

# Hallux Valgus among an 18th Century Population of the Canary Islands

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**ABSTRACT** Hallux valgus is defined as the lateral deviation of the great toe. It is considered a disease mainly related to the use of boots or shoes that constrict the foot. This process usually ensues along many years and is accompanied by changes at the metatarsophalangeal joint, which serve to make the diagnosis on bare bones. Diagnostic criteria include lateral deviation of the metatarsophalangeal joint (1), lateral subluxation of the first phalanx, degenerative changes of the sesamoid articular facets, and exostosis or remodelling of the medial tuberosity. Following other authors, we have defined hallux valgus as the presence of (1) and any of the other three criteria. In a series of the 18th century burials from the church La Concepción, in Tenerife, Canary Islands, we found 35 cases of hallux valgus out of the 117 cases for which necessary data for the diagnosis could be recorded (29.91%). A significant association was found between changes in the left toe and burial site near the altar, where priests and other people of the high social status were interred. Copyright © 2012 John Wiley & Sons, Ltd.

*Key words:* bare bones; Canary Islands; 18th century; footwear; hallux valgus; paleopathology

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## Introduction

Hallux valgus is defined as the lateral deviation of the great toe. It is mainly related to the use of footwear that constricts the toes. Although possibly influenced by genetic factors (Coughlin, 1995), it is uncommon in unshod populations (Coughlin, 1984; Sim-Fook & Hodgson, 1958). In developed countries, or in those that adopted Western footwear (Kato & Watanabe, 1981), it is more frequently observed in women, even at a young age (Houghton & Dickson, 1979), especially among those who usually wear narrow pointed shoes with narrow, pointed toes (Al-Addulwahab & Al-Dosry, 2000). The diagnosis of hallux valgus in the living individual is readily performed by plain X-ray film or by mere inspection of the toes. Because the first metatarsal bone (which becomes medially deviated) and the first phalanx (which suffers a lateral deviation) are not normally aligned, measurement of the angle formed by the intersection

of the long axes of both bones may serve to establish the diagnosis and assess severity (D'Arcangelo *et al.*, 2010). In addition, the medial deviation of the first metatarsal leads to chronic pressure at the medial aspect of the metatarsal head from footwear so that a bunion develops. Bunion formation leads to foot pain and disability. These symptoms, which also derive from accompanying osteoarthritis of the metatarsophalangeal joint, constitute the main reasons for seeking medical advice (Roddy *et al.*, 2008).

Unfortunately, anatomical position is lost during decay, so, in skeletal remains, hallux valgus might be more difficult to diagnose. Usually, lateral deviation of the first phalanx is accompanied by a medial deviation of the first metatarsal bone, with subluxation of the metatarsophalangeal joint. Subluxation of the metatarsophalangeal joint alters the articular surface, leading to the formation of the so called *sulcus sagittalis* in the medial margin of the articular surface of the metatarsal head. In the plantar aspect of the joint, there is also a lateral subluxation of the sesamoid complex. This process takes place over several years and erodes the intersesamoid crest of the plantar aspect of the first

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metatarsal bone. Therefore, erosion, lipping and smoothing of the intersesamoid ridge and changes in the metatarsophalangeal joint surface constitute major criteria that serve to establish a presumptive diagnosis of hallux valgus in bare bones (Mays, 2005).

Additional criteria, such as alterations of the medial epiphysis, are also useful. Changes in the medial epiphysis are especially marked when a bunion develops. However, the chronic, progressive medial deviation of the first metatarsal also leads to changes in the head of the first metatarsal so that it becomes eroded. These erosions range from small holes to large, irregular cavities (Haines & McDoughall, 1954; Weinfeld & Schon, 1998). In addition, medial exostosis develops, as an osteogenic response to the traction on the laterally stretched medial collateral and sesamoid ligaments (Mays, 2005).

The presence of erosion and exostosis, together with the previously mentioned changes in metatarsal head, allows the diagnosis of hallux valgus in skeletal remains. Basically, these criteria have been defined and followed by Mays (2005) and Mafart (2007) in two main studies dealing with the prevalence of hallux valgus in ancient skeletal remains. In the first of these studies involving two British skeletal series, it was found that hallux valgus was restricted to later medieval burials, in contrast with earlier medieval periods. In the second one, an increase in the prevalence of this disease was observed over time, with a higher frequency in 16th/17th century men when compared with 11th–13th century men. The increase in the prevalence of hallux valgus over time suggests an influence of changes in footwear, in accordance with historical data that point to a more generalised use of tip-pointed shoes.

