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RESEARCH ARTICLE

Conditions of life and death at Panama Viejo: a bioarchaeological study of human skeletal remains (1519-1671)

[version 1; peer review: 1 approved with reservations, 1 not approved]

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v1 **First published:** 04 Aug 2021, **1**:88
https://doi.org/10.12688/openreseurope.13873.1
Latest published: 04 Aug 2021, **1**:88
https://doi.org/10.12688/openreseurope.13873.1

Abstract

Panama, founded in 1519, became one of the most important sites for the Spanish Crown, consolidating itself as an economic center that connected the trade routes between the Pacific and the Atlantic oceans. This situation produced a convergence of people of different origins (indigenous, African, and European) in the city, generating a strong process of biological as well as social and cultural mixture, which impacted daily life during the sixteenth and seventeenth centuries.

These processes were addressed by the research project: An ARTery of Empire (ARTEmpire) (European Research Council, Consolidator of Grant [CoG] 648535), which included archaeological excavations at the two sites occupied by Panama's main temple: one to the south-east of the Main Square (1519-1541) and the other where the cathedral was installed from 1542 until the city's destruction in 1671. This article presents the results of the bioarchaeological study of 175 individuals recovered during the aforementioned archaeological excavations, reconstructing their living conditions. The sample consists mostly of female (55.43%) and young adult individuals (52.57%), highlighting the absence of older adults and the underrepresentation of children and juveniles. The preservation of the sample limited observations of population affiliation, but individuals with traits predominant in African (23.43%), European (21.71%), and Amerindian (9.71%) populations were identified.

Paleopathological analysis shows mostly lesions associated with infectious diseases, entheseal changes, porotic hyperostosis, degenerative joint disease, and trauma. In addition, the teeth reveal masticatory wear, calculus, decay, periodontal disease, and chipping. However, an initial observation of the sample indicates no significant differences that show that one sector of the population may have been more affected than another. This is interesting since individuals from diverse origins converged at Old Panama, responding to the

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Approval Status ✗ ?

	1	2
version 1 04 Aug 2021	✗ view	? view

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process of globalization at this port.

Keywords
Historical Bioarchaeology, Colonial Period, Panama Viejo, Living Conditions, Paleopathology



This article is included in the Horizon 2020 gateway.



This article is included in the European Research Council (ERC) gateway.



This article is included in the History and Archaeology gateway.

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Author roles: Rivera-Sandoval J: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 648535).

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How to cite this article: Rivera-Sandoval J. **Conditions of life and death at Panama Viejo: a bioarchaeological study of human skeletal remains (1519-1671) [version 1; peer review: 1 approved with reservations, 1 not approved]** Open Research Europe 2021, **1**:88 https://doi.org/10.12688/openreseurope.13873.1

First published: 04 Aug 2021, **1**:88 https://doi.org/10.12688/openreseurope.13873.1

Plain language summary

The contact between Europe, America, Africa, and Asia since the late fifteenth century generated several changes in the daily lives of peoples of different origins. Panama Viejo was the first city founded in the American Pacific in 1519 and became one of the most important ports for the Spanish crown. The arrival of Europeans, together with Africans and the local indigenous population formed a diverse colonial society. As a Bioarchaeologist I am interested in investigating the impact of this process on the living conditions and health of the Panamanian population between the sixteenth and seventeenth centuries.

To do this, I took data from 175 human burials excavated in the nave and atrium of Panama's cathedral and south-east of the Main Square. Skeletons record several of the events in a person's life, including the processes of growth and aging, the differences between men and women, and many of the diseases and conditions they suffered in life.

The analysis of all these aspects allowed us to approach how the population of Panama Viejo was formed. Most individuals were adult women between 18 and 34 years old, and many of them with traits of African origin.

The research also indicated that the former Panamanians suffered from infectious and joint diseases, in addition to marked muscle insertions, and injuries associated with metabolic problems and blows. On the other hand, the teeth showed problems of decay, tartar accumulation, wear by chewing processes, and some dental modifications associated with cultural practices. The information collected suggests that Panamanians buried in the spaces occupied by the cathedral between the sixteenth and seventeenth centuries were susceptible to different types of disease, regardless of their sex, age, or ethnic affiliation.

Introduction

Historical context of the city of Panama Viejo

Founded in 1519, Panama Viejo comprised the first European city on the American Pacific. Its location and geographical configuration acquired great importance for the Spanish Crown from the 16th century onwards, becoming a point of confluence that connects Spain's economy to its American colonies, especially the Peruvian market. The city began to lay out its streets and allocate plots and parcels that would be occupied by important buildings in colonial urban life, such as the Cabildo, the Casas Reales and the cathedral (Castillero Reyes, 1950; Mena García, 1992).

As a port, Panamá allowed many different groups to arrive and concentrate, leading to a significant population mixture, even despite the evident decline of the indigenous population, which was inversely proportional to the number of African slaves who came to the city, and by far exceeded the number of white Europeans. By the 16th century, the Spanish part of Panama's inhabitants were described as men who came mostly from the city of Seville, dedicated basically to commercial activities, except for a small percentage who settled in the countryside to work in cattle raising (Anderson, 1944:273).

The particularities of population mixture in Panamá are linked, firstly, to the limited number of white women and relations with indigenous women in the early years of the conquest. Other categories such as *zambaigos* and *mulatos* were constructed later on with fuller insertion of African elements into the population dynamic. In this way, the *mulato* population became one of the fastest growing sectors on the entire isthmus, doubling the average for the continent by the beginning of the 17th century (Jopling, 1994; Mena García, 1984).

However, in 1671 Panamá was invaded and sacked by the buccaneer Henry Morgan and his troops (Anderson, 1944; Castillero Calvo, 2006; Shafroth, 1953). The city, which was defended by a small garrison and some armed locals, was no match for the group of pirates who gradually seized control, occupying several public buildings as their barracks. Moreover, a fire swept through a large part of the timber houses, which could not be stopped due to the collapse of several buildings combined with the use of powder (Sosa & Arce, 2003:128). This presented an opportunity to plunder the city, causing many locals to flee; some managed to gather their goods and move to other destinations such as Peru, where some religious members of the convents also headed (Castillero Calvo, 2006:981; Castillero Reyes, 1959:54).

A new foundation was formalised two years later, following many delays in the process of deciding whether or not it was convenient to relocate the city. Some local residents saw the move as counterproductive, for fear of negatively affecting the port's mercantile trading (Mena García, 1997:6). Nevertheless, in 1673 a small 16-hectare peninsula of volcanic rocks located next to Ancon Mount, two leagues to the west of the former site, was chosen as a new location. The geographical characteristics of this site meant that it would have a better defence system, which was the main factor in choosing it and in designing the city walls (Jaén Suárez, 1986; Mena García, 1997).

Archaeological excavations in Panama Viejo's cathedral

With the establishment of the Patronato Panama Viejo in 1995, work began on the heritage management of this important archaeological and historical site, which UNESCO declared as a World Heritage Site in 2003. The Patronato Panama Viejo developed a permanent research programme aimed at protecting, conserving, and enhancing the monumental complex, with its evidence of the pre-Hispanic as well as colonial occupations (Martín & de Arango, 2013; Martín & Rovira, 2012).

Many of the remains of the ancient city's buildings have been subject to interdisciplinary interventions in which archaeology has played an important role in reconstructing the urban layout and daily life in many of the spaces that were part of Panama, including its main temple. Several archaeological explorations were carried out in the cathedral between 1998 and 2005, as part of the restoration project and adaptation

for public visitors, identifying the temple's original floor level and several burial sites in the central nave and atrium (Hernández Mora *et al.*, 2021). Furthermore, in 2003 an area was excavated on the south-east flank of the main square, identifying 22 additional tombs with funerary patterns characteristic of the colonial period; this information was later associated with the first temple site, between 1519 and 1541 (Hernández Mora *et al.*, 2021).

This background led to the development of the interdisciplinary research project An ARTery of Empire (ARTEmpire), funded by the European Research Council (ERC, Consolidator Grant [CoG] 648535) in the Horizon 2020 research program, and directed by historian Bethany Aram, who, together with a team of historians, archaeologists, bioarchaeologists, geneticists, specialists in isotopes and other fields of knowledge, began to question the impact of processes of early globalisation on everyday life in Panama Viejo (Aram *et al.*, 2020; Hernández Mora *et al.*, 2021). Accordingly, the main temple was chosen as the site that could reflect the dynamics of the confluence of different population groups in the first city founded on the American Pacific, leading to two excavation seasons in 2017 and 2018 (Figure 1) under archaeologists Juan Guillermo Martín, Iosvany Hernández Mora and Tomás Mendizabal, with the support of the Patronato Panama Viejo.

Following the principles of archaeological stratigraphy as a recording methodology, attention was paid to reconstructing the sequence of events that led to the archaeological site's formation as well as their chronological relationships. This procedure allowed us to identify the building's range of construction stages, both in its first location to the south-east of the square (1519–1541) and also in its relocation and subsequent modifications up to 1671 (Aram *et al.*, 2020). Furthermore, several inhumation events were recorded in the level of the two areas occupied by the main temple, where 159 individuals were recovered from the main nave and atrium of the cathedral, and a further 16 to the south-east of the square (Aram *et al.*, 2020; Hernández Mora *et al.*, 2021). The chronological sequence identified in the cathedral space was marked by the events of the insertion in 1626 of the stonework bases for the timber columns that supported the temple's roof (Aram *et al.*, 2020: 501), which were excavated and acted as a chronological marker for burials before and after this date. In the atrium sector, there was no information available to determine the precise moment of the inhumations, although by association with elements of the material culture it is estimated that they date from the 17th century (Aram *et al.*, 2020).

Methods

Bioanthropological work begins with the macroscopic observation of the bone material excavated during archaeological interventions. However, several intrinsic and extrinsic factors affect the preservation of bone and dental remains, hindering analysis due to processes related to funerary practices, as in the case of cremations. Other factors impact diagenesis at the moment the bodies are inhumed, including environmental conditions, soil, microbial activity, and the action of plants, animals,

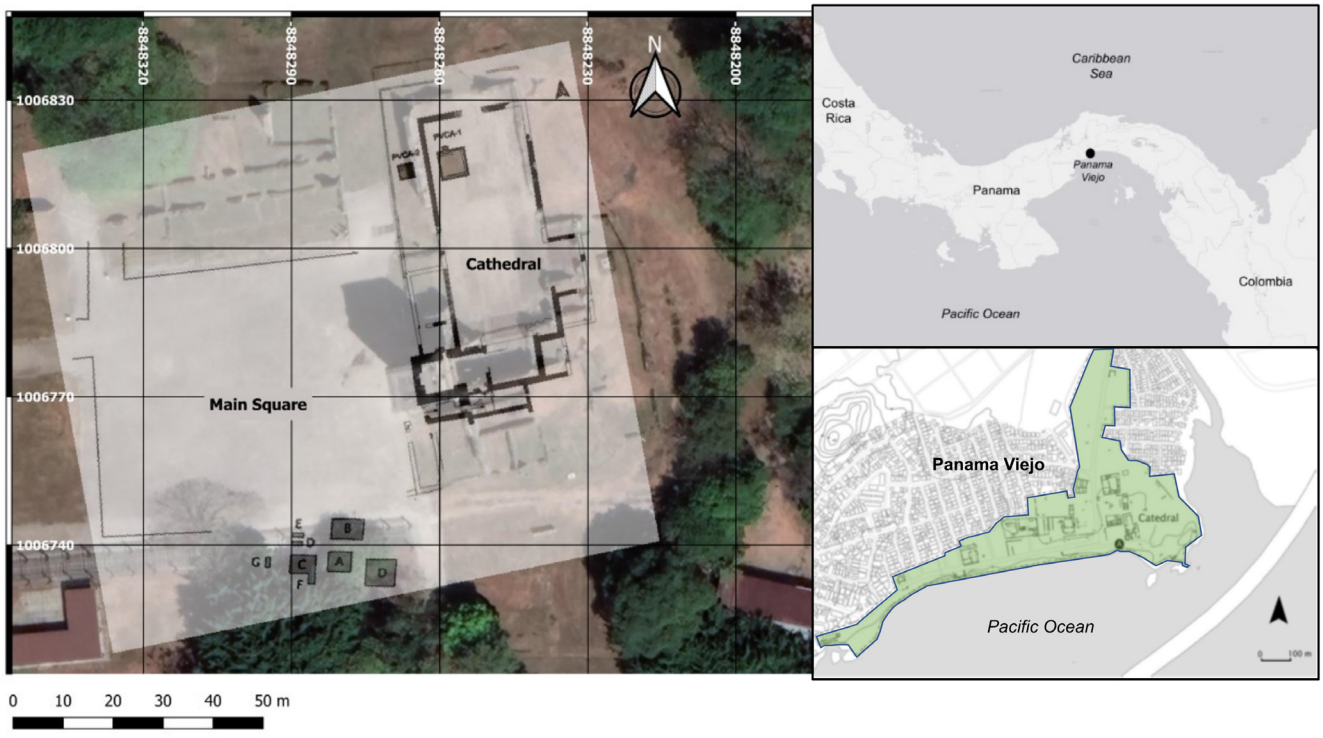

Figure 1. Archaeological excavation areas in the South-East of Panama Viejo's Main Square (2018) and cathedral (2017).

and humans (Buikstra & Ubelaker, 1994; Haglung & Sorg, 2006; Mays, 2010; Nikita, 2017; Roberts, 2009; White, 2000). This is why the state of preservation of the skeletal remains was evaluated prior to analysis, recording the degree of deterioration due to taphonomic agents observable on the cortical surface of the bone and the fragmentation conditions of the material. Severity was recorded on a scale of 0 to 3, in which 0 was unobservable material. Grade 1 was material with considerable structural damage, highly fragmented, and generally with no conservation of trabecular (spongy or cancellous) tissue, therefore hindering any type of analysis. In grade 2, skeletal remains were recorded with some damage on the surface of the bone and the epiphyseal and trabecular areas, all with a moderate degree of fragmentation, although it was possible to adequately observe any lesions or diagnostic elements for the purpose of osteobiographic analysis. Finally, for grade 3, skeletal remains are generally preserved in good condition, without observable taphonomic alterations and with low fragmentation frequency.

The degree of representativeness or completeness of each bone structure of the analysed individuals was also recorded, based on a scale in which the percentage of the total bone structure present was calculated, with grade 1 corresponding to ≥ 75%, grade 2 between 50 and 75%, grade 3 between 25 and 50%, and grade 4 ≤ 25%. The dental pieces were also inventoried, according to whether they were in position in the alveolus or isolated. The alveolar cavity closure process was also recorded in order to differentiate *antemortem* from *postmortem* losses. All the information collected was organised in a database that can be queried at the website: https://artempire.cica.es/.

Once the inventory had been completed, diagnostic traits were identified in order to reconstruct the osteobiographic profile of each of the 175 individuals recovered in the archaeological excavations carried out in 2017 and 2018. This information was used to address several aspects related to living conditions, health and disease of the population of Panama Viejo buried to the south-east of the main square, specifically in the first cathedral site between 1519 and 1541, with 16 individuals, and, subsequently, in the new temple built around 1542, until the city was abandoned in 1671, with 159 individuals (Aram *et al.*, 2020; Hernández-Mora *et al.*, 2021).

The study comprises a range of analytic units that follow a deductive model, moving from particular to general. To this end, the individual is taken as the basic unit of observation, striving to identify characteristic traits through the method of biological reconstruction and applying the basic quartet of identification, consisting of:

- Determining sex
- Estimating age
- Estimating probable biological affiliations or ancestries
- Estimating stature

Furthermore, diagnoses related to paleopathological traits, which are associated with lesions or anomalies present in the bone tissue structure, allow us to reconstruct various aspects of the state of health and disease of past populations. However, as mentioned above, analysis of these characteristics may be limited by the state of preservation of the remains.

The data obtained for each individual allowed us to observe variability within the group the subjects belonged to, and to identify the general phenotypes that characterised the population, in addition to general characteristics of the group's paleodemographic make-up (age groups, sex ratio, mortality and morbidity rates, life expectancy, etc.).

Moreover, the intragroup unit of analysis can be used to establish comparative frameworks with other previously studied populations, in order to identify similarities, differences and relational networks between groups for particular synchronic and diachronic contexts.

In order to analyse this sample, once the work of cleaning and restoration had been completed, techniques were applied to individualise the remains, bearing in mind that in Panama Viejo's cathedral the site's formation process involved events that altered the original arrangement of several skeletons. On the one hand, the contexts associated with reduced burials that can be associated with an individual were formed, and, on the other hand, the so-called *commingled* contexts, which correspond to mixed remains that cannot be associated with other bone or dental pieces recovered in the excavation.

However, in the case of reduced burials, some observations were made on the traits associated with the bone structures' size and taphonomic characteristics, which allowed the process of individualisation of the remains to be carried out. Similarly, the development of muscular insertions in the long bones and the degree of wear and dental eruption acted as indicators in this stage of the analysis.

With regard to the commingled remains, where a precise individualisation was not possible, the bone and dental structures were documented using *Osteoware* software, designed by the Smithsonian Institute, which allowed us to record quantitative and qualitative observations regarding these bones and teeth (Smithsonian Institute, 2016). This information was used to calculate the minimum number of individuals (MNI), together with the diagnostic traits observed in them.

Once individualisation was complete, the skeletons were arranged in anatomical position, drawing up the inventory and entering the information in the database designed for the project. Information was recorded for the basic quartet of identification, metric and non-metric traits, analysis of bone alterations, and observations of dental morphology and morbidity. The following procedures were carried out to this end:

- Macroscopic observation

- Application of individualisation methods
- Elaboration of bone inventory
- Identification of the basic quartet (sex, age, biological affiliations, and stature)
- Osteometric and craniometric measurement (depending on the state of preservation of the bone material)
- Description and analysis of bone lesions or anomalies
- Documentation of morphological variation, lesions and dental anomalies
- Graphic and photographic record

In general terms, the standards applied in bioanthropological observations correspond to the *Standards for Data Collection from Human Skeletal Remains* by Buikstra & Ubelaker (1994), who compiled a series of methods and techniques developed by several authors, and which subsequently served as a basis for other works (Canci & Minozzi, 2012; Nikita, 2017; Rodríguez Cuenca, 1994; Rodríguez Cuenca, 2004). However, depending on the preservation of the sample and the particularities of each individual, different methods were applied to reconstruct the basic quartet of identification, as presented below.

Estimating the basic quartet in adult individuals

The main aspects observed in order to establish sex were the characteristics of the cranium and pelvic girdle, followed by applying the coefficient of sexualisation (Acsádi & Nemeskéri, 1970), whenever diagnostic structures were available. Consideration of the cranium and mandible, included the following aspects: size and general appearance, development of external occipital protuberance, nuchal plane surface, mastoid process of the temporal bone, zygomatic bone, supraorbital margin, supraorbital ridge, shape of orbit, glabella, mental eminence, and mandibular ramus. The general aspect of the bone structure, greater sciatic notch, presence of preauricular sulcus, ventral arc, subpubic concavity, ischiopubic crest, and shape of iliac crest were all observed in the pelvis (Buikstra and Ubelaker; Nikita, 2017; Rodríguez Cuenca, 1994). Furthermore, a series of observations were made when applying the methods on the pubic bone (Phenice, 1969); the flexure of posterior margin of the mandibular ramus (Loth & Henneberg, 1996); the vertical diameter of the humeral head, the maximum diameter of the femoral head, and diameter of the radial head (Bass, 2005; Steward, 1979); and the measurements of the mastoid triangle (de Paiva & Segre, 2003).

With regard to age estimation, the following parameters were recorded for adult individuals, depending on the state of preservation of the materials: obliteration of secondary ossification centres (Buikstra & Ubelaker, 1994; Iscan & Steyn, 2013; Schaefer *et al.*, 2009), characteristics of the auricular surface of the ilium (Buckberry & Chamberlain, 2002; Lovejoy *et al.*, 1985), changes in morphology of the pubic symphysis (Brooks & Suchey, 1990), and sternal surface of the fourth rib (Iscan *et al.*, 1984a; Iscan *et al.*, 1984b; Iscan *et al.*, 1985). Observations on the acetabulum were also made for male individuals (Rissech *et al.*, 2006). However, in the absence of any of these structures, the methods of cranial suture closure (Meindl & Lovejoy, 1985) and degree of tooth wear (Brothwell, 1989; Lovejoy, 1985) were applied, although such methods are not particularly accurate and should only be used as a last resort (Garvin & Passalacqua, 2012). Correspondence to each of the three age groups defined for the adult population was established after estimating the age range of the individuals using the different methods, namely young adult (18–34 years), middle adult (35–55 years), and older adult (55+ years).

The evaluation of ancestry or biological affiliation, grounded in bioanthropological discussions of the theoretical, methodological and ethical difficulties involved, bears in mind that the aim is not to classify human beings into racial categories –a concept that does not exist in the discipline–, but rather to identify geographical patterns that can provide information about the populations' biological origins and diversity (Iscan & Steyn, 2013: 195). Methods based on the morphological characteristics of the cranium and facial skeleton were therefore used (Gill & Gilbert, 1990; Hefner, 2009; L'Abbé *et al.*, 2011; Rhine, 1990), such as flattening of the facial bones, projection of the nasal bones and nasal spine, nasal bone contour, nasal aperture width, inferior nasal margin, zygomatic projection, chin, and palatal suture shape. A series of non-metric characters or discrete traits that seem to be associated with population variability, such as the presence of wormian bones and post-bregmatic depression, were also recorded.

At a dental level, observations on variability in dental morphology were also made using the Arizona State University Dental Anthropology System (ASUDAS) criteria, initially compiled by Turner and Colleagues (1991), Scott & Turner (1997), and recently revised by Scott & Irish (2017), with this latest revision being used as a reference for analysis of the Panama Viejo sample.

The information collected from observation of the craniometric data and the morphology of the cranium, facial skeleton (Hefner, 2009), and teeth was subsequently processed in three web applications on the *Osteomics* platform (D'Oliveira-Coelho & Navega, 2014; D'Oliveira-Coelho *et al.*, 2020). *AncesTrees* was used for the first set of data, in line with the proposals made by Navega & collaborators (2015) to take the craniometric analysis data and apply non-linear and non-parametric classification techniques with the help of the random forest algorithm. This method generates decision trees to calculate the likelihood of the analysed individual corresponding one of the six population groups established by the application: African, Amerindian, Asian, European, Australo-Melanesian and Polynesian. The *hefneR* analytical programme was used for morphology of the cranium and facial skeleton, which based on standardisation principles for registering 11 macromorphoscopic cranial traits, and a large set of population data (Hefner, 2009), allows semiparametric statistical analyses based on naive Bayesian classification methods that calculate the ancestry

of individuals based on four groups: African, Amerindian, Asian, and European (Dunn *et al.*, 2020).

rASUDAS was used for dental morphology, which estimates ancestry based on the information collected from 30,000 individuals in seven (7) geographic areas in accordance with the traits proposed by the ASUDAS system, in which a Bayesian classification algorithm is calculated in order to establish the likelihood of correspondence in one of the established geographic groups (Scott *et al.*, 2018). Moreover, these groups will correspond to the three ancestral stocks recorded for populations in post-Hispanic America: European, Amerindian and African (Rodríguez Cuenca, 2004).

Finally, anthropometric methods based on the measurements taken in the long bones of the upper and lower extremities were used to estimate stature, subsequently applying regression formulas and adjusting them, according to the method, to the corresponding sex and ancestry. To this end, the proposals of Manouvrier (1892), Pearson (1899) and Olivier *et al.* (1978) were used for the European population, the Genovés method (1967) for the Mesoamerican population, and Trotter & Glesser (1958) for the population of European and African descent. Moreover, the Steele & McKern (1969) method was used in the case of fragmented elements of long bones, finally obtaining a statural mean with the results (Rodríguez Cuenca, 1994).

Estimating the basic quartet of identification in infant and juvenile individuals

This group of individuals represents 37.5% of the sample excavated in the southern sector of the square (6/16), and 6.91% in the cathedral area (11/159) (9.71% of the whole sample) where skeletal remains of different age groups were identified. Despite the fragility of the remains and the difficulty in making a precise diagnosis, some important data for the bioanthropological analysis were nevertheless obtained.

When estimating sex, it must be considered that this type of individual has not yet developed dimorphic characters in the skeleton, which makes an accurate analysis of this category difficult. However, some observations were made regarding the morphology of the mandible and the ilium, particularly on the projection and angle of the pubic symphysis and the curvature of the crest (Rodríguez Cuenca, 1994; Schutkowski, 1993).

Unlike sex, age estimation is much more reliable thanks to the processes inherent in growth and maturation during osteogenesis and odontogenesis, which include the formation of ossification centres, dental development and eruption, and the growth of various bone structures (Iscan & Steyn, 2013: 59). However, biological age ranges tend to widen and estimation becomes less accurate as the individual approaches adulthood. For this sample, the ages of non-adult individuals were grouped into infant I (0–6 years), infant II (7–12 years) and juvenile (13–17 years).

The methods used for age estimation in these individuals include the maturation processes of the primary and secondary ossification centres, the epiphyseal union process (Schaefer *et al.*, 2009; Scheuer & Black, 2000), and the correlation between long bone diaphysis length and biological age (Schaefer *et al.*, 2009; Scheuer & Black, 2000; Ubelaker, 1989a). The proposals of Ubelaker (1989b) for recording dental formation and eruption, the dental maturation method of Demirjian & Colleagues (1973), and the method for recording the process of formation and eruption of the third molar of Mincer & Colleagues (1993) were also used.

With regard to observations regarding ancestry or biological affiliation, we find a situation similar to that with the estimation of sex, since the diagnostic structures for this evaluation have not been fully formed, with the scarcity of available variables available for analysis making it virtually impossible to make this estimation (Scheuer & Black, 2000).

Finally, although some regression formulas have been proposed to estimate height in foetal individuals (Fazekas & Kósa, 1978; Olivier, 1969), there is not much literature in this regard for infant individuals; moreover, there have been no studies indicating the inter-population and sex variations that may affect the height of these individuals (Iscan & Steyn, 2013: 250). However, Olivier (1969) proposes some data based on femoral length, although without specifying the variations mentioned above.

Ethics

This study does not involve live human or other living subjects. It has been undertaken with all of the requisite permissions from the Panamanian authorities (Resolution No. 139-16 of November 11, 2016, and Resolution No. 006-18 DNPH January 8, 2018), and in collaboration with the Patronato Panamá Viejo. The principal investigator has provided the ERC with copies of all of the requisite permissions and evidence of compliance with the ethical standards, which the ERC approved on 16 October 2018. As a part of the larger project, this particular study has followed appropriate ethical procedures for the archaeological study of human remains.

Results

The burial sites of the cathedral and its first location to the south-east of the square show a constant reuse of space, a situation also observed in other funerary contexts of the colonial period. Such practices meant that several burials were altered in order to house new corpses, which explains the amount of mixed skeletal remains throughout the excavation, and the fact that several of the individuals do not have all of their bone structures. The analysis of the sample excavated during the 2017 field season in the nave and atrium of Panama Viejo's cathedral included recording 159 individuals, of which 66 correspond to complete or partially complete individuals, in addition to 93 crania, which, given the information obtained from this bone structure, were also considered individuals. Meanwhile, 16 individuals were recovered in the interventions carried out to the south-east of the main square in 2018, of which 14 are complete or partially complete individuals and two are crania (Table 1).

Table 1. Distribution of osteological sample according to state of representation.

State of the individuals	Frequency	%
Complete or partially complete	80	45.71
Crania	95	54.29
Total	175	100.00

With regard to the chronological distribution of the sample, analysis of the stratigraphic sequence shows that about 9.14% of the individuals are associated with stratigraphic units situated between 1519 and 1541, all associated with inhumation events carried out to the south-east of the main square, corresponding to the temple's first location. Subsequently, 88 individuals (50.29%) identified as buried between 1542 and 1626, associated with the relocation of the cathedral and its first decades of use. Due to the insertion of stonework bases for the timber columns that supported the church's roof in 1626, 63 individuals excavated were identified as having been deposited between 1627 and 1671 (36%), and, finally, 8 individuals who were buried in the atrium of the cathedral, all of them linked to the 17th century, made up 4.57% of the sample (Table 2 and Figure 2).

Preservation state and completeness of individuals

The conditions of inhumation and action of taphonomic processes in the funerary contexts of the cathedral and the south-east

Table 2. Distribution of osteological sample by chronological periods.

Chronology	N (Individuals)	%
1519–1541	16	9.14
1542–1626	88	50.29
1627–1671	63	36.00
1600–1671	8	4.57
Total	175	100.00

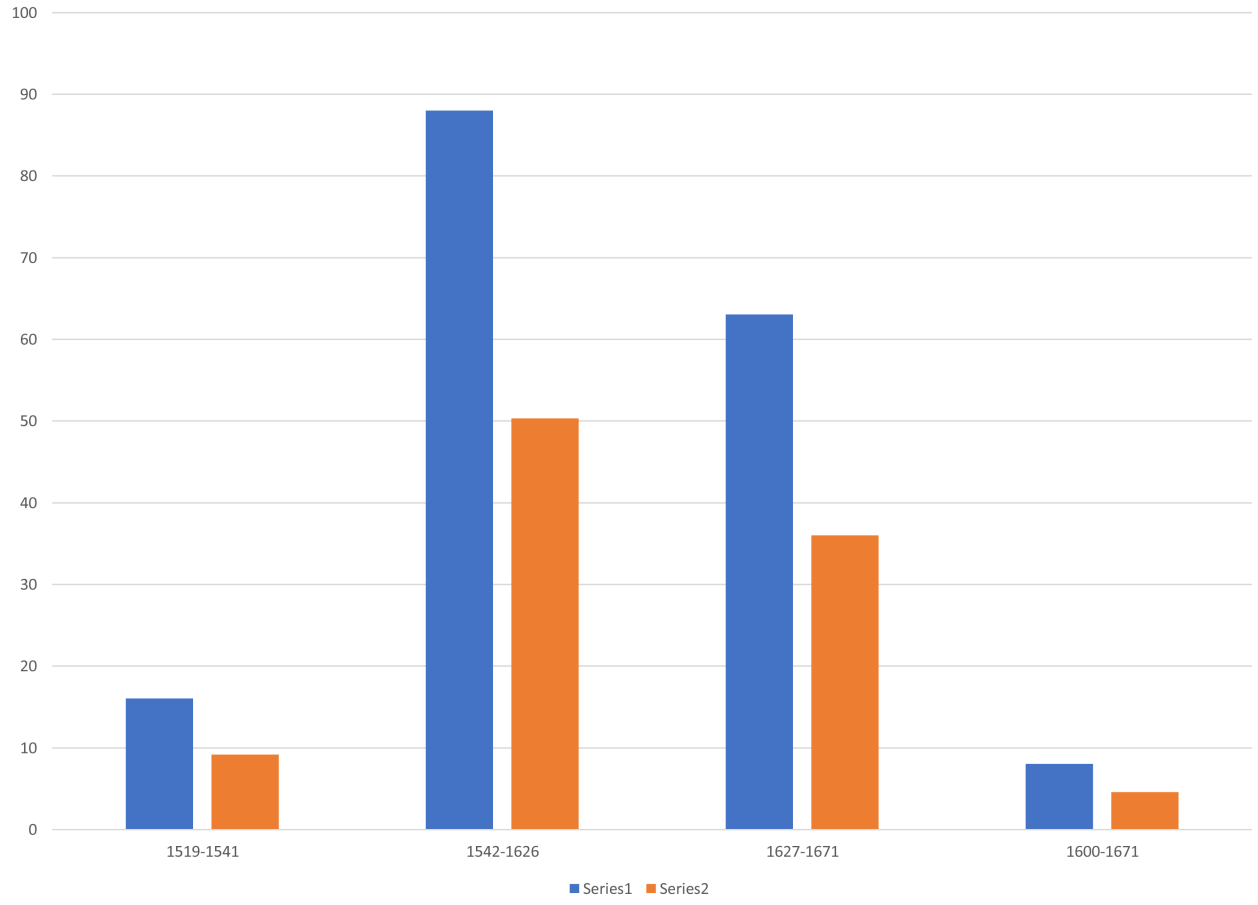

Figure 2. Chronology distribution in the whole sample.

of the square show a high incidence of conservation grade 2 (49.71%) for the whole sample, corresponding to skeletal remains with some surface alterations, damage in epiphyseal areas, and a moderate degree of fragmentation that can nevertheless limit bioanthropological analysis. Next, in grade 3 are those individuals with better preservation conditions (32.57%), which present modifications or lesser degrees of fragmentation and, finally, with 17.71% are those skeletons with greater taphonomic damage, also linked to high fragmentation (Table 3).

However, when observing the information in each archaeological intervention area, the cathedral sector has a higher preservation index (2.13) than the south-east of the square (1.81), where highly fragmented individuals with evident taphonomic damage that considerably affected their conservation, possibly due to the type of soil and the environmental conditions of the area in which the bodies were deposited, were recovered.

With regard to preservation by anatomical areas, the upper extremities were the best preserved, with an index of 2.46 for the right side and 2.32 for the left side, followed by the lower extremities, where the right side has an index of 2.24 and the left side 2.07. Close behind is the cranium with a mean value of 2.15 and, to a lesser extent, the shoulder girdle (1.83), thorax (1.81) and pelvis (1.74), which tend to be the most affected in archaeological contexts due to the fragility of these bone structures (Table 4).

Table 3. Degree of preservation in the burial sites in the cathedral and south-east of the square in Panamá Viejo.

Preservation	N (Individuals)	%
Poor	31	17.71
Fair	87	49.71
Good	57	32.57
Total	175	100

Table 4. Degree of preservation by anatomical area.

