Caries correction factors applied to a Punic (6th - 2nd BC) population from Ibiza (Spain)

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Abstract

Caries correction factors were applied to a Punic (6th-2nd century BC) rural sample from the island of Ibiza (Spain). Data obtained on dental caries and ante-mortem tooth loss provided a corrected rate of 12.8% of teeth with caries. This result, in conjunction with other sources of information such as stable isotope analysis and documentary evidence, indicated a diet based on terrestrial protein (mainly carbohydrates) and a low component of marine protein. The paper suggests further research avenues and promotes the use of caries correction factors in archaeological populations.

Keywords: Caries Correction Factor; Dental Caries; Diet; Ibiza; Punic

Introduction

This paper summarizes the results from a study on a limited sample of human remains from the island of Ibiza, Spain. This paper will concentrate on dental caries and ante-mortem tooth loss and explores the application of caries correction factors. The sample provides an opportunity to reconstruct the Punic diet (6th-2nd century BC), during a period when Ibiza became one of the most important Punic centres in the Mediterranean.

Diet and nutrition

Briefly, diet can be defined as the kinds of foods that are eaten (e.g. beef, bread) and the pattern of its consumption; nutrition as the nutritional value (nourishment) of that food (e.g. protein, carbohydrate); and subsistence, in relation to diet, as the way in which people managed to acquire foodstuffs (e.g. hunting, farming).

An understanding of the diet, nutrition and the subsistence economy of past populations can contribute to an understanding of the health status of a population. Dietary patterns may influence disease response, cognitive functions, intellectual development, work output, physical performance, productivity, social and behavioural functions and morbidity and mortality, amongst others (1). Diet and nutrition can be associated with mortality and fertility. Malnutrition is the most important associated factor leading to high mortality rates in developing countries and can affect the age of menarche in females and increase their risk of miscarriage and stillbirth (1). Stature is also influenced by nutrition. An understanding of diet and nutrition might provide an indication as to possible contributing factors influencing the presence of pathological conditions such as cribra orbitalia. Similarly, poor oral health (e.g. gingivitis, abscess) can promote poor nutrition if the pathological conditions are painful (2).

In the study of archaeological populations, diet may be inferred from various sources (3). These include animal and plant remains, stomach contents in mummies, coprolites, artefacts, epigraphy, and documentary sources. Cultural factors must be taken into account too, since food selection may be associated with political, moral, religious and spiritual issues (4). Direct evidence of diet and nutrition from human skeletal remains can be inferred from a number of dental indicators including attrition and dental microwear, oral pathology (e.g. dental caries), chemical analysis (e.g. stable isotopes) and perhaps certain pathological lesions. All methods complement eachother and different types of evidence should be employed in order to obtain a more complete picture of a population's diet. For example, oral pathology might reveal general patterns of consumption (e.g. high carbohydrate intake) but will not provide evidence of particular foodstuffs that were consumed (e.g. olives, fish sauce, honey) which may be indicated through documentary evidence.

This study focuses on dental caries and ante-mortem tooth loss in a Punic population from Ibiza. In order to interpret the results and to further reconstruct the diet of the population, the data on oral pathology are combined with other sources of information such as stable isotope analysis and documentary evidence.

Background to dental caries and ante-mortem tooth loss

Dental caries (DC) is a chronic disease consisting of an infection that destroys tooth enamel and on occasions also the dentine and the cementum, as a consequence of the acid produced by bacteria in the dental plaque on fermentable carbohydrates (5). Prevalence of DC is strongly influenced by diet and subsistence technology (6). Ante-mortem tooth loss (AMTL) refers to teeth that have been lost (e.g. by intentional extraction or through pathological processes) during an individual's life. In clinical dentistry, most AMTL is a result of extraction of a tooth with advanced DC (7). For this reason, rates of AMTL and DC must be analysed together in order to obtain a more reliable estimate of the real DC frequency in a population (7-10).

