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Medial and lateral exostoses of the distal phalanx of the hallux: A potentially painful *bunion-like* structure. Part 1: Incidence and clinical application

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ABSTRACT

Background: Exostoses at the base of the distal phalanx of the great toe are usually asymptomatic. The literature has not generally considered them as the origin of a possible problem resulting from a pressure conflict between hallux and shoe (medial aspect) or second toe (lateral aspect) nor a potential complication of surgical correction of hallux valgus deformity. No studies, to our knowledge, have evaluated its possible correlation with other foot disorders. When one of these neglected exostoses became painful after surgical correction of hallux valgus, we decided to start a study to determine their possible origin, prevalence in daily practice and histo-pathological morphology.
Methods: Two hundred and fifty-four feet of patients (average age 41.7 y.) were enrolled in the study from January 2007 to June 2009. Dorsoplantar weight-bearing radiographs were used to analyze the presence of exostoses and their correlation with the distal phalanx morphology, metatarsal formula (or transverse plane orientation of the metatarsal heads parabola) and hallux valgus angles. Patients were classified according to their age and main symptom for consultation. Four exostoses removed from cadaver feet were also analyzed microscopically.
Results: Osseous excrescences arising on the medial or lateral aspect at the proximal part of the terminal phalanx of the hallux were observed in 132 feet (51.9%). Thirty-five feet out of these 132 (13.7%) had exostoses on both sides of the phalanx.A statistically significant positive correlation was found between the presence of a medial exostosis of the phalanx and the severity of HVA. Patients with higher IPH and asymmetry angles have a lower prevalence of medial exostoses ($p < 0.05$). Amongst the different morphologies of the second phalanx, exostoses were most likely found in the standard form.
Conclusions: Prevalence of exostoses at the base of the distal phalanx is high (51.9% of the studied feet). Histological findings would suggest that these exostoses could be considered a mechanical reactive process, produced by a chronic irritation by shoes. We encourage surgeons to be aware of its potential clinical implications. Direct resection is very simple and the most appropriate treatment for symptomatic cases.

1. Introduction

Exostoses are isolated bony prominences that can appear in every part of the skeleton and are consistent with diverse clinical and radiologic conditions [1,2]. Toes and especially the distal phalanx (Ph2) of the great toe are a common location.

Differential diagnosis of a Ph2 exostosis includes subungual exostosis, osteochondroma, subungual verruca, granuloma pyogenicum, glomus tumor, nail bed carcinoma, melanotic whitlow, enchondroma, and ingrown toenail among others [3].

The most well-known symptomatic prominence of the distal phalanx is the subungueal exostosis. This is an outgrowth of normal bone tissue (sometime covered by a thin cartilaginous sheet) which causes firm swelling below the nail and develops during adolescence. The pathogenesis is not clearly understood, as there are many factors involved, including: trauma, chronic infection, tumor and hereditary abnormality. Subungueal prominences have a very low prevalence in general population [1].

In our daily practice, when paying attention to patient's radiographs, we have observed a surprisingly high prevalence of exostoses at the medial or lateral aspects of the distal phalanx of the hallux. Although they are common, they often go unrecognized. They protrude from the medial or lateral aspects of the base of the distal phalanx, just distal to the medial and lateral tubercle;

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sometimes, rather than a real bony prominence on the lateral side, the epiphyseal lateral part is itself prominent. This osseous outgrowth has been described as a normal variant that rarely results in clinical symptoms [4], or as a possible effect of trauma [5]. Winter et al. [6] described in 1989 an interosseous supporting ligament running from between the phalangeal tuft and the proximal metaphyseal flare in a number of cadaver great toes. The ligament indicated the limit between the plantar pulp and the dorsal compartment of the phalanx but it was not connected to any other soft tissues and its functional role was never clarified. Carmona et al. [7] classified these exostoses as a type IV exostosis and Lelièvre in 1967 described its resection using a direct approach when symptomatic [8].

