BIPARTITE HALLUCAL SESAMOID BONES: RELATIONSHIP WITH HALLUX VALGUS AND METATARSAL INDEX

ABSTRACT

Objective. To relate the incidence of the partition of the hallucal sesamoid bones with the size of the first metatarsal and the hallux valgus deformity.

Materials and Methods. In a sample of 474 radiographs, the frequency of appearance of bipartite sesamoids was studied. The length and relative protrusion of the first metatarsal, and the hallux abductus angle, were measured and compared between the feet with and without sesamoid partition.

Results. The results showed that 14.6% of the feet studied had at least one partite sesamoid, that the sesamoid most frequently divided was the medial, and that unilateral partition was the most common. No difference was found in the incidence of partite sesamoids between men and women, or between left and right feet.

Conclusion. Protrusion and length of the first metatarsal are higher in feet with partite sesamoids than in feet without this condition. A significantly higher incidence of bipartite medial sesamoid was obtained in feet with hallux valgus compared with normal feet.

KEYWORDS

Bipartite hallucal sesamoid bones, first metatarsal length, hallux valgus.

INTRODUCTION

The sesamoids are small bones of rounded or oval morphology that owe their name to their similarity to the seed of *Sesamun indicum*, a plant of eastern India used as a purgative by physicians of Ancient Greece. The bones are located completely or partially within a tendon, and although their anatomical location is usually the same, some sesamoids appear infrequently. There are sesamoids that always ossify, and others that remain in a cartilaginous or fibrocartilaginous state throughout life, so authors differ in reporting the frequency of appearance of particular sesamoids [1].

In the forefoot, two sesamoids are constantly found under the head of the first metatarsal. These sesamoids often develop from several ossification centres. When the fusion of these ossification centres is defective, partition of the sesamoids takes place [2]. The form and size of the segments of a partite sesamoid can vary considerably, and have been described previously [3].

Sometimes, the presence of bipartite sesamoids has been associated with a painful pathology of the great toe, but association between hallux valgus and bipartite sesamoids of the hallux has been reported on few occasions [4-7]. In 1992, Weil and Hill [4] carried out what is, as far as we know, the only existing study on the frequency of appearance of partite sesamoids in feet with and without hallux valgus. Occasionally, it has also been related with variations in the length of the first metatarsal — specifically, with the metatarsal formula “index plus” [7, 8]. We are unaware of any study in the medical literature that has been carried out until now with the aim of determining whether such relationship exists or not.

Hallux valgus has often been related with an increase in the length of the first metatarsal [9-15]. This leads to the notion that if the presence of bipartite sesamoids is related with the hallux valgus deformity, it might also be related with variations in the length of the first metatarsal.

This study has been designed with the aim of (1) testing whether the presence of bipartite sesamoids is greater in feet with hallux valgus than in normal feet; and (2)

determining whether its appearance is more frequent in “index plus” feet than in feet with another type of *metatarsal index*.

MATERIAL AND METHOD

The sample of this study comprised 474 feet (237 left and 237 right) belonging to 238 individuals (in two individuals, only one foot was X-rayed), of whom 99 were women and 139 men, with a mean age of 23.82 ± 2.68 years old. These subjects were patients attending the Clinical Podiatric Service at the University of Seville during the period 2003-2006 due to hallux valgus or some other problem of the rest foot (124 subjects), and podiatry students volunteering to take part in the research (114 subjects). Each subject was asked for written consent. The work was approved by the Experimentation Ethics Committee of the University of Seville.

Inclusion criteria were (1) to be in the third decade of life (20-30 years old), so that the growth physes had already closed [16-18], and to avoid degenerative alterations of the first metatarsal that could affect its length; (2) never to have undergone osteoarticular surgery on the first ray; (3) never to have suffered serious traumatisms to the first ray that could have altered its osseous morphology; and (4) not to suffer from degenerative osteoarticular diseases or neuromuscular imbalances.