Skeleton area	Average preservation
Cranium	2.15
Thorax	1.81
Shoulder girdle	1.83
Right upper limb	2.46
Left upper limb	2.32
Pelvic girdle	1.74
Right lower limb	2.07
Left lower limb	2.24

Despite the relatively good conservation conditions of the sample overall, there is no direct correspondence with the completeness of the individuals analysed, since 60.57% of those in the sample are represented by 25% of bone elements or less, followed some distance behind by those with a degree of completeness between 50% and 75% (20%) and those with 25% to 50% (14.29%). Moreover, those with better representation indices correspond to only 5.145% of the sample (Table 5).

However, these figures may be skewed by including both individuals represented by complete and partially complete skeletons, as well as those associated only with crania, which in this sample corresponds to 95 individuals (54.29% of the whole sample). It was therefore decided to analyse this aspect in accordance with the type of bone structure involved.

In this sense, if we consider the data obtained only for the individuals corresponding to complete and partially complete skeletons, it can be seen that 43.75% of them have good representativeness (between 50% and 75% of the skeleton), while 31.25% have a completeness ranging from 25% to 50%. Individuals with a representation below 25% correspond to 13.75% of individuals not represented by crania, and those with a high representation (above 75%) total about 11.25% of individuals (Table 6 and Figure 3).

With regard to the crania, it can be seen that most individuals show degrees of completeness above 50%, corresponding to

Table 5. Degree of completeness of analysed individuals.

Completeness	N (Individuals)	%
0–25%	106	60.57
25–50%	25	14.29
50–75%	35	20
>75%	9	5.143
Total	175	100

Table 6. Degree of completeness according to area represented.

Completeness	Cranium		Complete or partially complete individuals	
	N	%	N	%
0–25%	11	11.58	11	13.75
25–50%	22	23.16	25	31.25
50–75%	31	32.63	35	43.75
>75%	31	32.63	9	11.25
Total	95	100	80	100

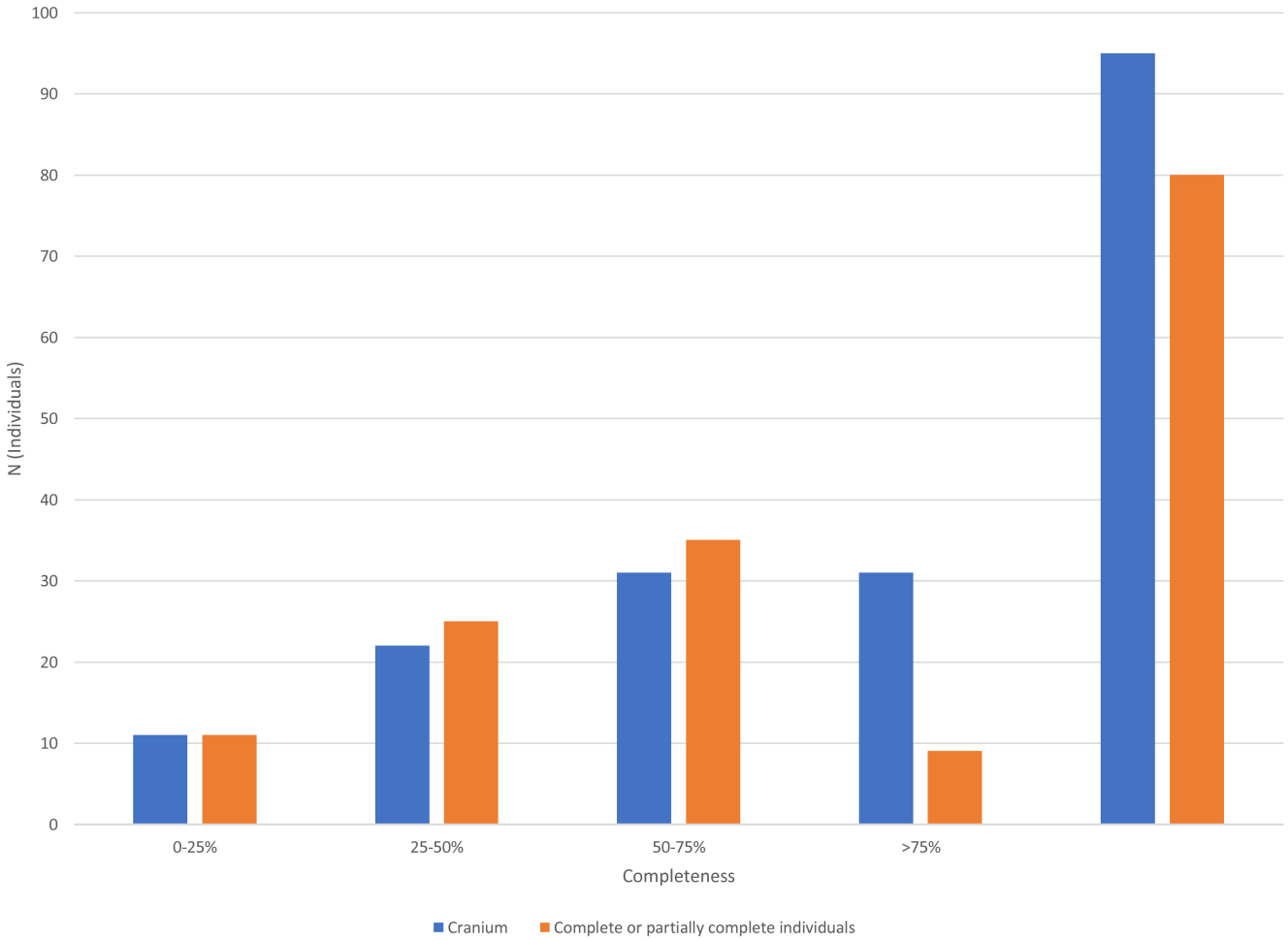

Figure 3. Completeness degree of sample.

65.26% of the sample in this category, slightly higher than for the skeletons. Moreover, it can be seen that 23.16% of the crania had a completeness ranging between 25% and 50%, while those conserving about 25% of this anatomical region correspond to 11.58%.

However, several factors that may influence these figures should be discussed. First, we should consider the conditions of the site formation processes and taphonomic agents involved in the differential conservation of the skeletal remains (Figure 4). The conditions and characteristics of the soils in this region of Panamá, which tend to be quite clayey and acidic, mean preservation of organic material is affected. However, in general terms the sample was relatively well preserved and represented, although signs of advanced deterioration were also observed in some individuals, particularly in infants and juveniles, in which bioanthropological observations were limited. Moreover, while the low frequency of subadults identified in the sample is striking, this is perhaps due to the particularities of the inhumation context, since these individuals may have been buried in a space different from that of the archaeological interventions.

Preservation of skeletal material has a direct effect on the proportion of skeletal remains that can be associated with an individual, and, therefore, on the completeness rates of the sample. In many cases, an individual may be represented by just a few bone structures, which leads to several methodological problems when analysing this type of series. The characteristics of the formation processes of the archaeological contexts also have an impact on preservation and representation (Figure 5 and Figure 6). For example, anthropic alterations of the skeletons were recorded in many of the sepulchres excavated in the Cathedral and south-east of the square, as a result of the funerary spaces being constantly reused in order to make room for others, reduced the sepulchres previously found there, while also altering the position in which they had been deposited and causing a loss of connection among many bone elements (Martín, 2002; Martín & Figueroa, 2001; Rivera-Sandoval, 2006; Rivera-Sandoval, 2014).

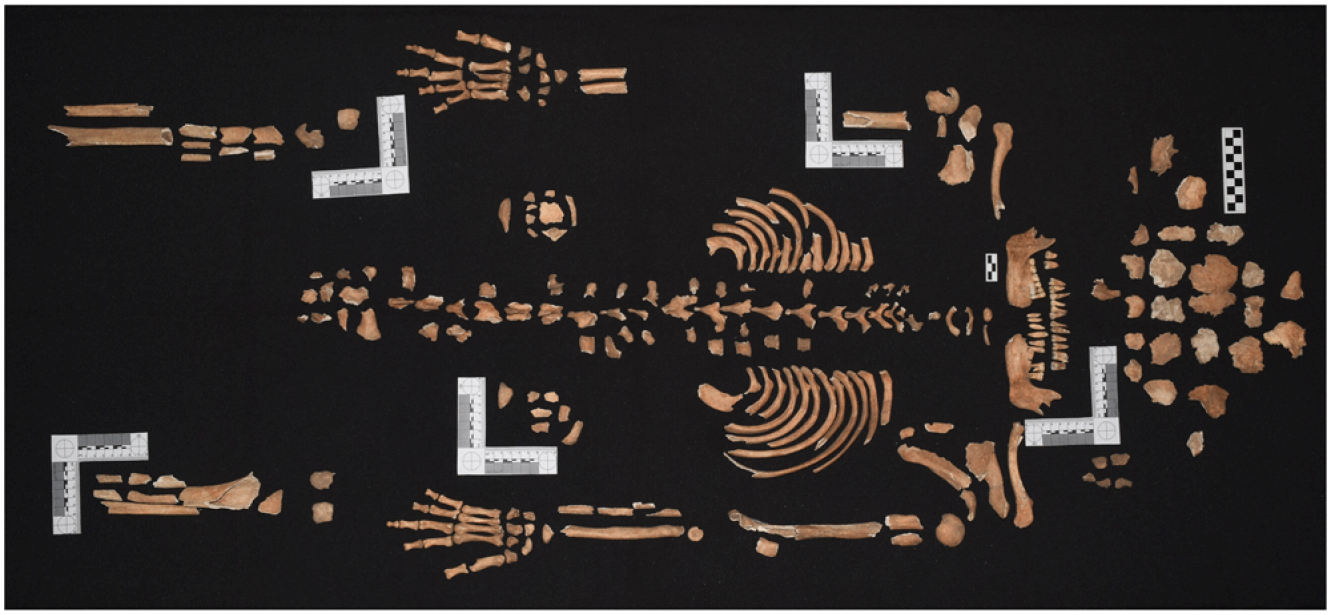

Figure 4. Individual 4015 with relatively good state of conservation in costal arches, mandible and hands, average in the other skeletal structures, and poor in vertebrae and pelvic girdle.

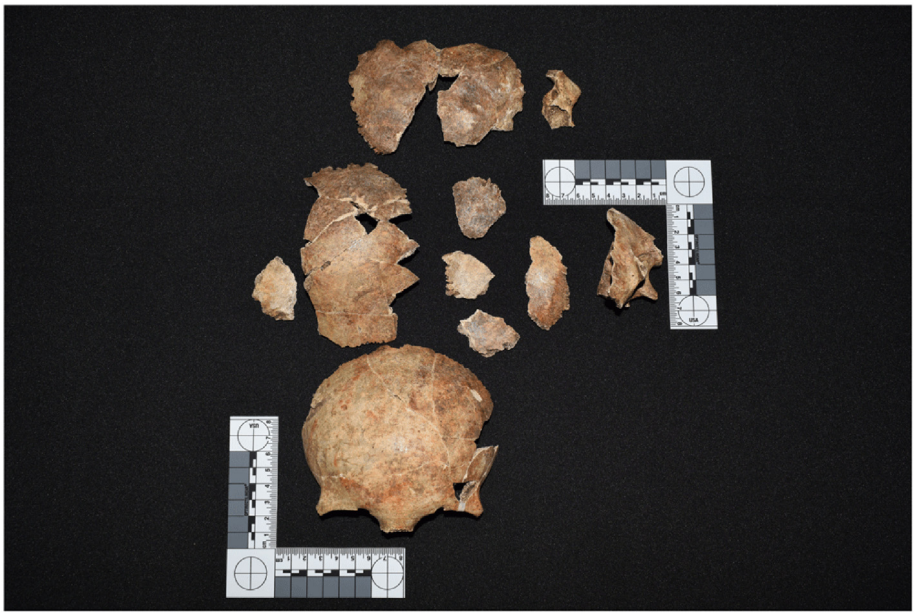

Figure 5. Cranium of individual 1015 in a regular state of preservation and completeness.

This suggests that the completeness figures for the series excavated at Panamá Viejo may be associated with the particularities of the funerary contexts, given the high degree of alteration present in the sepulchres and the constant presence of reduced burials, causing the disarticulation of the skeletons and therefore making individualisation difficult, which is reflected in the completeness figures of the sample.

Paleodemographic analysis

Distribution by sex. Analysis of the sample yielded data that does not match that previously seen for the colonial occupation of other sectors of Panamá Viejo, where a relatively symmetrical distribution between the number of male and female individuals had been observed (Martín *et al.*, 2009; Rojas-Sepúlveda *et al.*, 2011). For the whole sample analyses,



Figure 6. Individual 1148 represented only by the lower limbs.

it is observed that 55.43% correspond to female or probably female individuals, which is considerably higher than the figure of 28.57% for male and possibly male individuals. There was a low representation of individuals with unknown sex (5.14%), which correspond to infant individuals who had not yet developed dimorphic sexual characteristics. Finally, in about 10.86% of the sample it was not possible to estimate sex due to the fragmentation or absence of the anatomical diagnostic parts for analysis (Table 7 and Figure 7).

The high percentage of female individuals has strong implications at a paleodemographic level, as it tends to skew the information. However, these figures can perhaps be explained by the particularities of the funerary context, inhumation patterns and the demographic situation at the time. First, although ecclesiastical sepulchres were generally distributed according to economic and social considerations rather than sexual differences during the colonial period, in some cases activities linked to death involved the confraternities, namely corporate institutions that, among other things, organised the funerals and burial of their members, even helping to finance

Table 7. Distribution of sample by sex.

	N (Individuals)	%
Female	80	45.71
Probably Female	17	9.71
Male	23	13.14
Probably Male	27	15.43
Unknown sex	9	5.14
Unobservable	19	10.86
Total	175	100.00

inhumations (Rodríguez González, 1999). However, the historical documentation for Panama Viejo does not clarify the role women played in these types of organisations.

In the archaeological literature, it is possible to identify colonial sites with an apparent segregation of burial sites based on gender. For example, Stojanowski (2013), based on his analysis of burials in the church of the Spanish mission of San Pedro and San Pablo de Patale in Florida, a site that was active for two decades in the early 17th century, finds that there is a tendency to bury male individuals in the left nave of the temple or church, although he points out that the sample may be somewhat limited (Stojanowski, 2013: 43). Secondly, a relatively high proportion of female individuals is found in the central part of the church of the mission Santa Catalina de Guale de Santa María, a circumstance that fails to fit into a specific interpretation but which is notable for the distribution by sex in the burial space (Stojanowski, 2013: 134).

We must also consider the itinerant life of many of the men in Panamá who, due to the activities of the port, had to be away from the city for long periods of time, leaving the women behind. This could explain the large number of female individuals found in the sample, which in turn could be associated with information that will be presented below when discussing other criteria of the bioanthropological analysis.

If we consider the information from the sample according to its chronological distribution, as proposed in the stratigraphic analysis of the two excavated spaces, it can be seen that for the period 1519–1541, 43.75% corresponds to individuals with unobservable sex estimation, followed by probably male individuals (31.25%), those with undetermined sex (18.75%), and, finally, women, represented with just one individual (6.25%). The low incidence of the female population is striking compared to that reported for the area excavated in 2017, but this could be due to the particularities of the representativeness and conservation of the sample, which may skew the results. It is also possible that these figures are due to the low female presence in the first decades

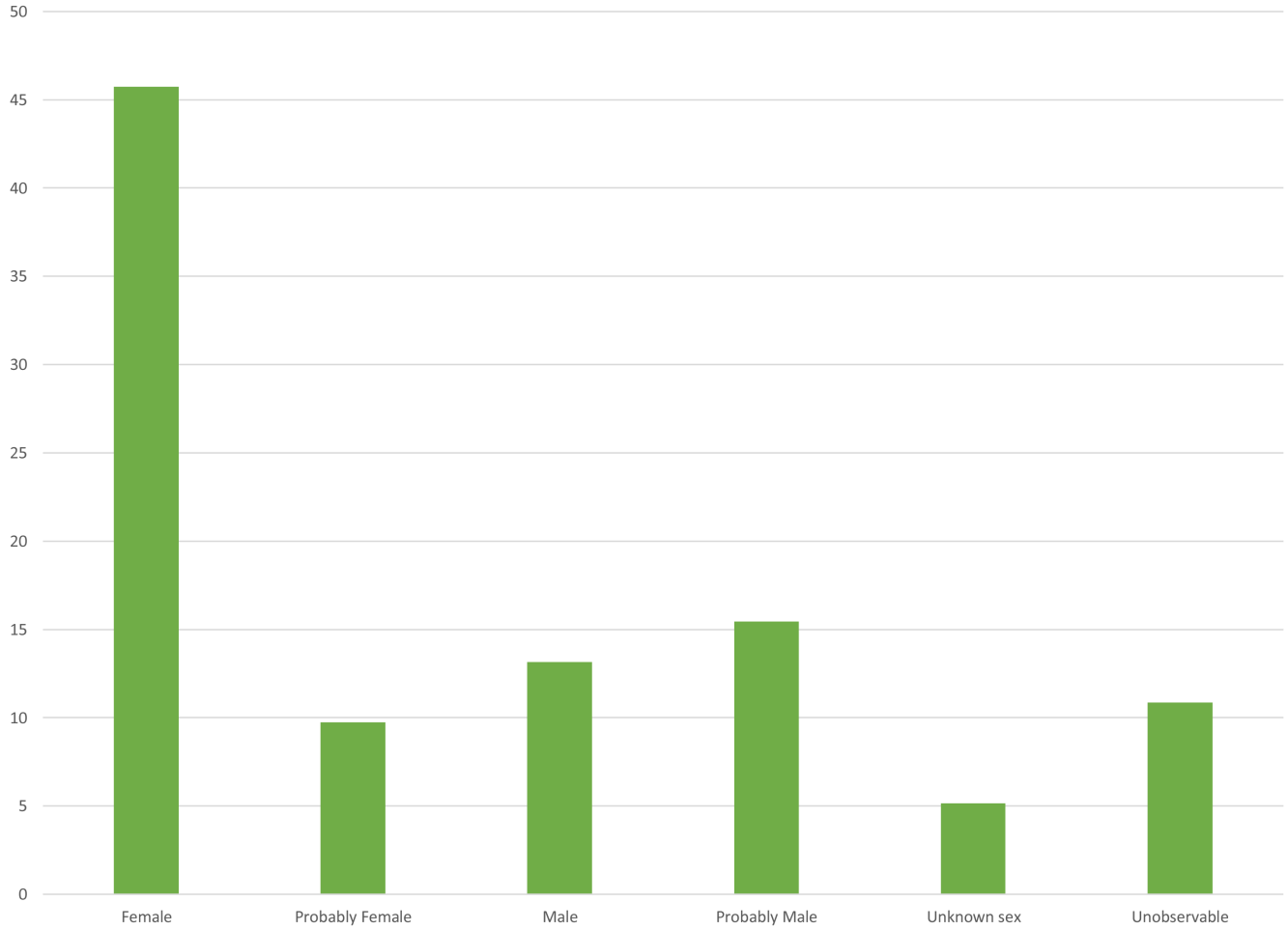

Figure 7. Distribution of sample excavated in the cathedral by sex.

of life in the city, a time when most of the women present were indigenous, as is the case of the individual identified in the sample.

This result contrasts with that recorded in the subsequent Cathedral site, which, between 1542 and 1626 provides 56.82% of the sample for female and probably female individuals, while males account for 28.41%. Individuals with undetermined (5.68%) and unobservable (9.09%) sex appear in smaller proportion.

The figures are slightly more accentuated for the period 1627–1671, where women total 65.08% and men 28.57%, with only 4.76% of individuals who could not be estimated due to a lack of diagnostic structures. Finally, the trend is maintained for the individuals excavated in the atrium of the cathedral (1600–1671), where women represent 62.5% and men 25% of the sample in this sector, although it should be noted that they are only represented by five and two individuals, respectively (Table 8 and Figure 8).

***Distribution by age range*.** When analysing the data in terms of age distribution, it can be seen that the cathedral sample shows a very low proportion of subadult individuals, representing 9.14% of the analysed sample, with individuals aged 0 to 6 (2.86%), 7 to 12 (2.29%) and 13 to 17 (4%). This situation is most likely due to the preservation conditions of the skeletal remains in this type of population and to burial patterns of the time, when some temples had sectors specifically for children. A good example is the church of the Patale mission, where most subadult individual burials are concentrated in the area near the temple's façade while those located in other sectors of the nave were associated with females, suggesting kinship between the individuals (Stojanowski, 2013: 43–50). In the case of Panama Viejo, five of the 16 subadult individuals were excavated south-east of the main square (1519–1541), associated with 31.25% of individuals for this site. If we consider the earliest time of occupation in the cathedral (1542–1626), the figure drops considerably to 9.09% of individuals, increasing slightly to 12.5% between 1627 and 1671, although in this case related to a single juvenile

Table 8. Distribution of sample by sex according to chronological period.

	1519-1541		1542-1626		1627-1671		1600-1671		Total	
	N	%	N	%	N	%	N	%	N	%
Female	1	6.25	41	46.59	35	55.56	3	37.5	80	45.71
Probably Female	0	0	9	10.23	6	9.52	2	25	17	9.71
Male	0	0	15	17.05	6	9.52	2	25	23	13.14
Probably Male	5	31.25	10	11.36	12	19.05	0	0	27	15.43
Unknown sex	3	18.75	5	5.68	1	1.59	0	0	9	5.14
Unobservable	7	43.75	8	9.09	3	4.76	1	12.5	19	10.86
Total	16	100	88	100	63	100	8	100	175	100

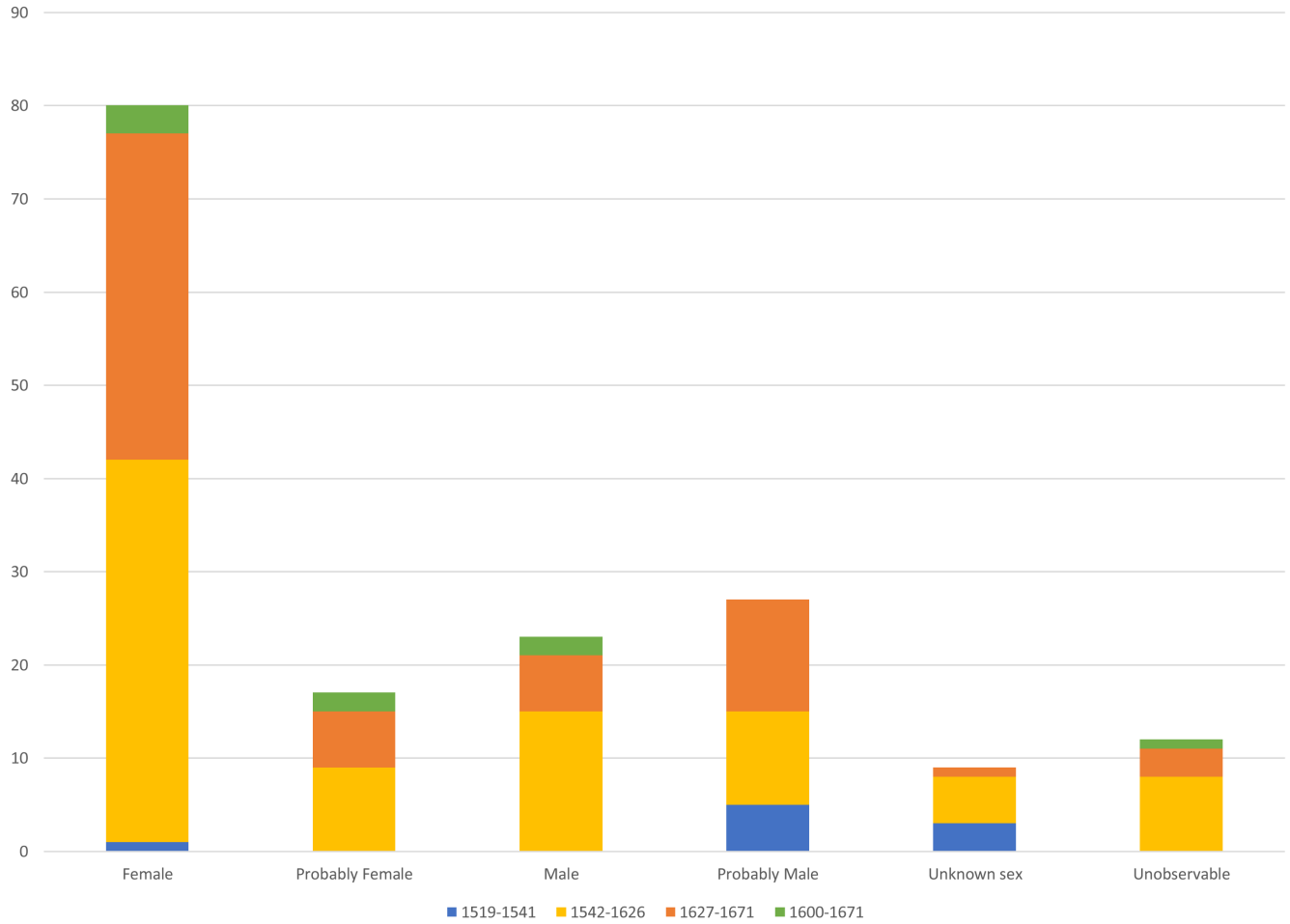

Figure 8. Distribution of sample by sex according to timing.

individual. Finally, two subadult individuals were recorded in the atrium area (1600–1671), one aged 7 to 12 and the other 13 to 17, which add up to 25% for those individuals excavated in the atrium. This would seem to suggest, firstly, that there was initially no age distinction when burying subadult individuals in the temple space, although over time this changed

towards having a special sector for the inhumation of these individuals. Secondly, we should consider the high rates of infant mortality that may have occurred in the first years following the foundation of the city, caused by both epidemiological factors and changes in living conditions as the population had to adjust to new dynamics.

Regarding adult individuals, it can be observed that young adults (52.57%) are found in a greater proportion than middle adults (12.57%), and the absence of older adults in the sample is particularly striking. There were also cases of individuals whose age range could not be determined due to the lack of representativeness or conservation of the diagnostic structures required for estimation, which meant they were grouped in the adult category, making up 25.71% of the whole sample (Table 9 and Figure 9). These figures follow the trend observed in other colonial skeletal series of Panamá Viejo (Martín *et al.*, 2009; Rojas-Sepúlveda *et al.*, 2011).

These data may be a result of the difficult conditions faced by the European, indigenous and African population during the

Table 9. Distribution of sample by age group.

Age	N (Individuals)	%
Neonatal	0	0.00
Infant I (0–6)	5	2.86
Infant II (7–12)	4	2.29
Juvenile (13–17)	7	4.00
Total Non-adults	16	9.14
Young Adult (18–34)	92	52.57
Middle Adult (35–55)	22	12.57
Old Adult (+55)	0	0.00
Adult (+18)	45	25.71
Total adults	159	90.86
TOTAL	175	100

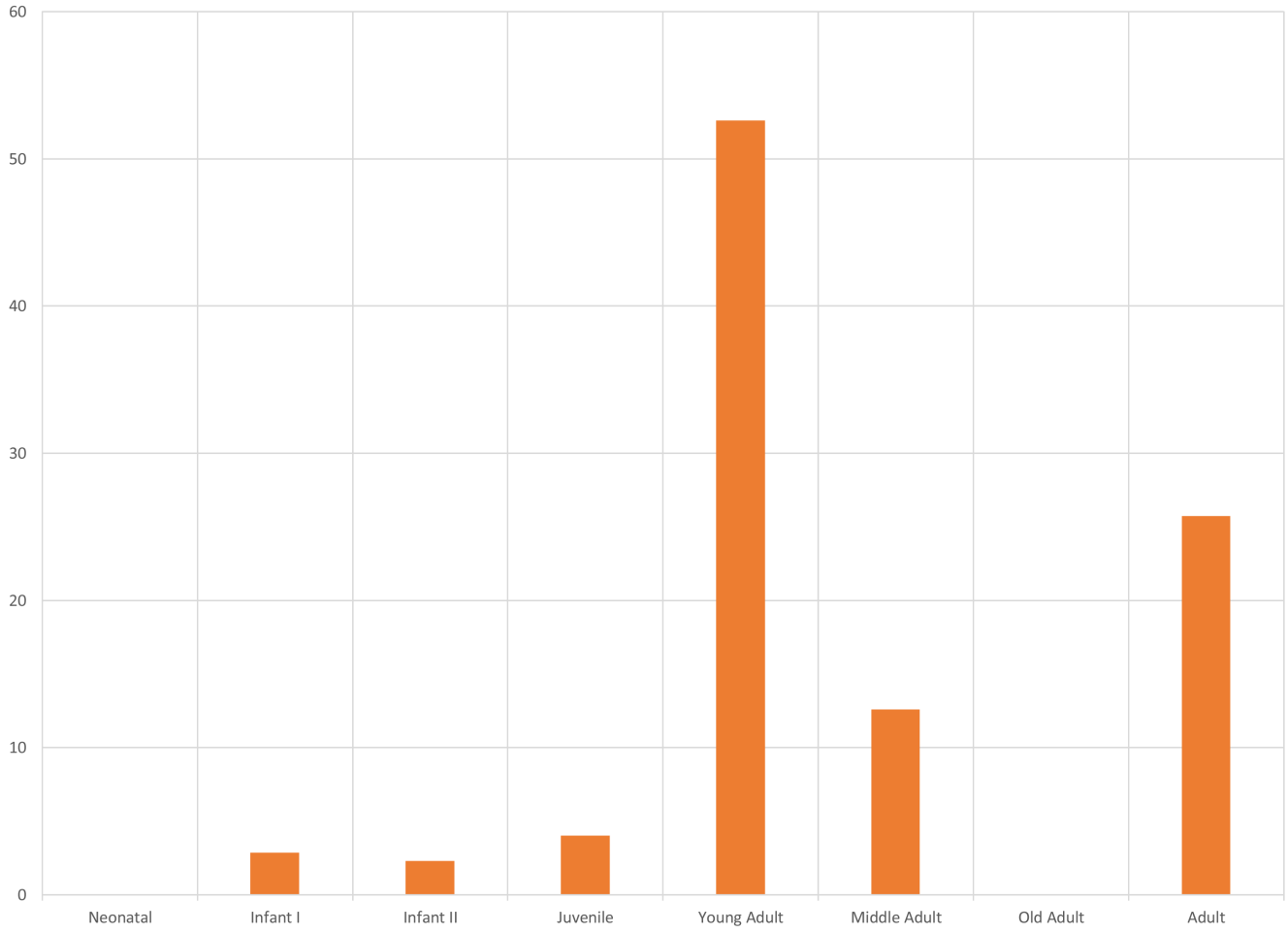

Figure 9. Age distribution of sample excavated in the cathedral and south-east of the square.

contact period and in subsequent decades, which led to stressful situations (nutritional, environmental, social, health, etc.) that differentially affected certain sectors, including young adults (18–34 years of age).

This situation also influences the survival rates of individuals, producing low life expectancy, which perhaps explains the lack of older adults. In addition to the information previously obtained in PanamaViejo, where a similar trend is seen when analysing the ages of the adult population (Martín *et al.*, 2009 and Rojas-Sepúlveda *et al.*, 2011), this high proportion of young individuals can be found in other colonial sites, followed by middle adults, such as in the temple of Nuestra Señora de la Concepción in Campeche, Mexico. The researcher explains that this situation is due to the precarious living conditions the Campeche population endured because of living in a port, where the constant arrival and circulation of different human groups led to the proliferation of diseases, epidemics, and famines, producing high mortality rates in the young population (Rodríguez Pérez, 2010: 107).

If we cross-reference the information on age with sex, young adult female individuals are the best represented in the whole sample (33.14%), followed by males in the same age range (17.71%). In the other age categories, in contrast, the distance between male and female individuals tends to decrease considerably, although female individuals are always better represented (Table 10 and Figure 10).

Analysing the data according to chronology, we can see that young adults are also the best represented after the relocation of the Cathedral in 1542, decreasing slightly from 56.82% for 1542–1626, to 52.38% for 1627–1671. Moreover, young adults appear most frequently (62.5%) in the atrium area (1600–1671), despite there being few individuals in this sector. The proportion of individuals aged between 35 and 55 increases from 12.5% in years 1542–1626 to 15.87% in the period between 1627 and 1671, although no individual is reported in this age range in the temple's first site (Table 11 and Figure 11).

Population affiliation or phenotypic variation. Observations were made on 54.85% of the sample, despite its complexity in terms of conservation and representation of teeth and skeletal remains of the cranium and facial skeleton, as used to estimate ancestry or phenotypic variation. The craniometric, morphological and dental information was used to group the sample into one of the three population groups linked to phenotypic variation, namely European, Amerindian or African, although in some cases individuals with characteristics of two population affiliations were found, albeit with one of them always predominating. Nine groups were identified when taking these considerations into account.

Table 12 and Figure 12 show that the best represented population groups are African and European, each with 14.86% of the whole sample. In smaller proportions are the groups predominantly European with African traits and predominantly African with European traits, each with 5.71%, followed by the Amerindian population (5.14%). Of the four remaining groups, 2.86% are predominantly Amerindian individuals with European traits, the same as for predominantly African with Amerindian traits, while predominantly Amerindian with African traits (1.71%) and predominantly European with Amerindian traits (1.14%) are the least represented in the sample.

It is striking that adding the individuals associated with African and predominantly African groups brings a total of 23.43%, slightly higher than those represented with European and predominantly European populations (21.71%). In contrast to what happened in other temples, where the cost of inhumation depended on the deceased's socioeconomic capacity and preference to be located close to the altar (Rivera-Sandoval, 2006),

Table 10. Distribution of sample by age group according to sex.