During the 18th century, individuals of the high social class living in urban environments frequently wore tip-pointed shoes similar to those described elsewhere (Cintora, 1988), one of which is depicted in Figure 1A. Until the end of the 18th century, it was usual that all baptised Catholics, regardless of the social class, were buried in holy ground, within the limits of the church's walls. 'Important' people (priests and those belonging to the highest social class) were buried near the altar, whereas those of the lowest class were generally buried near the door (Sanz de Magallanes, 2001). In documents of the 18th century regarding the population of Tenerife, only 2% of the landowners and 3% of the middle-class inhabitants of the city were interred in places destined to low-class individuals, whereas 29% of the former and 26% of the latter were buried near the altar or in private chapels (Arbelo García, 1998; Hernández-González, 2004). It was performed in this way at the church of 'Nuestra Señora de La Concepción'

(La Concepción), the main temple of Santa Cruz de Tenerife, in the Canary Islands, at that time an active port connecting Europe, America and Africa. This church was built in the very last years of the 15th century near the place where the conquerors had arrived for the first time ('Añaza' beach) and had founded the city of Santa Cruz in 1494, as shown in the maps of the 18th century compiled by Tous (1996). In 1636, the church received the current name 'Nuestra Señora de La Concepción' (Cioranescu, 1993). The marked demographic burst of Santa Cruz during the 17th and, especially, 18<sup>th</sup> centuries led to the enlargement of the building, with the addition of two naves so that in the first decades of the 18th century, the church acquired its current size and aspect. Located near to the seashore (Figure 2), columns and walls were progressively damaged along the centuries so that architectural restoration was planned and executed in the last decade of the 20th century, in conjunction with an archaeological excavation of the floor of the church, which was directed by one of us (Matilde Arnay-de-la-Rosa, co-author of this paper). Despite the bad preservation of the skeletal remains, it was possible to recover enough materials to perform this study, which aims to determine the prevalence of hallux valgus among individuals buried in the church of La Concepción, and to assess if there was a relationship between the prevalence of this disease and the burial site (near to the altar or far from it).

## Materials and methods

We analysed first metatarsal bones belonging to individuals buried in the church of 'Nuestra Señora de la Concepción', in Santa Cruz de Tenerife, Canary Islands. This was the first church built up by the Spanish conquerors in the newly founded city, at the end of the 15th century (Arnay-de la Rosa *et al.*, 2009). Excavation of the floor of the church took place during 1993/1995, at the same time as the architectural restoration of the temple was performed (Figure 3). The floor of the church contained many skeletal remains, belonging to at least 776 individuals. The majority of these remains consisted of teeth or bone fragments belonging to different individuals, as the result of the re-utilisation of the tombs. However, there were 207 well-defined tombs that correspond to the individuals lastly interred in the floor of the church, before the new laws forbid inhumation in temples. Some of these tombs were also re-utilised several times and contained remains of several individuals, buried simultaneously or after a short interval. These tombs contained skeletons and other archaeological materials, such as clothes, coins or adornments, which allowed a

*Hallux Valgus in an 18th Century Population*

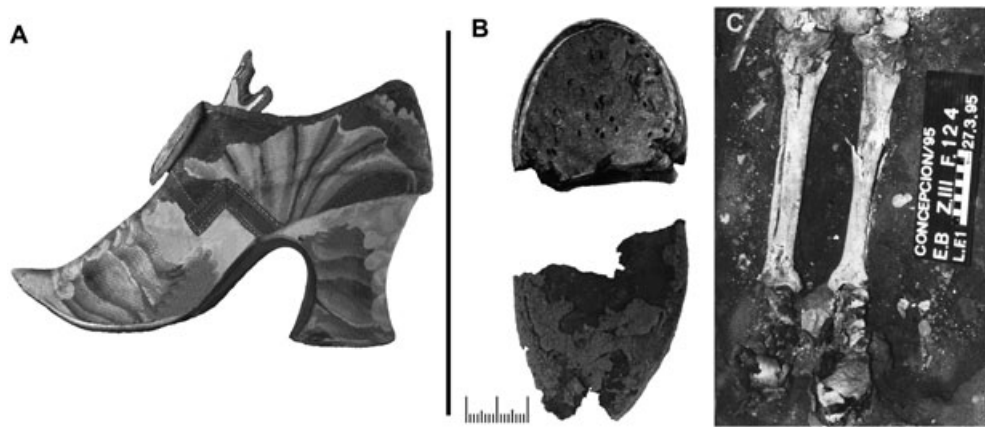


Figure 1. Footwear commonly used by individuals of the highest social classes during the 18th century (A) and skeletal remains of the lower limbs with leather remains corresponding to shoes (B, C).