In each individual, a weight-bearing dorsoplantar radiography was made with the two feet together, the ray centred between the naviculars of both feet, with the tube inclined 15º with respect to the vertical, and at a distance of one metre from the foot. The kilovolts and milliamps per second were fixed as indicated by the manufacturer (45 kV and 4.0 mAs). A digital image of each radiograph was created, using a scanner, enabling the exploration of images on positive film (EPSON EXPRESSION 1680 Pro®, Seiko Epson Corporation, Nagano, Japan). The radiographic measurements were made using the AutoCAD® software (Autodesk Inc, San Rafael, California), whose effectiveness for the measurement of radiographs has previously been demonstrated [19]. The following measurements were made: relative protrusion between the first and second metatarsals, to test whether the metatarsal formula is index plus, index minus, or index plus-minus [20]; length of the first metatarsal, to test whether, in the feet with

bipartite sesamoids, only the protrusion of the first metatarsal varies, or also the absolute length; hallux abductus angle, to compare it between feet with bipartite sesamoids and those not having them; and length of the second metatarsal, to enable expressing the length of the first metatarsal as a percentage of the length of the second. All measurements were made by the same observer (PVM), who also recorded the appearance of partite sesamoids. Intra-observer reliability of these radiographic measurements has previously been tested, and the high intra-class correlation coefficient obtained showed that it was acceptable [21-23].

The first metatarsal protrusion is not an absolute measurement but rather a measurement of the length of the first metatarsal relative to that of the second metatarsal. This metatarsal protrusion distance is a measurement between the two arcs that represent the first and second metatarsal lengths. The method used to measure relative metatarsal protrusion is that proposed by Hardy and Clapham [9]. This consisted of tracing a transverse line on the tarsus, joining the posterior end of the tubercle of the navicular and the lateral-distal end of the calcaneus. The point where the axis of the second metatarsal intersects this line was the centre of two arcs that pass through the most-distal points of the first and second metatarsal heads (figure 1). The relative protrusion between these two metatarsals was obtained measuring the distance between the two arcs. With the values for the protrusion of the first metatarsal, three groups were created in accord with the “metatarsal index” described by Nilsonne [20]: index plus-minus, if the protrusion of the first metatarsal was equal to that of the second, or differed by values not exceeding ± 0.5 millimetres; index plus, if the protrusion of the first metatarsal was greater than that of the second by more than 0.5 millimetres; and index minus, if the protrusion of the first metatarsal was less than that of the second by more than 0.5 millimetres.