Age	Unobservable		Unknown sex		Male		Female	
	N	%	N	%	N	%	N	%
Neonatal	0	0.00	0	0.00	0	0.00	0	0.00
Infant I (0–6)	0	0.00	5	2.86	0	0.00	0	0.00
Infant II (7–12)	0	0.00	4	2.29	0	0.00	0	0.00
Juvenile (13–17)	2	1.14	0	0.00	2	1.14	3	1.71
Young Adult (18–34)	3	1.71	0	0.00	31	17.71	58	33.14
Middle Adult (35–55)	0	0.00	0	0.00	8	4.57	14	8.00
Old Adult (+55)	0	0.00	0	0.00	0	0.00	0	0.00
Adult (+18)	14	8.00	0	0.00	9	5.14	22	12.57
Total	19	10.86	9	5.14	50	28.57	97	55.43

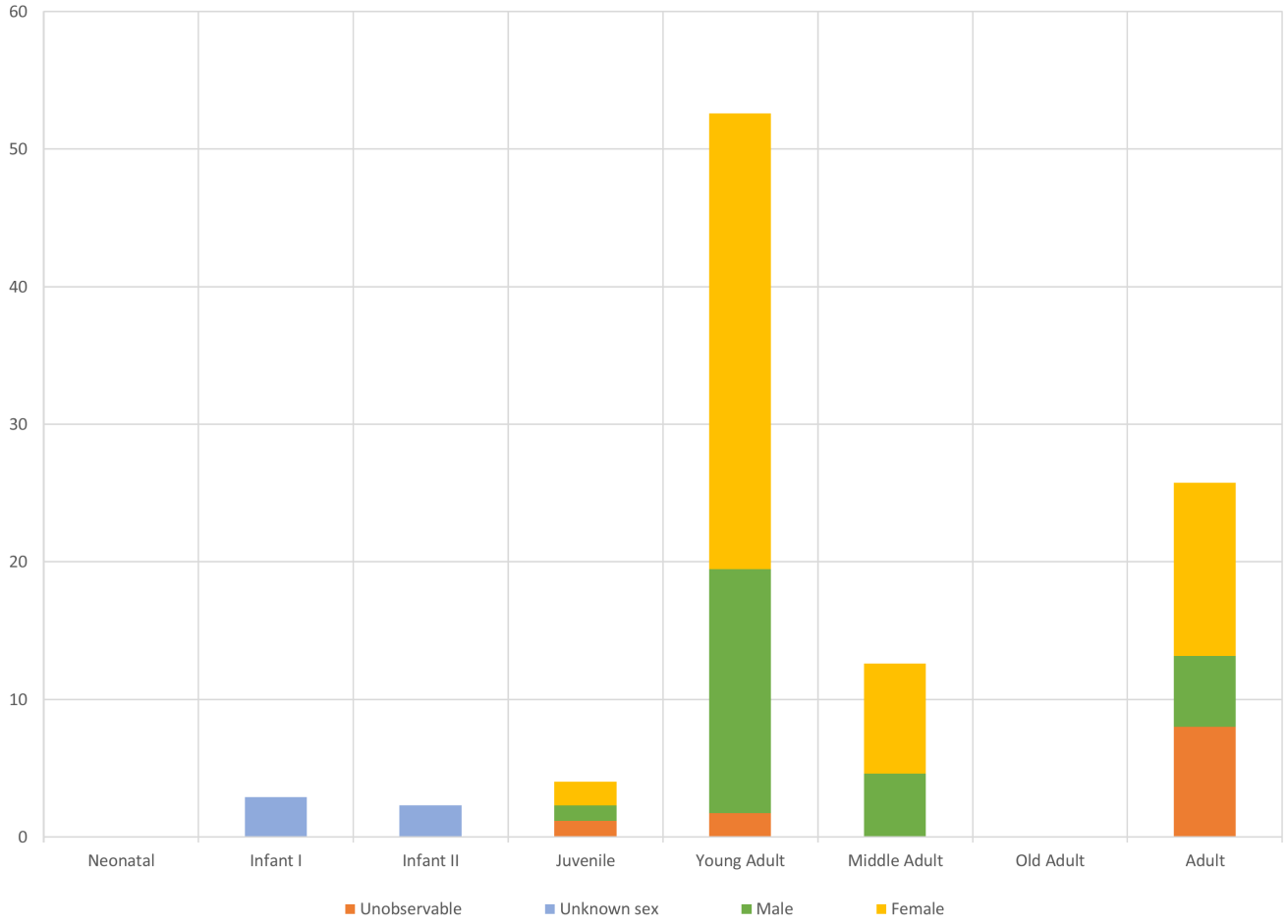

Figure 10. Age distribution of individuals by sex.

Table 11. Distribution of sample by age groups according to chronological period.

Age	1519-1541		1542-1626		1627-1671		1600-1671		Total	
	N	%	N	%	N	%	N	%	N	%
Neonatal	0	0	0	0	0	0.00	0	0	0	0.00
Infant I (0–6)	1	6.25	4	4.55	0	0.00	0	0	5	2.86
Infant II (7–12)	2	12.5	1	1.14	1	1.59	0	0	4	2.29
Juvenile (13–17)	2	12.5	3	3.41	1	1.59	1	12.50	7	4.00
Young Adult (18–34)	4	25	50	56.82	33	52.38	5	62.50	92	52.57
Middle Adult (35–55)	0	0	11	12.50	10	15.87	1	12.50	22	12.57
Old Adult (+55)	0	0	0	0.00	0	0.00	0	0	0	0.00
Adult (+18)	7	43.75	19	21.59	18	28.57	1	12.50	45	25.71
Total	16	100	88	100	63	100	8	100	175	100

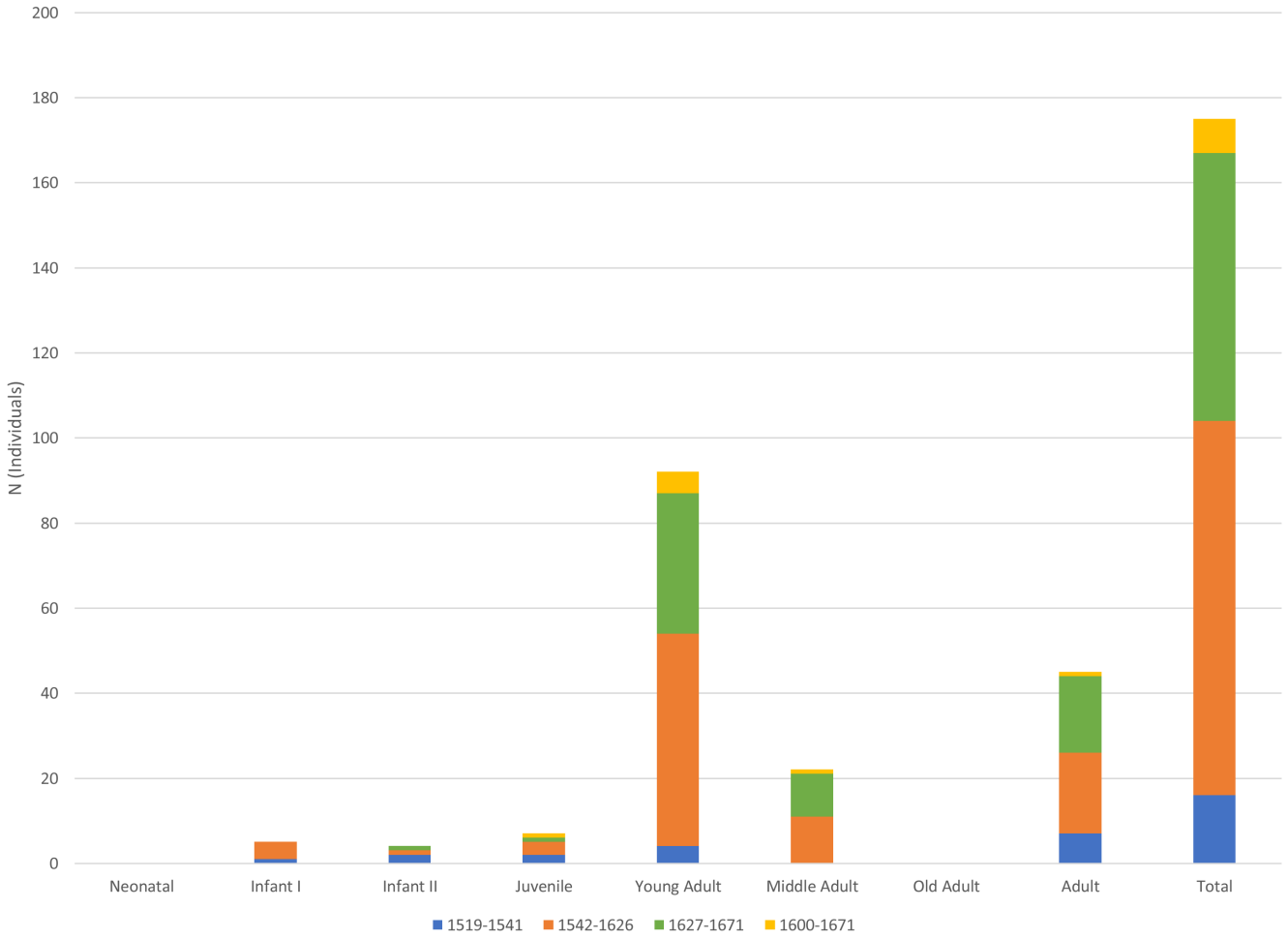

Figure 11. Distribution of sample by age according to timing.

Table 12. Distribution of sample by population affiliation.

Population Affiliation	N (Individuals)	%
European	26	14.86
European/Amerindian	2	1.14
European/African	10	5.71
Amerindian	9	5.14
Amerindian/European	5	2.86
Amerindian/African	3	1.71
African	26	14.86
African/European	10	5.71
African/Amerindian	5	2.86
Unobservable	79	45.14
TOTAL	175	100.00

it seems that Panama Viejo's Cathedral was the best option for those wishing to have an ecclesiastical burial at a moderate cost (Aram *et al.*, 2020: 506). This would allow access for a wide diversity of social and ethnic sectors that were living or passing through in Panamá, including the population of African and indigenous descent, a situation corroborated by documentary information (Aram *et al.*, 2020).

The exploration of historical documentation also clarifies that it was quite frequent to receive "the solemnly poor" in the Cathedral and for the slave population to be buried there, while sectors in a more privileged economic position might choose one of the churches of the city's convents for their interment (Aram *et al.*, 2020: 506). This situation also responded to the need to bury the bulk of the Panamanian population that had become predominantly of African ancestry during the 16th and 17th centuries.

Furthermore, there is a low proportion of individuals of Amerindian descent (9.71%, also adding those predominantly Amerindians with traits of other phenotypes) compared to the

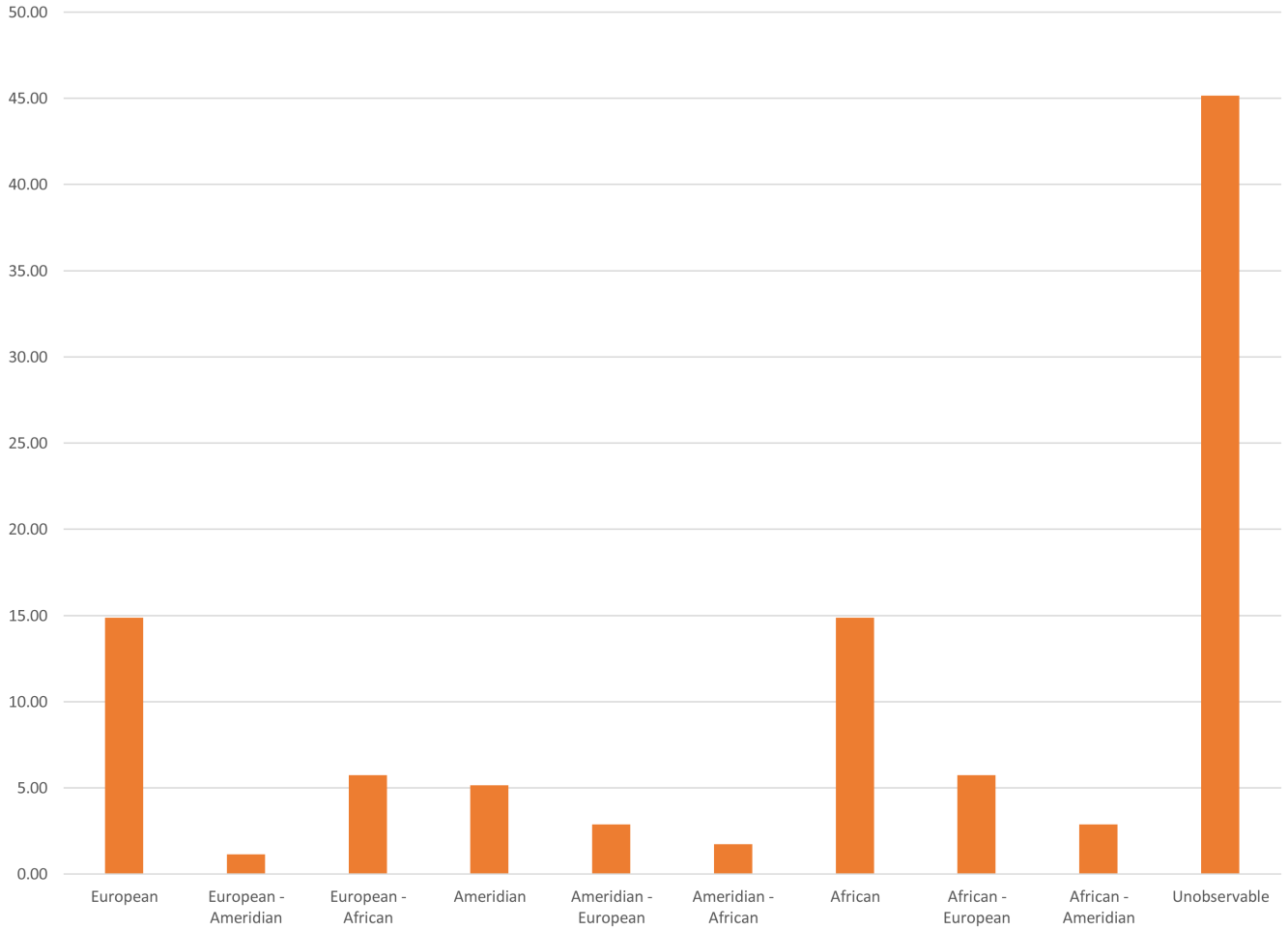

Figure 12. Distribution of sample analysed by population affiliation.

other population groups. This may be due to the epidemiological shock suffered by the indigenous groups after coming into contact with the Europeans, a situation described in the written documentation, and which decimated the population. In this regard, Jaén Suárez (1986) estimates that 225,000 people died on the isthmus during the contact period. For Panama Viejo alone, the author comments that, while in 1533 there was a record of approximately 500 indigenous people, the figure drops drastically in subsequent years, totalling just 22 in 1607 (Jaén Suárez, 1986:52). The chronicler of the Indies Fernández de Oviedo even states that around two million indigenous people had already disappeared in Castilla de Oro alone by 1542 (Cooke & Sánchez Herrera, 2004:48), which, beyond evaluating the accuracy of the figure, indicates a reality in terms of perceptions of the death of Panaman's indigenous people.

This situation is also related to the processes of population mixture that began very early on, representing a significant part of the sample analysed (around 20% for the whole sample). The particularities of biological mixture in Panamá are linked, to some degree, to the low number of white women, and particularly single ones, which encouraged relations with indigenous women in the early years of the conquest. Despite being a punishable practice, unmarried co-habitation was nevertheless commonplace in America. Indeed, authors such as Mena García (1984:93) state that the medieval figure known as "barraganía" (concubine) constituted an important element in the legitimacy of free cohabitation between men and women, which, despite not having the same significance as marriage, helped regulate and extend relations between Spaniards and indigenous women, and possibly also between Europeans and Africans. This gave rise to terms such as *zambaigos* and *mulatos*, who were already a well-represented population group in Panamanian society by the 17th century (Jopling, 1994; Mena García,1984).

In this regard, Table 13 and Figure 13 show that female individuals with African traits are the best represented in the sample (12%). This trend is maintained in those individuals of

Table 13. Distribution of sample by population affiliation according to sex.

Population Affiliation	Unobservable / Unknown sex		Male		Female	
	N	%	N	%	N	%
European	3	1.71	9	5.14	14	8.00
European/Amerindian	0	0.00	1	0.57	1	0.57
European/African	0	0.00	4	2.29	6	3.43
Amerindian	1	0.57	3	1.71	5	2.86
Amerindian/European	0	0.00	3	1.71	2	1.14
Amerindian/African	0	0.00	0	0.00	3	1.71
African	0	0.00	5	2.86	21	12.00
African/European	1	0.57	2	1.14	7	4.00
African/Amerindian	1	0.57	0	0.00	4	2.29
Unobservable	22	12.57	23	13.14	34	19.43
Total	28	16.00	50	28.57	97	55.43

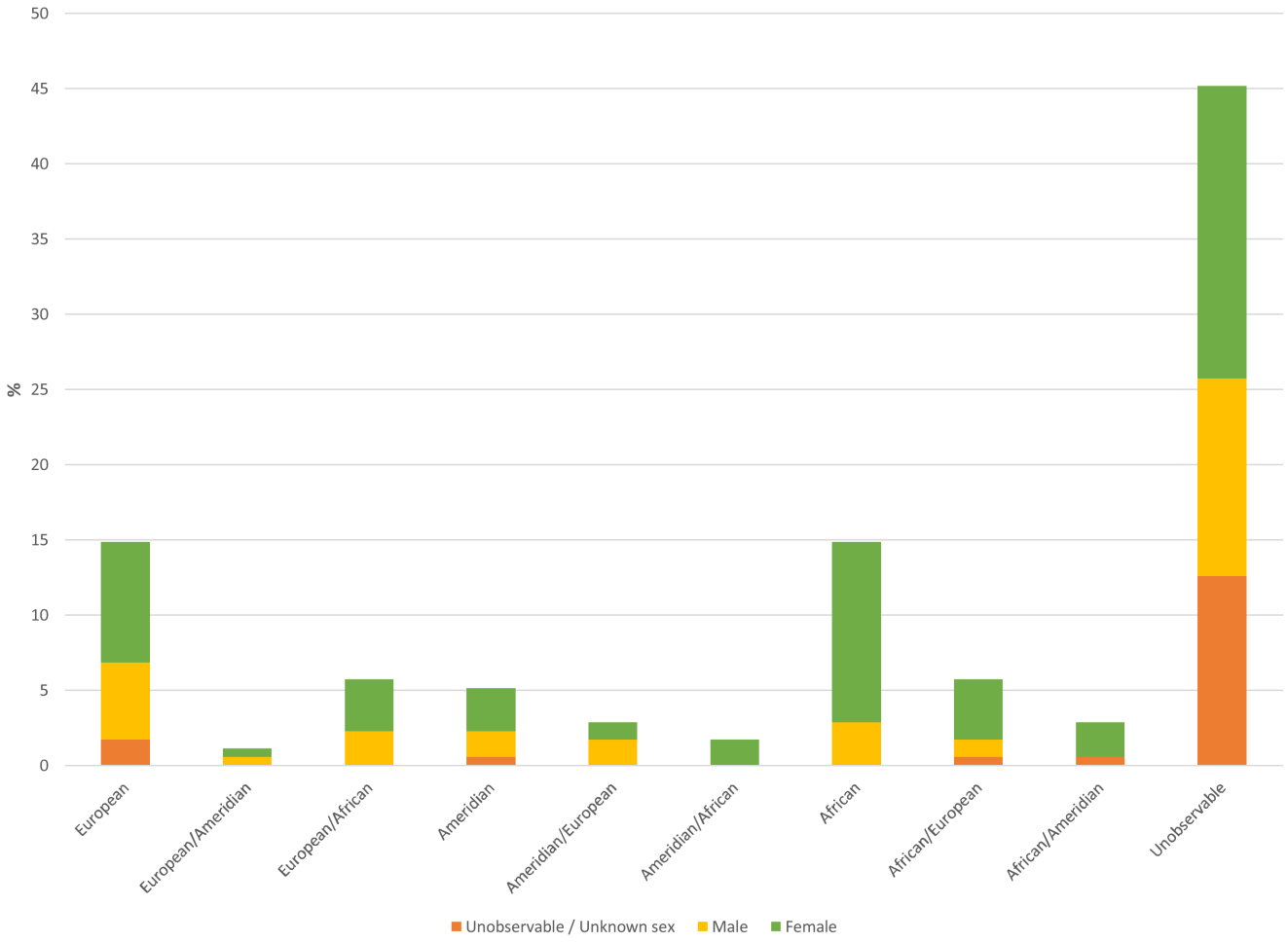

Figure 13. Distribution by population affiliation of sample, discriminated by sex.

African descent with Amerindian or European traits, suggesting an important role of women of African affiliation in the demographic structure of the population buried in the Cathedral. The proportion of male and female individuals in groups with European and Amerindian phenotypic variation, including combinations that do not include African components, tends to be much more balanced, except in individuals with European traits, where females represent 8% of the whole sample and males 5.14%.

Comparing the data according to the chronological distribution of the sample, we find that between 1519 and 1541 there is an apparent proportionality between several of the identified population groups, although this may be due to the small size of the sample excavated in the sector located to the south-east of the main square. The population of African (12.5%) and European (10.23%) descent is most represented for the period 1542–1626, followed by predominantly African individuals with European traits (5.68%) and predominantly European individuals with African traits (4.55%).

The situation is slightly reversed when looking at the data for 1627–1671, where Europeans are the best represented (23.81%), followed by Africans (20.63%). However, when adding these individuals with the subgroups in which there is a presence of traits from other populations, we find that Africans and predominantly Africans represent 31.75% in this period, while Europeans and predominantly Europeans amount to 30.16%. Moreover, it is noteworthy that in this same period there is an increase in the proportion of the indigenous population compared to the previous period (1542–1626), from a moderate 2.27% to 9.52%.

In the atrium (1600–1671), the most represented group is predominantly European with African traits (37.5%), followed by those of African descent (25%), and, with 12.5% each, Europeans and predominantly Amerindians with African traits; however, as in the south-east of the square, caution must be exercised due to the size of the sample (Table 14 and Figure 14).

Estimating stature. The state of preservation and completeness of the bone structures meant that height could only be estimated in 53 individuals in the sample (30.28%). Table 15 includes the number of observations of individuals discriminated by sex, showing that the male individuals reached an average height of 168.14 cm with a standard deviation of 6.54 cm. The tallest individuals reached 181.25 cm, while the shortest were around 152.57 cm. A mean of 161.04 cm and a standard deviation of 4.43 cm was obtained for female individuals, where the tallest women did not exceed 170.55 cm and the shortest 152.24 cm (Table 15 and Figure 15).

The small number of samples within each of the groups identified by population variation does not allow more detailed analysis of population growth characteristics. However, this trend corresponds to the figures presented for other collections of the colonial period, which show relatively low heights in all ancestral groups; in this regard, it is mentioned that populations on the Iberian Peninsula were not very tall, although Amerindians were generally shorter than those of European or African origin (Ubelaker, 1989b). Moreover, the phenotypic characteristics of Amerindian populations are also related to a coarse build, due to their physical activities and to their processes of adaptation to the environmental conditions (Rodríguez González, 1999).

Table 14. Distribution of sample by population affiliation according to the chronological period.

Population Affiliation	1519-1541		1542-1626		1627-1671		1600-1671		Total	
	N	%	N	%	N	%	N	%	N	%
European	1	6.25	9	10.23	15	23.81	1	12.5	26	14.86
European/Amerindian	1	6.25	0	0.00	1	1.59	0	0	2	1.14
European/African	0	0	4	4.55	3	4.76	3	37.5	10	5.71
Amerindian	1	6.25	2	2.27	6	9.52	0	0	9	5.14
Amerindian/European	1	6.25	2	2.27	2	3.17	0	0	5	2.86
Amerindian/African	0	0	2	2.27	0	0.00	1	12.5	3	1.71
African	0	0	11	12.50	13	20.63	2	25	26	14.86
African/European	0	0	5	5.68	5	7.94	0	0	10	5.71
African/Amerindian	1	6.25	2	2.27	2	3.17	0	0	5	2.86
Unobservable	11	68.75	51	57.95	16	25.40	1	12.5	79	45.14
Total	16	100	88	100	63	100	8	100	175	100

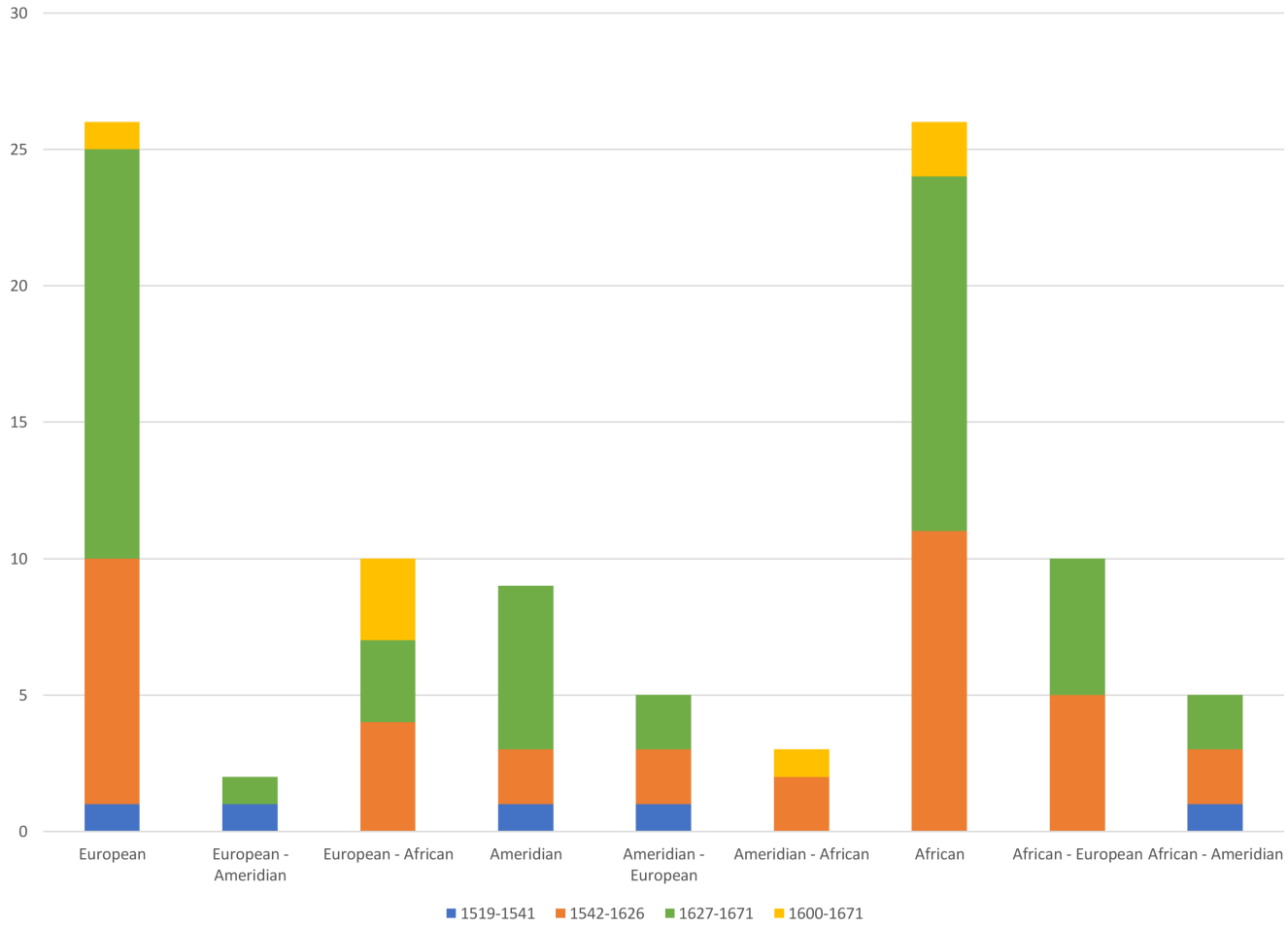

Figure 14. Distribution of sample by population affiliation according to timing.

Table 15. Estimation of height of individuals by sex.

Sex	Average	Standard deviation	Observations
Female	161.04	4.43	26
Male	168.14	6.54	26
Unobservable	165.53	5.13	1

Paleoepidemiology

In human ecology, the appearance of diseases in a group depends on a series of factors that interrelate individuals with the ecological environment in which populations develop, considering them dependent on and subject to changes that subsequently translate into processes of evolution and adaption.

Taking this interpretative model, disease is seen as an indicator of stress, understood as an imbalance in the process of homoeostasis, i.e. the energy balance between the environment (input) and human consumption (output), which allows the survival of a population and is conditioned by environmental and cultural variables (Rodríguez González, 1999; Rodríguez Cuenca, 2006). It is therefore necessary to measure the degree of adaptability of the population through aspects such as quality of diet, state of health and disease, and the effectiveness of the mechanisms regulating population growth.

Understanding the processes associated with disease in past populations requires a clear understanding of the context in

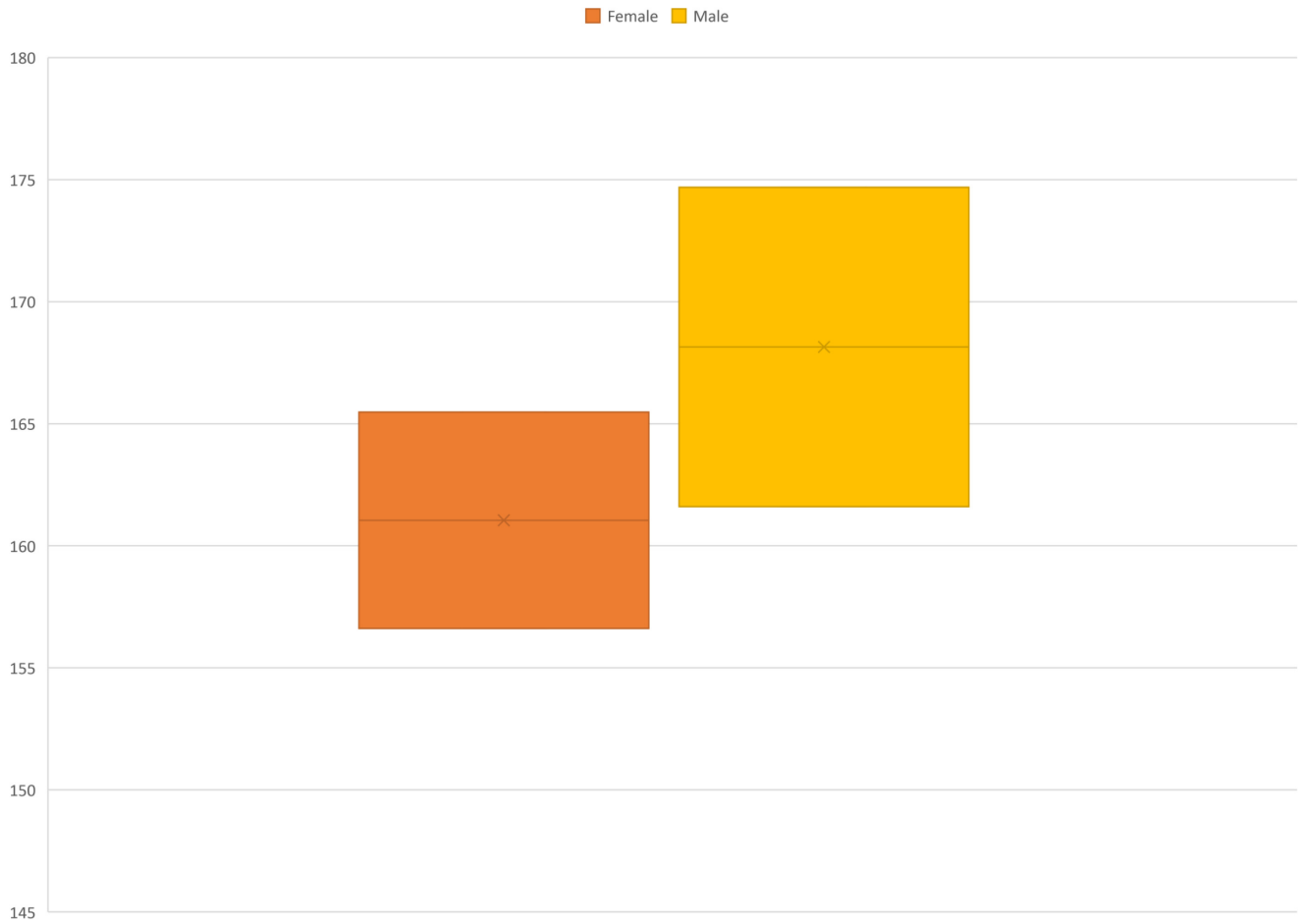

Figure 15. Estimated height ranges in Panamá Viejo Cathedral sample, discriminated by sex.

which the skeletal remains were found to develop a more reliable interpretation. This type of observation makes it possible to explain processes extending over time, and also how these groups generated responses to the action of a range of factors that led to lesions or disease. However, some problems limit the reconstruction of a paleopathological and paleoepidemiological profile of past populations, including the absence of soft tissue that would provide insight into disease symptomatology, and limitations in establishing an accurate diagnosis based on just a few bone fragments.

Overall frequency of bone anomalies for the whole sample. As mentioned in the methodology, the paleoepidemiological analysis must consider unobservable aspects of both the individual and the overall sample. The information presented therefore includes those data that could not be collected and were coded as "Unobservable" due to the state of preservation of the elements, particularly in the case of the crania. Furthermore, the percentage of the whole sample is presented, as well as the percentage associated with the number of possible observations made, which is called the effective percentage.