The presence of DC depends on three interacting factors: a susceptible host, a sufficiently virulent agent and a caries-promoting environment (11). The main factor associated with the presence of DC is the consumption of carbohydrates, in particular sugar (5, 12), although other factors must also be considered (13). High frequencies of DC are usually present in populations that base their diet mainly on vegetables (14). Generally speaking, a high incidence of DC in past populations has been

attributed to deteriorating living conditions (15). In more recent times, however, 'improvements' in living standards have also been associated to an increase in degeneration of oral health (16). Periods of technological innovation, increased trade relations, increased products with refined sugars, and increased longevity may be factors influencing this trend. Further information on the aetiology of caries can be found elsewhere (2, 5, 11, 12).

Materials and methods

Materials

A skeletal sample from Ibiza dating to the Punic (or Carthaginian) period (6th-2nd BC) was employed. Ibiza is an island in the Western Mediterranean (Balearic Islands, Spain) with a land surface of c.570 km2. After the Phoenician period in the sixth century BC, Ibiza came under the influence of Carthage (North Africa). This resulted in deep transformations in the social, economic, political, ideological and religious spheres. These changes included an apparent demographic growth, colonization of the rural landscape, agricultural activity, different funerary rites, intensive production of goods and the creation of a coin mint (17). During this period Ibiza, with its strategic location, became one of the most important Punic centres in the Mediterranean.

The human skeletal material employed here represents the largest sample of a rural Punic context that has ever been studied in the Mediterranean. The necropolis, known as Ses Païsses de Cala d'Hort or Can Sorà on the SW of the island (18), however, only comprises a minimum of 75 individuals buried in rock-cut tombs (19). Of these individuals, nine were subadult (<18 years) and 66 adult. Unfortunately, only 20 adults could be sexed (6 females, 14 males). This limitation is due to the disarticulated and commingled context, as well as the highly fragmented condition in which the bones were found. This limited the potential for age and sex distribution as well as palaeopathological analysis. Another limitation is the wide chronological range of the cemetery. Further information regarding the site and the human skeletal samples and methodology employed can be found in Márquez-Grant, 2006 (19).

Methods

In this investigation, the examination of oral pathology for dietary reconstruction took into account dental caries and ante-mortem tooth loss. Alongside other indicators, such as dental attrition and stable isotopes, dental caries is regarded as 'one of the most important ways in which the diet of past populations can be reconstructed (20).

The identification and recording of dental caries was undertaken in accordance with Hillson (20). The number of teeth rather than the number of mandibles/individuals affected was counted. Original scoring took into account prevalence according to surface (e.g occlusal pit and fissure caries, coronal caries - mesial, distal, buccal, lingual-, gross caries), type and severity. Although information was obtained for each tooth and tooth surface, and according to side, upper and lower dentition, DC frequencies were finally pooled and overall tooth frequencies presented according to anterior teeth (incisors, canines) and posterior teeth (premolars, molars). According to Hillson (5), if tooth classes are not separated, the overall percentage is influenced by the pattern of postmortem tooth loss. Dental caries is more common in molars than anterior teeth and molars are less likely to be lost postmortem

so that archaeological collections with poor anterior tooth preservation will have artificially inflated caries rates. Some potential problems to consider when employing DC are diagnostic in nature, and by the fact that rates are influenced by age and sex (20, 21).

Ante-mortem tooth loss was identified by observing the degree of alveolar bone resorption. All observable alveoli were counted and a note was made of those that had started to regenerate or were completely regenerated before death.

Caries correction factors

In skeletal studies, the conventional caries rate, calculated as the number of teeth with DC divided by the number of teeth observed, does not reflect a real prevalence of DC because AMTL and post-mortem tooth loss (PMTL) are not taken into account (9, 10). In modern living populations, caries rates are calculated counting the number of decayed, missing and filled teeth (DMF index). A modified version of the DMF Index, only considering decayed and missing teeth ante-mortem (DM Index), has been used in archaeological studies (7). However, this assumes that all AMTL is due to dental caries (20). While the caries rate estimated from carious teeth alone underestimates the true caries rate for the population (22), the DM index overestimates it (8). This assumption is inappropriate for archaeological populations experiencing heavy wear, considerable periodontal disease and/or dental trauma (22).