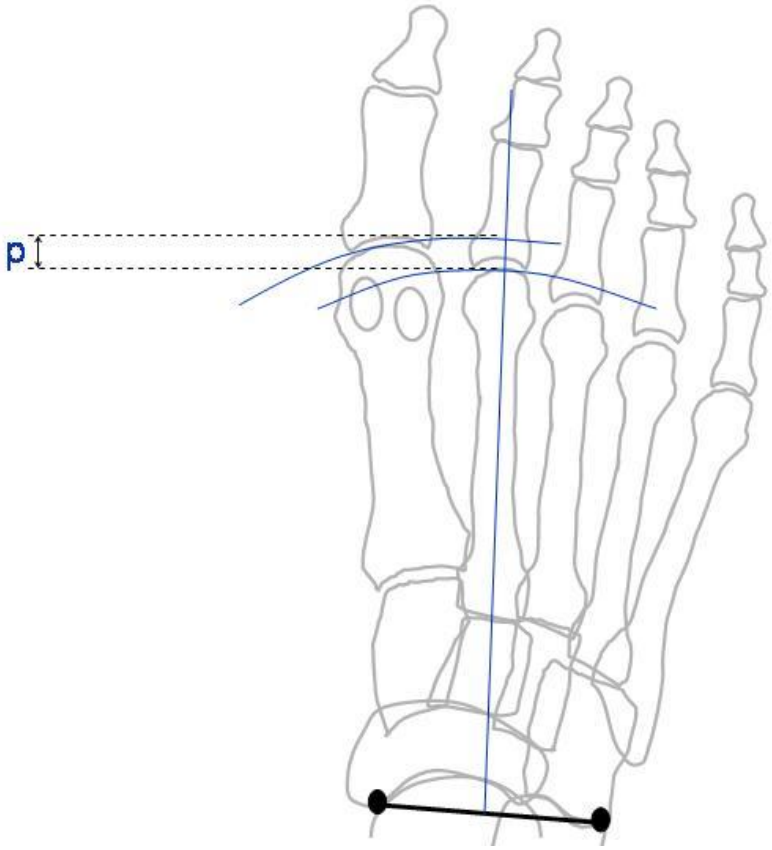

Figure 1

The method for measuring the length of the first and second metatarsals was that used by Heden and Sorto [10] in 1981 (figure 2). It consisted of determining the distance between the distal end of the metatarsal head and the bisection of its base. The point that those authors identified as bisection of the metatarsal base was the point of intersection of the longitudinal axis of the metatarsal with a line connecting the proximal-medial and proximal-lateral ends of the metatarsal base.

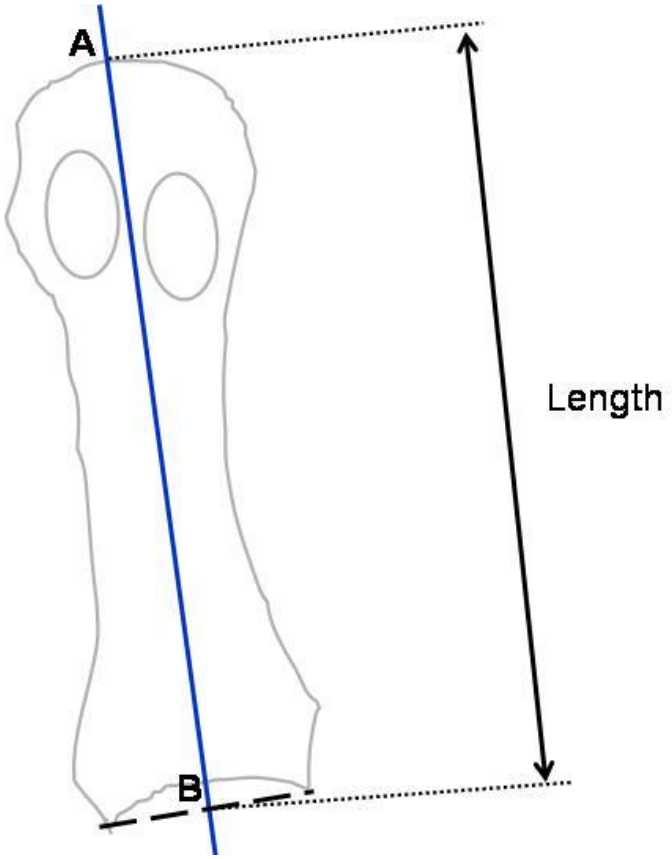

Figure 2

In order to standardise the measurement of the length of the first metatarsal, its value was expressed as a percentage of the total length of the second metatarsal. This procedure was previously carried out to the same end by other authors [13, 24]. The hallux abductus angle was measured in accord with the procedure described by Coughlin et al [25]. The values of this angle were used to create two groups: feet without hallux valgus, in which the hallux abductus angle was less than or equal to 15 degrees; and feet with hallux valgus, in which this angle exceeded 15 degrees [25].