Table 16 shows the proportion of individuals who present some bone anomaly, and those who do not present any. With regard to individuals excavated in the Cathedral and at the south-east site of the square, this percentage stands at 22.86% of individuals without anomalies, while those with some type of anomaly represent 66.86%; this figure is high in comparison to that analysed from other sites of Panama Viejo's monumental complex, where an effective prevalence of 50% had been obtained for individuals from the colonial period with anomalies (Martín *et al.*, 2009; Rojas-Sepúlveda *et al.*, 2011).

Specific frequency of bone anomalies for the whole sample. In accordance with the bone changes observed in the sample (in which diseases, lesions or biocultural practices can be identified), Table 17 and Figure 22 present the frequency and percentage of those individuals for which some of these elements were diagnosed, as related to the paleopathological profile of the population buried in the two sites of Panama Viejo's cathedral. These aspects are associated with stress activities as a consequence of adaptive expressions, but they are not all necessarily related to pathological processes

Table 16. Proportion of individuals with bone anomalies in the sample analysed.

	Frequency	% Total	% Effective
Unobservable	18	10.29	
No anomalies	40	22.86	25.48
Anomaly	117	66.86	74.52
Total	175	100.00	
Total Effective	157	89.71	100.00

Table 17. Proportion of bone anomalies identified in the cathedral sample.

Bone lesions or anomalies	Frequency	% Effective	% Total
Periostosis	48	30.57	27.43
Entheseal changes	46	29.30	26.29
Degenerative Joint Disease	38	24.20	21.71
Trauma	28	17.83	16.00
Porotic hyperostosis	43	27.39	24.57
Cribra orbitalia	13	8.28	7.43
Neoplastic Lesions	14	8.92	8.00
Hyperostosis frontalis interna	5	3.18	2.86
Inflammatory processes	5	3.18	2.86
Spondylolysis	4	2.55	2.29
Developmental anomalies	1	0.64	0.57
Heterotopic ossification	2	1.27	1.14
Trepanation	1	0.64	0.57
Cranial flattening	1	0.64	0.57

(Mendonça de Souza, 1999:4). Among the lesions, those related to infectious processes (30.57%) (Figure 16), porotic hyperostosis (27.39%) (Figure 17), and degenerative joint disease (DJD) (24.20%) (Figure 21) are particularly worthy of note. Meanwhile, although it is not a specific lesion, entheseal changes (Figure 18 and Figure 19) are found with an effective prevalence of 29.30%. To a lesser degree, some cases of traumatic lesions (14.65%) (Figure 20), cribra orbitalia and neoplastic formations are reported, each with 8.97%, as well as the presence of hyperostosis frontalis interna and inflammatory processes, with 3.45% each. Finally, there are some cases of developmental anomalies (4.83%), heterotopic ossification (1.38%), one case of unintentional cranial flattening (0.69%), and one case of trepanation (0.69%).

These figures suggest a significant impact on the living conditions of the population during the 16th and 17th centuries, in which changes that include type of diet, exposure to pathogens, and the effect of labour activities on the state of health of these human groups are all evident. The indigenous people, for example, had designed a structure to harness resources based on adaptation processes developed according to the particularities of their environment, and invested their energy mainly in producing and consuming food, although they also set aside time for other activities, such as those associated with rituals (Rodríguez Cuenca, 1999; Rodríguez Cuenca, 2006). In this regard, the most frequent lesions in these populations were related to DJD, porotic hyperostosis, and trauma. However, the presence of infectious diseases such as



Figure 16. **Periostosis associated with infectious process in left tibia of 1174.**



Figure 17. **Porotic hyperostosis in occipital of 1030.**



Figure 18. **Entheseal change in right clavicle of 1087.**

treponematosis and tuberculosis in the New World also had an impact on the health conditions of the indigenous population (Rodríguez Cuenca, 2006).



Figure 19. **Entheseal change in right radial tuberosity of 4007.**

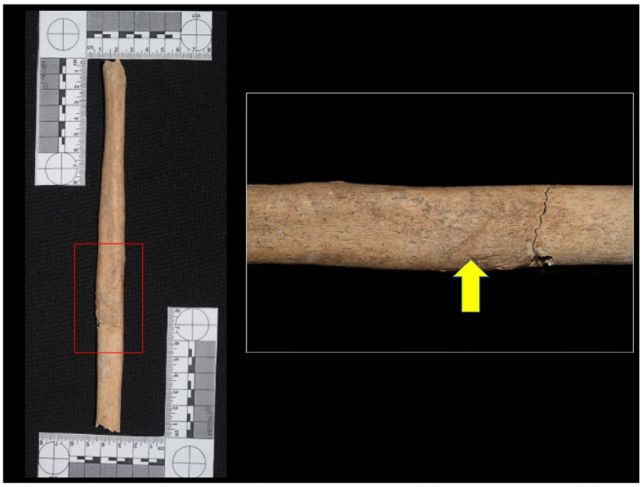

Figure 20. **Traumatic lesion in left fibula of 5006.**

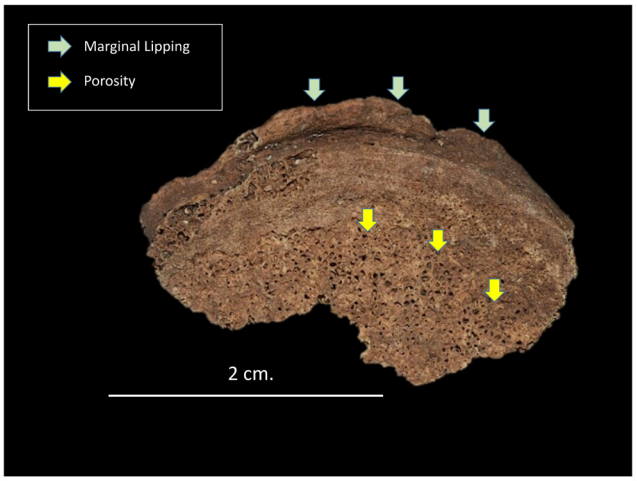

Figure 21. **Degenerative joint disease processes in vertebral body of 4007.**

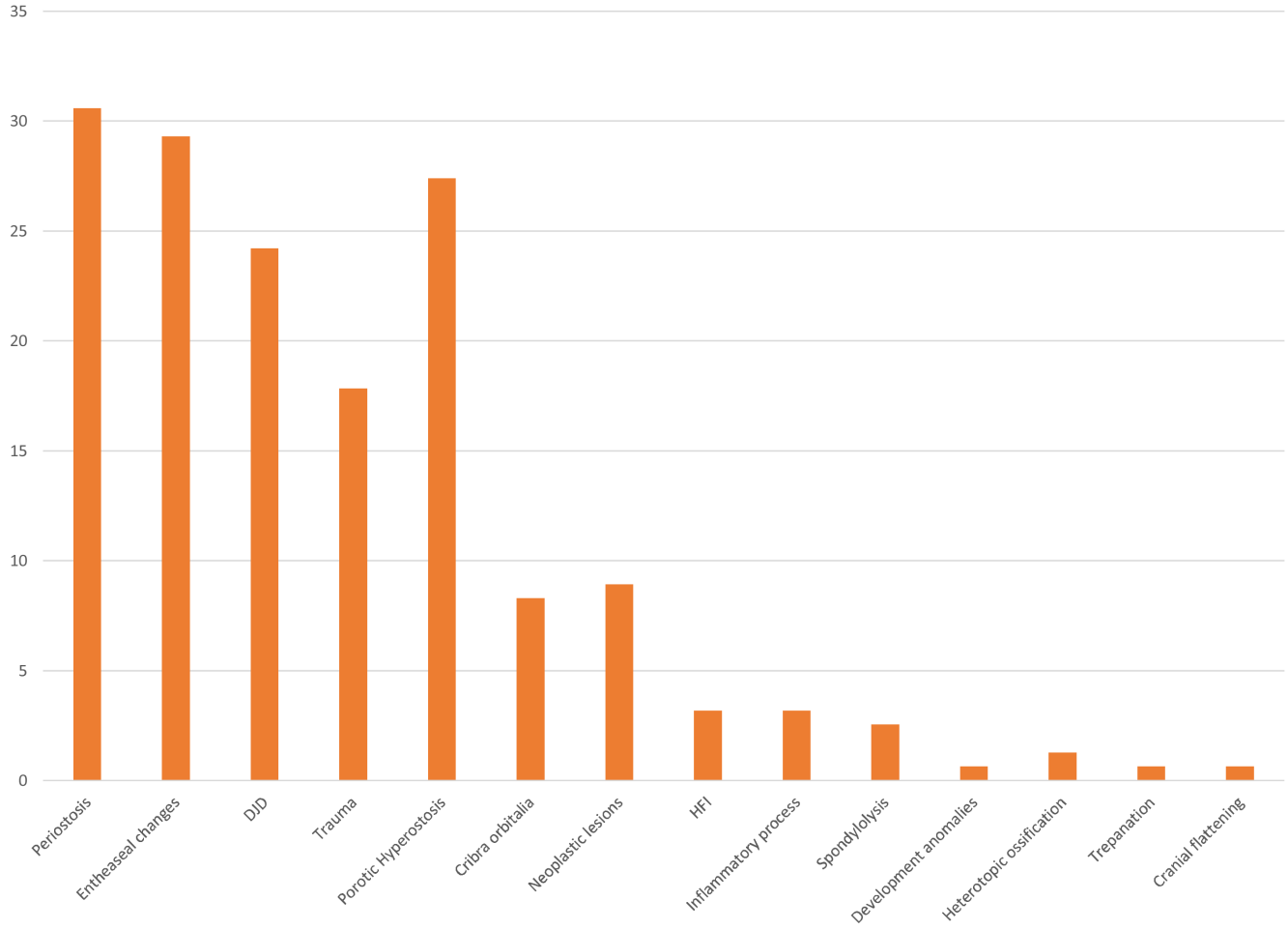

Figure 22. Effective percentage of bone anomalies identified in sample.

About bones, lesions related to infectious processes generally correspond to periostosis, which manifests itself in the outer layer of the bone, and osteomyelitis, which involves both the periosteum and the medullary cavity of the bone. These processes involve a response to some type of external pathogen such as staphylococci, streptococci and pneumococci, which cause diseases including leprosy, syphilis and tuberculosis.

In this regard, the sample analysed shows a high effective percentage (30.57%) of infectious lesions, all associated with periostosis, both localised and extended mainly in the lower limbs. In the first case, it is possible that this is related to traumatic lesions, but it may also be related to haemorrhagic, metabolic, congenital, and tumoral ailments. It should be noted that the lesion is much more likely to be due to infectious factors when extended in several anatomical regions. However, it is necessary to distinguish between specific and non-specific infections, since the same bone reaction may be due to different aetiologies, which makes diagnosis difficult if the complete skeleton has not been preserved, as was the case for the sample excavated from Panama Viejo's Cathedral and to the south-east of its main square.

However, it was possible to identify that 37.5% of the individuals analysed with evidence of infectious lesions (10.28% of the whole sample) corresponded to lesions compatible with treponematosis, related to diseases such as yaws or framboesia, bejel, syphilis and pinta, the latter being the only one that does not affect the bone. With regard to bone response, it is difficult to macroscopically distinguish the type of treponematosis suffered by the individual, although in all cases the tibia is the most affected, while the fibulae and cranium may also be involved, and to a lesser extent the femur, forearm and fingers, depending on the aetiology of the disease (Aufderheide & Rodríguez-Martín, 1998; Fornaciari & Giuffra, 2009). The cases recorded in the sample analysed correspond to individuals affected bilaterally in the tibia and/or fibula, with different degrees of severity of the lesion, but involving a periosteal reaction in all cases (Figure 23 to Figure 28).



Figure 23. Periostosis compatible with infectious treponematosis process in right tibia of 1171.



Figure 24. Periostosis in tibia compatible with treponematosis of 1053.



Figure 25. Periostosis in fibula compatible with treponematosis of 1096.

On the other hand, individual 1042 shows extended infectious processes at spine level, characterised by lytic lesions



Figure 26. Periostosis in fibula compatible with treponematosis of 1126.

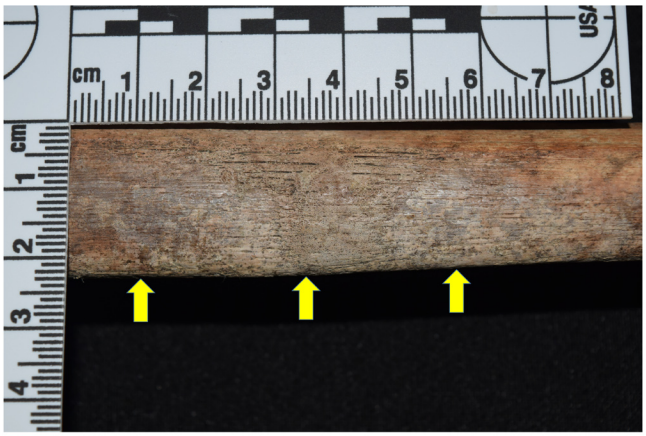

Figure 27. Periostosis in tibia compatible with treponematosis of 1122.

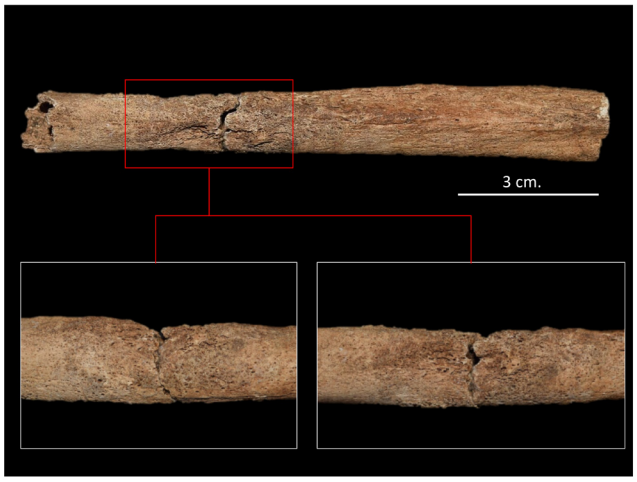

Figure 28. Widespread active periostitis in left fibula compatible with infectious process of 4017.

in the form of cavitations on vertebral bodies T8 to T11, concentrated in the anterior portion and on the lateral surfaces without affecting the upper and lower margins, with these lesions being compatible with tuberculosis (TB) or brucellosis.

In the case of TB, the presence of the disease could be underestimated in bioarchaeological contexts due to the low frequency of lesions present in the skeleton, given that it is estimated that between 1% and 7% of individuals suffering from the disease manifest bone reactions (Fornaciari & Giuffra, 2009: 63). The lesions are caused by the diffusion of bacilli through the bloodstream, affecting the portions rich in haematopoietic bone marrow, located basically in the metaphyseal sections of the long bones, vertebral bodies, and ribs. Paleopathological literature shows that over 40% of lesions associated with TB in the skeleton are concentrated in the spine, affecting the anterior region of bodies located in the lower portion of the thorax, as well as the intervertebral discs; although this frequently affects two or more vertebrae of the lower half of the dorsal and lumbar spine, it is in L1 where cavitations are most evident. In more severe cases, it generates a pathological fracture that causes so-called Pott's disease, along with marked kyphosis, while in other cases there may be fusion of the vertebrae (Aufderheide & Rodríguez-Martin, 1998; Campillo, 2001; Fornaciari & Giuffra, 2009; Waldron, 2009).

TB has another series of manifestations in the skeleton, for example periostosis can be observed on the pleura side of the rib arches, while articular tuberculosis can also develop, principally affecting the coxofemoral joint, followed by the sacroiliac, knee, tibio-astragalic and talocalcaneal (Fornaciari & Giuffra, 2009:72).

The individual 1042, despite having lytic lesions in the vertebral bodies without affecting the arches (one of the characteristics of TB), does not present the other lesions described above (Figure 29 to Figure 31). Moreover, brucellosis similarly affects the spine, and, although recurrence is found in the lumbar region, it can be found in other portions of the spine and, less frequently, can affect the long bones (Aufderheide & Rodríguez-Martín, 1998; Campillo, 2001). The differential diagnosis with TB considers that brucellosis lesions generally do not cause paravertebral abscesses, collapse of bodies or kyphosis, and tend to present destructive and reparative processes simultaneously (Aufderheide & Rodríguez-Martín, 1998: 193). It is also suggested that radiographic analysis could identify a sclerotic lesion typical of this disease that affects the anteroposterior angle of the body (Campillo, 2001:249–250).

Observing individual 1042 allows us to see the reparative processes alongside the lytic lesions, although a radiological evaluation could confirm the diagnosis. However, two individuals

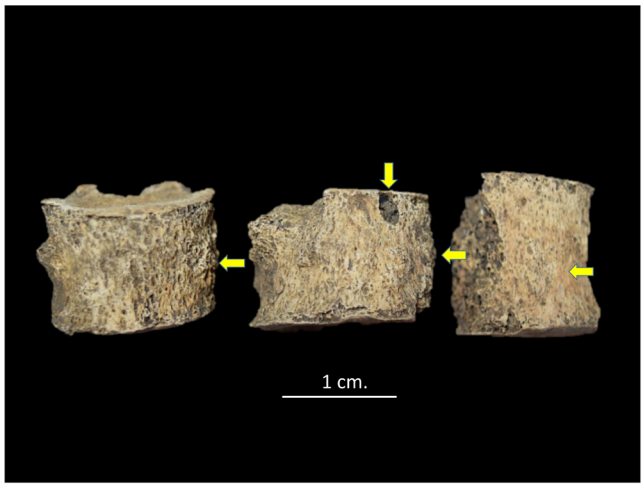

Figure 29. Lytic lesions and reparative processes in T8, 9 and 10 of 1042.

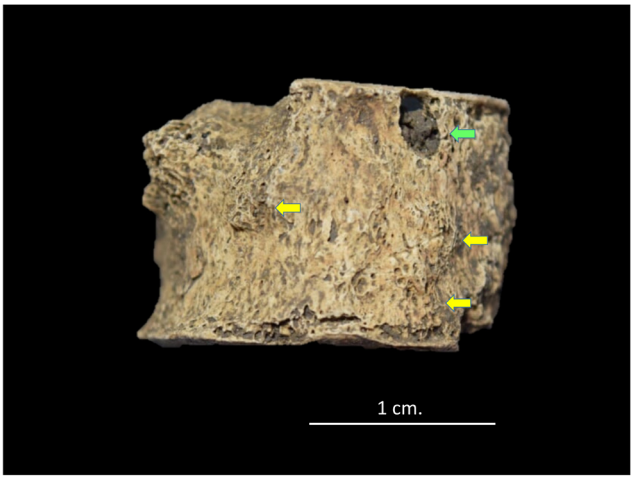

Figure 30. Lytic lesions (green) and reparative processes (yellow) in T10 of 1042.

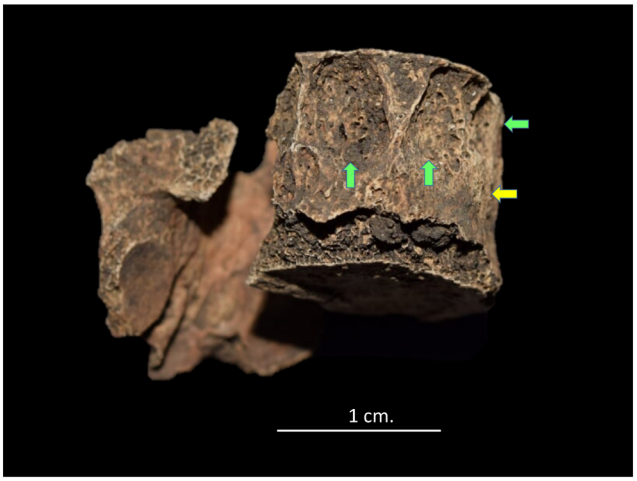

Figure 31. Lytic lesions (green) and reparative processes (yellow) in T11 of 1042.

with cavitating lytic lesions similar to those described for individual 1042 from Panama Viejo's cathedral were identified in an osteological sample from a medieval context in Albania, with the same region of the spine affected, but in this case it was possible to verify the diagnosis with molecular tests of the genetic markers of the bacterium *Brucella spp.* (Mutolo *et al.*, 2012).

Another interesting case associated with infectious diseases is that of individual 1020, in which a process of severe inflammation is observed in the splanchnocranium, affecting the frontal, sphenoid, ethmoid, left palatine and both maxillae, generating nodular formations inside the paranasal and maxillary sinuses, together with inflammation of the dental alveoli and the consequent loss of some teeth (Figure 32 to Figure 38). Furthermore, the infection affects the interior of the pyriform aperture, and bone resorption is observed in the anterior nasal

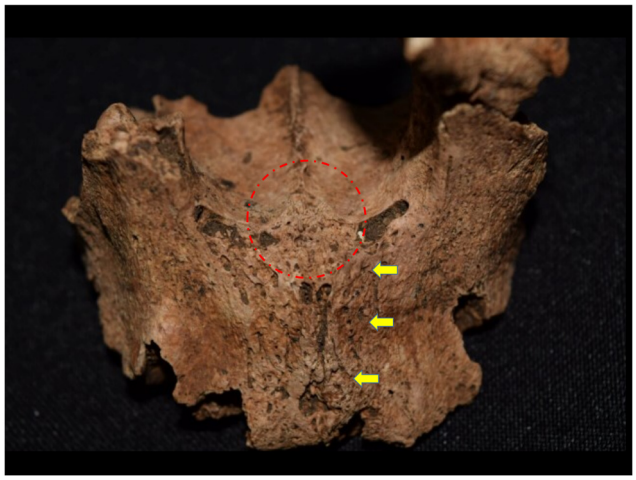

Figure 32. Reactive process in maxillary sinuses (yellow) and resorption of anterior nasal spine (red).



Figure 33. Nodular formations in maxillary sinus cavity, left zygomatic.

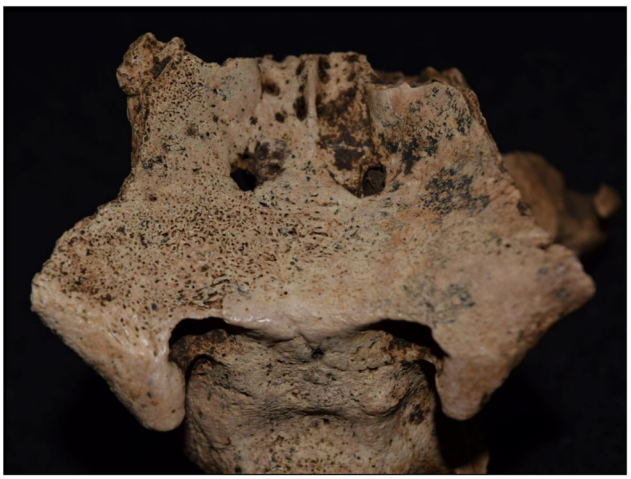

Figure 34. Reactive processes in body and lesser wings of the sphenoid.



Figure 35. Inflammatory process in crista galli.

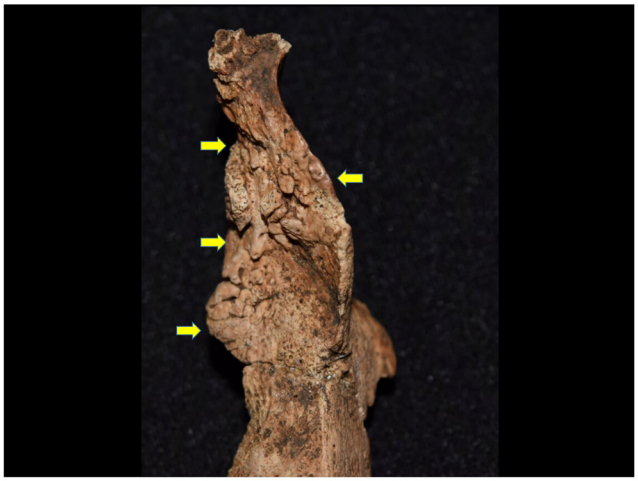

Figure 36. Lesions in pyriform aperture.



Figure 37. Lesions in maxilla and alveolar resorption in incisors.



Figure 38. Some of the lesions identified in facial skeleton of 1020.

spine. There is also thickening of structures such as the crista galli of the ethmoid, as well as the body and greater wings of the sphenoid. These types of lesions are compatible with diseases such as leprosy, leishmaniasis and severe sinusitis.

Leprosy is a mycobacterial disease that originated in East Africa and the Middle East, from where it spread to Europe and later reached the Americas during the conquest and colonisation (Waldron, 2009:97). Although this disease mainly affects the nervous system and the skin, it also generates bone responses in advanced stages of tuberculoid leprosy. However, not all individuals who suffer from leprosy manifest lesions in the bone, which explains why it is found with very low frequency in archaeological contexts (Aufderheide & Rodríguez-Martín, 1998; Fornaciari & Giuffra, 2009; Waldron, 2009). In the 1960s, Moller-Christensen identified the bone characteristics of the disease under the term "facies leprosa" or rhinomaxillary syndrome, which is characterised by chronic inflammation of the bones of the nose with consequent atrophy and resorption of the anterior nasal spine, remodelling of the margins and base of the pyriform aperture, and erosion of the nasal bones, the nasal pavement, and the palatine, which may be perforated. Finally, resorption of the alveolar processes in the maxilla is also observed with loss of central incisors (Aufderheide & Rodríguez-Martin, 1998; Fornaciari & Giuffra, 2009; Waldron, 2009).

All of these elements can be identified in individual 1020. However, the fact that this individual is only represented by the cranium makes it impossible to identify the characteristic lesions of this disease in the postcranial skeleton, including concentric erosion of bone at the feet and hand level, leading to the loss of phalanges, and significantly affecting the metatarsal phalangeal joint, giving the metatarsals the appearance of a pencil tip. It is also possible to find osteomyelitis in the bones of the foot or neuropathic changes in its joints. However, the fact that the aetiology of this disease is not so clear in paleopathology has led some to recommend mycobacterial DNA analysis (Waldron, 2009:101).

Individual 1020 also presents lesions compatible with chronic maxillary sinusitis due to the nodular formations observed in these cavities, together with the inflammatory processes of the bone; such lesions may be caused by the action of different infectious agents affecting the individual (Campillo, 2001; Waldron, 2009), among which leprosy or leishmaniasis cannot be ruled out. Leishmaniasis is a parasitic infection of the skin and mucous membranes that affects populations in humid regions of Central and South America. In an advanced stage, the disease affects the mucocutaneous cavities of the nose, involving the bone and generating destructive processes that can also affect the orbits and paranasal sinuses; however, in this case the disease is diagnosed using histologic (Aufderheide & Rodríguez-Martín, 1998: 257) or molecular methods (Costa *et al.*, 2009).

After infectious type lesions, entheseal changes (Figure 39 to Figure 41) and DJD (Figure 42 to Figure 44) were the most frequent in the sample, with effective prevalences of 29.3% and 24.2%, respectively. As the Europeans arrived, people coming together to form the new cities of the New World became involved in a range of more physically demanding activities, as they faced the difficulties of adapting to a totally different environment and lifestyle. Along these lines, it would not seem strange that the population of Panama Viejo had to engage in arduous tasks that led to lesions associated with muscular hypertrophy or enthesis, as evinced in the marked insertions left on the bones or in the marked stress on the body's articular mechanisms, creating space for the formation of lesions associated with DJD.

However, it should be noted that DJD is not always associated with mechanical stress due to physical activity, but is directly related to the ageing processes of individuals, with these



Figure 39. Entheseal changes for pectoralis major (1), deltoid (2), latissimus dorsi (3), teres major (4). Left humerus of 1082.



Figure 42. Condyles of right femur of 1153, evidence of eburnation and marginal lipping (degenerative joint disease).



Figure 40. Development of enthesis for insertion of biceps brachii in right radius of 1048.



Figure 43. Spondyloarthrosis (degenerative joint disease) with osteophytosis (yellow) and marginal lipping (green) at T8 to T11 of 1139.



Figure 41. Entheseal change for insertion of pectoralis muscle in the right clavicle of 4023.



Figure 44. Ankylosis of distal and middle phalanges of fifth finger of left hand of 4013 generated by degenerative joint disease.

lesions being more frequent in older persons. However, the characteristics of the Panama Viejo sample show the presence of mostly young or medium adults, suggesting a higher incidence of processes associated with physical activity. In other words, it is likely that the population for the colonial period was exposed to much more demanding work processes than those of the pre-Hispanic period, which directly or indirectly generated bone responses showing marked physical activity and lesions compatible with DJD.

Moreover, the high frequency of porotic hyperostosis in the sample (27.39%) suggests that the population was subjected to nutritional stress factors that caused this type of lesion in the bone (Figure 45), although it does not seem to match other characteristic traits of this type of condition, such as cribra orbitalia (8.28%) (Figure 46) and, as discussed below, nor does it correspond with linear enamel hypoplasias (LEH). In this case, it is necessary to consider not only aspects related



Figure 45. Porotic hyperostosis in parietals and occipital of 1022.

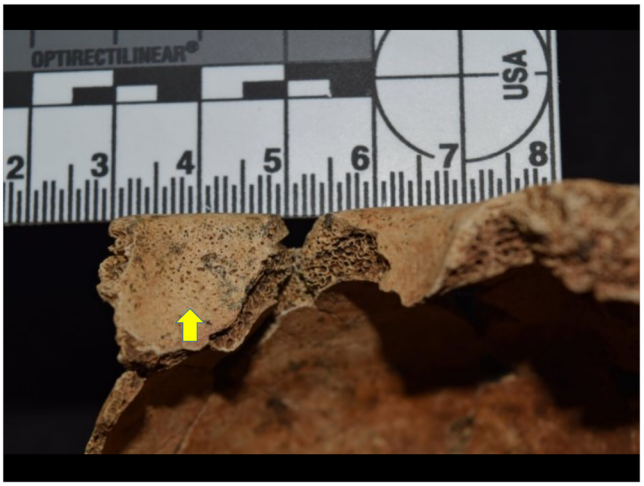

Figure 46. Cribra orbitalia on the right side in 1034.

to the diet of these populations, but also the incidence of other factors that can cause these lesions, such as parasitosis and intestinal problems; such factors tend to be much more frequent in lowlands such as Panamá, where the prevalence of these types of lesions is much higher than in mountainous regions (Rodríguez Cuenca, 2006: 178).

However, if we take the hypothesis that porotic hyperostosis is related to nutritional stress events, it is important to relate the data to the type of population that makes up the sample excavated in the cathedral, which consists mostly of women and individuals with predominantly European and African traits, as will be addressed below. However, in this regard it should be noted that for many peoples the distribution of food tended to vary according to social position, with the largest portions and the most nutritious foods generally going to the group's authorities, leaving the rest for those at the bottom of the social pyramid. This type of practice evidently left in survivors a series of traces that show the nutritional stress they were subjected to, which is compatible with the indicators of porotic hyperostosis in the crania, cribra orbitalia in the roof of the ocular orbits, and linear enamel hypoplasias. Academic literature has associated these lesions mostly with anaemic events acquired due to nutritional deficiencies, as well as congenital factors such as thalassaemia, sickle cell anaemia and spherocytosis, among others (Fornaciari & Giuffra, 2009; Larsen, 2015; Walker *et al.*, 2009). However, as they are non-specific indicators, other factors such as diarrhoea, chronic haemorrhages or parasitosis also play a role. Moreover, the association between porotic hyperostosis and cribra orbitalia is not always constant, which makes diagnosis and aetiology even more difficult.

Several discussions state that porotic hyperostosis and cribra orbitalia should not be used as pathognomonic markers of iron deficiency anaemia, which is perhaps the most frequent interpretation in the literature; indeed, according to some authors this condition in itself causes a decrease in red blood cells that does not allow bone reaction in the hypertrophic and porous processes of these lesions (Walker *et al.*, 2009). However, subsequent works have come to demonstrate that the relationship between the manifestation of porous lesions and iron deficiency cannot be completely ruled out, since, according to the medical literature, this type of anaemia stimulates erythropoietic activity and, in turn, generates hyperostosis (McIlvaine, 2015; Oxenham & Cavil, 2010).

However, there are other types of anaemia that elevate red blood cell production and are thus compatible with the development of the lesions recorded in the porotic hyperostosis and the cribra orbitalia, e.g. ameloblastic anaemia and haemolytic anaemia (Walker *et al.*, 2009). The former are associated with deficiency or malabsorption of vitamins B12 and B9 (folic acid), alongside iron deficiency (McIlvaine, 2015). The second comes about through the premature destruction of erythrocytes, which, by exceeding the production capacity of red blood cells, stimulates bone hyperostosis, a condition that will be observed in congenital anaemias such as thalassaemia

and sickle cell disease (Walker *et al.*, 2009: 112). Moreover, in some regions of the world, processes of adaptation to endemic diseases such as malaria may play a big role in the development of this type of hereditary haemolytic anaemias (Angel, 1966; Larsen, 2015; Smith-Guzmán, 2015; Walker *et al.*, 2009).

Associated with other metabolic disorders, we found evidence of a series of lesions that systemically affected the internal table of the cranium in five of the excavated individuals, specifically in the frontal bone (Figure 47 to Figure 51). The anomalies are characterised by an inflammatory periosteal reaction in different degrees of development, observing a bone apposition of nodular appearance that affects the endocranial view of the frontal, with the lesion concentrated mainly in the frontal crest and, bilaterally and symmetrically, in the orbital portion. In only one case does the lesion extend into the superior sagittal sulcus. These traits are compatible with type-B hyperostosis frontalis interna (HFI), according to the

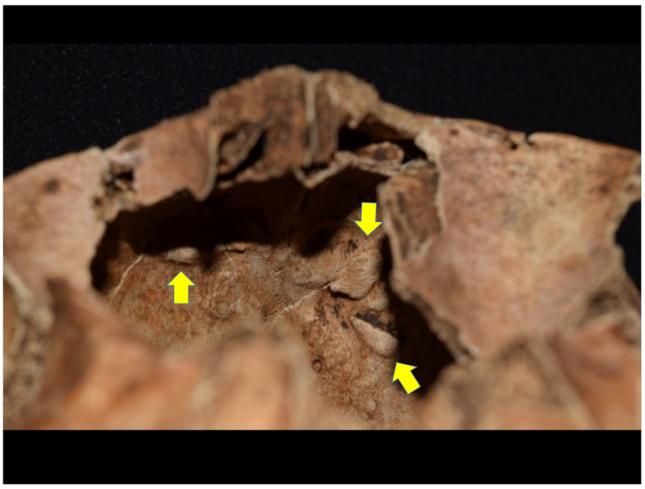

Figure 49. Lesions compatible with hyperostosis frontalis interna in 1030, male individual.