After encountering several symptomatic exostoses on the base of the distal phalanx in clinical practice (5 of which required surgery and will be reported in the second part of this manuscript as part of a multicentric study), and reviewing the literature, we realized that there is a real sparseness of information regarding the prevalence of lateral or medial exostoses and their potential clinical implications. We have only found one formal study on the incidence and origin of these exostoses [9], and one case report of a bony prominence on the base of the distal phalanx that became symptomatic after surgical correction of hallux valgus, published by our senior author [10]. Although readers might find the clinical relevance of these Ph2 exostoses modest, we decided to study them from a morphological point of view in order to compare our data with the one reported by Lee et al. in 1992 [9] and fill the void of information concerning the second phalanx morphology and its possible correlation with other foot disorders, hallux angles and Ph2 shape.

2. Patients/materials and methods

We performed a retrospective study of 254 feet of patients who came to our clinic between January 2007 and June 2009, selected using a consecutive sampling technique. Our inclusion criteria included: patients aged 2–81 years (mean 41.7 years), with a dorsoplantar weight-bearing foot radiograph of one foot and no pain or symptoms specifically on the distal phalanx of the hallux. Exclusion criteria were deforming arthritis, previous foot surgery or neurological disease. Out of the 254 feet, 197 were right and 57 were left. Eighty-six patient were men (26.7%) and 168 were women (73.3%).

We used dorsoplantar weight-bearing radiographs that were taken with the X-ray beam tilted at 20° to the vertical in the sagittal plane at a distance of 100 cm, directed vertical to the cassette in the coronal plane, and centered in the middle of the third metatarsal.

The hallux valgus angle (HVA), the intermetatarsal angle (IMA), the distal metatarsal articular angle (DMAA), the proximal articular set angle (PASA) and the interphalangeal angle (IPH) were measured according to standard guidelines by the same examiner [11,12] (Fig. 1).

Asymmetry angle of Ph2 (AF2) is defined, by Sorto et al. [13] as the angular relationship between the articular surface of the base of the distal phalanx and its longitudinal bisection (Fig. 1) and its longitudinal bisection. Metatarsal formula – or coronal plane alignment of the metatarsal heads – was evaluated too as described by Viladot [14,15].

Patients were also divided into six groups depending on their main symptoms leading to consultation: hallux valgus (HV), hallux rigidus (HR), metatarsalgia, trauma, flat foot and others (tendinitis, hammer toes . . .).

The morphology of the distal phalanx of the hallux was classified in three groups (Fig. 2a–c):

Longitudinal (Fig. 2a): This group corresponds to those phalanges with a disproportionate long diaphysis regarding the rest of structures. The distal tuberosity is slimmed following the shaft.

Pyramidal (Fig. 2b): Corresponding to phalanges with a wide base and a slim shaft that becomes progressively narrower and finishes in a small distal tuberosity. This morphology does not allow clear discrimination of the base of the shaft and distal tuberosity.

Standard (Fig. 2c): Corresponding to phalanges described on anatomical classic texts, with a clear wide base, followed by a short shaft and finishing on the distal ungual tuberosity.

We furthermore divided the sample in three groups: patients sixteen years old or younger with opened physis (77 patients 30.3%), patients between sixteen and sixty years old (103 patients 40.5%) and finally patients aged sixty or older with arthritic changes (74 cases, 29.2%)