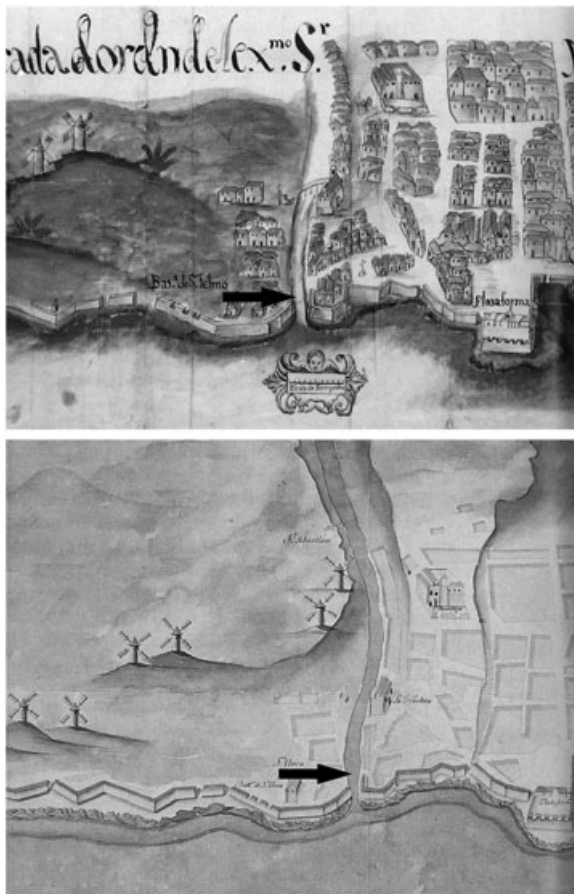


Figure 2. Location of the church of 'Nuestra Señora de la Concepción' (arrow) in an 18th century map of Santa Cruz de Tenerife (modified from Tous, 1996).



Figure 3. Burial site at the bottom of a column (upper image) and several tombs during the excavation process (lower image).

precise dating of the corpses: they were interred towards the end of the 18th century. In some cases, there were also remains of leather around or near the feet bones,

interpreted as remains of footwear (Figure 1B and 1C). Skeletons were usually poorly preserved, mainly because of the location of La Concepción near the seashore.

We only analysed adult individuals (i.e. those with the epiphyses of the first metatarsal bone already fused; Scheuer & Black, 2000). In most cases, it was not possible to accurately determine sex or age at death from inspection of the pelvis, because of the poor preservation, and of the difficulty, in some cases, in ascribing a given metatarsal to a concrete skeleton. Therefore, age at death was not estimated; and, for sex estimation, we used the discriminant functions described by Robling and Ubelaker (1997). Given the heterogeneous nature of the population buried at La Concepción (Maca-Meyer *et al.*, 2005), the formula used was that one proposed for sex estimation of individuals of pooled ethnicity.

Following the Catholic uses, priests and/or 'important' people were interred near the altar, whereas inhumation of the remaining individuals took place in other parts of the temple. Therefore, we classified the analysed population in three groups. As shown in Figure 4, we divided the total area of the church in

three parts (areas A, B and C) and compared the prevalence of hallux valgus among those interred in areas A (near the door of the temple), B (middle zone) and C (near the high altar).

We recorded several criteria, which may indicate the presence of hallux valgus. These include (Figure 5) lateral deviation of the metatarsophalangeal joint, based on the inspection of the articular surface of the first metatarsal bone, assessing changes in the aspect of the metatarsal head derived from the progressive lateral displacement of the articular surface (Figure 5A); in some cases, this surface was clearly deviated from the normal alignment so that they were indicative of lateral subluxation of the first phalanx (Figure 5B). We also recorded degenerative changes of the sesamoid articular facets both for the medial sesamoid bone and lateral protrusion and, eventually, the formation of a new facet in relation with complete dislocation of the lateral sesamoid (Figure 5C). We also looked for degenerative changes, ranging from erosion to eburnation, of the