Figure 47. Lesions compatible with hyperostosis frontalis interna in 1022, female individual.

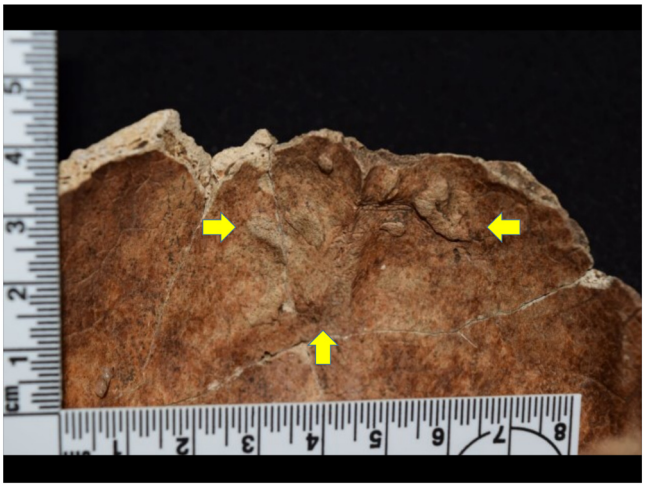

Figure 50. Lesions compatible with Hyperostosis frontalis interna in 1078, female individual.

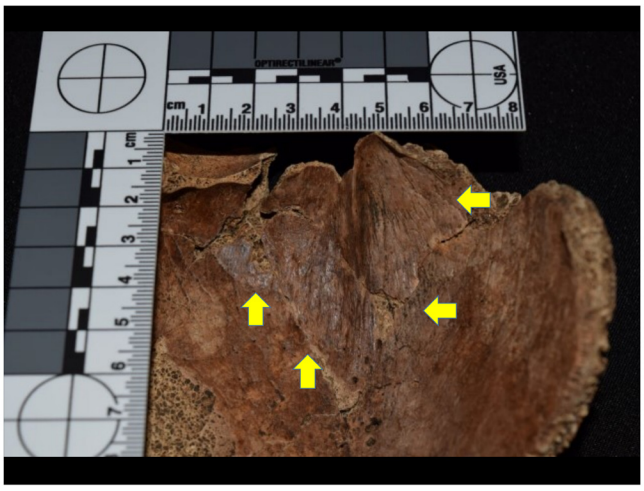

Figure 48. Lesions compatible with hyperostosis frontalis interna in 1029, male individual.



Figure 51. Lesions compatible with type-C hyperostosis frontalis interna in 1118, female individual.

scale proposed by Hershkovitz & Colleagues (1999), whose lesions affect less than 25% of the frontal surface. However, more severe lesion damage is only seen in one of the cases, which would be a type-C on the Hershkovitz scale (Figure 38).

The prevalence of this lesion in modern populations is still debated, although it is much more frequent in females (24%) than in males (5%), and its aetiology is still unclear. For example, it is reported that HFI is related to hormonal disorders, abnormal glucose regulation, arterial hypertension, obesity, and genetic factors (Belcastro *et al.*, 2011). The crania identified with these lesions in the Cathedral correspond to three female individuals, two young adults and another middle adult, and two males, both identified as adults, but without specifying the age group. It is noteworthy that the increase in the severity and frequency of the lesion in women is related to age, and that moderate manifestations (types A and B) do not seem to have a significant relationship to ethnic groups, unlike in African populations, where a higher frequency and more severe manifestations have been detected (Hershkovitz *et al.*, 1999: 310–311). In the case of male individuals, the mildest manifestation of the lesion (type A) is often present, but when type B is present it is usually in individuals over 50 years of age (Hershkovitz *et al.*, 1999: 311). Despite the few cases reported in the literature, the aetiology in male individuals seems to correspond to disorders in sex hormones, associated with feminisation processes, testosterone reduction and testicular atrophy (Belcastro *et al.*, 2011). However, it is difficult to identify the cause of the lesion in individuals from Panama Viejo's Cathedral.

The number of traumatic lesions in the sample is also striking (Figure 52 to Figure 57), reaching an effective prevalence of 17.83%, of which 55.17% are concentrated in the cranium and the rest are fractures recorded in the upper limbs (13.79%), lower limbs (13.79%) and spine (17.24%). With regard to cranium fractures, it is evident that all except two healed during the lifetime of the individuals, and are linked to blows that may have been carried out with blunt instruments. In two

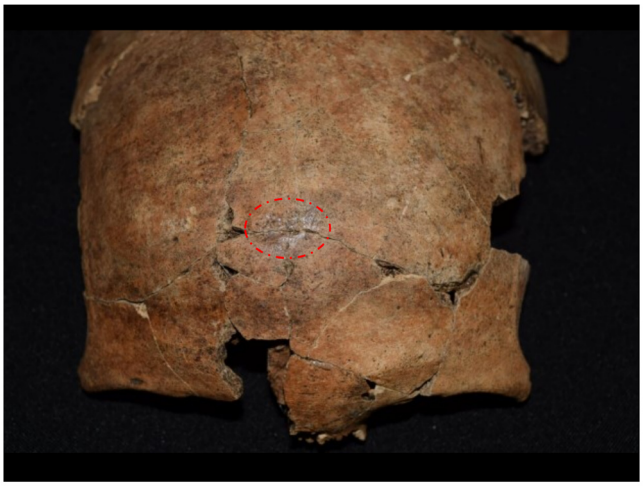

Figure 52. Healed traumatic lesion in frontal of 1056.

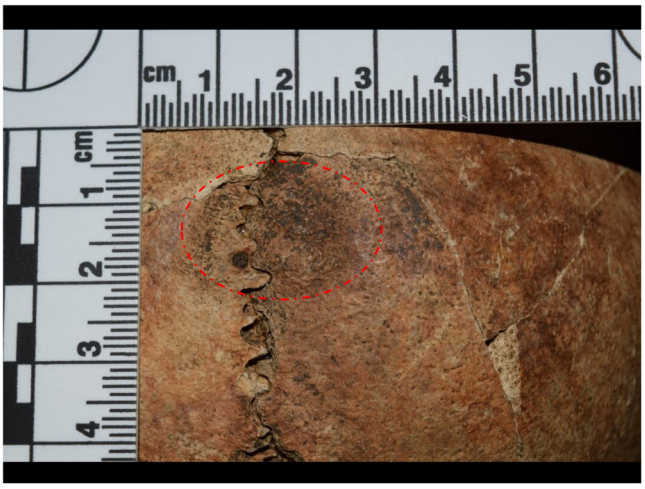

Figure 53. Healed traumatic lesion in parietals of 1066.

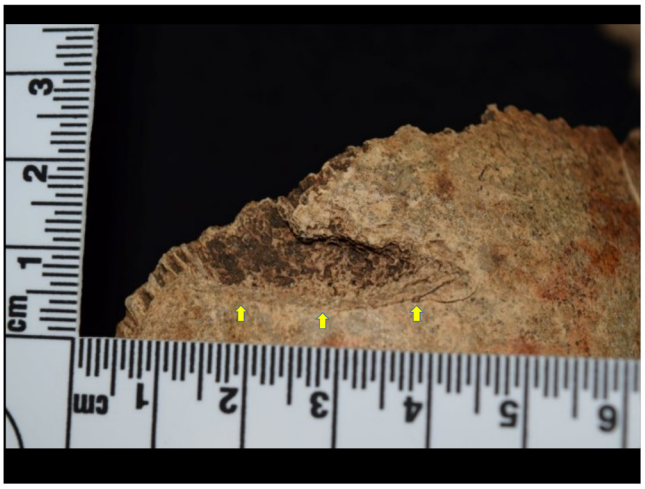

Figure 54. Perimortem lesion consistent with wound from blunt short weapon in 1015.

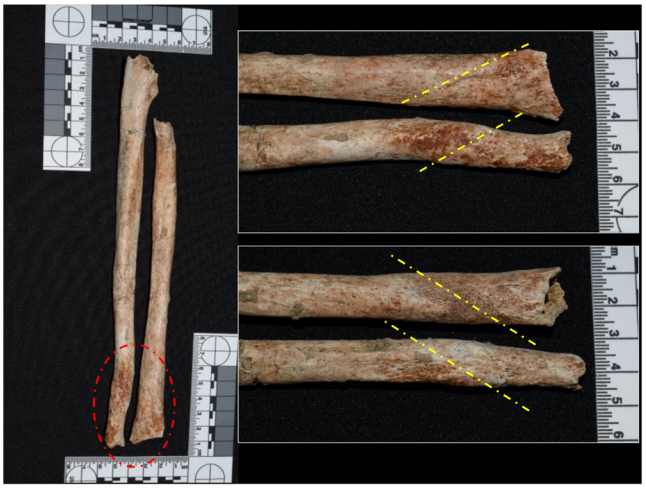

Figure 55. Healed fracture in distal third of left ulna and radius of 1180.



Figure 56. Healed fracture in the first coccygeal vertebra of 1167, and incomplete spina bifida.



Figure 57. Healed fracture in left femur of 1171.

of the cases, the lesion is observed to have an elastic appearance with colouration at the fracture margins consistent with a perimortem event. In one of them, it is also observed that the lesion left a regular, deep, elongated lanceolate-shaped margin which is consistent with a sharp weapon, but on the other side there is an irregular wall that may be due to the movement made to remove the blade of the instrument that caused the wound, leading to the fracture in this portion of the bone; such characteristics would suggest the use of a sharp heavy weapon. However, care must be taken in this type of observation, since the taphonomy of the site may have caused this fracture, although a microscopic analysis (SEM) could verify the timing of the lesion (peri or postmortem) and whether the weapon left any kind of trace in the bone.

With an effective prevalence of 8.92% in the whole sample, neoplasms or tumours have a relatively high prevalence in which about 78.57% of individuals diagnosed with neoplasms have button osteoma in the cranium (Figure 58 and Figure 59). The remaining percentage corresponds to three individuals who present bone tumour formations, one in the pelvic region (Figure 60) and the other two with non-reactive compact bone neoplasias in the femoral diaphysis, both with well-delimited rims, although with different sizes (one of 20 mm approximately, and the other about 4 mm). These two individuals may be associated with cases of enostosis, also known as bone islands (Figure 61), which are benign tumours that have no sex or age difference in their prevalence (Waldron, 2009: 172). Moreover, osteomata have no clinical significance and are quite frequent, characterised by forming in the periosteum with well-delimited borders, compact bone and generally small (no larger than 10 mm in diameter), being more frequent in the frontal and parietals, and occurring in both sexes and in all ages (Fornaciari & Giuffra, 2009; Waldron, 2009). In the sample, it was possible to identify a case of multiple osteomata (Figure 62), which are not very frequent in the paleopathological

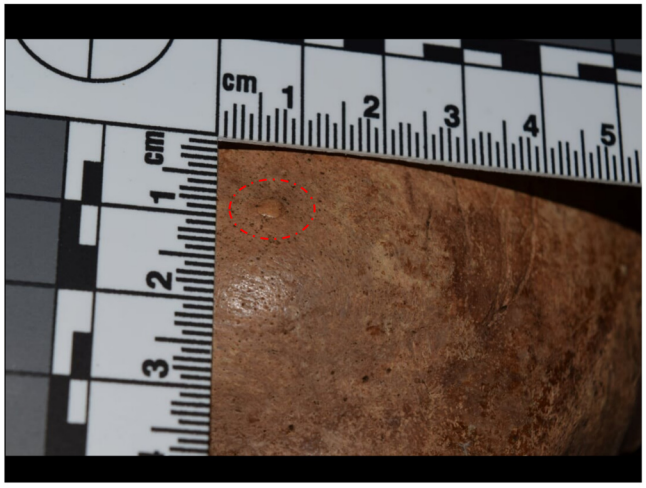

Figure 58. Osteoma identified in frontal of 1018.

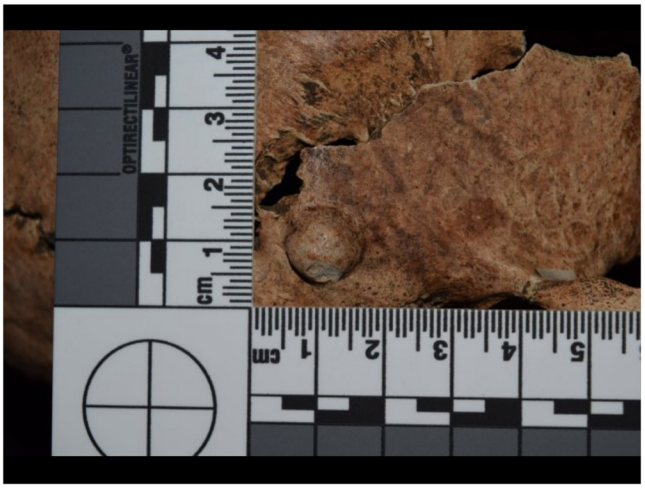

Figure 59. Osteoma identified in right temporalis of 1123.

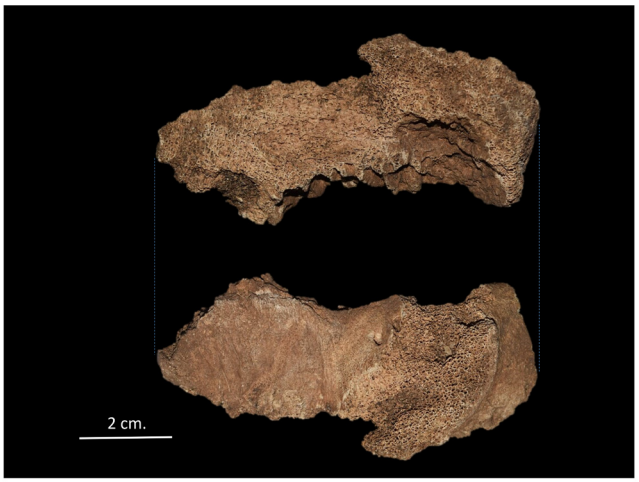

Figure 60. **Neoplasm in left innominate bone of 4019.**

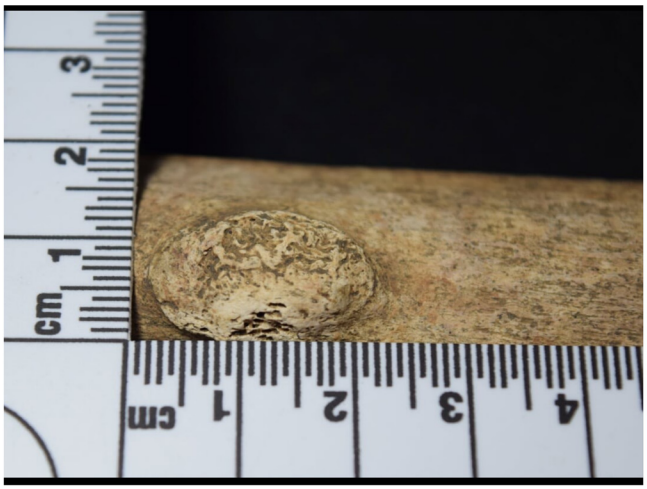

Figure 61. **Enostosis in right tibia of 1042.**



Figure 62. **Multiple osteomata in cranium of 1125.**

context, but which are linked to secondary manifestations of diseases such as Gardner's syndrome, a hereditary disorder characterised by colon polyps (Aufderheide & Rodríguez-Martín, 1998: 375; Fornaciari & Giuffra, 2009: 306).

With regard to the bone development anomalies, it was identified that about 3.18% of the sample developed this type of lesion, with more than half of them (2.55%) corresponding to spondylolysis (Figure 63 to Figure 66). This anomaly occurs when the posterior arch separates from the vertebral body, subjecting the spine to continuous stress, and increases with the fragility of this bone element (Aufderheide & Rodríguez-Martín, 1998; Fornaciari & Giuffra, 2009; Ortner, 2003).

The fracture in the vertebral arch can generally be complete or incomplete, occurs in the juvenile stage, and leads to the formation of a pseudoarticulation, where the arch remains



Figure 63. **L4 with complete spondylolysis in 1159; in yellow, the remodelling of the fractured pedicle.**



Figure 64. **Incomplete spondylolysis in L5 of 1051.**



Figure 65. Complete spondylolysis in L4 and L5 of 1050.



Figure 66. Complete spondylolysis in L5 of 1145.

attached to the body thanks to the ligaments and fibrous tissue in this region; it can therefore be symptomatic, although in some cases the lesion may be complicated by slippage, generating compression of the spinal cord, a condition known as spondylolisthesis (Fornaciari & Giuffra, 2009: 290–291).

The lesion is usually present in L5 and less frequently in L4; in the four cases reported, there was one case with complete spondylolysis of L4, one complete one in L5, one incomplete one in L5, and one individual showed complete spondylolysis of L4 and L5.

Other malformations observed in the sample are related to congenital anomalies such as spina bifida, present in one of the cases in incomplete form, meaning it is unlikely to have caused any mobility problem in the individual, but which is distinguished by incomplete closure of the posterior neural arches for sacral vertebrae 4 and 5. Moreover, a case with transitional vertebrae was recorded, specifically lumbarisation of the first sacral vertebra (Figure 67), which takes a shape similar to a lumbar vertebra and predominantly affects female individuals (Fornaciari & Giuffra, 2009: 292). Finally, a bone asymmetry between the semilunar bones of the hands of the individual was recorded, where the one on the left had an atrophy of the articular cartilage for the pyramidal bone, in this case smaller (Figure 68).

Finally, there were three or four interesting cases from a paleopathological perspective, although statistically they are not significant since they are due to different lesions. Firstly, two cases of heterotopic ossification were recorded (Figure 69 and Figure 70), related to bone formation in soft tissue as a result of traumatic processes, surgery, burns, prolonged immobility or disorders of the central nervous system (Waldron, 2009: 79). In the literature it can also be found under the



Figure 67. Lumbarisation of S1 in 1122.



Figure 68. Asymmetry in semilunar bones of 1046.



Figure 69. Heterotopic ossification of vastus lateralis in left femur of 1160.



Figure 70. Heterotopic ossification of vastus lateralis and medialis in right femur of 1052.

name myositis ossificans traumatica (Aufderheide & Rodríguez-Martin, 1998:26–27), although use of this term is not recommended as it may cause confusion with myositis ossificans progressiva, which has other aetiological implications. Heterotopic ossification is caused either by muscle trauma, that produces a haematoma that also involves the periosteum, or by avulsion of the tendons, where the muscle is attached to the bone (Aufderheide & Rodríguez-Martin, 1998; Waldron, 2009). The areas where this lesion most frequently manifests itself are the elbow, shoulder, pelvis, and the rough line of the femur (Aufderheide & Rodríguez-Martin, 1998:26). It is precisely the two cases recorded in the Cathedral that are associated with the insertion of the vastus medialis and vastus lateralis, whose origin and insertion are located in the posterior and medial part of the femur, respectively.

Moreover, unintentional cranial flattening was recorded in one of the individuals at the level of the posterior portion of the parietal bones in articulation with the occipital; given the slightness of the deformation and the way in which it occurred, it is likely to be related to the fixed position that the head may have had during the individual's development and growth process (Figure 71). Finally, a case of trepanation was observed (Figure 72). This intervention was performed on the left parietal, it being possible to see that the individual survived, thanks to the remodelled bone that is evident in the diploe of the cranium. This type of intervention was frequent during the medieval and post-medieval period in Europe, involving several techniques and instruments (Fornaciari & Giuffra, 2009). In this case it could be due to an abrasive technique, given the ellipsoidal shape of the lesion, surrounded by the reduced thickness of the osseous table.

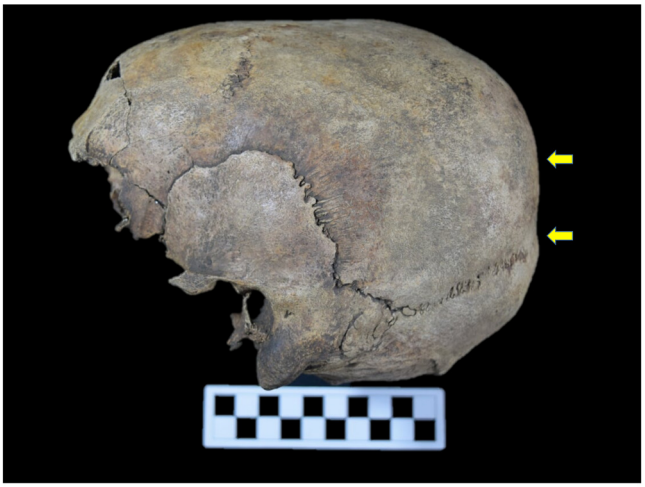

Figure 71. Unintentional flattening of cranium of 1043.

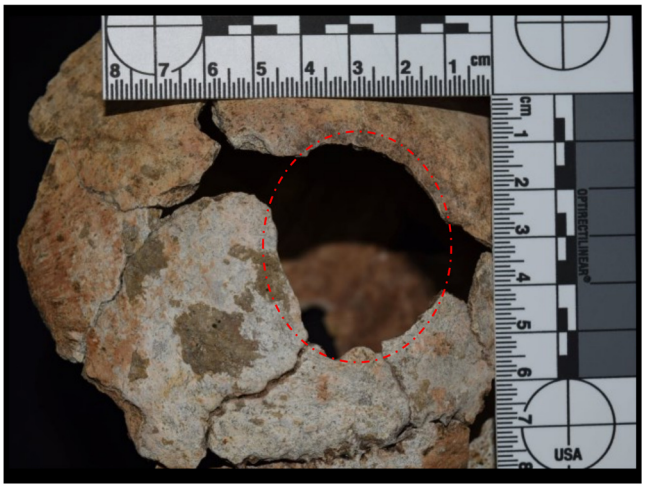

Figure 72. Evidence of trepanation in left parietal of 1202.

Overall frequency of dental anomalies for the whole sample. With regard to teeth, a good proportion of individuals revealed anomalies associated with dental morbidity, totalling 46.29% of the whole sample with an effective prevalence of 100% in the recording of dental lesions or anomalies (Table 18), where the number of unobservable cases in the sample was also considered. In this regard, the high numbers of unobservable cases are due to teeth representation or conservation factors, despite the fact they are the hardest and most resistant tissue in the human body and, in an archaeological context, are often better preserved than skeletal remains; however, several of these elements may have been lost or decontextualised due to reductions and alterations in the Cathedral site.

Specific frequency of dental anomalies for the whole sample. The information obtained from dental morbidity can help reconstruct some aspects of diet, episodes of nutritional stress or disease, and behavioural elements recorded in the teeth, which serve as indicators of the health conditions and quality of life of the population. These structures do not change during the course of life and, unlike bone, do not have reparative capacity, the only exception being dentin, whose processes have little functionality in terms of the health of the tooth.

With regard to dental anomalies or lesions recorded in the sample of the two sites of Panama Viejo's Cathedral, the most frequent was dental wear due to masticatory processes, with an effective prevalence of 97.53%, followed closely by the presence of dental calculus, with 95.06%. Subsequently, there were cases of caries with 58.02%, alveolar retraction associated with periodontal disease with 54.32%, and enamel fractures or chipping with 51.85%. Enamel defects, including linear hypoplasias, are found in a smaller proportion with 22.22%, in addition to some cases of cultural modification with 12.35%, and, finally, cases of periapical abscesses and hypercementosis, with an effective prevalence of 3.7% for each lesion (Table 19 and Figure 73).

In these data, the lesion caused by wear on the occlusal surface of the teeth was associated with the processes of chewing food, which was manifested in different degrees for the inhumed population (Figure 74 to Figure 78); other types of wear associated with labour activity, biocultural practices or the frequent holding of objects with the teeth were recorded as cultural modifications. Moreover, wear due to attrition or bruxism was not identified in the sample. It should be noted that occlusal wear is due to the contact with abrasive particles that may be associated with food or other elements food is prepared with. For example, *metates* and *mano* stones were used to process and grind maize during the pre-Hispanic period, and certainly during the colonial period, with such instruments giving off particles that consequently made the wear even more pronounced. Moreover, abrasive diets such as maize may have been a determining factor in this type of lesion.

Table 18. Proportion of individuals with dental anomalies in the sample analysed.

	Frequency	% Total	% Effective
Unobservable	94	53.71	
No anomalies	0	0.00	0.00
Anomaly	81	46.29	100.00
Total	175	100.00	
Total Effective	81	46.29	100.00

Table 19. Proportion of dental anomalies identified in sample.

Abnormality or lesion	Frequency	% Effective	% Total
Caries	47	58.02	26.86
Calculus	77	95.06	44.00
Masticatory Wear	79	97.53	45.14
Enamel defect	18	22.22	10.29
Abscess	3	3.70	1.71
Alveolar retraction	44	54.32	25.14
Chipping	42	51.85	24.00
Cultural modification	10	12.35	5.71
Hypercementosis	3	3.70	1.71

An abrasive diet also produces enamel fractures or chipping, which in some cases also affects the dentin (Figure 79 to Figure 81). They are generally located in the incisal margin of the anterior teeth or in the cusp crests of the crown (Chai *et al.*, 2011; Towle *et al.*, 2017). These fractures can often be mistaken for post-depositional events, making it necessary to examine any smooth, rounded margins that may be chipped or show some sign of wear and a shade similar to the adjacent enamel. This is one of the most frequent traumatic lesions to the enamel, and involves contact between the teeth and a hard element that causes the lesion, which, in masticatory processes, can be generated in two ways: 1) by cumulative micro contacts associated with small particles related to diet, and 2) by individual macro contacts with harder items such as nuts, grains and seeds (Chai *et al.*, 2011). Although enamel fractures are generally associated with dietary causes, it is also possible to relate them to the processing of food, environmental contaminants, traumatic events and cultural practices (Towle *et al.*, 2017), which makes it difficult to identify the origin of these lesions. However, it is striking that it reaches an effective prevalence of 51.85% in the sample analysed, and this context is probably also related to processes associated with diet.

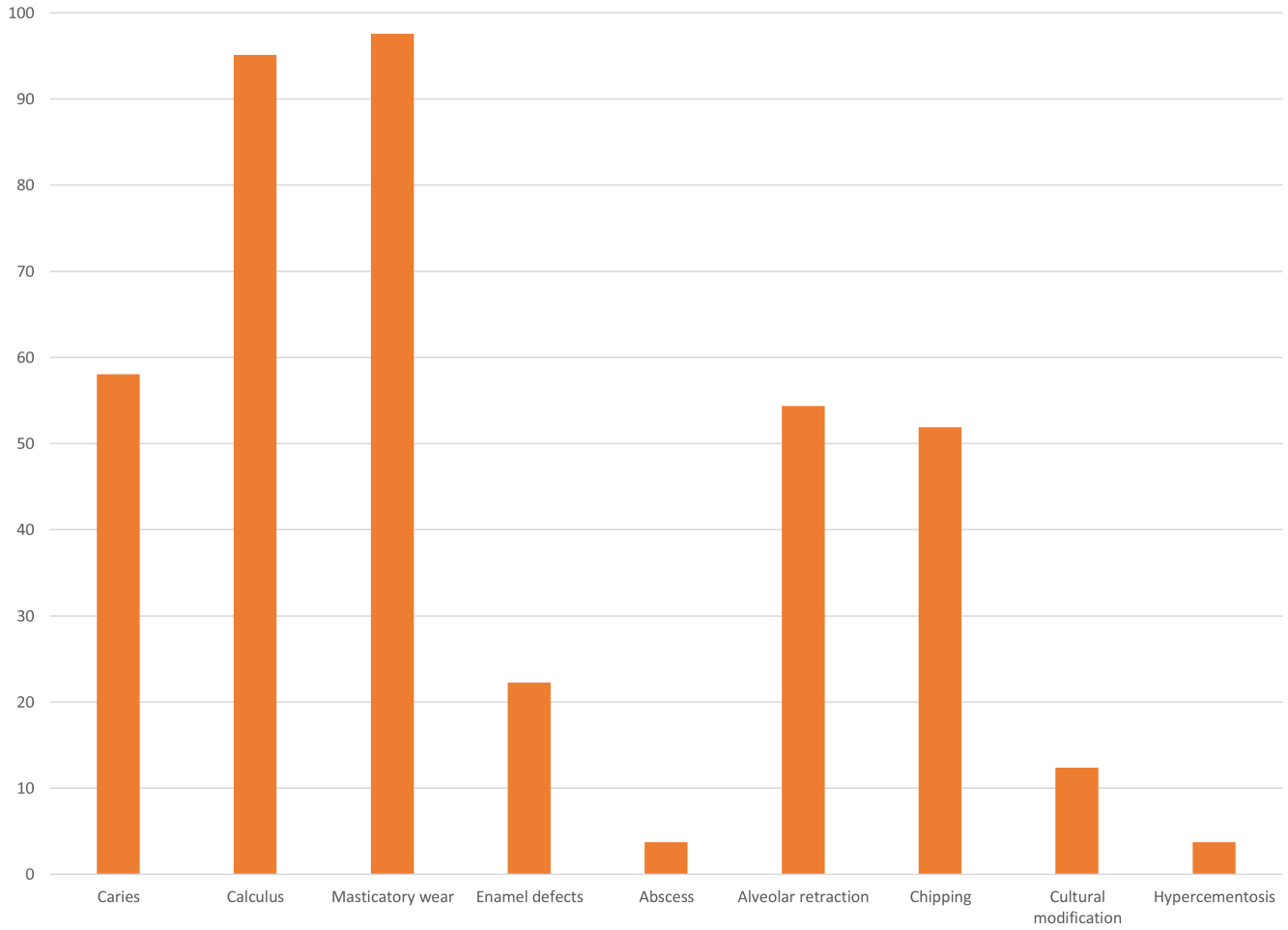

Figure 73. **Effective percentage of dental anomalies identified in sample.**



Figure 74. **Occlusal wear processes in lower teeth of 1012.**



Figure 75. **Moderate occlusal wear processes in upper teeth of 2005.**



Figure 76. Different degrees of wear in mandible of 1086.



Figure 77. Occlusal wear processes in upper teeth of 1135.



Figure 78. Masticatory wear processes in different degrees of manifestation in mandible of 4023.



Figure 79. Chipping in left upper M1 of 1027.



Figure 80. Chipping in right lower M2 of 2008.



Figure 81. Chipping in right upper P2 of 1060.

A high prevalence of dental calculus is also observed in the sample (95.06% effective) (Figure 82 to Figure 85), characterised by mineralisation of the bacterial plaque aided by the presence of saliva, meaning teeth located near the salivary ducts are most affected (Canci & Minozzi, 2012; Hillson, 1996). There are two types of dental calculus, supragingival and subgingival. The former is attached to the enamel on the gingival margin and, although in life it is very attached to the crown, it tends to be easily lost in the archaeological context. Subgingival calculus is deposited on the root surface and is thinner, harder, and more mineralised than supragingival calculus (Hillson, 1996: 256–257).

Calculus is usually related to carbohydrate-rich diets, although inadequate oral hygiene also plays a role by allowing bacterial plaque to build up. Other related processes can be malocclusion or facial paralysis that create spaces in which calculus begins to deposit, although age also plays a role, becoming more frequent as the individual gets older (Hillson, 1996). Moreover, there is an inverse relationship between the presence of calculus and dental caries, and, although both anomalies may appear in the same tooth, the tendency is for caries to appear in sectors of the tooth that are devoid of dental calculus (Hillson, 1996); this is in line with that observed in the sample, where the effective prevalence of caries is 58.02%.

Caries are characterised as a degenerative disease of the hard tissue of the tooth (i.e. the enamel), although in advanced stages it can affect the dentin and the cementum (Figure 86 to Figure 90). This is caused by the presence of commensal bacteria that are activated by the imbalance of bacterial flora and the progressive demineralisation of enamel; this



Figure 82. Dental calculus on the lingual surface of left lower molars of 2012.



Figure 83. Dental calculus in left upper M2 and M3 covering the occlusal, lingual, and vestibular surfaces in 1102.

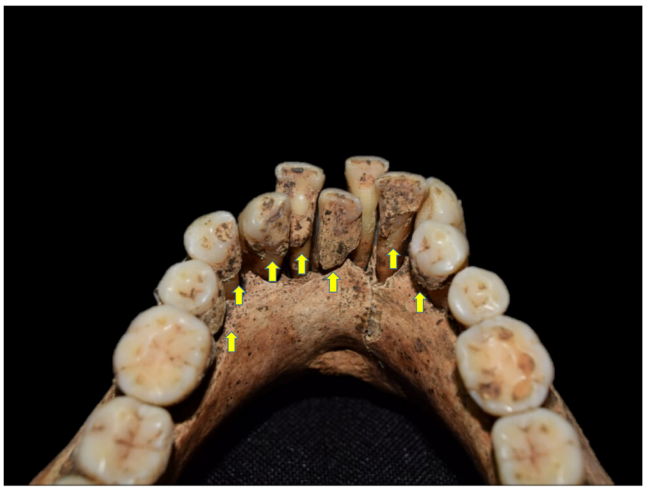

Figure 84. Calculus deposited on the lingual surface on lower teeth of 1049.



Figure 85. Calculus deposited on the lingual surface on upper teeth of 1201.