The data were analysed with the SPSS 14.0 for Windows computer package (SPSS Science, Chicago, Illinois). A descriptive analysis was made of the frequency of appearance of bipartite sesamoids, their distribution by gender, the bilaterality, and the groups created. The descriptive analysis also yielded the mean, standard deviation, and 95% confidence interval for each radiographic measurement. The frequency of appearance of bipartite sesamoids was compared between the three types of “metatarsal index”, using the Chi-square test, comparing the groups two by two. The Chi-square test

was also used to compare the occurrence of bipartite sesamoids between feet with and those without hallux valgus, between men and women, and between left and right feet. In addition, the values for first metatarsal protrusion, length of the first metatarsal, and hallux abductus angle were compared between the feet that presented bipartite sesamoids and those that did not, using the student t test for independent samples. The use of this statistical test was decided on after checking that the data followed a normal distribution by the Kolmogorov-Smirnov test. P values below 0.05 were considered statistically significant.

RESULTS

Frequency of appearance and distribution of partite sesamoids

In the 474 feet studied, 76 partite sesamoids were observed. We found one foot with tripartite medial sesamoid, one foot with multipartite medial sesamoid, and one foot with tripartite lateral sesamoid. The remaining cases were all bipartite sesamoids. These results are shown in table 1. Comparison of the male feet in which there was at least one partite sesamoid with the female feet in which there was at least one partite sesamoid yielded a Pearson Chi-square value of 0.73, meaning there was no difference regarding the frequency of appearance of partite sesamoids between men and women.

With regard to the side affected, the sample studied was 237 left feet and 237 right feet. Twenty-eight medial sesamoids and 8 lateral sesamoids were found partite in left feet. Twenty-nine medial sesamoids and 8 laterals were found partite in right feet. There was no significant difference in the occurrence of partite sesamoids between left and right feet ($P = 0.90$).

Bipartite sesamoids according to the metatarsal index and the size of the first metatarsal

The descriptive values of the radiographic measurements made in all the subjects of the sample of this study are shown in table 2. According to the method used in this study to measure the protrusion of the first metatarsal, 71.5% of the feet were “index plus” type,

19.6% of the feet were “index minus” type, and 8.9% of the feet were “index plus-minus” type. The distribution of partite sesamoids according to the metatarsal index is shown in table 3. The results of comparing the frequency with which the feet of the three groups presented partition in any of the sesamoids are shown in table 4. The differences were not significant. In contrast, when comparing the values of the protrusion and the length of the first metatarsal between the feet that presented partite sesamoids and those that did not, significant differences were obtained. There was also a significant difference when these values were compared between the feet that presented partition in the medial sesamoid. However, the difference was not significant when comparing between feet that presented partition in the lateral sesamoid. The results of these comparisons can be seen in table 5.

Bipartite sesamoids in feet with and without hallux valgus

Of the 474 feet studied, 119 (25.1%) presented a hallux abductus angle greater than 15º, and 355 (74.9%) presented a hallux abductus angle equal to or less than 15º. The distribution of partite sesamoids according to the hallux abductus angle is shown in table 6. In three feet without hallux valgus and in one foot with hallux valgus, both the medial and the lateral sesamoid were partite. When comparing the frequency of partition in either of the two sesamoids between feet with and without hallux valgus using the Pearson Chi-square, the difference was significant ($P < 0.0001$). When comparing the frequency of partition in the medial sesamoid between feet with and without hallux valgus, the difference was also significant ($P < 0.0001$). However, when comparing the frequency of partition in the lateral sesamoid between feet with and without hallux valgus, there was no significant difference ($P = 0.99$). When comparing the hallux abductus angle values between the feet that presented partite sesamoids and those that did not, significant differences were obtained. The difference was also significant when these values were compared for the feet that presented partition in the medial sesamoid (figure 3). However, the difference was not significant when compared for the feet that presented partition in the lateral sesamoid. The results of this comparison can be seen in table 7.