Lukacs devised a 'caries correction factor' (CCF) which estimates the proportion of AMTL due to caries by considering the proportion of teeth with pulps exposed due to caries and those with pulps exposed due to attrition (8). The number of teeth lost ante-mortem is multiplied by the ratio of teeth with exposed pulp chambers due to caries. Duyar and Erdal (10) are of the opinion that Lukacs (8) CCF achieves reasonable results, although they emphasize the need to distinguish between anterior and posterior teeth. There also is a need to consider post-mortem tooth loss since anterior and posterior teeth are lost at different proportions, thus distorting the results (22). To account for AMTL and PMTL in both anterior and posterior teeth separately, the 'proportional correction factor' or PCF (9) was developed.

In this study, the application of the CCF and PCF is applied to a Punic rural sample. Some limitations, however, must be taken into account. Firstly, not all AMTL is due to wear or caries so that factors such as periodontitis, trauma or even cultural factors (such as tooth ablation) must be considered. Secondly, the methods used here to take into account the number of surfaces observed (only overall presence or absence of caries in a particular tooth) haven't yet been applied in the literature. A worn tooth might be classified as having no caries but previously it may have had pit/fissure caries. Regarding the Punic rural sample, potential differences in age and sex, which influence caries rates, could not be included in the CCF and PCF due to the disarticulated and commingled nature of the sample.

Results

No deciduous or permanent subadult teeth were recovered from the Punic rural cemetery. Table 1

provides the dental information available for the adult Punic rural sample. A small sample of 222 permanent teeth was present with only 209 available for analysis of caries, since 13 teeth had considerable calculus deposits, were badly preserved or fragmented or too worn to be included. Both sides of upper and lower dentition were pooled. A further breakdown according to teeth and tooth surface, caries type and location, a detailed methodology and more detailed analysis can be found in Márquez-Grant (2006) (19). Uncorrected rates are given first, followed by the application of the CCF and PCF.

Table 1. Number of teeth present, AMTL, PMTL and missing data

Permanent dentition	**PUNIC RURAL (MNI = 66 adults)**		
	Anterior teeth	**Posterior teeth**	**Total**
Total teeth expected for 66 complete adult dentitions[1] (a)	792 (66 x 12)	1320 (66 x 20)	2112 (66 x 32)
Teeth preserved *in situ* (in sockets) (b)	46	153	199
Teeth found loose/isolated (adults) (c)	6	11	17
Teeth found loose/isolated (unaged) (d)	3	3	6
Teeth lost *ante-mortem* (e)	15	33	48
Total teeth present and lost *ante-mortem* (f) = (b) + (c) + (d) + (e)	**70**	**200**	**270**
Total sockets present (g)	252	360	612
Teeth missing *post-mortem* (h) = (g) – (f)	182	160	342
Number of teeth not present (i) = (a) – (f)	**722**	**1120**	**1842**
Percentage of teeth missing (j) = (i)/(a)	91.3%	84.8%	87.2%
Number of teeth for which status (AMTL, PMTL) is unknown (no sockets preserved)[2] (k) = (i) – (h)	540	960	1500

[1] The expected number of anterior and posterior teeth results from multiplying this number (66) by the number of anterior teeth (12) and posterior teeth (20) that would be present. This assumes all adults would have fully erupted permanent dentitions, which may not always be the case; [2] This count refers to the number of teeth that are not present and their unknown status (AMTL, PMTL) since their alveoli have not been preserved and thus were not analysed.

Uncorrected caries rates

The proportion of missing teeth is considerably high in this assemblage. From Márquez-Grant (2006) (19), the estimated uncorrected caries rate for the Punic rural sample was 2.3% (1/42) for anterior teeth, 10.1% (17/167) for posterior teeth and 8.6% (18/209) for teeth overall. The AMTL prevalence was 5.9% (15/252) for anterior teeth, 9.1% (33/360) for posterior teeth, with an overall rate of 7.8% (48/612).