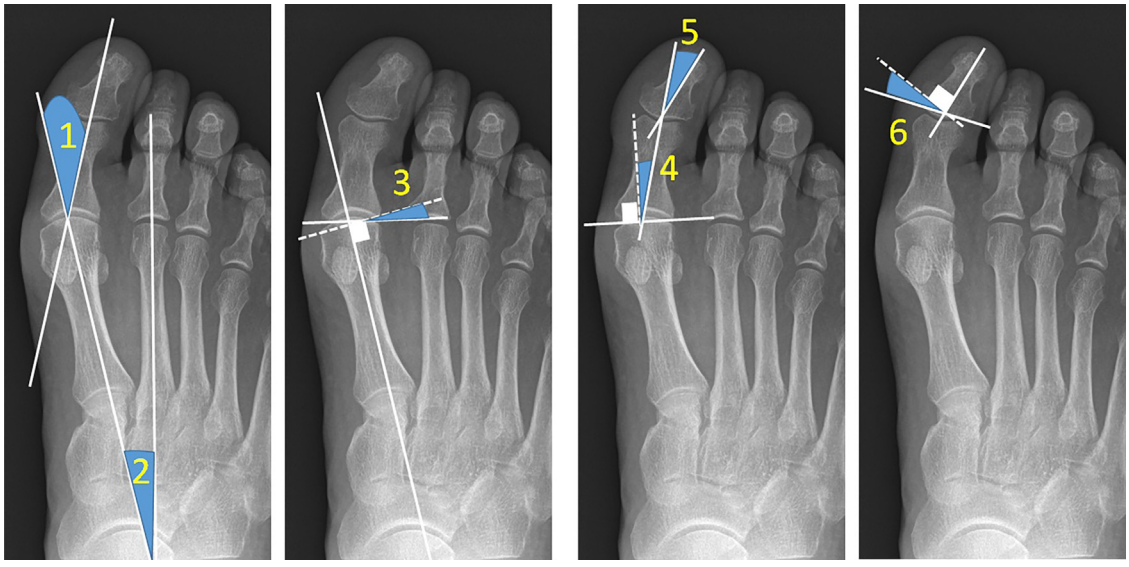

Fig. 1. (1) Hallux valgus angle (HVA). (2) Intermetatarsal angle (IMA). (3) Distal metatarsal articular angle (DMAA). (4) Proximal articular set angle (PASA). (5) Interphalangeal angle (IPH). (6) Asymmetry (AF2).

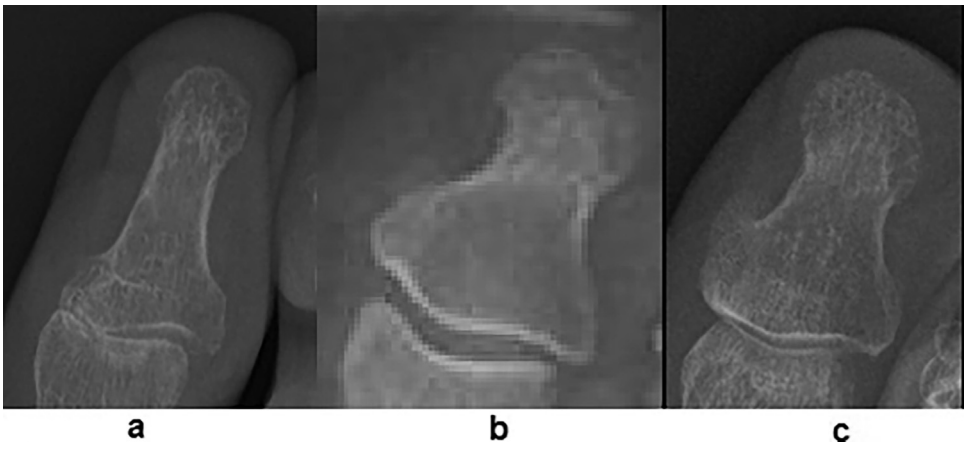

Fig. 2. Morphology of the distal phalanx of the hallux classified in three groups.
Longitudinal (a): This group corresponds to those phalanges with a long diaphysis, disproportionate with regard to the rest of structures. The distal tuberosity is slimmed following the diaphysis.
Pyramidal (b): Corresponding to phalanges with a wide base and a slim diaphysis that becomes progressively narrower and finishes in a small distal tuberosity. This morphology does not allow clear discrimination of the base of the diaphysis and distal tuberosity.
Standard (c): Corresponding to phalanges described on anatomical classic texts, with a clear wide base, followed by the diaphysis and finishing on the distal ungual tuberosity.