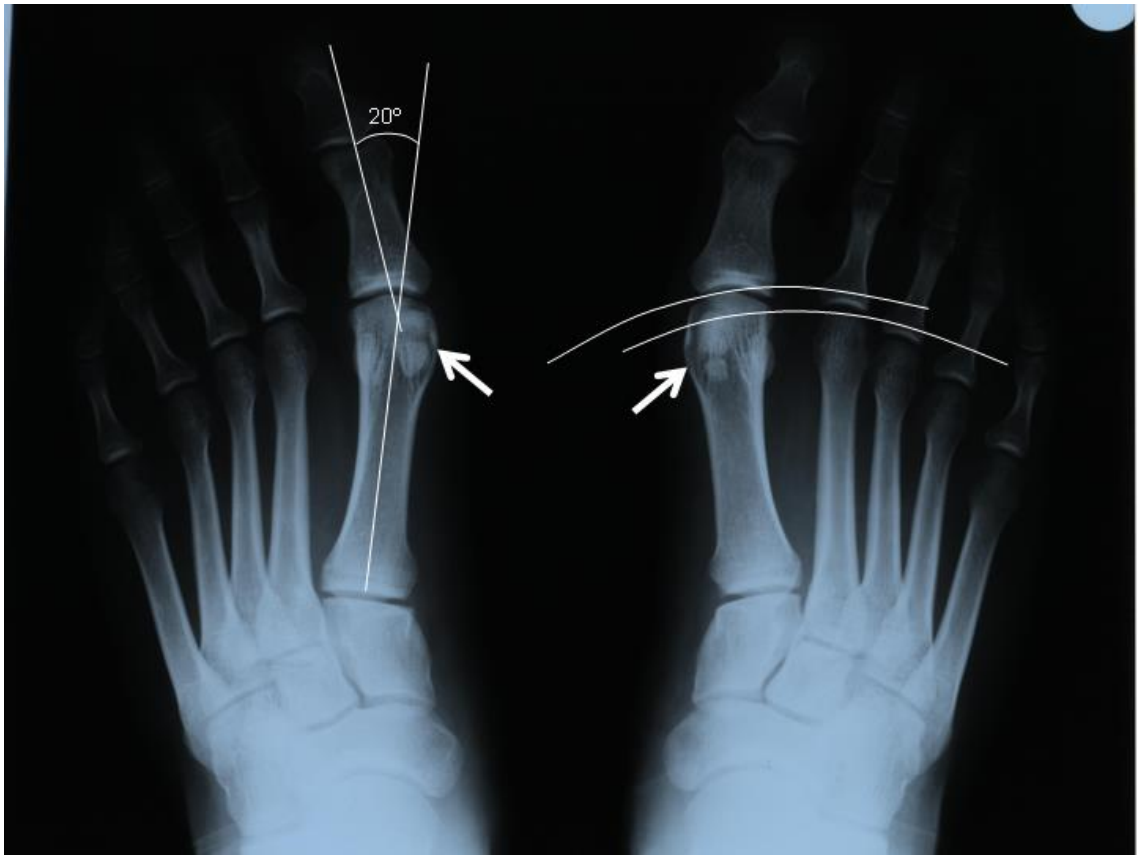

Figure 3

DISCUSSION

Intra-observer reliability of the measurement procedure has been tested by the authors in previous works [21-23]. In those studies, the reproducibility of the measurement procedure was checked by using five radiographs chosen at random from each group, and by making the measurements on three occasions, with intervals of a week between measurements. The data obtained were used to calculate the intra-class correlation coefficient, which was greater than 0.90 for these measurements. According to these data, the reproducibility of the measurements is acceptable with the methods used.

Frequency of appearance and distribution of partite sesamoids

Several earlier works have reported data on the frequency of partition in the sesamoids of the first metatarsophalangeal joint. The percentage can vary from 4% [26, 27] to 33.5% [28]. Our results regarding the frequency of appearance were closest to those of

Dobas and Silvers [29], who reported that 19.3% of the feet in their sample presented at least one partite sesamoid, and those of Inge and Ferguson [3], who reported a frequency of 10.7%. We observed that 15.2% of the feet in our sample presented at least one partite sesamoid. We coincide with all the authors consulted in that the sesamoid most frequently found partite was the medial [2-4, 8, 26-30]. Some authors attribute the cause to the fact that the medial sesamoid is more subject to trauma than is the lateral because of its location [3, 6, 28, 30], as in normal conditions the medial sesamoid is found more plantar than the lateral [31].