Corrected caries rates

Correction factors for DC prevalence in this sample were applied in order to achieve a more reliable estimate of the caries rate in the population. Table 2 provides the steps required to calculate the CCF and PCF, and reveals a corrected caries rate for the population of 12.8% (as opposed to an uncorrected caries rate of 8.6%).

The PCF corrected for the disproportion caused by post-mortem tooth loss. After applying the CCF, the results obtained for anterior and posterior teeth were multiplied by 0.375 and 0.625 respectively. In a complete permanent dentition, these rates refer to the proportion of anterior teeth to overall teeth (12/32; or per quadrant 3/8), and to the proportion of posterior teeth to the number of teeth overall (20/32; or per quadrant 5/8) respectively.

Table 2. Steps followed in calculating CCF and PCF for the Punic rural population.

Step	Instructions	EXAMPLE (Punic rural site)	
		ANTERIOR	POSTERIOR
A	Number of teeth lost *ante-mortem* (A)	**15**	**33**
B	Ratio of teeth with pulp exposed due to caries (B)[1]	**0.50** (1/2)	**0.20** (6/30)
C	Estimated teeth lost ante-mortem due to DC (C) = (A) x (B)	**7.5** (15 x 0.50)	**6.6** (33 x 0.20)
D	Number of carious teeth present (D)	**1**	**17**
E	Total estimated number of teeth with DC (E) = (C) + (D)	**8.5** (7.5 + 1)	**23.6** (6.6 + 17)
F	Total number of teeth observed (F)	**42**	**167**
G	Total number of original teeth (G) = (A) + (F)	**57** (15 + 42)	**200** (33 + 167)
H	**Caries correction factor or CCF** (Lukacs, 1995) (H) = (E)/(G)	**14.9%** (8.5/57)	**11.8%** (23.6/200)
I	**Proportional correction factor or PCF** (Erdal and Duyar, 1999, 2003)[2]	**5.5%** (14.9 x 0.375)	**7.3%** (11.8 x 0.625)
J	Sum of corrected rates for anterior and posterior teeth	**Total = 12.8%** (5.5 + 7.3)	

[1] Ratio calculated from all teeth with exposed pulps. The percentage was calculated by dividing the number of teeth with pulp exposed due to DC (rather than attrition) by the total number of teeth observed with pulp exposure; [2] The PCF is calculated by taking the CCF result for anterior teeth and multiplying it by 0.375 and the CCF for posterior teeth and multiplying that by 0.625.

Discussion

The prevalence obtained for the Punic sample compared to other sites in Ibiza, is higher than prehistoric populations (c.2100 BC) and Mediaeval Islamic populations (10th-13th AD), while slightly higher rates were obtained in the Late Antiquity-Early Byzantine periods (4th-7th AD) (19). Differences have also been observed from stable isotope data (19). Stable isotope analysis shows a heavy reliance on terrestrial protein, with a higher meat intake in the Prehistoric population, a very homogenous diet amongst all the individuals in the Punic rural samples, and the least terrestrial animal protein intake during the Late Antiquity-Early Byzantine and the Medieval Islamic periods, the

latter indicating a heavier reliance on marine protein. Caries rates between various Punic rural samples from Ibiza are very similar and reveal a higher frequency compared to the Punic urban environment (19). The use of corrected caries rates has also been compared between Punic rural and Punic urban samples and between the overall Punic period and the overall Late Antiquity-Early Byzantine period (Figure 1). These results also suggest a higher incidence of DC in this Punic rural population in comparison to the Punic urban assemblage, but lower frequencies for the Punic period (PERIOD 1) as compared to the Late Antiquity-Early Byzantine period (PERIOD 2); after Márquez-Grant, 2006 (19).