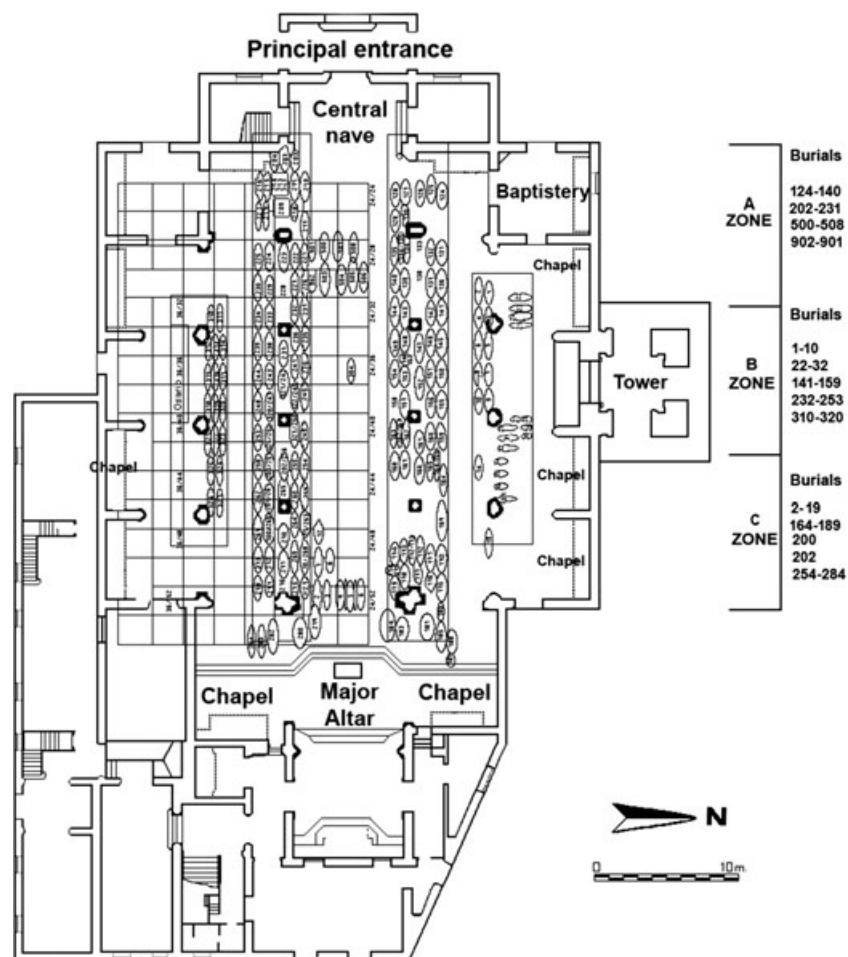


Figure 4. Map of the church of La Concepción, indicating the number of the tombs located in each of the three areas (A, B and C, according to distance to the high altar) in which the burial space was divided.



Figure 5. Bone alterations observed in cases of hallux valgus: (A) dorsal and plantar views of lateral deviation of the metatarsophalangeal joint (Tomb 154), (B) subluxation of the metatarsophalangeal joint (Tomb 163), (C) plantar aspect of the metatarsophalangeal joint with alteration of the articular faces for the sesamoids (Tomb 500), (D) eburnation of the metatarsal joint surface (Tomb 321) and (E) medial lesions, including erosions, geodes and exostosis (Tomb 505).

intersesamoid crest (Figure 5D), following Mafart (2007). Another criterion for diagnosis was defined by the presence of exostosis or remodelling of the medial tuberosity (Figure 5E). Following Mays (2005), diagnosis of hallux valgus was established when lateral deviation of the metatarsophalangeal joint was present and at least one of the remaining criteria.

### Statistics

We analysed if there was any association among the prevalence of bone changes indicative of hallux valgus and the burial site (A–C), as well as among the presence of bone changes indicative of hallux valgus and remains of footwear in the same tomb. These analyses were performed using either  $\chi^2$  with Yates' correction or Fisher's exact test when the expected frequency was less than 5 in at least 25% of the cells of the contingency tables.

### Results

A total of 152 first metatarsal bones were analysed, 77 belonging to the left feet and 75 to right feet. In Table 1, we show the alterations observed. Considering only those cases in which the metatarsal head was clearly observable, we found that 33.33% showed lateral deviation of the metatarsophalangeal joint; 38.37% showed

lateral subluxation of the first phalanx; 45.76 %, lateral subluxation of the sesamoid complex; 29.52 % erosions of the medial aspect of the head of the first metatarsal bone; and 39.05%, medial exostosis (Table 2). These alterations were closely associated among each other ( $\chi^2 > 30$  in all the cases;  $p < 0.001$ ).

Considering only the left foot, there was a nearly significant association between the burial site and the presence of lateral deviation of the metatarsophalangeal joint ( $\chi^2 = 3.90$ ;  $p = 0.048$ ; Fisher's exact test,  $p = 0.07$ ; Table 3). However, no other associations were found, but the prevalence of any of the criteria indicative for hallux valgus was higher among those buried near the altar (47.37%) than among those buried far from the altar (33.04%), although this association was not statistically significant ( $\chi^2 = 3.43$ ,  $0.05 < p < 0.10$ ). Hallux valgus was observed in 35 of the 117 cases for which necessary data for the diagnosis could be recorded (29.91%). In 20 cases, the right foot was affected; and in 15 cases, it was the left foot. Considering only left feet, there was a trend to a significant association among burial sites near the altar and hallux valgus ( $\chi^2 = 4.92$ ;  $p = 0.027$ ;  $p = 0.056$  with Fisher's exact test). Only 3 of 20 individuals buried near the door showed hallux valgus, compared with 6 of 12 buried near the altar. This association was statistically significant (Fisher's exact test,  $p = 0.049$ ,  $\chi^2 = 4.40$ ;  $p = 0.036$ ). Data relative to the right feet are shown in Table 4.