With regard to bilaterality, the literature contains different opinions. Some authors, such as García and Parkes [32] or Jahss [2], state that the most frequent circumstance is that the sesamoids are bilaterally partite, while others, such as Rodeo et al [30] or Inge and Ferguson [3], dissent, claiming that they are most frequently unilateral. Our results were more in concordance with the authors who assert that it is more frequent to find unilateral partitions. Specifically, these results were similar to those obtained by Dobas and Silvers [29], who reported 35.7% of bilaterality for the tibial sesamoid, and 4.3% of bilaterality for the peroneal sesamoid. Fifty-three of the subjects of our sample presented partite sesamoids, of whom 19 (34%) presented partite sesamoids bilaterally.

We have found few studies addressing the distribution of partite sesamoids between men and women. Rodeo et al [30] sustained that the incidence was equal for the two sexes. From the data of Dobas and Silvers [29], it can be extracted that 20.9% of the male feet and 17.1% of the female feet studied presented partition in one or more sesamoids. Although they did not make a statistical analysis to compare these values between men and women, we can see that the percentages are very similar. Carpintero et al [8], however, observed a significantly higher incidence of partite sesamoids in female feet than in male feet. The results of our study were in accord with those works that reported a similar incidence for the two sexes.

With regard to the side affected, we studied the same number of left and right feet, and found practically the same number of partite medial and lateral sesamoids in

the feet of both sides. This similarity in the distribution of partite sesamoids between left and right feet was also observed by Dobas and Silvers [29], and by Kiter et al [27].

Bipartite sesamoids according to the metatarsal index and the size of the first metatarsal

We found only one study relating partition of the sesamoids with the metatarsal index [8]. In that work, the authors reported a higher frequency of bipartite sesamoids in Egyptian- and "index plus"-type feet. In our sample, we observed that the percentage of "index plus"-type feet in which partite sesamoids appeared was higher than for "index minus"- or "index plus-minus"-type feet. However, the Chi-square test did not show significant differences in the frequency of appearance of partite sesamoids between the three groups. In contrast, the group of feet with partite sesamoids showed greater length and greater protrusion of the first metatarsal. Carpintero et al [8] attributed this higher incidence of bipartite sesamoids in "index plus"-type feet to the increase in pressure that a longer first metatarsal exerts on the sesamoids.

The sesamoids appear where tendons change their direction, and in these zones they protect the tendon and give it mechanical support. The hallucal sesamoids, besides protecting the tendon of the flexor hallucis longus, give mechanical support to the intrinsic musculature inserted partially in them, so that the vector of plantar force is greater on the hallux, helping to stabilise the hallux on the ground during the push-off phase [33]. It is possible that the plantar intrinsic musculature of the hallux exerts greater traction on the sesamoids by passing under a metatarsal that is longer and has more protrusion. If the tension received in the sesamoids were sufficient to fragment the ossification centre and divide it in two (or more) nuclei, the subsequent ossification of these separate centres would give rise to partition of the sesamoid. It is thought that the defective fusion of various centres of ossification is the cause of partition in the sesamoids [2, 3, 26]. Further research would be necessary regarding how the size of the first metatarsal could affect partition of the sesamoids