We described the presence or absence of an exostosis at the base of the distal phalanx (medial or lateral) and their correlation with the other measurements (Fig. 3).

Given that the microscopic analysis of the bone paste resulting from the percutaneous resection (usual surgical technique) of these exostoses is not valid, an anatomical and histological parallel examination of the bony outgrowths of four cadaveric feet from multiorgan donors was performed using hematoxylin and eosin stain. Dorsoplantar radiographs were taken to select 4 donors with these exostoses and perform this anatomical and histological examination.

Statistical analysis was performed using SPSS 11.0 for Windows. Independent-samples T-test was used to compare the mean angles between two groups and ANOVA when there were more than two groups. Chi-squared test was used to do proportion analysis. Simple linear regression was used to evaluate the influence of constant variables (angles) and Logistic Regression for dichotomous variables (presence of exostoses).

The $p < 0.05$ was considered to indicate statistical significance.

3. Results

The patients' main reasons for consultation were trauma with 47 feet (18.4%), hallux valgus in 85 feet (33.5%), hallux rigidus in 21 (8.2%), flat foot in 46 (18.2%), metatarsalgia in 33 (13%) and others in 22 patients (8.6%).

The mean HVA was 20.0° (18.6–21.4), the mean IMA was 9.8° (9.3–10.3), DMAA was 5.4° (4.9–5.3). PASA was 5.62 (5.2–6.0), IPH was 11.4° (10.8–12.1) and AF2 was 7.9° (7.4–8.4) (76.9% of IPH).

The most frequent metatarsal formula was index plus-minus (106 feet, 41.7%), followed by index-minus (89 feet, 35%) and index-plus formula (59 feet, 23.2%).

Fig. 3. Exostosis at the medial side of the base of the distal phalanx.

Table 1
Shows a demographic description of the population we studied, the main reasons for consultation, the mean angles measured, metatarsal formula, phalanx morphology and the presence of medial and lateral exostoses.

		Women	Men	Total
Age	–	47.73	29.97 years	41.7 years
Sex	–	168 (73.3%)	86 (26.7%)	254
Groups	≤16 years	30 (38.9%)	47 (61.1%)	77 (30.3%)
	>16 < 60 years	72 (69.9%)	31 (30.9%)	103 (40.5%)
	≥60 years	24 (32.5)	50 (67.5%)	74 (29.2%)
Consultation	Trauma	23 (13.69%)	24 (27.9%)	47 (18.4%)
	HV	72 (42.86%)	13 (15.2%)	85 (33.5%)
	HR	17 (10.12%)	4 (4.65%)	21 (8.2%)
	Pes Planus	18 (10.71%)	28 (32.56%)	46 (18.2%)
	Metatarsalgia	24 (14.29%)	9 (10.47%)	33 (13%)
	Other	14 (8.33%)	8 (9.3%)	22 (8.6%)
Angles	HVA	22.23°	15.68°	20.01°
	IMA	10.36°	8.77°	9.83°
	DMAA	5.88°	5.1°	5.42°
	PASA	5.75°	4.79°	5.62°
	IPH	10.72°	12.97°	11.48°
	Asymmetry	7.57°	8.72°	7.46°
Metatarsal formula	Index plus	24 (40.6%)	35 (59.4%)	59 (23.2%)
	Index minus	42 (47.1%)	47 (52.9%)	89 (35%)
	Index plus-minus	57 (53.7%)	49 (46.3%)	106 (41.8%)
Phalanx morphology	Standard	121 (47.6%)	61 (24%)	182 (71.6%)
	Longitudinal	30 (11.9%)	14 (5.5%)	41 (16.2%)
	Pyramidal	17 (6.6%)	11 (4.3%)	31 (12.2%)
Medial exostosis	Yes	96	36	132
	No	72	50	122
Lateral exostosis	Yes	26	9	35
	No	142	77	219

Regarding morphology, 182 phalanges presented a standard morphology, 31 phalanges were pyramidal and 41 of them a longitudinal form (Table 1).

