not large in type I and type II bunionette deformity cases, indicating that bunionette deformity is not caused solely by the valgus of the fifth metatarsal and that metatarsal morphology contributes to its onset.

On comparing bunionette deformity feet with control feet using a mapping system, we found that equally lateral splaying of the third, fourth, and fifth metatarsals, similar to that seen in the hallux valgus,[14] was evident in feet with bunionette deformity. However, the characteristics of bunionette deformity included almost no change in the positions of the tips of the third, fourth, and fifth toes and lateral displacement of the heads of these metatarsals compared with the positions of their bases. Moreover, the angles between the metatarsals were large in patients with bunionette deformity. Specifically, the angles between the second and third metatarsals and between the third and fourth metatarsals were large in type II feet, while the angles between the second and third metatarsals and between the fourth and fifth metatarsals were large in type III and type IV feet. Although the enlargement of the angle between the fourth and fifth metatarsals has been considered to be a cause of bunionette deformity conventionally, our findings suggest that the splaying of all the metatarsals, which was reported by Nestor et al., including the supination of the first metatarsal, causes the fifth metatarsal head to protrude laterally and the forefoot width to enlarge, contributing to the development of this deformity.

The feet in our proposed category of type V exhibited large angles between the first and second metatarsals, second and third metatarsals, and third and fourth metatarsals, with supination of the fifth toe at the MTP joint or clinical symptoms resembling those of bunionette deformity, suggesting an association between bunionette deformity and splaying of the metatarsals.

Kitaoka et al.[8] measured the forefoot width before and after osteotomy of the fifth metatarsal, and proposed correction of the forefoot width as one of the items in the evaluation of surgical treatment for bunionette deformity. There have been several subsequent reports on measurement of the forefoot width before and after osteotomy of the fifth metatarsal, [2,7,17] and correction of the lateral splaying of the fifth metatarsal to reduce the forefoot width is a possible surgical treatment.

The present study had some limitations. The study was performed using radiography. Therefore, it was not possible to undertake a detailed investigation of the associations with symptoms. All of the patients with bunionette deformity were symptomatic; however, because they consulted our hospital with a complaint of pain in the bunionette region and underwent treatment, they were investigated as a group of patients. Additionally, lateral radiographic images were not analyzed; thus, the contribution of the longitudinal arch to this deformity remains to be clarified.

Conclusion

In conclusion, it is necessary to not only focus on the fourth and fifth metatarsals, but also assess the morphological characteristics of the entire foot in individual patients, including the splaying of all the metatarsals and the forefoot width, when planning surgery.

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Fig.1

Diagram showing the points that were plotted on the two-dimensional coordinate system. D1-D5 : Distal end of the distal phalanx of the first to fifth digits ; MH1-MH5 : the points of intersection of the axis of the metatarsals with the distal ends of the metatarsals ; MB1-MB5 : the points of intersection of the axis of the metatarsals with the proximal ends of the metatarsals ; NC : the mid-point of the apparent joint space of the medial margin of the navicular-first cuneiform joint ; TN : the mid-point of the joint space of the medial margin of the talonavicular joint ; CC : the mid-point of the joint space of the lateral margin of the calcaneocuboid joint . The point of origin of the coordinate system is MB2. Values of X that are distal to the Y axis are positive; values of Y that are medial to the X axis are positive.

Fig.2

Measurement of the fifth metatarsal head width and the lateral deviation angle of the fifth metatarsal. ; a : the fifth metatarsal head width ; b : the fifth metatarsal neck width ; c : the lateral deviation angle of the fifth metatarsal.

Fig.3

Classification by Fallat

Type I tailor's bunion is characterized by an enlargement on the lateral surface of the fifth metatarsal head. Lateral metatarsal bowing indicative of a type II tailor's bunion. Type III tailor's bunion depicted by an increased intermetatarsal angle. Type IV tailor's bunion consisting of a combination of deformities. (quote from the literature 5)

Fig.4

Type V

This is the condition of a new bunionette deformity type which we defined. Both the second and third and the third and fourth metatarsal spaces spread, but the fourth and fifth metatarsal space doesn't spread. Not including enlargement of the fifth metatarsal head and lateral bowing of the fifth metatarsal.

Fig.5

Diagram comparing the mean values of the X and Y coordinates of the patients who had the control subjects and bunionette. a : the probability of the significance of the difference of the mean values of the X coordinates between the two groups, b : the probability of the significance of the difference of the mean values of the Y coordinates between the two groups, C : the control subjects, B : the patients who had bunionette, X : the mean value of the X coordinates and one standard deviation, Y : the mean value of the Y coordinates and one standard deviation. The unit is the percentage of the length of the second metatarsal (MB2 to MH2). *** : $p<0.001$, ** : $p<0.01$, * : $p<0.05$, ns : not significant ($p\geq0.05$).