Bipartite sesamoids in feet with and without hallux valgus

Apart from Weil and Hill [4], who specifically related the hallux valgus deformity with the presence of bipartite sesamoids, few authors have reported the presence of partite sesamoids in feet with this deformity [5-7]. Weil and Hill [4], in a retrospective radiographic study, detected that 32.3% of the studied 500 feet with hallux valgus had the tibial sesamoid bipartite, against 15.2% of the 500 feet without hallux valgus in their sample. The authors concluded that there was a high incidence of bipartism in hallux valgus, and that it could be a contributory factor in the development of this deformity. In our study, the incidence of partite sesamoids was higher in feet with hallux valgus than in normal feet. The Chi-square test showed that this was a significant difference. The incidence of partition in the feet with hallux valgus approached that reported by Weil and Hill [4]. Furthermore, comparison of the hallux abductus angle between the group of feet in which there was partition of one or more sesamoids and the group of feet without such partition showed a statistically significant difference ($P < 0.0001$). However, the two comparisons made in this section of the study (Chi-square and t student) showed no significant difference when this comparison was limited to a bipartite lateral sesamoid. This suggests that the differences observed involve the medial sesamoid specifically.

Although it has been demonstrated that there is a higher incidence of partition of the medial sesamoid in feet with hallux valgus, it is not clear whether the partition occurs as a result of the deformity or, contrarily, the development of the deformity is furthered by the presence of a partite sesamoid. Assuming the following hypotheses, it is deduced that the medial sesamoid is divided as a consequence of the hallux valgus deformity: it is known that in the advanced hallux valgus deformity, the medial sesamoid takes on a more-plantar position and falls below the intersesamoid plantar crest of the first metatarsal, which ends up eroding it [26, 34]. This would result in excessive trauma and stress in the medial sesamoid, which could cause the partition of the sesamoid if such stress fragments the ossification centre and the resulting nuclei do not fuse. It is also known that the abductor hallucis muscle produces more flexion than abduction when the hallux rotates in valgus as the deformity advances [7, 35]. This would increase the antero-posterior tension received by the medial sesamoid, and could contribute to the transverse division of the medial sesamoid before it ossifies.

Weil and Hill [4] claimed that a bipartite medial sesamoid could contribute to the development of the hallux valgus deformity. They asserted that when there is a transverse separation of the sesamoid, a mechanical lengthening of the musculature takes place on the medial side of the metatarsophalangeal joint, creating the tendency towards hallux abductus. However, Aper et al [33, 36] demonstrated that excision of the distal half of the medial sesamoid did not compromise the normal working of the flexor musculature of the hallux.

Whether partition of the medial sesamoid promotes hallux valgus, or hallux valgus promotes partition of the medial sesamoid, remains unknown. What is put forward by the authors in this section of the work is no more than hypothesis. A study comparing the incidence of partite tibial sesamoid between feet in which hallux valgus has begun before sesamoid ossification starts, and feet in which hallux valgus has appeared after ossification of the sesamoids, would help to resolve this question.

CONCLUSION

In the sample studied in this work, partition of the hallucal sesamoids affected men and women, and the left and right sides, equally, and was more frequent unilaterally. The feet presenting partition of one or more sesamoids had greater protrusion and greater length of the first metatarsal than the feet without partite sesamoids. A significantly higher incidence of partition of the medial sesamoid was observed in the feet with hallux valgus than in the feet without hallux valgus. However, it remains unknown whether the partition of the medial sesamoid is the cause or the consequence of this deformity.

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Table 1

Frequency of appearance and distribution of partite sesamoids.

	Subjects (238)		**Feet (474)**		**Total amount**	
	Male (139)	Female (99)	Male (277)	Female (197)	Medial	Lateral
Medial unilateral	8	14	8	14	22	-
Medial bilateral	8	8	16	16	32	-
Lateral unilateral	8	2	8	2	-	10
Lateral bilateral	1	0	2	0	-	2
Both unilateral	2	0	2	0	2	2
Both bilateral	1	0	2	0	2	2
Medial unilateral in one foot, and lateral unilateral in the other foot	1	0	2	0	1	1
					59	17
Total	29	24	40	32		

Table 2

Mean, standard deviation, and 95% confidence interval, of the radiographic variables measured.