At Ses Païsses de Cala d'Hort, apart from oil and wine, the inhabitants would have consumed grapes, dates, figs, almonds, fruit and legumes, with exact details of cereal consumption still somewhat unclear from the archaeological and documentary evidence (18, 23, and 24). Ethnographic accounts of traditional rural families in Ibiza have shown cereals and pulses to be the basic dietary staple, complemented by figs, olives and dairy products (25). Few zooarchaeological studies have been undertaken, but the types of livestock present in Punic Ibiza included predominantly sheep and goat; although pigs, cows and birds would have been consumed too (26-28). Evidence of cut marks on dog remains from Ibiza might also suggest their consumption (26). Documentary evidence states that Punic people did not eat pork, but the high representation of pig remains in habitat contexts from Punic Ibiza seems to suggest they were eaten (28, 29). Ostrich eggs were common Punic grave-goods but whether ostrich eggs and ostriches were consumed remains unknown. Fishing would have been a secondary subsistence activity in Punic times (18, 30) although fish sauce and salted fish appear to have been popular (31).

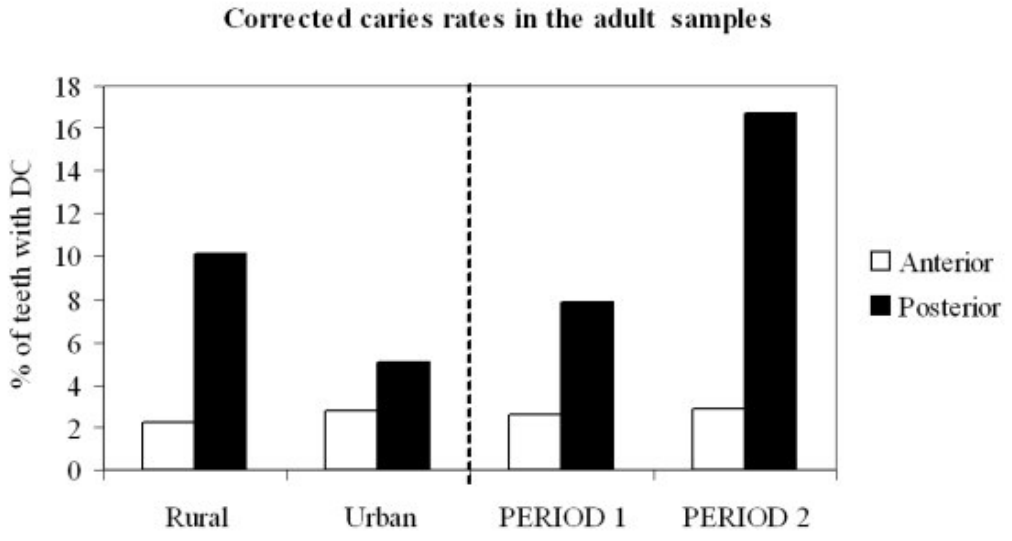

Figure 1. Corrected caries rates between samples in Ibiza (after Márquez-Grant, 2006)

Conclusions

This brief summary paper focused on applying caries correction factors to a rural Punic (6th-2nd BC) sample from Ibiza, with the purpose of obtaining a more reliable estimate of true caries prevalence which will aid dietary reconstruction. The corrected caries rate provided an estimate of 12.8% of teeth affected. By employing other sources of information alongside the dental data, the Punic diet of the rural population was interpreted as mainly based on terrestrial protein with a high carbohydrate component. On promoting the use of caries correction factors and a biocultural approach to dietary reconstruction, researchers are encouraged to undertake these analyses, provide the data according to anterior and posterior teeth, and to record the number of teeth with pulps exposed due to caries as well as those exposed due to attrition. Future research on Ibiza and the Punic period will focus on three main aspects: 1) provide corrected caries rates for Ibizan populations dating from Prehistory to the Medieval period; 2) increase the sample size for the Punic period in Ibiza and in the Mediterranean in order to obtain a bette reconstruction of the Punic diet; 3) Where possible, provide analysis according to age and sex, and explore the application of the correction factors according to dental surfaces only; 4) explore how the political, cultural, social and economic conditions in the different periods may influence prevalence of dental caries.

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