Table 1. Characteristics of the sample analysed

Identification (tomb number)	Leather (1 = yes; 2 = no)	Near the altar/far from the altar (1/2)	Right (1) left (2)	Lateral deviation of the distal joint surface	Lateral subluxation of the basal phalanx	Lateral subluxation of the sesamoid complex	Medial bone changes	Sex-pooled ethnicity (1 = men; 2 = women)
500	1	2	1	No	No	No		2
328	2	2	2	No	No	No		
328	2	2	1	No	No	No		2
328	2	2	2	No	No	No		2
328	2	2	1	No	No	No		2
501-508	2	2	2	No	No	No		2
507-508	2	2	2	No	No	No		2
168	2	1	2	No	No	No		2
181C	2	1	1	No	No	No		2
181C	2	1	2	No	No	No		2
320	1	2	2	No	No	No		
327	1	2	2	No	No	No		2
321-321A	2	2	1	No	No	No		
501-508	2	2	2	No	No	No		
501-508	2	2	1	No	No	Yes		2
501-508	2	2	2	No	No	No		
501-508	2	2	2	No	No	No		2
320	1	2	2	No	No	No		2
500	1	2	1	No	No	No		2
501-508	2	2	2	No	No	No		2
500	1	2	1	Yes	Yes	No		2
273	2	1	1	Yes	Yes	Yes		2
149	1	2	1	Yes	Yes	Yes		2
154	1	2	1	Yes	Yes	Yes		2
149	1	2	2	No	No	No		2
163	1	2	2	No	No	No		2
500	1	2	2	Yes	Yes	Yes		1
325	2	2	1	Yes	Yes	Yes		2
321	2	2	1	Yes	Yes	Yes		2
170	2	1	2	No	No	No		2
170	2	1	1	No	No	No		2
320	1	2	1	No	No	No		2
141	2	2	2	No	No	Yes		2
174	1	1	1	No	No	No		
134	2	2	1	No	No	No		
134	2	2	2	Yes	Yes	Yes		
151	1	2	1	Yes	Yes	Yes		
151	1	2	2	Yes	Yes	Yes		
500	1	2	2	Yes	Yes	Yes		
500	1	2	1	Yes	Yes	Yes		
500	1	2	1	Yes	Yes	Yes		2
319	2	2	1	Yes	Yes	Yes		2
319	2	2	1	Yes	Yes	Yes		2
319	2	2	1	No	No	Yes		2
319	2	2	2	No	No	No		2

(Continues)

Table 1. (Continued)

Identification (tomb number)	Leather (1 = yes; 2 = no)	Near the altar/far from the altar (1/2)	Right (1) left (2)	Lateral deviation of the distal joint surface	Lateral subluxation of the basal phalanx	Lateral sublux. of sesamoid complex	Medial bone changes	Sex-pooled ethnicity (1 = men; 2 = women)
319	2	2	1	Yes		No		2
319	2	2	2	No	No	No		
319	2	2	1	No	No	No		
319	2	2	2	No	No	No		2
320	1	2	1	No	No	No		
320	1	2	1	No	No	No		
5	1	1	1	Yes	Yes	Yes	No	2
321A	2	2	2	No	No	No		
173	1	1	1	No	No	No		
159	2	2	1	No	No	No		2
325	2	2	1	No	No	No		2
320	1	2	2	No	No	No		2
320	1	2	2	No	No	No		
326	2	2	2	No	No	No		
321	2	2	2	No	No	Yes		
326	2	2	1	No	No	No		
320	1	2	2	No	No	No		1
320	1	2	1	Yes	Yes	Yes		
320	1	2	1	No	No	No		
320	1	2	1	No	No	No		
168	2	2	1	No	No	No		2
134	2	2	1	No	No	No		
134	2	2	2	No	No	No		2
505	2	2	1	No	No	Yes		
505	2	2	1	No	No	No		
320	1	2	2	No	No	No		
320	1	2	2	No	No	No		
322	2	2	1	No	Yes	Yes		2
160	2	2	1	No	No	No		
160	2	2	1	No	No	No		
141	2	2	2	No	No	No		
5	1	2	1	No	Yes	Yes		
128	2	2	1	No	No	Yes		
128	2	2	1	Yes	Yes	Yes		2
6	1	1	2	Yes	Yes	Yes		2
505A	2	1	2	No	No	No		
3	1	2	1	Yes	Yes	Yes	No	2
3	1	1	2	Yes	Yes	Yes		
500	1	2	1	No	Yes	Yes		2
500	1	2	1	No	No	No		
500	1	2	1	Yes	Yes	Yes		
500	1	2	2	Yes	Yes	Yes		
136	1	2	2	No	No	No		
151	1	2	2	No	No	No		1
123	2	2	2	No	No	No		
162	2	2	2	Yes	Yes	Yes		2