An osseous excrescence arising on the medial aspect of the terminal phalanx of the hallux was a common finding, observed in 132 feet (51.9%) and not seen in 122 (48.1%). Radiographs of patients under sixteen exceptionally disclosed a medial exostosis (1 case). Feet from the adult group presented a bony prominence on the medial side in 80% of the second phalanges (Ph2) and the group of over 60 had a medial exostosis in 65%. Such differences were statically significant ($p < 0.05$). This difference amongst groups is probably due to the inconsistency in the men:women ratio and the uneven prevalence of HV throughout the 3 groups.

Our results showed a higher prevalence of medial exostoses on distal phalanx of the hallux in patients complaining about HV — 44% of the patients with a medial exostosis had HV ($p < 0.05$). Although, there was a statistically significant positive correlation between the presence of medial exostoses and the HVA alone ($p < 0.05$), no correlation was found between the presence of medial exostoses and the DMAA, PASA, IMA which also grade the severity of the HV.

IPH and Asymmetry angles displayed an inverse correlation with the prevalence of medial exostoses. Larger mean IPH and Asymmetry angles had a lower prevalence of these bony outgrowths ($p < 0.05$) and feet with smaller IPH and Asymmetry angles had higher medial exostoses prevalence.

Statistically high prevalence of medial exostoses was found (Chi^2 13.1, $p < 0.05$) in the standard morphology of the distal phalanx.

On the lateral side, epiphyseal bony excrescences were observed in only 35 feet (13.7%) and were not seen in 219 cases (86.3%). Lateral exostoses always appeared associated to medial exostoses in our patients. We did not find isolated lateral exostoses in any feet.

No differences were found between index metatarsal formula or the motive of consultation and the presence of Ph2 exostosis.

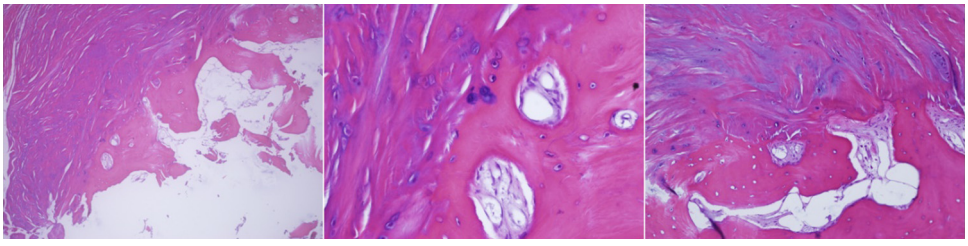

Fig. 4. Microscopy of exostosis (hematoxylin and eosin): normal cancellous bone with a thin layer of cortical bone. There is no cartilage cap on the surface. Blood vessels with endothelium and a muscular layer are observed within the trabecular bone, close to its surface. No inflammatory cells or changes were found.

In the microscopic report, exostoses were reported as normal cancellous bone with a thin layer of cortical bone. No cartilage cap was identified in the surface of any of the studied prominence. Blood vessels with endothelium and a muscular layer were observed within the trabecular bone, close to its surface. These vessels were surrounded by fibrofatty tissue and many of them were observed within the periosteum in reactive periosteal areas. No inflammatory cells or changes were found and no signs of neoplasia were present. The histologic findings were interpreted as reactive changes (Fig. 4). On anatomical macroscopic examination of the few great toes we dissected (only 4 in total), we did not find the lateral supporting ligament reported by Winter et al. [6] therefore we cannot theorize about its role in the Ph2 exostoses development.

4. Discussion

Following our clinical experience on problems caused by these exostoses at the base of the distal phalanx, that has already been published [10], we decided to pay more attention to their presence in daily practice. Owing to a lack of reports regarding this entity in the literature [4,7,8] we started to study its prevalence and possible origins more in depth to better understand the morphology of the second phalanx of the hallux.