Figure 86. **Caries affecting pulp chamber in right upper premolar 1 of 1123.**



Figure 87. **Cervical caries in right upper M2 of 2013.**



Figure 88. **Caries in left lower M1 and M2 of 1129.**



Figure 89. **Cervical caries in right upper P1 of 1095.**



Figure 90. **Caries with lesion in pulp chamber in right lower M2 of 4015.**

situation is aggravated by the consumption of carbohydrates and sugars, for which experimental tests have been carried out in order to verify their cariogenic potential in diet (Hillson, 1996: 276–278). Factors such as inadequate oral hygiene, exposure of dental surfaces devoid of enamel, age, odontogenic anomalies, and systemic and periodontal diseases may also predispose to this condition (Canci & Minozzi, 2012: 201–202).

Caries can cause tooth loss, although the most frequent cause is parandontopathy or inflammation of the supporting tissues of the tooth, caused by the action of bacterial plaque which initially affects the gum and spreads to the mucosa, periodontal ligament, and alveolar bone, causing inflammation and retraction of the alveolar margin and, in advanced cases, inflammation of the root that leads to periapical granulomas, with consequent loss of the tooth (Canci & Minozzi, 2012; Hillson, 1996). In the sample, this type of lesion corresponds

to an effective prevalence of 54.32% (Figure 91 to Figure 95), with significant representation in the population analysed; however, the causes are of multifactorial origin that include genetic, environmental, hygenic and dietary aspects, making it difficult to associate it with a specific cause.

Inflammation of periodontal tissues can facilitate the entry of bacteria through caries, dental fracture or excessive wear, generating inflammation and subsequent necrosis of the pulp tissue; this subsequently crosses the root and generates an infection in the apex with accumulation of pus, forming a periapical abscess that can drain through a fistula in the maxillary bone which is not always macroscopically visible. In the sample analysed, these lesions correspond to an effective prevalence of just 3.7%, i.e. three cases (Figure 96 to Figure 98).

One of the most frequent indicators of nutritional stress in paleopathology are enamel defects and particularly hypoplasias,



Figure 91. Advanced alveolar retraction in left lower premolar 2 and complete resorption of molars of 4023.



Figure 92. Retraction of alveolar margin in mandible of 2012.



Figure 93. Retraction of alveolar margin in mandible of 1043.



Figure 94. Retraction of alveolar margin in maxilla of 1078.



Figure 95. Antemortem dental loss in 1097, probably due to periodontal disease.



Figure 96. Drainage fistula in abscess of space for right lower M3 in 1176.



Figure 97. Periapical abscess in right lower M1 of 1019.



Figure 98. Periapical abscess in right upper M1 space of 1031.

which are manifested in the form of lines or pits on the surface of the crown and, since they are only formed during dental formation and growth, provide information on the health conditions of infant populations, signalling specific episodes of limited duration associated with events of nutritional deficiency (hypovitaminosis A or D), diseases (infections, influenza, gestational diabetes, etc.), parasitosis and gastroenteritis, among other causes (Canci & Monozzi, 2012). A prevalence of 22.22% was recorded in Panama Viejo (Figure 99 to Figure 102).

It was possible to record different types of cultural modification in the teeth in 12.35% of the sample, particularly concentrated in the anterior teeth (Figure 103 to Figure 105), which in four of the 10 cases recorded correspond to dental sharpening, mainly involving the incisors, although it is also possible to see some canines, both in the lower and upper arches

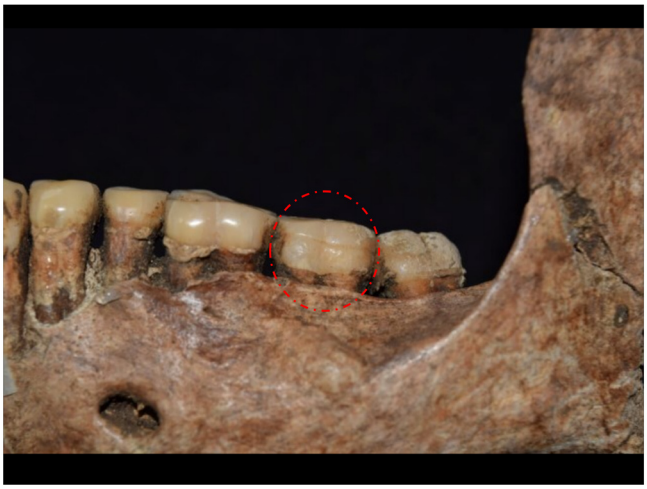

Figure 99. Linear enamel hypoplasia in left upper M2, associated with 1180.



Figure 100. Linear enamel hypoplasia in left lower canine, associated with 1016.



Figure 101. Linear enamel hypoplasia in canine and right upper lateral incisor, associated with 1070.



Figure 102. Linear enamel hypoplasia in right upper M1 and M2, associated with 1201.

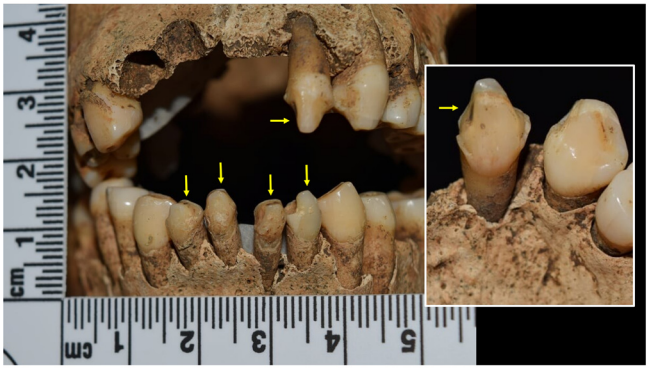

Figure 103. Dental sharpening in incisors of individual of 1082.



Figure 104. Dental sharpening in left upper I2 of 1082.



Figure 105. Dental sharpening in left upper I2 of 1162.

(Smith-Guzmán *et al.*, 2020). This modification can be linked to biocultural practices in Sub-Saharan Africa, where sharpening is often related to aesthetic aspects and ethnic differentiation, and, to a lesser extent, to rites of passage to adulthood, punishment, pain resistance and other cultural traditions (Irish, 2017: 35).

The technique used for this modification has been ethnographically recorded for the Aka peoples of the Central African Republic. Here, patients rest their heads on the lap of the person performing the intervention, and are then made to bite on a branch with their molars in order to expose the incisors. The teeth are then struck with the help of a knife or chisel and a stone mallet in order to give them the desired shape, and finally filed to correct possible imperfections (Irish, 2017: 40–41). The complications that can be generated with this intervention include caries, death or loss of the tooth, abscesses, and

trauma due to pulp exposure; however, none of these lesions were recorded in the teeth that presented sharpening in the sample.

In four other individuals, there is interproximal wear that is manifested through concavities or grooves in buccolingual direction in the middle portion of the crown or cervical neck, located mostly in the anterior teeth, although they can also be found elsewhere (Figure 106 and Figure 107). This type of modification is generally associated with the use of tooth-picks or miliary objects used for dental hygiene, or with work activities such as removing the tendons of animals (Hillson, 1996: 251), preparing plant fibres, or as a "third hand" in producing artefacts (Canci & Minozzi, 2012: 208).

Other anomalous wear recorded in the sample is compatible with wear of the lingual surface of the maxillary anterior teeth or LSAMAT (Figure 108 to Figure 110), which has frequently been reported in bioarchaeological material for pre-Hispanic



Figure 106. Interproximal wear between right upper P1 and C of 1043.



Figure 107. Interproximal wear in lower incisors of 2008.



Figure 108. Evidence of wear of the lingual surface of the maxillary anterior teeth in upper central incisors of 4023.



Figure 109. Evidence of wear of the lingual surface of the maxillary anterior teeth in right upper incisors of 1043.



Figure 110. Evidence of wear of the lingual surface of the maxillary anterior teeth in left upper incisors of 1091.

American contexts, and has been associated with diet or the use of teeth in preparing food or producing instruments (Hillson, 1996: 252–253). This suggests the continuity of some indigenous practices after contact, although it cannot be ruled out that populations of African or European origin also used their teeth in some or other activity, which ultimately led to the formation of LSAMAT; indeed, three of the four individuals associated with this modification are of European descent.

Finally, with an effective prevalence of 3.7% corresponding to three cases, in some teeth it was possible to identify a massive overproduction of cementum in the roots, an anomaly known as hypercementosis, which gives roots a bulbous, irregular appearance (Figure 111 and Figure 112). Although its origin is unknown, it may be related to excessive wear or malocclusion, although it has also been reported for diseases such as Piaget's disease and in bone changes of the mandible and maxilla (Hillson, 1996: 205–206).



Figure 111. Hypercementosis in right upper M1 root of 1078.



Figure 112. Hypercementosis in root of left upper P1 of 1078.

Overall frequency of bone abnormalities by sex, age, and ancestry. Observing bone anomalies in the defined groups according to sex shows a marked difference between male and female individuals for the excavated sample. While women present an effective prevalence of 67.82%, the proportion of men who manifest at least one bone anomaly stands at 95.53%. The effective percentage for those individuals whose sex could not be estimated was 76.92% (Table 20).

That said, if the sample is organised according to age groups, only 33.33% correspond to subadult individuals with at least one lesion or bone anomaly, where juveniles (57.14%) and infants II (50%) have the highest values. However, it should be considered that these individuals are underrepresented in the sample, meaning the observations may be skewed. With regard to adults, middle adults present a high prevalence of individuals with the presence of at least one anomaly (90.91%), while young adults total 77.91%, and the figure for those adults whose age range could not be determined is 73.53% (Table 21). This corresponds to epidemiological models, where abnormalities and lesions are expected to increase proportionally with age.

The sample organised by population groups according to phenotypic variation (Table 22) shows results with very similar effective percentages for presence of lesions or anomalies among Europeans, Amerindians and Africans, with Europeans showing a slight increase (77.78%) compared to the other two groups, suggesting that individuals of different ancestries were affected in similar proportion.

Specific frequency of bone anomalies by sex, age, and ancestry. The differences found in the specific prevalence of lesions in the individuals from the Cathedral are presented below, grouped by sex, age, and ancestral group (Table 23 to Table 25, and Figure 113 to Figure 115). These show some important differences compared to the epidemiological models that have been built around the incidence of these pathological manifestations at population level, allowing us to address the living and health conditions of the individuals buried in the cathedral and to the south-east of Panama Viejo's main square.

First of all, with infectious diseases being the most frequent in the sample, observing prevalence according to sex shows a significant proportional difference that affects men (47.92%) much more than women (25.29%). This contrasts with that reported for the collection of colonial period human skeletal remains from Panama Viejo (Rojas-Sepúlveda *et al.*, 2011), which, for infectious diseases, identified that men had an effective prevalence of 20%, while for women this figure was 18.75%. However, the number of cases reported by Rojas-Sepúlveda & colleagues (2011) tends to be low, which may have influenced the results.

However, when we look in detail at the proportion of specific and non-specific infections, we see that those related to treponematosis have a prevalence of 50% for both men and women, while non-specific infections have a slightly higher prevalence in men (46.67%) than in women (43.33%), although

Table 20. Proportion of individuals by sex with bone anomalies in sample.

	Female			Male			Unobservable / Unknown sex		
	N	% Total	% Effec.	Freq.	% Total	% Effec.	Freq.	% Total	% Effec.
Unobservable	10	10.31	-	2	4.00	-	2	7.14	-
No anomalies	28	28.87	32.18	2	4.00	4.17	6	21.43	23.08
Anomalies	59	60.82	67.82	46	92.00	95.83	20	71.43	76.92
Total	97	100.00	-	50	100.00	-	28	100.00	-
Total Effective	87	89.69	100.00	48	96.00	100.00	26	92.86	100.00

Table 21. Proportion of individuals by age group with bone abnormalities in sample.

	Infant I			Infant II			Juvenile		
	N	% Tot.	% Effec.	N	% Tot.	% Effec.	N	% Tot.	% Effec.
Unobservable	1	0.00		0	0.00		0	0.00	
No anomalies	4	80.00	100.00	3	50.00	50.00	3	42.86	42.86
Anomalies	0	0.00	0.00	1	50.00	50.00	4	57.14	57.14
Total	5	100.00		4	100.00		7	100.00	
Total Effective	4	80.00	100.00	4	100.00	100.00	7	100.00	100.00
	Young Adult			Middle Adult			Adult		
	N	% Tot.	% Effec.	N	% Tot.	% Effec.	N	% Tot.	% Effec.
Unobservable	6	6.52	-	0	0	-	11	24.44	-
No anomalies	19	20.65	22.09	2	9.09	9.09	9	20.00	26.47
Anomalies	67	72.83	77.91	20	90.91	90.91	25	55.56	73.53
Total	92	100.00	-	22	100.00	-	45	100.00	-
Total Effective	86	93.48	100.00	22	100.00	100.00	34	75.56	100.00

the figures are much closer to those for the complete set of infectious lesions (Table 26).

When the same exercise is carried out by age group and ancestry, it is observed that infections in general terms are more prevalent in middle adults (54.55%) compared to young people (31.40%) or subadults (13.33%). Moreover, individuals with European or predominantly European population affiliation (30.56%) show a higher prevalence of infectious diseases than both Africans and predominantly Africans (25%) and also Amerindians and predominantly Amerindians (17.65%). However, if we compare the data for treponematosic and non-specific infections, we see that the figures are reversed in the age groups, with young adults being more affected by treponematosis (66.67%) than middle adults (22.22%), and the same also being true for non-specific infections, with 50% in young adults and 26.67% in middle adults (Table 27).

The frequencies are more balanced when observing ancestry groups, but taking into account that there was a relatively low number of cases associated with each population stock. Hence, treponeme-associated diseases are more frequent in individuals with predominantly European and African population affiliations (11.11% each), and to a lesser extent in Amerindians (5.56%). This trend is maintained when looking at non-specific infections, with a similar percentage

Table 22. **Proportion of individuals by ancestry group with bone abnormalities in sample.**

	European and predominantly European			Amerindian and predominantly Amerindian		
	N	% Tot.	% Effec.	N	% Tot.	% Effec.
Unobservable	2	5.26	-	0	0.00	-
No anomalies	8	21.05	22.22	4	23.53	23.53
Anomalies	28	73.68	77.78	13	76.47	76.47
Total	38	100.00	-	17	100.00	-
Total Effective	36	94.74	100.00	17	100.00	100.00
	African and predominantly African			Unobservable		
	N	% Tot.	% Effec.	N	% Tot.	% Effec.
Unobservable	1	2.44	-	15	18.99	-
No anomalies	11	26.83	27.50	17	21.52	26.56
Anomalies	29	70.73	72.50	47	59.49	73.44
Total	41	100.00	-	79	100.00	-
Total Effective	40	97.56	100.00	64	81.01	100.00

Table 23. **Prevalence of bone lesions in individuals grouped by sex.**

Anomaly or lesion	Female		Male		Unobservable / Unknown sex	
	N	% Effective	N	% Effective	N	% Effective
Periostosis (infections)	22	25.29	23	47.92	3	11.54
Entheseal changes	22	25.29	22	45.83	2	7.69
Degenerative joint disease	21	24.14	16	33.33	1	3.85
Trauma	16	18.39	9	18.75	3	11.54
Porotic Hyperostosis	24	27.59	18	37.50	1	3.85
Cribra orbitalia	8	9.20	5	10.42	0	0.00
Neoplastic lesions	11	12.64	2	4.17	1	3.85
Hyperostosis frontalis interna	3	3.45	2	4.17	0	0.00
Inflammatory process	1	1.15	2	4.17	2	7.69
Spondylolysis	2	2.30	2	4.17	0	0.00
Development anomalies	2	2.30	1	2.08	0	0.00
Heterotopic ossification	0	0.00	2	4.17	0	0.00
Trepanation	0	0.00	0	0.00	1	3.85
Cranial flattening	1	1.15	0	0.00	0	0.00

Table 24. **Prevalence of bone lesions by age group.**

Anomaly or lesion	No Adult		Young Adult		Middle Adult		Adult	
	N	% Effec	N	% Effec	N	% Effec	N	% Effec
Periostosis (Infections)	2	13.33	27	31.40	12	54.55	7	20.59
Entheseal changes	1	6.67	30	34.88	12	54.55	3	8.82
Degenerative joint disease	0	0.00	21	24.42	14	63.64	3	8.82
Trauma	1	6.67	15	17.44	2	9.09	10	29.41
Porotic Hyperostosis	2	13.33	27	31.40	4	18.18	10	29.41
Cribra orbitalia	1	6.67	9	10.47	2	9.09	1	2.94
Neoplastic lesions	0	0.00	7	8.14	3	13.64	4	11.76
Hyperostosis frontalis interna	0	0.00	2	2.33	1	4.55	2	5.88
Inflammatory process	0	0.00	1	1.16	1	4.55	3	8.82
Spondylolysis	0	0.00	4	4.65	0	0.00	0	0.00
Development anomalies	0	0.00	3	3.49	0	0.00	0	0.00
Heterotopic ossification	0	0.00	0	0.00	2	9.09	0	0.00
Trepanation	0	0.00	0	0.00	0	0.00	1	2.94
Cranial flattening	0	0.00	0	0.00	1	4.55	0	0.00

Table 25. **Prevalence of bone lesions in individuals grouped by population affiliation.**

Anomaly or lesion	European and predominantly European		Amerindian and predominantly Amerindian		African and predominantly African		Unobservable	
	N	% Effec	N	% Effec	N	% Effec	N	% Effec
Periostosis (Infections)	11	30.56	3	17.65	10	25.00	24	37.50
Entheseal changes	8	22.22	6	35.29	8	20.00	24	37.50
Degenerative joint disease	7	19.44	3	17.65	10	25.00	18	28.13
Trauma	5	13.89	2	11.76	6	15.00	12	18.75
Porotic Hyperostosis	17	47.22	6	35.29	11	27.50	9	14.06
Cribra orbitalia	7	19.44	2	11.76	4	10.00	0	0.00
Neoplastic lesions	3	8.33	1	5.88	7	17.50	3	4.69
Hyperostosis frontalis interna	2	5.56	0	0.00	2	5.00	1	1.56
Inflammatory process	0	0.00	2	11.76	2	5.00	1	1.56
Spondylolysis	0	0.00	0	0.00	1	2.50	3	4.69
Development anomalies	0	0.00	0	0.00	1	2.50	2	3.13
Heterotopic ossification	0	0.00	0	0.00	0	0.00	2	3.13
Trepanation	0	0.00	0	0.00	0	0.00	1	1.56
Cranial flattening	0	0.00	0	0.00	1	2.50	0	0.00

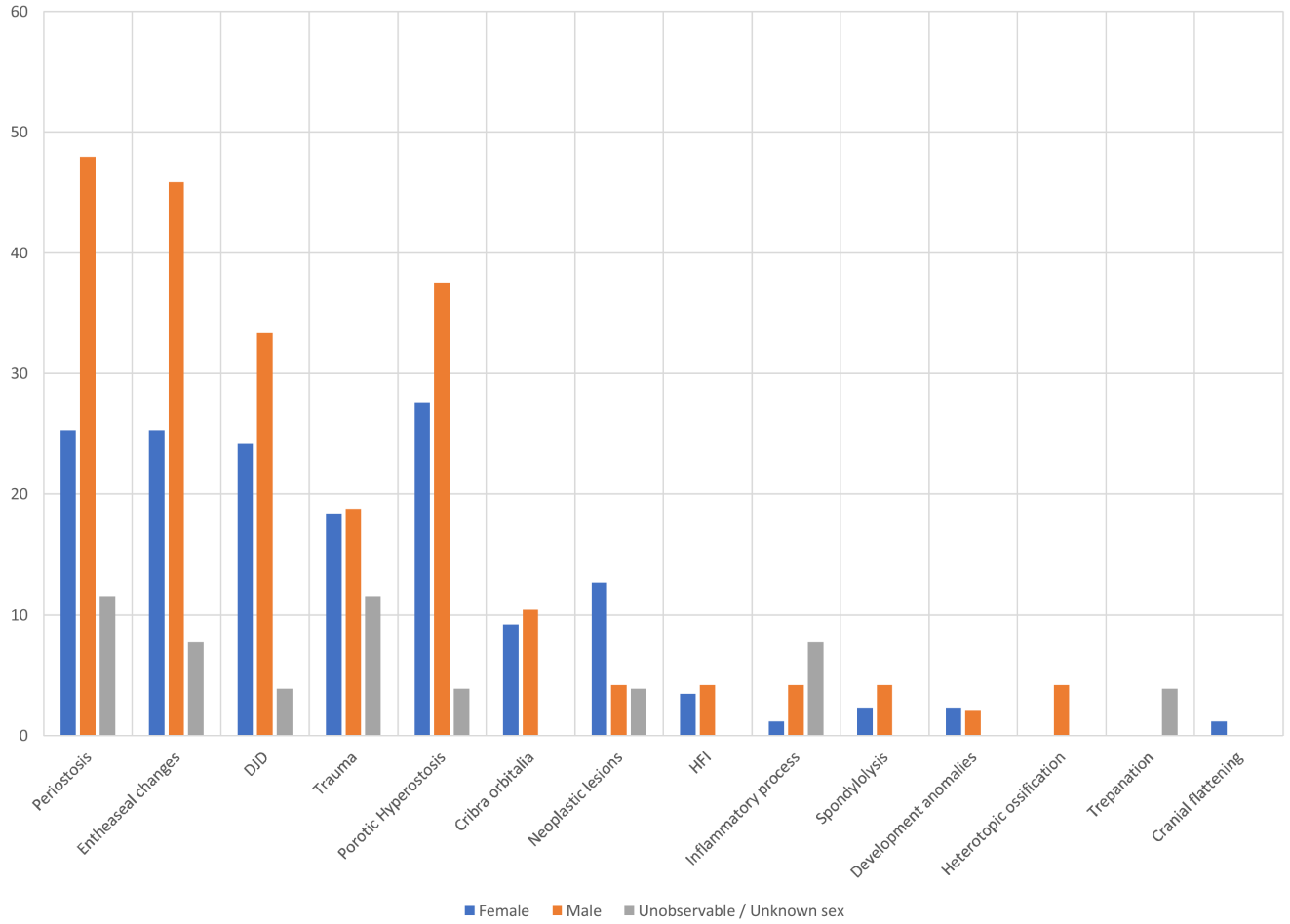

Figure 113. Prevalence of bone lesions in individuals grouped by sex.

in Amerindians (6.67%) and a moderate increase in both Europeans and Africans, who both have a prevalence of 30% and 26.67%, respectively (Table 28).

These data fit the proposed epidemiological models, where treponematosic diseases are generally found in a higher proportion in male individuals and in young people, with a higher incidence between 15 and 30 years of age for pinta and syphilis, and in subadults for yaws and bejel. Moreover, it appears that there is no direct relationship between population affiliations and the presence of lesions associated with this set of diseases (Aufderheide & Rodríguez-Martín, 1998: 155–158).

With respect to entheses, a marked difference is observed between male and female individuals, with 45.83% and 25.29%, respectively, this being greater than the difference previously recorded for the Panama Viejo colonial series, which presented closer figures between the two groups (Rojas-Sepúlveda *et al.*, 2011). However, if analysed by age group, the trend is similar to that reported previously in Panama Viejo, where there is a higher prevalence of this type of marker in medium adults than in young people (54.55% and 34.88%, respectively, for the cathedral). The three main population groups show a similar trend among individuals predominantly linked to European (22.22%) and African (20%) populations, while those with Amerindian affiliation show a higher prevalence with 35.29%, suggesting that these individuals were more liable to develop hypertrophic processes.

In this sense, the colonial population in Panamá Viejo, regardless of its origins, may have faced physical conditions that led to the development of the musculoskeletal system, but it was the men who were probably engaged in more demanding activities. Considering that this is a cumulative process, it is logical to think that this type of marker is manifested with greater intensity in medium adults than in young people, as was evident in the sample. However, the fact that this information cannot be cross-referenced with the work and activities the individuals may have carried out during their lifetime considerably limits the scope of the interpretation.

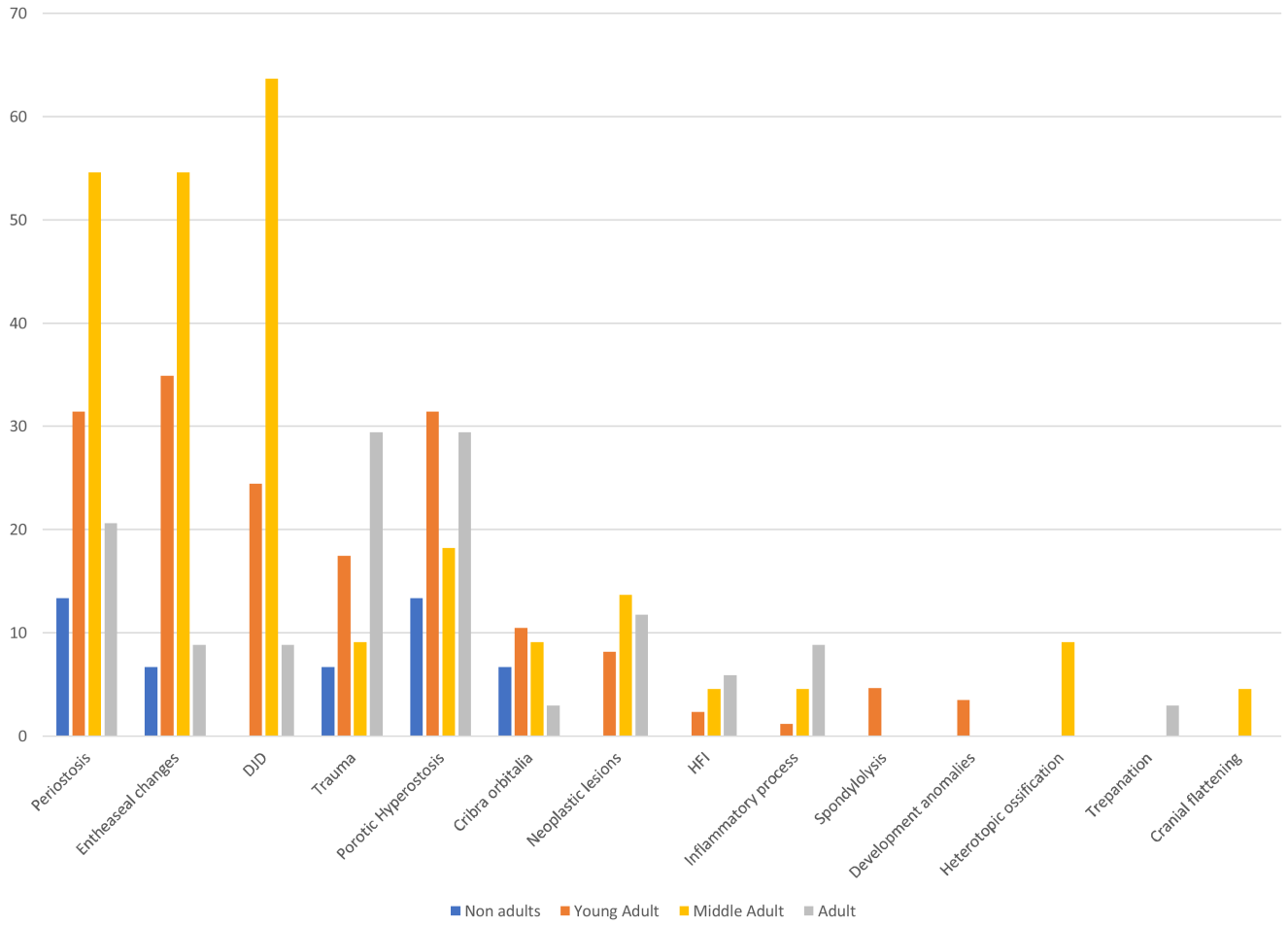

Figure 114. Prevalence of bone lesions by age group.

Also associated with these anomalies are lesions caused by DJD, which, despite being directly related to individuals' ageing processes, can also be associated with mechanical stress factors caused by activities carried out during life, aggravated by the fact they are cumulative in nature (Figure 116 to Figure 118). As with entheses, the sample analysed shows that prevalence is higher in men (33.33%) than women (24.14%); however, when comparing age groups, the distance between middle adults and young adults is much greater, with 63.64% and 24.42%, respectively, in line with the expected paleoepidemiological model. But it is interesting to see how the population shows some differences when looking at population affiliation groups, where individuals with African affiliation have a higher prevalence (25%), compared to Europeans (19.44%) and Amerindians (17.65%).

It should be clarified that these data show the frequency but not the severity of lesions, which also tends to increase with age and to affect the joints to a greater extent in women than in men. However, regardless of time and type of society, male individuals generally have the highest numbers of such lesions, although agro-pottery groups tend to show more cases than hunter-gatherers. In post-contact populations, such as in Panama, lesions increase at the spinal and lower limb levels, perhaps as a result of mobility activities, agricultural tasks and construction work, but with greater biomechanical stress in urban than in rural populations (Fornaciari & Giuffra, 2009: 199–204).

Moving on to other types of lesions, porotic hyperostosis is found more frequently in male (37.5%) than in female individuals (27.59%), while according to age groups it is young adults who manifest the lesion most frequently, with 31.4% compared to middle adults (18.18%) and subadults (13.33%). European groups are the most affected (47.22%), followed by Amerindians (35.29%) and Africans (27.5%). As mentioned above, this lesion is generally associated with nutritional stress processes, including chronic anaemia, although it is also related to environmental factors, parasitosis and other chronic diseases, while in the child population it is more likely to

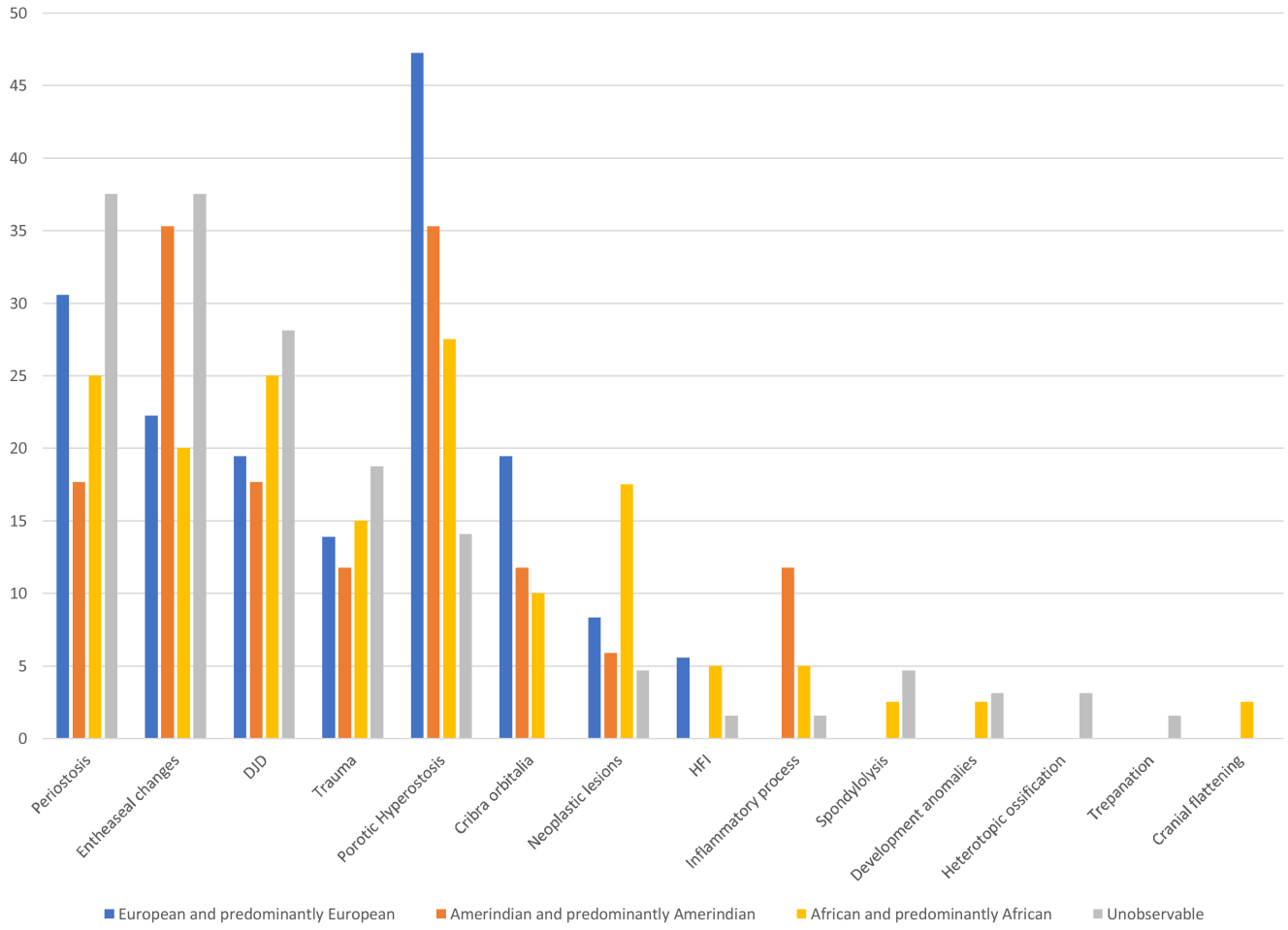

Figure 115. **Prevalence of bone lesions in individuals grouped by ancestry.**

Table 26. **Prevalence of infectious lesions in individuals grouped by sex.**

	Treponematosis		Non-specific infections	
	Frequency	% Prevalence	Frequency	% Prevalence
Female	9	50.00	13	43.33
Male	9	50.00	14	46.67
Undetermined	0	0	3	10.00
Total	18	100.00	30	100.00

be caused by anaemia (Fornaciari & Giuffra, 2009: 233). However, if we start from the idea that porotic hyperostosis is an indicator of nutritional stress, it can be seen that there is a greater impact in male individuals, suggesting that females were less exposed to the difficult dietary conditions faced by this population, although this does not match that seen previously for the colonial period at Panama Viejo, where an inverse situation is presented (Rojas-Sepúlveda *et al.*, 2011).