(Continues)

Table 1. (Continued)

Identification (tomb number)	Leather (1 = yes; 2 = no)	Near the altar/far from the altar (1/2)	Right (1) left (2)	Lateral deviation of the distal joint surface	Lateral subluxation of the basal phalanx	Lateral sublux. of sesamoid complex	Medial bone changes	Sex-pooled ethnicity (1 = men; 2 = women)
173	1	1	2	Yes		Yes	No	2
327	1	2	1	Yes	Yes	Yes	No	2
4	2	1	2	Yes	No	Yes	Yes	2
4	2	1	1	Yes	No	No	Yes	2
321	1	2	2	Yes	Yes	Yes	No	2
304	2	2	2	No		Yes	No	
4	2	1	1	No		Yes	No	
327	1	2	2	No	Yes	No	No	
148	1	2	2	No	No	Yes	No	
202-256	1	2	1	Yes	No	Yes	No	2
149	1	2	1	Yes	No	Yes	Yes	2
322	2	2	2	Yes	Yes	Yes	No	2
5	1	1	2	Yes	Yes	Yes	No	2
304	1	2	1	Yes	Yes	No	Yes	2
304	1	2	2	No		Yes	Yes	2
320	1	2	1	No		Yes	No	2
500	2	2	1	No		Yes	No	2
2	2	1	2	No		No	No	1
144	2	2	2	Yes	Yes	Yes	No	2
154	1	2	2	Yes	Yes	Yes	No	2
505	2	2	2	Yes	Yes	Yes	No	2
140	2	2	1	No		Yes	No	2
321A	2	2	2	No		Yes	No	2
4	2	1	2	No		Yes	No	2
4	2	1	1	Yes	Yes	Yes	No	2
4	2	1	1	Yes	Yes	Yes	No	2
2	2	1	1	Yes	Yes	Yes	Yes	2
2	2	1	1	Yes	Yes	Yes	No	2
500	1	2	2	Yes	Yes	Yes	No	2
500	1	2	1	Yes	Yes	Yes	No	2
500	1	2	1	No		Yes	No	2
500	1	2	2	No		Yes	No	2
500	1	2	2	No		No	Yes	2
500	1	2	2	No		Yes	No	2
525	2	2	1	Yes	Yes	Yes	No	2
525	2	2	1	Yes	Yes	Yes	Yes	2
525	2	2	1	Yes	Yes	Yes	Yes	2
131	2	2	1	No		No	Yes	2
168	2	1	2	No		No	No	2
500	1	2	1	No		No	No	2
127A	2	2	1	No		No	No	2
127B	2	2	2	No		No	No	2
136	2	2	1	No		No	No	2
156	1	2	2	No		No	No	2
321	2	2	2	No		No	Yes	2
136	2	2	2	No	Yes	Yes	No	2
500	1	2	1	No		No	No	2

(Continues)



Table 1. (Continued)

Identification (tomb number)	Leather (1 = yes; 2 = no)	Near the altar/far from the altar (1/2)	Right (1) left (2)	Lateral deviation of the distal joint surface	Lateral subluxation of the basal phalanx	Lateral sublux. of sesamoid complex	Medial bone changes	Sex-pooled ethnicity (1 = men; 2 = women)
162	2	2	1	No	No	No	No	2
8	2	1	2	Yes	Yes	No	No	2
167	2	2	2	No	No	No	No	2
144	2	2	1	Yes	Yes	Yes	No	2
224-204	2	2	2	No	No	No	No	2
1	1	1	1	No	No	No	No	2
135	2	2	2	Yes	Yes	Yes	Yes	2
163	1	2	1	Yes	Yes	No	Yes	2
128	2	2	2	No	No	No	Yes	2
134	2	2	2	No	No	No	Yes	2
179	2	2	2	No	No	No	No	2
143	2	1	1	No	No	No	No	2

Table 2. Summary of the alterations recorded (number and % of cases in which the alteration was present in relation to recorded cases)