Keats [4] described exostoses as a "normal variant" but our results showed a high prevalence (51%) of this medial exostosis in patients in our daily practice. Its absence in young patients, under sixteen, and its presence after the closure of the adjacent physis can serve as a guideline regarding the timeline of their development. We found a single case of a foot with an exostosis at the medial side with open physis (Fig. 5).

Fig. 5. Foot with open physis and exostosis at the medial side of the distal phalanx.

The high prevalence of exostoses and our histological findings exclude the presence of a tumor; its position discards an enthesophyte because there are no insertions of ligament or tendons or joint capsule in this area [16]. We did not find the lateral supporting ligament reported by Winter et al. [6] on our 4 anatomical macroscopic examinations, therefore we cannot assume nor reject any possible influence of this ligament on the development of the phalangeal exostoses. However, it seems unlikely that if the ligament is not attached to any other structures that can cause movement or tension it can cause an enthesophyte.

Histologically exostoses were identified as reactive bone, so we conclude that this bony prominence is probably caused by the reaction of normal bone against repeated compressive forces by the shoes or repetitive trauma as suggested by Wu [5]. It can be interpreted as a mechanical reactive process, produced by a chronic irritation of the periosteum with a variable amount of bone outgrowth in both margins of the phalanx, more frequently in the medial side.

Although the different proportion of males and females and right and left feet analyzed can appear unbalanced, it was a result of using a consecutive sampling technique to select our patients. We were only looking to do a descriptive study of the prevalence of these bony outgrowths in our population and therefore did not aim to obtain balanced groups. Despite this unbalance, this prominence was found to be more common in females than in males. One of the reasons could be that women's main complaint in our consultation were HV problems (42.8%), with larger HVA.

Although our selected cohort may form a selection bias because all the patients presented with some kind of foot symptoms, we were careful to select only those patients with no symptoms associated explicitly to the distal phalanx of the hallux to minimize bias and, therefore, be able to perform an incidence study of these bony prominences in asymptomatic patients.

We are uncertain why there is a higher prevalence of medial exostoses on Ph2 of the hallux in patients complaining about HV ($p < 0.05$) with larger HVA alone ($p < 0.05$) but no direct correlation with the DMAA, PASA, IMA which also grade the severity of the HV. This could mean that there is no real correlation between the severity of the HV and the presence of medial exostoses. However, maybe the occidental culture of footwear, which would lead to a higher prevalence of HV due to the shape of the shoes [17,18], could at the same time produce a greater pressure against the medial aspect of the Ph2 base. Nevertheless, this is only a theory and we have no proof supporting this statement.

The inverse relationship found between IPH, Asymmetry and the presence of exostoses ($p < 0.05$) would be possibly due to a higher distance of phalanx from shoe friction. Additionally, we would like to mention that naming the lateral deviation of the phalanx asymmetry is not very accurate because it does not represent a real asymmetry but a tilt from the longitudinal axis. Therefore, we suggest it should be referred to as tilting angle.

Our study is not accurate enough to determine a useful etiological correlation. However, this was never our goal. We were only attempting to establish the prevalence of these bony outgrowths in asymptomatic patients. Although the fact is that we have already encountered several symptomatic ones (that will be reported in further studies) and the only plausible reason that we can found for them becoming symptomatic is the result of narrow shoes causing friction along the medial aspect of the hallux, resulting on a hypertrophic painful medial epicondyle at the base of the distal phalanx (Fig. 6).

These possible etiological factors in conjunction with the histological results, the lack of focal symptoms and the absence of trauma suggested that repetitive forces occurring during