Table.1

HV : the hallux valgus angle, MTP5 : the fifth metatarsophalangeal angle, M1/2 : the angle between the axis of the first and second metatarsals, M2/3 : the angle between the axis of the second and third metatarsals, M3/4 : the angle between the axis of the third and fourth metatarsals, M4/5 : the angle between the axis of the fourth and fifth metatarsals, Lateral deviation : the lateral deviation angle of the fifth metatarsal, Head width : the fifth metatarsal head width. The values are given as the mean and standard deviation. ns : not significant ($p\geq0.05$).

Table.2

HV : the hallux valgus angle, MTP5 : the fifth metatarsophalangeal angle, M1/2 : the angle between the axis of the first and second metatarsals, M2/3 : the angle between the axis of the second and third metatarsals, M3/4 : the angle between the axis of the third and fourth metatarsals, M4/5 : the angle between the axis of the fourth and fifth metatarsals, Lateral deviation : the lateral deviation angle of the fifth metatarsal, Head width : the fifth metatarsal head width. The values are given as the mean and standard deviation. *** : $P<0.001$, ** : $P<0.01$, * : $P<0.05$, ns : not significant ($p\geq0.05$).

Fig.1

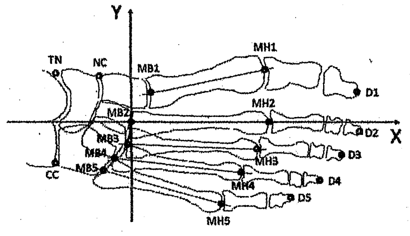

Fig.2

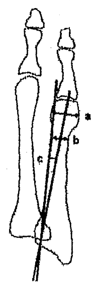

Fig.3

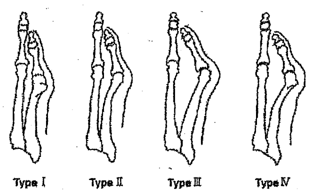

Fig.4

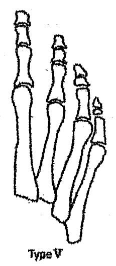

Fig.5

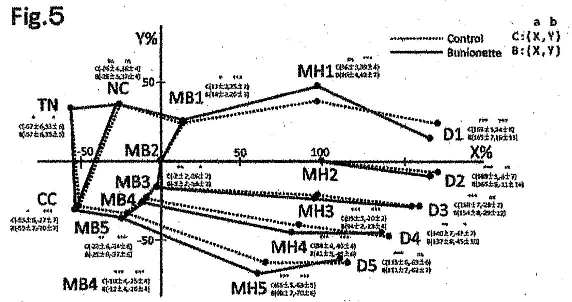

Table 1

ANGULAR MEASUREMENTS AND LENGTH OF THE FEET

Angle (Degrees)	Normal	Bunionette	Probability of Significant Difference (P Value)
HV	12.1±4.6	30.6±12.8	<0.001
MTP5	7.8±3.6	20.3± 6.8	<0.001
M1/2	9.5±2.6	15.6± 4.8	<0.001
M2/3	2.5±1.2	3.9± 2.7	<0.001
M3/4	6.5±1.9	7.1± 2.4	<0.05
M4/5	9.2±2.1	10.3± 2.8	<0.001
Lateral deviation	3.0±2.4	3.1± 2.6	ns
Head width(cm)	12.6±1.2	12.4± 1.2	ns

Table 2

ANGULAR MEASUREMENTS AND LENGTH ACCORDING TO FALLAT'S CLASSIFICATION

Angle (Degrees)	Normal	*Type I*	*Type II*	*Type III*	*Type IV*	*Type V*
HV	12.1±4.6	29.7±17.0***	30.5±15.3***	32.5±12.2***	29.8±12.5***	29.6±9.5***
MTP5	7.8±3.6	15.9± 9.6***	19.3± 6.2***	22.2± 6.6***	20.5± 6.3***	19.8±6.1***
M1/2	9.5±2.6	15.9± 3.7***	15.1± 4.7***	16.4± 5.5***	15.3± 5.2***	15.2±3.3***
M2/3	2.5±1.2	3.5± 2.5^{ns}	4.5± 2.9**	3.6± 2.5*	3.5± 2.6*	5.1±3.1**
M3/4	6.5±1.9	6.6± 2.7^{ns}	7.7± 2.5*	7.1± 2.6^{ns}	6.7± 2.2^{ns}	7.7±2.2*
M4/5	9.2±2.1	7.4± 1.8*	7.6± 1.7**	12.0± 1.7***	11.9± 2.5***	8.3±1.1*
Lateral deviation	3.0±2.4	1.3± 1.4*	5.9± 1.2***	1.4± 1.2***	4.3± 2.8**	1.4±1.1***
Head width (cm)	12.6±1.2	13.9± 0.6***	11.7± 0.8**	11.7± 0.8***	13.2± 1.1**	11.8±0.6***