	Yes [n (%)]	No	Not recordable
Lateral deviation of the metatarso-phalangeal joint	38 (33.33)	76	38
Phalangeal subluxation	33 (38.37)	53	66
Lateral subluxation of the sesamoid complex	54 (45.70)	64	34
Medial erosion	31 (29.52)	74	47
Exostosis	41 (39.05)	64	47

Table 3. Association of bone alterations and burial site considering only left feet

	Altar	Far from altar	$\chi^2$ ; p
Lateral deviation of the metatarso-phalangeal joint	6	9	3.895; 0.048
No lateral deviation of the metatarso-phalangeal joint	7	38	
Lateral subluxation	4	12	0.96; NS
No lateral subluxation	4	26	
Sesamoid subluxation	5	21	0.05; NS
No sesamoid subluxation	7	28	
Medial erosion	6	19	0.35; NS
No medial erosion	6	28	
Medial exostosis	6	14	1.59; NS
No medial exostosis	6	32	
Hallux valgus	6	9	4.92; 0.027
No hallux valgus	6	39	

NS, not significant.

Table 4. Association of bone alterations and burial site considering only right feet

	Altar	Far from altar	$\chi^2$ ; p
Lateral deviation of the metatarso-phalangeal joint	3	20	0.10; NS
No lateral deviation of the metatarso-phalangeal joint	5	26	
Lateral subluxation	2	15	0.24; NS
No lateral subluxation	4	19	
Sesamoid subluxation	4	24	0.87; NS
No sesamoid subluxation	7	22	
Medial erosion	3	21	0.22; NS
No medial erosion	4	19	
Medial exostosis	3	18	0.11; NS
No medial exostosis	4	22	
Hallux valgus	2	18	0.76; NS
No hallux valgus	7	30	

No association was found between the presence or not of shoe treads and changes in metatarsal bone, shoe treads and location of the tombs near or far from the altar or shoe treads and the presence of hallux valgus.

## Discussion

As commented, some alterations in the first metatarsal bone, such as changes of the metatarsal head and subluxation of the sesamoid complex, with degenerative changes affecting the sesamoid articular facets, are sufficiently specific to allow an accurate diagnosis of hallux valgus (Mays, 2005). Main differential diagnoses include osteoarthritis and hallux rigidus (Mafart, 2007). In patients affected by hallux rigidus, there is a limitation to normal movements of flexion and extension in the sagittal plane but not the typical lateral deviation and joint subluxation of hallux valgus (Gilheany *et al.*, 2008). Hallux rigidus is also usually accompanied by joint degeneration and even ankylosis, with osteophyte formation, which may bridge the joint space (Camasta, 1996), in contrast with hallux valgus. Degenerative osteoarthritis complicates the evolution of both hallux rigidus and hallux valgus. Although it may occur in the absence of any of the aforementioned entities (Weinfeld & Schon, 1998), differential diagnosis of pure osteoarthritis of the first metatarsophalangeal joint without deviation of the metatarsal, and hallux valgus is not difficult. Therefore, the findings reported in Tables 1–3 fully support the diagnosis of hallux valgus.

The proportion of individuals with any of the aforementioned alterations found in this study is quite high, in the range of those reported by others for ancient individuals. However, Mafart (2007) reports more than 40% of men of the 16th–17th centuries at the Notre-Dame du Bourg burial site affected by hallux valgus, a figure higher than that observed here, although it is important to consider that diagnosis of hallux valgus heavily relied on the presence of alterations of the sesamoid articular facets and not exactly on those used in this study. Indeed, if we analyse the prevalence of alterations of the sesamoid articular facet, we see that it was present in 45.8% (Table 2), a figure similar to that reported by Mafart (2007).

As commented, following the Catholic ritual, individuals of the wealthier social classes and priests were buried near the altar, in contrast with the remaining population. Overall, we observed a slightly higher proportion of metatarsal alterations among the remains dug out from the tombs located near the altar than among those buried far from the altar. Assuming that the main cause of hallux valgus is related to the use of footwear, which constricts the forefoot (Coughlin & Jones, 2007), this finding may support the view that this kind of footwear was in fact utilised only by some people of the highest social strata. In the 17th–18th centuries, people of the high social class wore shoes that caused considerable constriction to the toes and

the feet. These shoes had a high heel and relatively narrow toeboxes, vaguely similar to footwear used by women in modern years, among whom the prevalence of hallux valgus is high (D' Aout *et al.*, 2009). High-heeled boots, usually of stiff leather, were frequently worn by wealthy individuals. Horses were increasingly used in these centuries, and the form of these boots prevented the foot from slipping through the stirrup when mounting (Mafart, 2007). These boots place major constraint on the forefoot. In addition to boots, high-heeled shoes, similar to those depicted in Figure 1A, were also worn by individuals of high social strata, as can be observed in paintings and artworks of the 17th and 18th centuries and also in another excavation of skeletal remains of an 18th century nobleman buried in a crypt in La Laguna, the former capital of Tenerife (de la Cruz Rodríguez, 2004). In this sense, it is important to keep in mind that the European fashion, followed by the high class individuals of Tenerife, took some time to be adopted by the Islanders, mainly due to the distance to the continent so that a delay of decades was perfectly possible. This might have also affected footwear.