The same is true for the age groups, since in the cathedral there is a greater proportion of young adults in relation to middle adults, which is not the case in the rest of the colonial series.

Table 27. Prevalence of infectious lesions in individuals by age group.

	Treponematosis		Non-specific infections	
	Frequency	% Prevalence	Frequency	% Prevalence
Subadult	1	5.56	1	3.33
Young Adult	12	66.67	15	50.00
Medium Adult	4	22.22	8	26.67
Adult	1	5.56	6	20.00
Total	18	100.00	30	100.00

Table 28. Prevalence of infectious lesions in individuals by ancestry groups.

	Treponematosis		Non-specific infections	
	Frequency	% Prevalence	Frequency	% Prevalence
European and predominantly European	2	11.11	9	30.00
Amerindian and predominantly Amerindian	1	5.56	2	6.67
African and predominantly African	2	11.11	8	26.67
Undetermined	13	72.22	11	36.67
Total	18	100.00	30	100.00



Figure 116. Eburneal and marginal lipping (degenerative joint disease) processes in right femur of 1043.

This could possibly be due to the survival of individuals who suffered some type of nutritional deprivation during childhood. However, some epidemiological models suggest that the incidence of porotic hyperostosis tends to be high in post-contact populations (Fornaciari & Giuffra, 2009: 233–234), although these models show no specific information on the impact of the lesion according to phenotypic variation. According to the frequencies presented, it apparently affects Europeans in Panamá



Figure 117. Marginal lipping (degenerative joint disease) in glenoid cavity of right scapula in 1090.



Figure 118. Cervical spondyloarthrosis in individual of 1090.

Viejo Cathedral more, although there are no significant statistical differences with Amerindians or Africans.

It was mentioned above that porotic hyperostosis was related to cribra orbitalia, also associated with nutritional stress processes, and, although the osteological series shows a similar trend when observed by sex and ancestry, this is not the case with the age groups, where young adults present the highest prevalence with 10.47%, followed by middle adults (9.09%), and subadult individuals (6.67%). Again, comparing these groups with each other shows no statistical difference for the cribra orbitalia results.

With regard to traumatic lesions, male individuals are the most affected, with a prevalence of 18.75%, compared to females with 18.39%, while young adults show a higher proportion (17.44%) than middle adults (9.09%) and subadults (6.66%). About prevalence according to phenotypic variation, the difference between groups is relatively low, with predominantly African individuals being the most affected with 15%, followed by Europeans with 13.89% and Amerindians with 11.76%. When compiling the epidemiological models, it must be remembered that traumatology differs according to sex and age, for example, femoral neck fractures will be more frequent in older individuals due to the effects of diseases such as osteoporosis. In paleopathology, the lifestyle of populations in relation to the socioeconomic structure and the historical-cultural context will define the way in which these types of lesions manifest themselves and are studied through what are called "trauma models" (Fornaciari & Giuffra, 2009: 158).

In the case of individuals from Panama Viejo's cathedral, the traumatological model will be characterised by a very high frequency of cranial fractures (57.14% of the total number of traumas), with evidence also of healing of the lesions, pointing to the individuals surviving these events (Figure 119 and Figure 120). With the exception of two cases, the lesions were characterised as having been caused by blunt weapons, as evinced by the marks left on the cranium, which reproduce the diameter of the impact surface, generally circular or oval in shape. The other wounds recorded in the cranium are due to sharp heavy instruments, as evinced not only by their deep margins but also by the straight edges with evidence of entry and exit points (indicating a sharp weapon) and, most notably, the imprint left behind and the characteristic area of loss (indicating a heavy instrument requiring force to be removed) (Figure 121).

However, when the data were compared using statistical methods, no significant differences were observed between sex, age, or population affiliation groups, suggesting that all individuals in Panama Viejo were susceptible to some type of

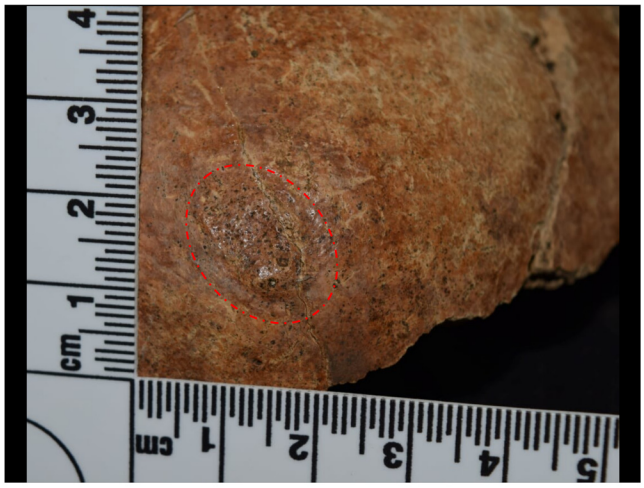

Figure 119. Traumatic oval-shaped lesion in right parietal in 1017.

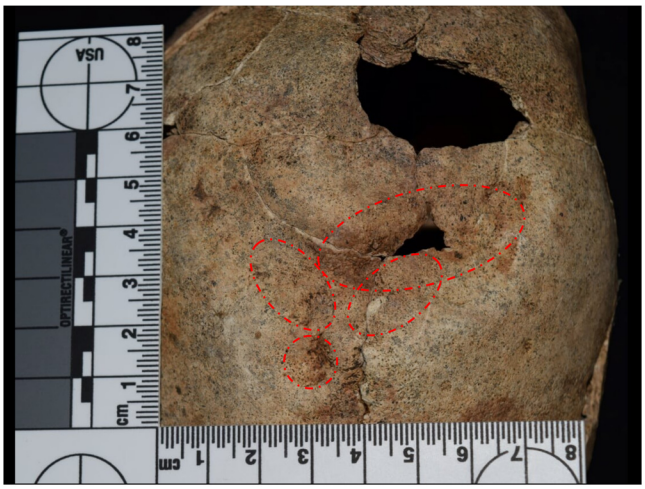

Figure 120. **Multiple contusion lesions in parietals of 1059.**

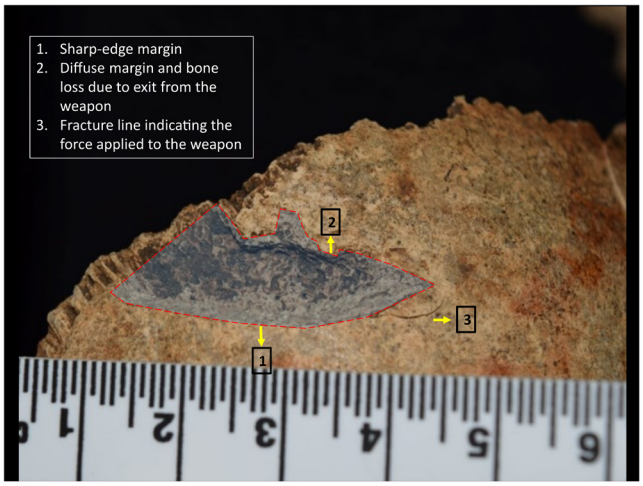

Figure 121. **Wound from a short blunt instrument in frontal of 1015.**



Figure 122. **Fracture in distal third of left ulna in 1044.**



Figure 123. **Fracture in distal third of left humerus in 1097.**

traumatic lesion. This is also verified in the multiple scenarios of violence recorded in historical documentation that show the participation of people from a range of sectors (Díaz Ceballos & Rivera-Sandoval, 2020).

Other traumatic lesions in the postcranial skeleton were also recorded, corresponding to 46.42% of the whole sample in this category. Trauma was concentrated basically at the upper (Figure 122 and Figure 123) and lower limb level (Figure 124 and Figure 125), with a prevalence of 14.29% each. These lesions may be related to accidents, particularly given that these are young and middle-aged individuals. However, fore-arm fractures are characteristic of defensive reactions in which this part of the body is used to protect the face, either in a fall or in a confrontation.

Associated with traumatic lesions are the cases reported as spondylolysis, which, as mentioned above, is generally related



Figure 124. **Right femoral neck fracture in 1168.**



Figure 125. Fracture in distal third of left tibia in 1127.

to mechanical stress in the juvenile stage when force is exerted on the lower spine from carrying heavy loads. In the sample, a higher prevalence is observed in men (4.17%) compared to women (2.3%) and reported only in young individuals (4.65%). This fits with the epidemiological models, where generally male individuals are the most impacted (Waldron, 2009), affecting between 4% and 8% of the population, with African populations affected less than European populations (Aufderheide & Rodríguez-Martin, 1998: 63). However, it was only possible to estimate population affiliation in one of the four individuals identified with the lesion in the sample analysed, which in this case had probable African ancestry.

With regard to neoplasms, female individuals present a higher frequency with 12.64%, compared to males with just 4.17%. Moreover, middle adults are the most affected, with 13.64%, compared to young adults (8.14%). In turn, it is the populations of African descent that show the highest number of reported cases with 17.5%, followed by European (8.33%) and Amerindian (5.88%) groups. According to epidemiological models, this type of anomaly has no sex preference and can occur in any age range, although it may be more common after the age of 40, which coincides with that seen in the Cathedral sample.

The other anomalies have a low frequency and representation, meaning it is not advisable to make population-based interpretations in relation to epidemiological models according to sex, age, or ancestry. However, some pertinent comments were made above for lesions such as hyperostosis frontalis interna and heterotopic ossification.

Overall frequency of dental anomalies by sex, age, and ancestry. With regard to anomalies observed in the teeth, it should be considered that all individuals with at least one tooth had some type of lesion or anomalous characteristic to record, especially in the case of adults in any age range, in which the processes of enamel wear are manifested in different stages, meaning the effective percentage is therefore 100%.

However, if we compare the number of individuals who report at least one of the criteria used in dental pathology, we find that 53.61% of the total number of female individuals present anomalies, compared to 46% of males (Table 29).

Very low frequencies were obtained in subadults when grouping the sample in the different age ranges, meaning these results may be quite skewed, even if the three categories are joined together, leading to there not being enough data to determine a pattern in the presence of anomalies.

For adults, we observe that for the totality of individuals registered as young adults, 67.39% present at least one lesion or anomaly, while middle adults have 50%, and those adults to whom we were unable to assign an age range represent 26.67% (Table 30).

Finally, the cathedral sample was organised by population groups in order to verify the frequency of cases reported within each of the groups, with African and predominantly African individuals having the highest proportion (80.49% of individuals with the presence of lesions or dental anomalies). Europeans, in contrast, show 73.68% and Amerindians 70.59% (Table 31).

Specific frequency of dental anomalies by sex, age and ancestry. Analysing the specific prevalence of dental lesions in Panama Viejo's Cathedral sample according to sex, age and ancestry allowed us to contrast them with some of the epidemiological models proposed to interpret the incidence of oral diseases in past populations, thus giving us an insight into the lifestyles of Panamanians in the 16th and 17th centuries (Table 32 to Table 34 and Figure 126 to Figure 128).

Initially, it is striking that caries, as one of the most frequent lesions in teeth, affects men and women in a similar way, with a prevalence of 61.64% and 65.22%, respectively, which suggests similar exposure to the factors that cause the lesion. Furthermore, this differs from that previously reported for the colonial series of Panama Viejo, in which males showed a much lower trend (Martín *et al.*, 2007).

Furthermore, the high frequency rate of caries in the population analysed is considerable, which may be associated with the increase in carbohydrates in the diet. In the paleopathological literature, the increase in these lesions is associated with populations moving to an agricultural model, for example, in America with the adoption of maize, and in Europe with the incorporation of starch-rich cereals (Fornaciari & Giuffra, 2009; Larsen, 2015). Another food that began to be introduced more frequently from the 16th century onwards was sugar, which consequently led to an increase in dental decay.

Epidemiological models indicate that women are the more affected by caries than men, arguing differences in the type

Table 29. **Proportion of individuals by sex with dental anomalies.**

	Female			Male			Unobservable / Unknown sex		
	N	% Total	% Effec.	N	% Total	% Effec.	N	% Total	% Effec.
Unobservable	45	46.39		27	54.00		22	78.57	
No anomalies	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Anomalies	52	53.61	100.00	23	46.00	100.00	6	21.43	100.00
Total	97	100.00		50	100.00		28	100.00	
Total Effective	52	53.61	100.00	23	46.00	100.00	6	21.43	100.00

Table 30. **Proportion of individuals by age group with dental anomalies.**

	Infant I			Infant II			Juvenile		
	N	% Total	% Effec.	N	% Total	% Effec.	N	% Total	% Effec.
Unobservable	5	100.00	-	1	25.00	-	3	42.86	-
No anomalies	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Anomalies	0	0.00	0.00	3	75.00	100.00	4	57.14	100.00
Total	5	100.00	-	4	100.00	-	7	100.00	-
Total Effective	0	0.00	0.00	3	75.00	100.00	4	57.14	100.00
	Young Adult			Middle Adult			Adult		
	N	% Total	% Effec.	N	% Total	% Effec.	N	% Total	% Effec.
Unobservable	30	32.61	-	11	50.00	-	33	73.33	-
No anomalies	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Anomalies	62	67.39	100.00	11	50.00	110.00	12	26.67	100.00
Total	92	100.00	-	22	100.00	-	45	100.00	-
Total Effective	62	67.39	100.00	11	50.00	110.00	12	26.67	100.00

of diet between genders, where it is assumed that males have access to meat protein and female individuals to vegetables and carbohydrates (Larsen, 2015: 74). However, this situation does not seem to match that described in the documentary sources in Panamá, since meat costs were relatively low, and this type of protein was relatively easy to obtain (Castillero Calvo, 2006).

With regard to age, the prevalence of caries is much more evident in middle adults, showing 100% in individuals with some dental lesion, compared to young adults (53.23%) and subadults (28.57%), which would imply the accumulation of these ailments as the individual ages, leading to problems such as periodontal disease, abscesses and loss of teeth.

Caries have also been associated with differences in social status and access to certain foods incorporated into diet, with the more privileged classes consuming much more protein and, therefore, showing a lower frequency of these lesions (Larsen, 2015: 77). However, when comparing the data in each of the three ancestry groups in Panamá Viejo, there is a relative similarity in the prevalence of caries, where the most affected are Europeans with 60.71%, followed closely by Amerindians with 58.33% and, finally, Africans with 54.55%. This situation suggests similar conditions in the type of foods that were being consumed in the city, with significant intake of carbohydrates and probably with a strong influence of maize. It is suggested that one of the most important new productions in Panamá was rice, a cereal that adapted well to the climatic and environmental conditions of the isthmus, as indicated in a 1614 document transcribed by Lucena Salmoral (2005: 158), in which he speaks of groups of slaves who *sowed maize, rice and other pulses* in Chepo and Chimán, which were then traded with people of

Table 31. Proportion of individuals by ancestry group with dental anomalies.

	European and predominantly European			Amerindian and predominantly Amerindian		
	N	% Total	% Effec.	N	% Total	% Effec.
Unobservable	10	26.32	-	5	29.41	-
No anomalies	0	0.00	0.00	0	0.00	0.00
Anomalies	28	73.68	100.00	12	70.59	100.00
Total	38	100.00	-	17	100.00	-
Total Effective	28	73.68	100.00	12	70.59	100.00
	African and predominantly African			Unobservable		
	N	% Total	% Effec.	N	% Total	% Effec.
Unobservable	8	19.51	-	71	89.87	-
No anomalies	0	0.00	0.00	0	0.00	0.00
Anomalies	33	80.49	100.00	8	10.13	100.00
Total	41	100.00	-	79	100.00	-
Total Effective	33	80.49	100.00	8	10.13	100.00

Table 32. Prevalence of dental lesions in individuals grouped by sex.

Anomaly or lesion	Female		Male		Unobservable / Unknown sex	
	N	% Effective	N	% Effective	N	% Effective
Caries	32	61.54	15	65.22	0	0.00
Calculus	52	100.00	21	91.30	4	66.67
Masticatory wear	52	100.00	23	100.00	3	50.00
Enamel defects	10	19.23	6	26.09	2	33.33
Abscess	2	3.85	0	0.00	1	16.67
Alveolar retraction	31	59.62	12	52.17	1	16.67
Chipping	27	51.92	13	56.52	2	33.33
Cultural modification	6	11.54	3	13.04	1	16.67
Hypercementosis	1	1.92	1	4.35	1	16.67

different ethnic origins. However, in a bioarchaeological context, rice-consuming Asian populations show a relatively low prevalence of caries compared to groups that base their diet on maize, suggesting the low cariogenic power of rice (Larsen, 2015: 71). However, the data obtained from analysis of starches in the dental calculus and in the stable isotopy will allow us to determine this population's diet in greater detail (Martín *et al.*, forthcoming).

Associated with these lesions, it can be observed that wear occurs with a prevalence of 100% in women and men, again clarifying that different degrees of wear of the occlusal surface

Table 33. Prevalence of dental lesions by age group.

Anomaly or lesion	No Adult		Young Adult		Middle Adult		Adult		Anomaly or lesion	
	N	% Effec	N	% Effec	N	% Effec	N	% Effec	N	% Effec
Caries	2	28.57	33	53.23	11	100.00	1	8.33	2	28.57
Calculus	4	57.14	60	96.77	10	90.91	3	25.00	4	57.14
Masticatory wear	4	57.14	62	100.00	10	90.91	3	25.00	4	57.14
Enamel defects	3	42.86	14	22.58	0	0.00	1	8.33	3	42.86
Abscess	0	0.00	3	4.84	0	0.00	0	0.00	0	0.00
Alveolar retraction	0	0.00	36	58.06	8	72.73	0	0.00	0	0.00
Chipping	2	28.57	32	51.61	8	72.73	0	0.00	2	28.57
Cultural modification	0	0.00	7	11.29	3	27.27	0	0.00	0	0.00
Hypercementosis	0	0.00	1	1.61	1	9.09	1	8.33	0	0.00

Table 34. Prevalence of dental lesions in individuals grouped by ancestry.

Anomaly or lesion	European and predominantly European		Amerindian and predominantly Amerindian		African and predominantly African		Unobservable	
	N	% Effec	N	% Effec		N	% Effec	N
Caries	17	60.71	7	58.33	18	54.55	5	62.50
Calculus	26	92.86	11	91.67	31	93.94	9	112.50
Masticatory wear	27	96.43	12	100.00	32	96.97	8	100.00
Enamel defects	6	21.43	3	25.00	6	18.18	3	37.50
Abscess	2	7.14	0	0.00	0	0.00	1	12.50
Alveolar retraction	18	64.29	7	58.33	19	57.58	0	0.00
Chipping	21	75.00	5	41.67	16	48.48	0	0.00
Cultural modification	4	14.29	0	0.00	6	18.18	0	0.00
Hypercementosis	2	7.14	0	0.00	1	3.03	0	0.00

of the teeth were recorded. This situation is equally evident in young adults and, to a lesser extent, in middle adults, with a prevalence of 90.91%. It is also striking that in the non-adult population, wear is registered in 57.14% of individuals who register some form of dental anomaly. With regard to population variation, in the African and Amerindian groups there is a prevalence of 100%, while in Europeans this reaches 96.43%. These high figures may be caused by hard diets that required the masticatory apparatus to be used in order to process food; in this sense, carbohydrates are again related to this type of evidence of mastication, although it is important to distinguish to what extent the wear is manifested in each individual.

Diet can also be tracked through dental calculus, which also shows a significant influence due to carbohydrate intake. In the sample, it was possible to identify different degrees of development with an effective prevalence of 100% of female individuals and 91.3% of males, which still suggests a similar degree of wear and a type of diet that did not distinguish between men and women. Moreover, it was possible to register dental calculus in 96.77% of young adults, 90.91% of middle adults, and 57.14% of subadults; this difference is probably related to the ageing processes this sector of the population would surely have suffered, in addition to poor oral hygiene, further causing the development of calculus. When observing population affiliation, 93.94% of African individuals

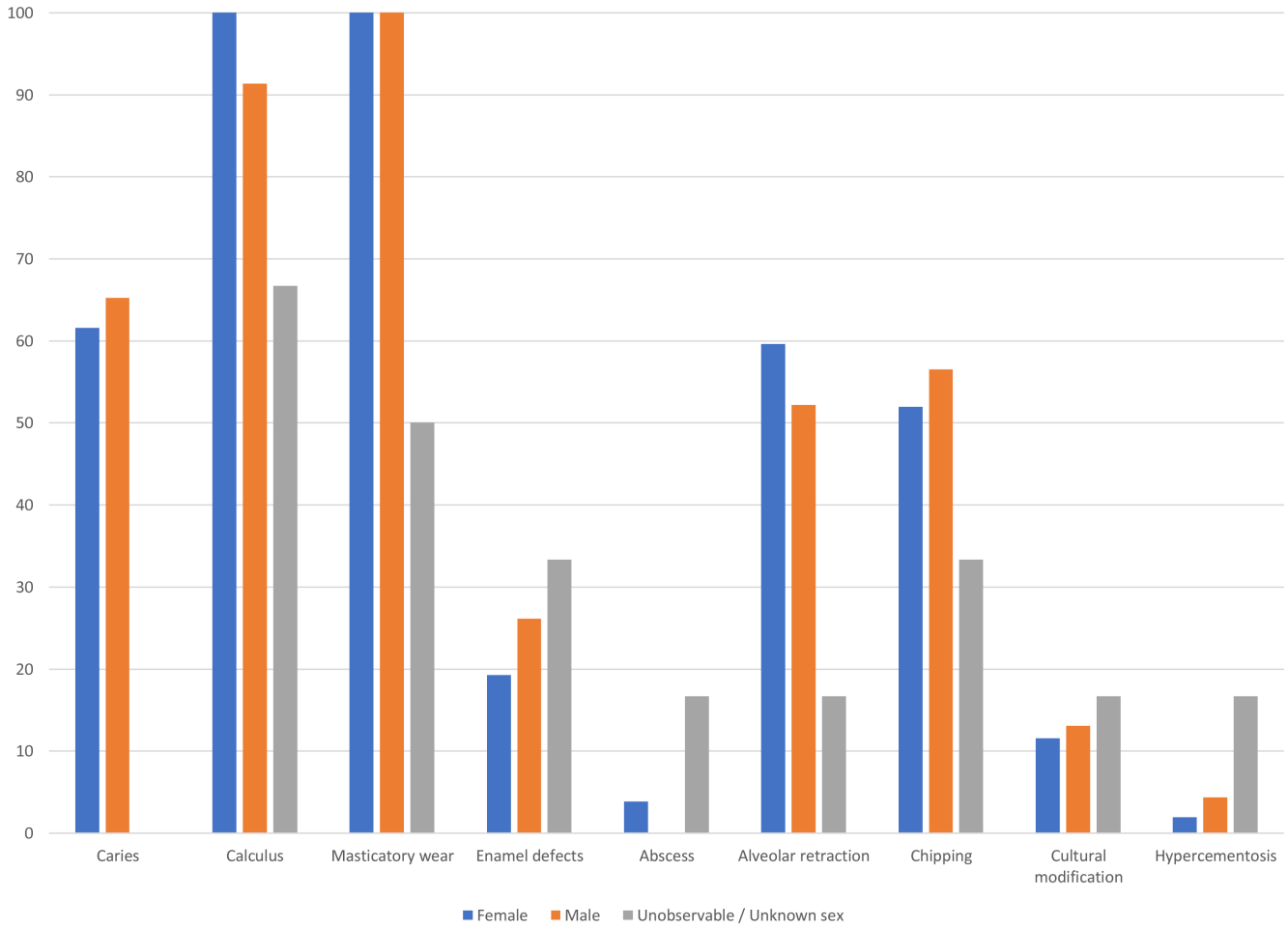

Figure 126. Prevalence of dental lesions in individuals grouped by sex.

present some degree of calculus severity, followed by Europeans with 92.86% and Amerindians with 91.67%, showing the same trend of wear and caries in which there is no significant difference between the groups.

With regard to evidence of periodontal disease, particularly in terms of alveolar retraction, women show a higher prevalence than men, with 59.62% and 52.17%, respectively. The epidemiological models do not show a consistent pattern regarding sex differences, although some data show an increased risk in men (Larsen, 2015: 83). However, it should be remembered that these lesions are due to multiple factors and specific sociocultural behavioural patterns in human populations. For example, it is reported that the prevalence of periodontal disease in women is higher than in men for those indigenous groups in South America that were in contact with Western populations (Larsen, 2015: 83), a situation that coincides with the sample from Panamá Viejo, where it is almost certainly associated with the processes of adapting to a new lifestyle and a new way of producing food.

Observing this criterion in the population affiliation groups, the population with European traits is the most affected, with 64.29%, while Amerindians have 58.33% and Africans 57.58%. Prevalence of periodontal disease also increases with the complexity of social organisation and the economic system in societies, with high numbers occurring in agricultural and industrialised groups (Larsen, 2015: 81). Moreover, the trend increases with age, a situation that is clearly evident in the sample analysed, where medium adults have a prevalence of 72.73%, compared to 58.06% in young adults.

These cumulative processes associated with age are also reflected in enamel fractures or chipping, where middle adults have 72.73%, compared to 51.61% in young adults and 28.57% in subadults. Remembering that this lesion can be multifactorial, including aspects related to hard diets, it is again likely that the carbohydrates incorporated in the diet of Panamanians of the 16th and 17th centuries influenced the frequency of these dental fractures. However, a slight difference is observed when comparing the data recorded for men and women, with

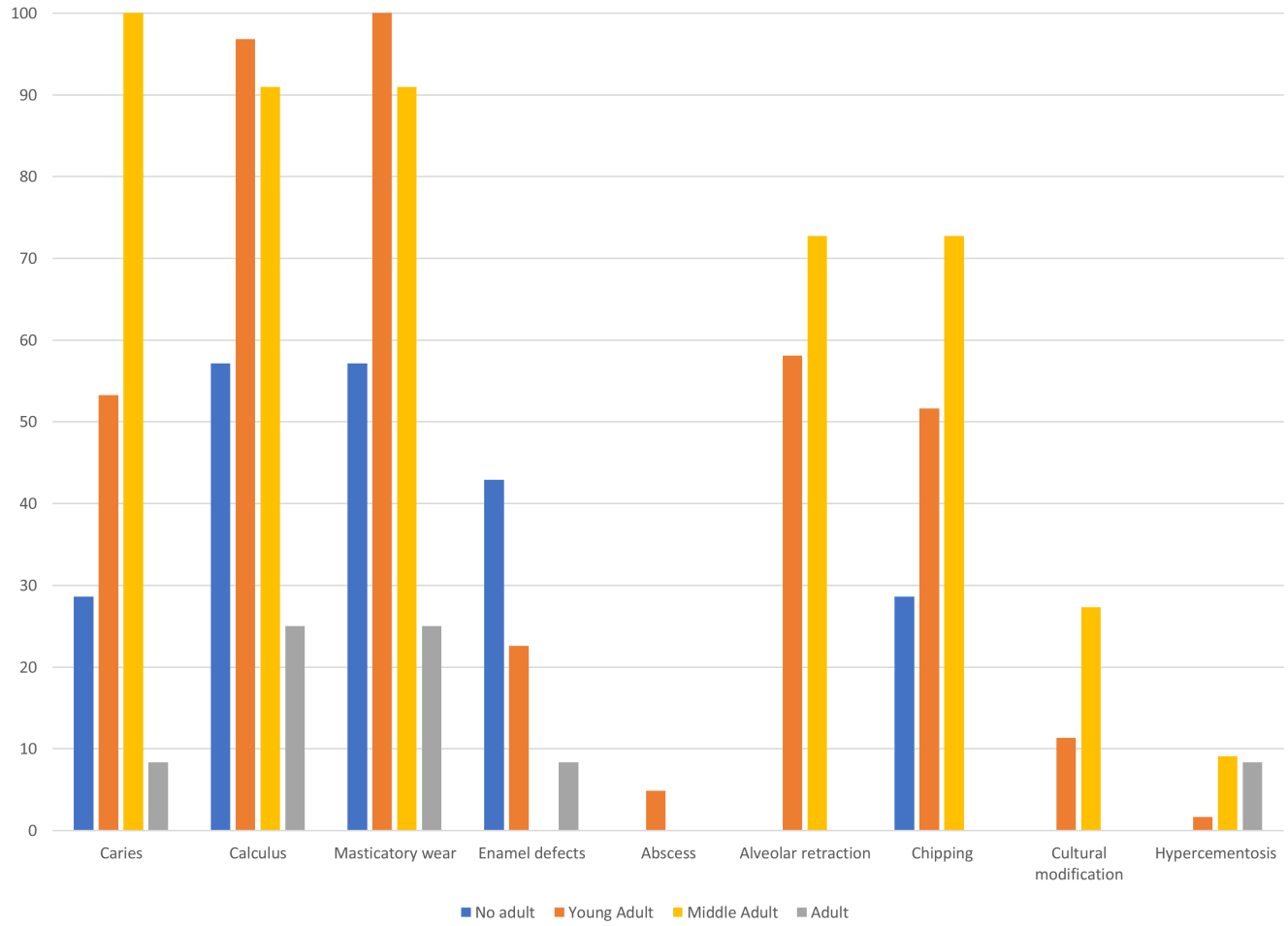

Figure 127. Prevalence of dental lesions by age group.

56.52% and 51.92%, respectively, while for ancestry groups it is Europeans who show a higher rate of lesions of this type (75%) than Africans (48.48%) and Amerindians (41.67%). These data may be due to other types of environmental, cultural, and dietary conditions that led to enamel fractures, although it is difficult to identify their causes.

Another indicator of the state of health of populations is enamel defects, since they are associated with nutritional stress events in the odontogenesis stages of individuals, affecting sub-adult individuals. The highest frequency of the lesion in the sample corresponds precisely to this group, together with young adults, with 42.86% and 22.58%, respectively. With regard to differences based on sex, a prevalence of 26.09% is observed in men, while women have a prevalence of 19.23%. Moreover, phenotypic variation shows slight differences between each of the three main groups, with Amerindians reaching a prevalence of 25%, Europeans 21.43%, and Africans 18.18%. This situation suggests a relatively symmetrical incidence throughout the population, which is also consistent with that described for nutritional stress bone indicators and other dental anomalies associated with dietary patterns.

Finally, the lesions related to abscesses, hypercementosis and cultural modifications do not provide sufficient data to sustain a paleodemographic discussion. However, it is important to consider some of the observations made above from a population perspective, particularly in the case of cultural modifications, since at least three types of alteration were found, of which dental sharpening is associated only with populations of African origin (Smith-Guzmán *et al.*, 2020).

Conclusions

Analysis of the 175 individuals excavated in the south-east space of the main square (1519–1641) and in the nave and atrium of Panama Viejo's Cathedral (1642–1671) allowed

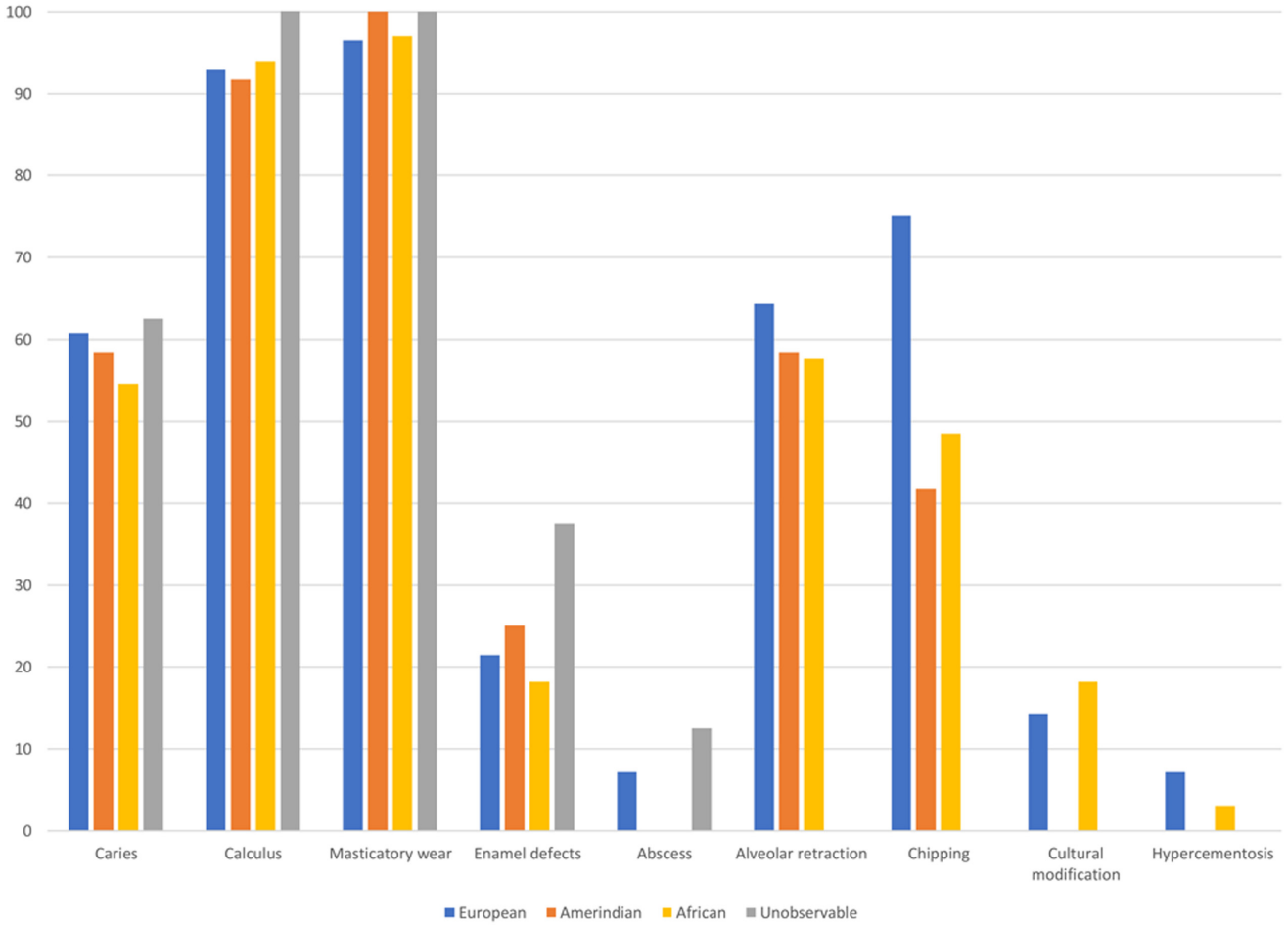

Figure 128. Prevalence of dental lesions in individuals grouped by ancestry.

us to make an initial approximation to the lifestyles and health conditions of the Panamanian population in the 16th and 17th centuries. However, there were some methodological problems associated with the state of conservation and representativeness of the sample, derived directly from the fact that ecclesiastical sepulchres in the colonial period were constantly affected by new burials, leading to burials being modified and reduced. This obviously limits the analysis and subsequent interpretation of the data obtained in the bioanthropological study.