	Mean ± SD	**95 % CI**
Hallux abductus angle (degrees)	12.4 ± 6.8	11.8 – 13.1
First metatarsal length (%)	85.2 ± 3.0	84.9 – 85.4
First metatarsal protrusion (mm)	2.2 ± 3.0	1.9 - 2.5

Table 3

Distribution of partite sesamoids according to the metatarsal index

	Feet with partite sesamoids	**Partite sesamoids**		**Total**
		Medial	Lateral	
Index Plus	56 of 339 (16.5%)	46	13	59 (80.8%)
Index Minus	9 of 93 (9.7%)	8	1	9 (12.3%)
Index Plus-Minus	4 of 42 (9.5%)	3	2	5 (6.9%)
Total	69 of 474 (14.6%)	57	16	73 (100%)

Table 4

Pearson Chi-square to compare the frequency of appearance of partite sesamoids between the three groups created according to the protrusion of the first metatarsal.

	P value
Index Plus vs **Index Minus**	0.11
Index Plus vs **Index Plus-Minus**	0.24
Index Minus vs **Index Minus**	0.98

Table 5

Comparison of the protrusion and length of the first metatarsal between feet presenting one or more partite sesamoids and those not, between feet presenting partite medial sesamoid and those not, and between feet presenting partite lateral sesamoid and those not.

	Mean ± SD	**Mean ± SD**	**P**
One or more partite sesamoids		No partition	
First metatarsal protrusion	3.4 ± 3.1 mm	1.9 ± 3.0 mm	< 0.0001*
First metatarsal length	86.1 ± 3.5 %	85.0 ± 2.8 %	0.006*
Medial sesamoid partition		No partition	
First metatarsal protrusion	3.3 ± 3.2 mm	2.0 ± 3.0 mm	0.003*
First metatarsal length	86.1 ± 3.5 %	85.0 ± 2.8 %	0.009*
Lateral sesamoid partition		No partition	
First metatarsal protrusion	3.3 ± 2.4 mm	2.1 ± 3.3 mm	0.122
First metatarsal length	85.4 ± 3.2 %	85.1 ± 2.9 %	0.739

* Significant difference

Table 6

Distribution of partite sesamoids according to the hallux abductus angle.

	Feet with partite sesamoids	**Partite sesamoids**		**Total**
		Medial	Lateral	
HAA > 15º	35 of 119 (29.4%)	32	4	36
HAA < 15º	34 of 355 (9.6%)	25	12	37
Total	69 of 474 (14.6%)	57	16	73

HAA: hallux abductus angle

Table 7

Comparison of the hallux abductus angle between feet presenting one or more partite sesamoids and those not, between feet presenting partite medial sesamoid and those not, and between feet presenting partite lateral sesamoid and those not.

	Mean ± SD	**Mean ± SD**	**P**
One or more partite sesamoids		No partition	
Hallux abductus angle	16.0 ± 6.8 º	11.8 ± 6.6 º	< 0.0001*
Medial sesamoid partition		No partition	
Hallux abductus angle	16.7 ± 6.8 º	11.8 ± 6.6 º	< 0.0001*
Lateral sesamoid partition		No partition	
Hallux abductus angle	12.4 ± 5.1 º	12.4 ± 6.8 º	1.00

* Significant difference

FIGURE LEGEND

Figure 1. Method of measuring the relative metatarsal protrusion between the first and second metatarsals, according to Hardy and Clapham [9]. p: protrusion.

Figure 2. Method of measuring the first metatarsal length. A: Distal end of the first metatarsal head. B: Point of intersection of the first metatarsal longitudinal axis with a line connecting the proximal-medial and proximal-lateral ends of the metatarsal base.

Figure 3. Bilateral bipartite medial sesamoid in a subject with bilateral index plus and hallux valgus. Hallux abductus angle value is represented in the right foot. Index plus is represented in the left foot. Arrows: bipartite medial sesamoid.