Interestingly, we found differences in the distribution of bone alterations in relation with the foot affected. These differences became statistically significant in the case of metatarsal head deviation, a striking feature of hallux valgus. In fact, the presence of hallux valgus affecting left feet was significantly higher among those buried near the altar but not when right feet were considered. This finding is difficult to explain. As commented by other authors (Mafart, 2007), the artisanal nature of shoe production in the 18th century could lead to differences in shoe's structure and size, which might have caused different effects on the right and left feet. Moreover, early boots (those produced around the beginning of the 17th century) were identical for the two feet (Mafart, 2007). If this was also the case for the inhabitants of Santa Cruz de Tenerife in the 18th century, it might explain the differences observed in this study. This is predicated on the idea that boney changes derived from the constricting effect of footwear could affect more intensely the left rather than the right foot. However, this is only a fully speculative explanation of an observed fact.

We tried to analyse if there was a relationship between the presence of shoe remains and the presence of hallux valgus, but, besides a few exceptions, only some relatively small pieces of leather were found in some tombs. As shown in Figure 1, these leather pieces correspond to footwear, at least in the vast majority of cases. However, the presence of these remains was associated neither to a 'privileged' burial site, such as altar, or to the presence of hallux valgus. This may be

explained in several ways. In the first place, environmental conditions of the tombs are quite adverse, mainly due to the vicinity of the church to the sea-shore, and may have led to the destruction of leather remains. More probably, these artefacts reflect the kind of clothes and footwear that the individuals were buried in and not necessarily what they used during life. In contrast with wealthy individuals, people of the low social strata were barefoot, or wore sandals, a habit maintained at least until the last decades of the 19th century (Stone, 1889) and even later. However, there are testaments in which wealthy people decided to be interred with the poorest clothes, to 'appear poor and pure in the presence of God' (Hernández-González, 2004), or with the habits of priests or monks, without any sign of luxuries and richness in their clothes and ornaments. This may explain the lack of relation between the remains of footwear and the presence of hallux valgus. Moreover, in some cases, there is a special remark in the testament in which a wealthy individual wanted to be interred at the door of the church, in the place preserved to the poorest people (Cioranescu, 1998). Therefore, the fact that some wealthy people were not interred in privileged places may also explain that the association of hallux valgus and burial place, although statistically significant, as commented, is relatively weak.

Although we tried to identify the sex of the bone remains analysed, using discriminant functions based on metatarsal measurements (Robling & Ubelaker, 1997), the proportion of women is exceedingly high. Probably, this may not reflect a true predominance of women in the sample analysed, but is attributable to morphologic differences between the population studied by Robling and Ubelaker (1997) and that of Santa Cruz de Tenerife, inhabited by a mixed population composed by descendants of the indigenous population of the Island (Guanches), Spaniards, some Berber servants, some sub-Saharan Africans and some individuals of European ancestry (Maca-Meyer *et al.*, 2005).

## Conclusions

Therefore, we conclude that, among people buried at the end of the 18th century in the church of 'Nuestra Señora de La Concepción', in Santa Cruz de Tenerife, Canary Islands, the prevalence of alterations of the first metatarsal bone suggestive of hallux valgus is high, in the range of other results obtained for ancient individuals of the modern era (16th–17th centuries) in other parts of the world (Mafart, 2007), but higher than the prevalence reported for individuals of the late medieval period (13th–16th centuries). Considering that the

main aetiology of hallux valgus depends on the constricting effect of footwear, this result may suggest that the use of such a footwear among the population of Tenerife during the 18th century was similar to that observed in European sites about 100 years earlier. There was a trend to an association of these alterations and the burial place in the church so that those buried near the altar – a space usually preserved for priests and individuals of the highest social strata – showed a higher prevalence of metatarsal alterations. A striking feature is the predominance of alterations of the left toe among those buried near the altar. Reasons for this predominance are unclear, but this finding may reflect a more intense constricting effect of footwear on the left foot, perhaps in relation with the artisanal nature of shoe production in the 18th century.

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