Notwithstanding such limitations, it was observed female and probably female individuals constituted 55.43% of the population buried in the Cathedrals, while 28.57% were identified as male. The population also proved quite young, with the 18–34 age range being the most represented (52.57%), an absence of adults older than 55 years and a low representation of children and juveniles (9.14%). Similarly, the burials show the confluence of different population groups at Panama Viejo, where the high number of individuals with probable African or predominantly African population affiliations buried in the two sites of the temple represent 23.43%, slightly exceeding Europeans with 21.71%, and, to a lesser extent, Amerindians with 9.71%, thus demonstrating the sociodemographic particularities that would shape daily life at Panama Viejo.

A large number of bone and dental lesions were recorded, with infectious processes, porotic hyperostosis, entheseal changes and DJD being the most frequent in the bones, while wear due to masticatory processes, dental calculus, caries, periodontal disease and enamel fractures (chipping) were the lesions that most affected teeth in this population. These data suggest that individuals living in Panamá had to face stressful situations in the process of adapting not only to a series of climatic and environmental conditions, but also to the configuration of a political, economic, and sociocultural structure

taking shape in first Spanish port founded on the American Pacific.

Data availability

All underlying data related with this manuscript are available in the ArtEmpire database that can be queried at the URL: https://artempire.cica.es/.

This project utilised the following underlying data:

- https://artempire.cica.es/archeo/excavations/50. Description of data: Archaeological and bioarchaeological dataset of the burials excavated in the main nave of Panama Viejo's cathedral in 2017.
- https://artempire.cica.es/archeo/excavations/55. Description of data: Archaeological and bioarchaeological dataset of the burials excavated in the atrium of Panama Viejo's cathedral in 2017.
- https://artempire.cica.es/archeo/excavations/53. Description of data: Archaeological and bioarchaeological dataset of the burials excavated in the south-east of Panama Viejo's Main Square in 2018.
- https://artempire.cica.es/archeo/excavations/54. Description of data: Archaeological and bioarchaeological dataset of the burials excavated in the south-east of Panama Viejo's Main Square in 2018.

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Current Peer Review Status: ✗ ?

Version 1

Reviewer Report 01 October 2021

https://doi.org/10.21956/openreseurope.14957.r27572

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The topic addressed in this work is of great relevance, as it provides new knowledge about the living and health conditions of the population that inhabited Panama City during the initial period of the Colony. It is, indeed, a subject on which there is very little work.

The author carried out the study of a set of skeletal remains dating from the 16th and 17th centuries, based on the registration of data from both the biological profile of the population and stress markers and other biocultural traits, under a bioarchaeological approach. The methodology chosen for this purpose is appropriate, although in some cases it is not the most up-to-date and recommended for the proposed analyzes. On the other hand, the methodology related to the analysis of the information is mentioned in a limited way and only in the section on the presentation of the results.

The information obtained is of great interest. A very important section corresponds to paleopathology, which examines the prevalence of bone and dental conditions, enthesopathies and skeletal abnormalities. These include a case of unintentional flattening of the skull, which should not be considered in this section (and rather be omitted), a case of trepanation (which is not evident in the illustration provided) and cases of dental filing; which they should not be included as anomalies or pathology either, since they are specific traits of cultural behavior. Your discussion, of interest, should be formulated independently.

On the other hand, the diagnoses offered, mainly in cases of specific infections - treponematosis, tuberculosis, leprosy-, are largely debatable, since the necessary elements for an appropriate differential diagnosis are lacking, and accurate paleopathological identification should be avoided, while maintaining a general diagnosis. Therefore, a adjustment of this section is recommended.

In the same way, some methodological issues that should be reviewed should be pointed out; include the method of registration of dentoalveolar diseases; dental pathological features as well as bone abnormalities must be analyzed separately. The presentation of the results, in tables and bar graphs, is largely redundant, since it is the same data, and unnecessarily lengthens the text. The images to illustrate paleopathological cases become more than those required, since they include several of them for the same trait, when only one example would suffice. The prevalence graphs of pathological conditions should be located at the beginning of the results section, and not at the end.

We consider that the manuscript should be reviewed in the indicated areas for its indexing to be acceptable.

Is the work clearly and accurately presented and does it engage with the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
No

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
No

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Skeletal Biology, paleopathology, bioarchaeology.

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however we have significant reservations, as outlined above.

Reviewer Report 26 August 2021

https://doi.org/10.21956/openreseurope.14957.r27420

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This is a research paper presenting a bioarchaeological analysis of a colonial site of Panama, Panamas Viejo, dated back between the 16th and 17th centuries. The osteological sample is interesting, and the author took into consideration several parameters; however, there is a general lack of a deep analysis and discussion of results, in particular about the bone and dental pathologies. The methodology is poorly developed, and in the case of bone and dental pathologies is completely missing; this negatively impacted the validity of the results and their discussion, since there are no sufficient data to elucidate a clear picture of the sample and to perform relevant comparisons. It is insufficient to provide a general frequency of each pathology; instead, if rough data are made available, this greatly allows the comparison of results according to sex and age at death, and to provide a scoring system for some of the pathologies (i.e. DJD, entheseal changes, occlusal wear, dental pathologies, etc.). The author should carry out some statistical test (e.g. Chi-square test) to verify the significance of the differences in the examined parameters. When the Author reports a frequency, the number of affected individuals should also be reported, along with the number of observed individuals. This lack hinders a full comprehension of results. As for the paleopathological analysis, for each pathology the author should provide sex and age at death of the affected individuals, while much of the osteoarchaeological and paleopathological literature is lacking or not updated; scientifically it is not correct to cite handbooks for the pathologies only. Moreover, some paragraphs throughout the paper need references.

Several major revisions are necessary to improve the manuscript and make it suitable for indexing.

Comments:

- Page 3, Plain language summary: tartar is uncommon, better to use calculus.
- Page 3, Historical context of the city of Panama Viejo: please clarify what do ‘zambaigos’ and ‘mulatos’ mean.
- Pages 3-4, Archaeological excavations in Panama Viejo’s cathedral: what does the Author mean with ‘temple’? Is there both a church and a pagan temple in Panama Viejo? Or does the term ‘temple’ be used as a synonym of church? It is not clear. Please check throughout the manuscript.
- Page 4: The author mentions burial sites in the central nave and atrium excavated between 1998 and 2005 and 22 additional tombs in the south-east flank of the main square excavated in 2003; later in the same page the Author mentions the excavation of 2017 and 2018 with 159 individuals from the main nave and atrium and 16 from the square. Therefore, in the present study the skeletons excavated before 2017 were not included, is it correct? Why were the previous excavated skeletons not included?
- Page 5 Methods: For the evaluation of the state of preservation of the skeletal material it would be better to refer to standard methods available in the literature, e. g that of Bello *et al*. (2006).

- Pages 5-6: The expression 'basic quartet' is unusual and misleading; please use proper expressions, for example not 'Estimating the basic quartet in adult individuals', instead 'Estimating biological sex, age at death, ancestry, and stature of adult individuals'.
- Page 6: It is not necessary to mention each feature that was evaluated to estimate sex, it is sufficient to cite the method used. Please refer to Klales 2020 for an update of sex estimation methods and to Klales *et al*. (2012) for seriation of Phenice original method; moreover, why not include Klales's work in the methodology? The elevation of the posterior border of the auricular surface is also a trait to be included for sex estimation (e.g. Wescott, 2015).
- Also, considering the nature of the osteological sample presented in p. 5 (i.e. commingled remains, reduced burials etc), it is worth to include multivariate discriminant function analysis for long bones. *'Obliteration of secondary ossification centres'*: do you mean timing of epiphyseal-diaphysis fusion? '*Sternal surface of the fourth*': please also include Burns (1999) suitable for assessing age-at-death to all sternal rib eds. '*Observations on the acetabulum were also made for male individuals (Rissech et al., 2006)'*: Why not does the author not use Rougè-Maillart *et al*. (2009)?
- Since extensive focus has been paid on the state of preservation, why not include the Transition Analysis (Boldsen *et al*., 2002) for age estimation? It might be a suitable method, especially when bone elements are fragmented, since the analysis can be performed regardless the state of preservation. Moreover, depending on the state of preservation of each individual, also the method by Falys and Prangle (2015) on degenerative changes of the sternal extremity of the clavicle may be useful. Adding as much as possible methods for age/sex estimation can positively impact the sample size available for observation and associated analysis.
- Page 6: for the three age groups defined for the adult population which is the reference? These age classes are quite similar to those proposed by Buikstra and Ubelaker (1994). We suggest using them instead adapting, unless the author specifies why the adaptation is necessary.
- Page 6: As for the Arizona State University Dental Anthropology System (ASUDAS), why not referring to the combination of the five dental non-metric traits (Rathmann and Reyes-Centeno 2020) that return to be the most useful for inferring genetic affinity compared to the full observation of 27 ASUDAS common traits?
- Page 7: Please specify which or Trotter and Gleser's formulae have been used for European individuals (those for Afro-American or for White individuals? - just for clarity, this is the original distinction made by Trotter and Gleser). Moreover, what about the formulae for estimating stature in individuals for which sex could not confidently estimated (i.e. formulae by Sjøvold 1990)?
- Page 7: Why does the author give the frequency of non-adults in the Methods section? This information should be provided in the Results section only. Moreover, frequency of adults within the sample has been not provided and this represents an inconsistency.
- Page 7: Please provide references for the non-adult classes (infant I, II and juvenile). Why does the author not include foetuses in the demography structure of the sample? This seems an odd choice (on this topic see Halcrow *et al*., 2017; Halcrow, 2020).
- Page 7: The subpubic angle (or pubic angle) is not a feature included in Schutkowski (1993), please refer to characters of the ilium as described by the original work. Otherwise you should include pelvic traits with relevant references, for instance the subpubic concavity as revised by Klales and Burnes (2017), suitable for non-adults. Finally, why not include the elevation of the auricular surface ? (Weaver *et al*., 1980) and – most importantly – why not

include sex estimation using the humerus for adolescents? (see Rogers, 2009).

- We suggest to reframe this section by presenting age estimation methods first, and then specify that depending on the age of the individual, sex was cautiously attempted using a different set of skeletal criteria.
- What do you mean presenting the correlation '*between long bone diaphysis length and biological age'* as a method for age estimation?
- Why does the author use Ubelaker's charts instead of the most recent and well-tested AlQahtani *et al*., 2010; 2014 diagrams? For the third molar development, we suggest to see and maybe to use Liversidge and Mardsen (2010) since the authors proposed a thorough methodological revision indicating which method of age estimation using mandibular M3 is best.
- Page 7: The author declares that of the 159 individuals, 66 were complete and 93 were crania: no other bones were found, only crania? Or were crania considered only to obtain the minimum number of individuals? If crania were found exclusively, this could reflect particular burial practices. Please clarify.
- Page 7: the author should also refer to the method used for the evaluation of entheseal changes.
- Page 9: '*Moreover, those with better representation indices correspond to only 5.145% of the sample*'. Why three decimal points? For consistency, please use two decimal points.
- Page 10: Please cite relevant literature about the conditions and characteristics of the soils in this region of Panama
- Page 10: The term non-adult is now preferred to subadult in the bioarchaeological literature, please check throughout the manuscript.
- Page 10, figure 3: what do the last two columns on the left represent?
- Page 12, Figure 6: as per our comments above, you have an individual here with no sexually dimorphic bones, but you can estimate biological sex using the multivariate formulae of long bones and then try to reconstruct the stature using the formulae for both sexes (i.e. Sjøvold, 1990) or those related to a specific sex if estimated previously.
- Page 12: we strongly encourage not using the term 'gender' (and thereafter 'men' and 'women' throughout the paper), since it implies a sociocultural dimension of an individual which cannot be reconstructed by analysing the human skeletal remains.
- Page 12: the term 'incidence' implies a specific epidemiological definition (i.e. the rate of new cases of a condition observed within a given period) which cannot estimated in palaeopathology. Rather, we suggest using the word 'prevalence'.
- Page 16: The author should provide some explanations about the increasing age at death related to chronology.
- Page 16, Table 10*:* Please specify that total number of males and females also includes individuals with a probable male or female sex, respectively.
- Page 21: In this section, it is not specified which cranial and dental features turned out to be more useful for establishing phenotypic variability. Moreover, the interpretation of the distribution of population groups (both in relation to chronology, archaeological area or biological sex) needs to take into account that nearly half of the osteological sample (45.14%) is unobservable. This is just briefly mentioned at the end of the section '*caution must be exercised due to the size of the sample (Table 14 and Figure 14)*'.
- Page 21: The author should provide some comments about the different distribution of ancestry through time.
- Page 21: It might be worth specifying the number of individuals for which stature has been reconstructed using measurements of the upper limbs from those elaborated using lower

limb measures, being the latter notoriously more reliable. Moreover, since different methods for stature reconstruction are listed according to different ethnic groups, results should be presented consistently. Indeed, it is briefly discussed that '*this trend corresponds to the figures presented for other collections of the colonial period, which show relatively low heights in all ancestral groups*'. However, this assumption cannot be verified since no comparison is provided between Panama data and other collections.

- Page 22, Table 15: Since no methods are detailed for stature reconstruction for individuals with unknown sex, how is the stature for the unobservable individual in Table 15 calculated?
- Page 22, 'Paleoepidemiology': In this brief introduction about paleopathological analysis is worth recalling the osteological paradox.
- Page 23, Figure 15: It would be more interesting - and mostly correct - to use boxplot for presenting the Panama data compared to other coeval collections segregated by sex (i.e. Panama males vs. male of other collections and Panama females vs. females of other collections) to see variation among females and males across series having similar chronology and/ or geography. As it stands now, the box plot does not add any further information, unless the Author might want add a brief description of data variability within the text. Finally, the box plot is not graphically presented as usual, since no whiskers are showed.
- Page 23, 'Overall frequency of bone anomalies for the whole sample': It does not make any sense calculating a unique frequency as presented in Table 16 since pathologies cannot be cumulated. Moreover, since some individuals are 'unobservable', it does not make any sense having calculation of two different frequencies, i.e. total and effective. You need just one frequency calculated both on individuals observable and/or on bone/dental elements of each category of pathology/anomaly. Moreover, please note that is also mandatory to specify the inclusion criteria for observation.
- Page 24 and following pages: The expression entheseal changes is too general; the author should evaluate the presence of a pathological expression of entheseal changes (i.e. enthesopathies) and/or evaluate the grade of expression of normal entheseal robusticity (low, medium, high development) and relate it to age at death. Otherwise, this parameter is not useful.
- Page 24: what does the author mean with inflammatory process?
- Page 24: Periostosis should be 'periosteal reaction'.
- Page 24: Porotic hyperostosis is a distinct condition related to anemia in which the porosity of the cranial external surface is accompanied by a thickening of the cranial vault, and this is usually evaluated through radiological analysis or macroscopically if a post mortem breakage occurs, allowing direct observation of the skull. Since no mention of radiological analysis is made in the text, we suppose that the author refers to *cribra cranii*, which is a condition limited to a porosity of the external cranial surface and can be linked to several conditions, including trauma, metabolic diseases, etc. Please correct throughout the text.
- Page 24: Trepanation should be classified as 'intentional lesion', while the other categories should fall under the rubric of skeletal anomalies, rather than pathological conditions; cranial flattening cannot be considered as a pathological condition.
- Page 24, Table 17: Not clear which is the ratio n/N for each category. You should present all the results having a column indicating the number of individuals/elements affected (n)/total number of individuals/elements observed (N). As per our comments above, 'observed individuals/elements' needs to be clarified in the methods section in order to understand and discuss results properly.

- Page 24: unless a diachronic comparison of paleopathological data is presented, no effective impact can be estimated and quantified for supporting this claim. By contrast, Panama results can be discussed in relation to the harsh living and health conditions as usual expected in an urban context.
- Page 25, figure 19: The radius seems to belong to a non-adult, as the epiphysis appears as not fused; or is it a post-mortem breakage? It is not clear from the picture. If it is a non-adult, the author should re-evaluate the entheseal change.
- Page 25: The author should provide the percentage of individuals with localised (that is attributable to traumas) and diffuse (it is inappropriate using the term 'extended') form of periosteal reaction. Which are congenital or tumoral diseases which can be related to periosteal reaction? The author should also provide the localisation of the localised form of periosteal reaction, as this is an important element to formulate a diagnosis. For example, among the metabolic diseases, scurvy shows a typical distribution (for example on the greater wing of the sphenoid and adjacent bones, on the hard palate, on the maxilla, etc. see Brickley and Mays, 2019). Therefore, on the basis of the localisation of periosteal reaction, it should be possible to distinguish between a trauma from other aetiology,
- Page 25, Figure 21: Marginal lipping is well-recognisable, while the porosity marked with the yellow arrow seems the normal texture of the vertebral body.
- Page 25: On which basis or criterion the 37.5% of individuals with evidence of infectious diseases were related to treponematosis? Periosteal reaction of the lower limbs is not sufficient to diagnose treponematosis; diagnostic features are located in the skull instead. Are there lesions typical of treponematosis present in any skulls? In our opinion, it is not possible to infer the aetiology of the periosteal reaction for the cases presented in figures 23 to 25; treponematosis is only one option. A very illuminating contribution on the topic of treponema and how to approach in its identification is provide by Baker *et al*. (2020). We strongly encourage you to better contextualize the topic of treponematosis considering the geographical, biocultural context and environmental conditions of the targeted sample (even providing at least sex and age at death of the pathological individuals).
- Pages 27-28: Which is the age at death of the individual with lytic lesions on the vertebral bodies? Again, diagnosis of TB needs the pathognomonic sign (i.e. Pott's sign) not described here. In a suspected case of TB, molecular analysis should be also provided. Moreover, the nature of the lytic and the reparative process as seen in the pictures seem to be more consistent with a case of thoracic aortic aneurysms (e.g. Grauer, 2019). We strongly recommend including a differential diagnosis that also includes neoplasms and circulatory disorders and not only brucellosis; if the available skeletal elements/methodological approach do not allow a robust paleopathological identification, it is better a broad diagnosis. In our view, the vertebral lesions of Panama 1042 are well different from those presented by Mutolo *et al*. (2012), which are indeed related to brucellosis.
- Page 29, Figure 32: Yellow arrow indicates the reactive process of the alveolar process of the maxilla, not of the sinuses.
- Page 29, Figure 33: Please add 'left zygomatic bone'. The bone formation within the sinuses are better classified as lobules (Boocock *et al.*, 1995).
- Page 29, Figure 35: Hard to appreciate the inflammatory process of the crista galli from the picture provided.
- Page 29, Figure 36: Please underscore the osteoblastic nature of the lesion.
- Page 29: Resorption of the alveolar bone is more proper terminology rather than inflammation of the dental alveoli.
- Page 30: While bone lesions of Panama 1020 could be consistent with leprosy, it is worth

noting that nasopalatal and maxillary antrum alterations may also be observed in the tertiary phase of syphilis and in tuberculosis (e.g., Brothwell, 1967; Møller-Christensen, 1967; Hackett, 1976; Manchester, 1994; Ortner, 2003). Since hands and feet are not preserved for Panama 1020, we suggest, again, to address a differential diagnosis considering other primary infectious diseases.

- Page 30: Please refer to relevant osteoarcheological literature related to maxillary sinusitis (e.g. Boocock *et al*., 1995; Merrett and Pfeiffer, 2000; Roberts, 2007; Davies-Barrett *et al*., 2020) and to clinical data for aetiological factors.
- Page 30: Beside DJD, entheseal changes are also related to age, therefore for a correct analysis entheseal changes and DJD should be evaluated in this sample by relating these parameters to age at death and to sex of the individuals. This lack of methodology hinders a full comprehension of results.
- Page 30 and following: For a correct analysis of DJD, a scoring system and distribution analysis of the lesions in the different joints should be applied. For example, which are the most affected joints in male and females? Are there significant differences in the DJD patterns between the sexes or age categories? This information could be useful in elucidating the pattern of physical activity carried out by this population.
- Page 31, Figure 40: It seems more a case of enthesopathy rather than normal robusticity of the enthesis.
- Page 31, Figure 43: These lesions could be better appreciated if the picture is placed in vertical direction.
- Page 31, Figure 44: How does the author determine the nature of the ankylosis being related to DJD instead as a result of a trauma? Also add the planes of reference within the picture (L= dorsal; R=volar).
- Page 32: It is difficult to ascertain the exact impact of the colonial period in terms of frequency of DJD since no diachronic comparison with sites of pre-Hispanic period is provided.
- Page 32: please see previous comments about porotic hyperostosis. A more updated bibliography should be consulted and cited about this condition (e.g. Wapler *et al*., 2004; Brickley, 2008; Schultz, 2012; Klaus, 2017; Brickley, 2018; Mays, 2018).
- Page 32: In the last years, other aetiologies of *cribra orbitalia* have been proposed. Beyond anemia, also metabolic diseases, trauma among others can be related to orbital porosities. In the recent literature, *cribra cranii* (and not porotic hyperostosis) and *cribra orbitalia* are considered indicators of stress, instead of to be an indicator of anemia; the references on these two conditions in paleopathology are not updated. Please also note that a common aetiology of *cribra cranii* and *cribra orbitalia* is also questioned (e.g. Rivera and Mirazón Lahr, 2017).
- Page 32, Figure 45: This is an example of *cribra cranii* and not PH. Pages 33-34: Are the nodules seen in the internal surface of the frontal bone accompanied by a thickening of the skull?
- Page 34: No criteria have been explained in the methods section for identifying (i.e. antemortem, perimortem or post mortem) and classify (blunt, linear etc) traumatic lesions. The author should provide further information also on the traumas on the post-cranial skeletons: are they healed or peri-mortem? Blunt or sharp? How many fractures can be detected? Which bones or bone portions are affected? In the evaluation of trauma, it is important also to provide information about intentional or accidental traumas. Furthermore, sex and age of the affected individuals is a relevant element; i.e. were males more affected than females? A table with all the info should be useful.

- Page 34, figure 52: Please provide a better picture as the lesion is not clearly visible.
- Page 35: What does the author mean with an 'elastic appearance'? How can a bone have an elastic appearance? The staining of the fracture margins is likely related to taphonomic damages.
- Page 35: Which is a possible diagnosis for the lesions on the pelvic region? A diagnosis of bone tumours cannot be delivered considering just two bone elements for which neither a differential diagnosis, nor a radiological analysis is provided. Moreover, no detailed information about the state of preservation of the individual is given, neither biological data (sex and age).
- Page 35, figure 56: The aperture of the last two sacral vertebrae is normal, so there is no spina bifida.
- Page 35: Enostoses are present within the medullary cavity, not on the cortical surface. The morphology of the lesion seems to be consistent with a case of musculoskeletal injury.
- Page 36, Figure 60: It is not even clear which parts of pelvis are; more useful an anatomical comparison with a healthy pelvis.
- Page 36, Figure 61: Not clear that the bone is a tibia from the picture. Please reframe the diagnosis of the bone lesion.
- Page 36: Multiple osteomata can be related to Gardner syndrome, but also they can be related to an isolated condition.
- Page 37, figure 67: It is not clear how the diagnosis of lumbarisation of S1 has been made, since the sacrum seems very incomplete.
- Page 37: Is the bone asymmetry of the semilunar bones a pathology? It should be considered as an anatomical variant.
- Page 37: They are three of four cases? Be specific. Moreover, it is unnecessary to mention the statistical perspective.
- Page 37: These cases can be described under the rubric of traumatic lesions since the aetiology of heterotopic ossification is mainly traumatic. We suggest to use clinical references when referring to pathophysiological mechanism of a pathological process (e.g. Meyers *et al.*, 2019).
- Page 38: In our opinion the case of unintentional cranial flattening is not significant as a pathological case and could be removed.
- Page 38, figure 72: Please provide a better picture for the cranial trepanation, as from the picture we are not sure whether this case actually represents a trepanation. Please cite at least Verano (2003), Andrusko and Verano (2008) and Kurin (2013) for trepanation in South America.
- Page 39, table 19: No methods for recording dentoalveolar diseases and anomalies is provided in the relevant section and is hard to evaluate results presented in Table 19.
- Page 39: Teeth more resistant than bone tissue: please add references.
- Page 39, Table 19: Please specify if frequencies are calculated on individuals or teeth.
- Page 39, dental tissues: Please add references. As for functionality of dentine, the tertiary or reactionary dentine has a protective role against, for example, carious lesions, excessive wear and microbial infection (e.g. Goldberg *et al.*, 2011; Towle, 2019).
- Page 39: As for dental diseases, the author should provide the percentages calculated on individuals and also on teeth. We cannot understand what does "frequency" and "% effective" stand for. For examples, as for carious lesions, how many individuals on the observable ones have at least one dental caries? How many teeth have caries on the observable ones? Alveolar resorption is more appropriate than alveolar retraction.

- Page 39: As for dental wear, severity and analysis related to sex and age should be provided. Since no details on methodology is given, it is not clear what is meant by 'wear due to attrition'. Does the author mean the occlusal dental wear related both to aging and masticatory forces? Please specify. Also, the identification of bruxism in osteoarcheological specimens needs a careful evaluation of a set of skeletal and dental criteria (e.g. Foley, 2020).
- Page 39: Please refer to Bonfiglioli *et al*. (2014) for scoring system of chipping. A detailed analysis about the distribution among sexes need to be performed as well as distribution analysis of the defect per tooth typology.
- Page 42: The term "caries" alone implies a general pathological process; for dental pathologies, it should be used the expression 'carious lesion' or 'dental caries'. Please check throughout the text and Figure legends.
- Pages 42-43: For both calculus and dental caries it should be interesting to have more information beyond the total frequency in the sample. For example, the degree of calculus (mild or strong?) Which grade of severity for dental caries, superficial, penetrating, destructive? Which teeth are more affected by caries and which surface, occlusal, interproximal, etc?, and the relationship with the age at death. Dental caries rate calculated on individuals and on tooth should be included: how many individuals out of the observed and how many teeth on the observed are affected by caries?
- Page 44: Please provide more details about the 3 cases of periapical abscesses.
- Page 44, Figures 92 and 94: Not sure about the presence of alveolar resorption (except for M1 in Figure 94) since it seems not exceeding 2 mm (and distance up to 2 mm is not considered evidence of periodontal disease, e.g. Ogden, 2008)
- Page 45: Similarly, to calculus and dental caries, referring to the sole total frequency of enamel hypoplasia is not informative: it should be important to provide the total number of observed individuals, the mean number of defects per tooth, severity, male vs female prevalence, and the age at onset of events occurred with associated calibration process (see Reid and Dean, 2006; Cares Henriquez and Oxenham 2018; 2019). Which are the teeth on which enamel hypoplasia were observed? The anterior teeth are usually observed, but from figures 99 and 102 it seems that this dental stress indicator was recorded also in posterior teeth. Please clarify. Should be 'Minozzi' and not 'Monozzi'. Please add relevant and recent references on multiple aetiologies of LEH. The prevalence of 22.22 % needs to be discusses compared to other LEH prevalence, for example to other coeval osteological series.
- Page 45, Figure 96: Please provide a clearer picture of the mandible with associated abscess of M3 and fistula; the choice of the term 'space' instead of 'alveolus' is rather odd.
- Page 45: Cultural modification should be scored according to Romero (1970) and this should be specified in the methods section. No comparison of V-shaped teeth with other colonial or pre-Hispanic osteological series? (e.g. Geller, 2006).
- Page 46: As the author explains that dental sharpening is attested among African cultures, he should verify if the 4 observed cases are in individuals with African ancestry.
- Page 47: Please refer to relevant literature on extramasticatory dental wear, e.g. Bonfiglioli *et al*., 2004; Erdal, 2008; Molnar, 2011. Furthermore, refer to relevant literature on LSAMAT. For example, Watson and Haas, 2017; Berbesque *et al.*, 2012; Irish and Turner, 1987 (it includes a prehistoric site from Panama); 1997; Turner and Machado, 1983.
- Page 47: Please refer to D'Incau *et al*. (2015) for methods on recording hypercementosis and note that it is also linked to bruxism (e.g. Foley, 2020), to progression of periodontal disease and other local or systemic factors (e.g. Corruccini *et al*., 1987; García-Gonzáles *et al*., 2019).
- Pages 47-48: Please provide more details about the individuals with dental modifications.

- Page 48: Please avoid the terms ‘incidence’ and ‘significant’ and replace with ‘prevalence’ and ‘remarkably’ since the term ‘significant’ is usually related to statistical analysis, something that it is not carried out in this research.
- Page 48: We suppose it is Paget’s disease and not Piaget.
- Page 48: How many teeth are observed for hypercementosis? Since only isolated teeth could be evaluated, it is important to report the number of observable elements and provide details about sex, age and ancestry of these individuals.
- Page 48: In our opinion, it is a nonsense to provide the frequency by sex, age and ancestry for all the bone anomalies. Each bone anomaly should be evaluated singularly.
- Page 48: As for infectious diseases and all the other bone diseases, the author should always report the number of individuals with the pathology and the number of observed individuals. In table 23 and 24 it is not clear if in the column ‘N’ the total number of observed individuals or the number of individuals with the pathology; both should be reported. As for the sex difference, a statistical test should be applied to verify if the difference between sexes is statistically significant or not.
- Page 49: Firstly, the author declares that infections in general are more prevalent in middle adults compared to young adults, but soon after he writes the contrary, that is for both treponematosic and non-specific infections the figures are reversed. It is not clear.
- Pages 48-49; Page 52, proportion of specific and non-specific infections: We strongly suggest reformulating and nuancing these assumptions on treponematosis as per our comments above.
- Page 52: Which muscular insertions were more developed? A detailed analysis of the distribution of entheseal changes and the score should be necessary. This could provide some information about the type of physical activities performed by the population.
- Page 53: same for DJD: A detailed analysis of the distribution of DJD and scoring system should be included. Moreover, it would be useful presenting a more detailed comparison with Panama Viejo colonial series (you mention Rojas-Sepúlveda *et al*., 2011) to better appreciated similarities or differences between the pre-colonial and colonial series. For a broad overview on the topic of DJD and entheses we suggest the recent publication by Becker (2020).
- Pages 53-54: As previously stated, without a radiological study it is not possible to assess the presence of porotic hyperostosis. The sole porosity on the cranial surface is referred to as *cribra cranii,* which have a range of possible different aetiologies. A statistical test to verify whether a statistically significant difference occurs between the sexes is necessary. The entire topic of PH needs to be reformulated in terms of terminology, interpretation and recent literature to be cited since *cribra cranii* and *cribra orbitalia* should be treated separately and not as whole.
- Pages 54-55: In table 26 and following the two columns ‘frequency’ and ‘prevalence’ are confusing. The author should present a column with the number of affected individuals, a column with the total number of observed individuals and a column with the percentage of affected individuals.
- Page 56: The author mentions a statistical test: which was used?
- Page 56: As regard to trauma, the author refers that male individuals are the most affected, but the prevalence of 18.75% is practically the same to the female one (18.39%). A statistical test is necessary. More references should be cited, for example Lovell (1997).
- Page 57: The 46.42% of traumatic lesions in postcranial skeleton is calculated on individuals?
- Page 57, Figure 120: Does the author mean multiple blunt lesions?

- Page 58: As for the adoption of maize, please add relevant literature, e.g. Cucina *et al*., 2011; Vega Lizama and Cucina, 2014; Smith, 2017; Simon, 2017. Please add references for the introduction of sugar.
- Page 58: It is not possible to discuss about neoplasms in general, as the type of neoplasms is necessary to evaluate the distribution based on sex and age.
- Page 58: Similarly, to bone anomalies, it is a nonsense to report the overall frequency of dental anomalies by sex, age, and ancestry, as each dental pathology should be discussed singularly.
- Page 58: A statistical test to verify if the difference among sexes is significant is necessary. It is also important to discuss the severity of dental caries, which teeth and surface are mostly affected, since these aspects may provide dietary information.
- Page 60: As previously stated, in table 32 and following the number of affected individuals, the number of observed individuals and the percentage of affected individuals should be reported.
- Page 60, '*the stable isotopy*': Odd word, does the author mean stable isotope analysis?
- Page 62: The frequencies of periodontal disease between the male and female subsample are quite similar, so there is actually no sex-specific trend here; moreover, no statistical test was used here to support or reject the statement.
- Page 63: Please specify that dental sharpening is exclusively documented in individuals with African origin in the Panama sample and not as general assumption.
- Page 64: Which are the climatic conditions that may have impacted lifestyle of Panama sample? Please provide details and references to support this statement.

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Is the work clearly and accurately presented and does it engage with the current literature?
No

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
No

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
No

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Bioarchaeology, paleopathology

We confirm that we have read this submission and believe that we have an appropriate level of expertise to state that we do not consider it to be of an acceptable scientific standard, for reasons outlined above.