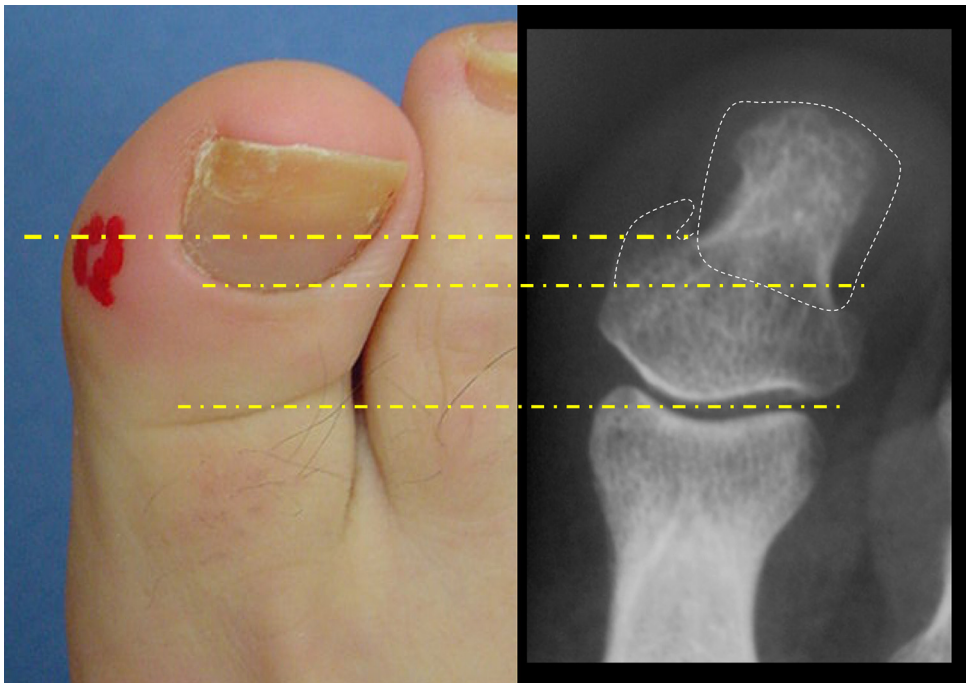

Fig. 6. Symptomatic medial exostosis that caused pain in the area marked in red due to friction with the medial aspect of the shoe.

ambulation (like shoe pressure) would induce the reactive bone formation, rather than an acute injury. Patients with HV – especially women – are always more influenced by shoe pressure in the base of the phalanx than hallux with interphalangeal HV.

The high prevalence indirectly implies that it is not specific of any particular foot morphology as inferred from the lack of a direct statistical significance found between a particular type of foot, morphology of the distal phalanx and the presence of this kind of exostosis.

Although our results seem to prove that the existence of bony prominences is common (51.9% of studied feet) at the base of the Ph2 of the great toe, the paucity of published papers implies that it goes unrecognized. The low incidence of clinical consequences may be because it only becomes symptomatic in association with certain HV angles, type of foot and phalanx. In patients with no HV deformity and a "square" digital formula a pressure conflict can arise between toe space and a triangular shaped shoe. Further studies would be needed to determine when exostoses become symptomatic.

We think that the possible impact of these exostoses in foot surgery is underestimated. After having some problems with them we encourage surgeons to be aware of their potential clinical significance. HV surgery sometimes leads to overcorrection of the position of the toe trying to find better cosmetic results. Overcorrection of the interphalangeal angle, could lead to a clinically relevant prominence of a pre-existing exostosis due to pressure on the exostosis by the shoe [9]. We encourage surgeons to consider excision of this bony prominence when we suspect that it can cause symptoms. The suggested treatment consists of direct percutaneous resection, but other techniques described by García et al. [7] and Lelièvre [8] could be used.

Lastly, we have not found may references to these bony outgrowths of Ph2, and amongst the ones we have found half of them were published before 1989. Consequently, it seems that knowledge is being lost because there are not many references to these bony excrescences in current papers. The purpose of this paper is to draw attention to these exostoses and encourage surgeons to look for them in symptomatic cases, despite their modest clinical relevance.

In conclusion, exostoses are a common finding. They are more frequent on the medial aspects of the great toe distal phalanx and may be a normal anatomical variant probably caused by chronic irritation of footwear. These bony prominences may represent a clinical problem by themselves and could be a possible cause of complication after HV surgery. We should consider prophylactic or direct resection when they are symptomatic.

Financial disclosure

None reported.

Conflict of interest

None reported.

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