Dental Caries Among the Prehispanic Population From Gran Canaria

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ABSTRACT The island of Gran Canaria was inhabited in pre-Hispanic times by people of North African origin who arrived on the island towards the second half of the first millennium BC. In previous studies, we reported that there are some differences between the coastal inhabitants from Gran Canaria, mainly buried in tumuli, and those from the central mountains, mainly buried in caves. For example, the prevalence of auricular exostoses is higher among the population interred in coastal tumuli when compared with the inland population. This finding may be explained by the practice of marine activities, as supported by chroniclers' reports, by archaeological data, and by bone trace-element analysis, which point to a more intense consumption of marine products by the inhabitants of the coastal regions. Dental caries epidemiology is one of the most important ways in which the diet of past populations can be reconstructed. The purpose of this study is to assess the prevalence and intensity of caries among the pre-Hispanic population of Gran Canaria, in order to increase our knowledge about the dietary habits of these people, and to search for differences among the population buried in caves and that buried in tumuli. We studied a total of 791 individuals. Sex was estimated in 561 cases, and age at death, following Brothwell's criteria, in 549. We found that 66.95% of individuals buried in caves and 58.91% of those buried in tumuli showed at least one carious lesion. The proportion of carious teeth was significantlty higher among the population buried in caves (median = 15.71%, interquartile range (IR) = 0–33.33%) than among the population buried in tumuli (median = 6.25%, IR = 0–20%, $P = 0.001$). Type of burial is the main factor associated with the proportion of carious teeth.These data suggest that the population buried in caves had a different dietary pattern from that of those buried in tumuli. Am J Phys Anthropol 128:560–568, 2005.

Dental caries epidemiology is one of the most important ways in which the diet of past populations can be reconstructed (Hillson, 2001). Caries is a disease process characterized by the focal demineralization of dental hard tissues by organic acids produced by bacterial fermentation of dietary carbohydrates (Larsen et al., 1991). The corrosive action of these acids leads to progressive destruction of the tooth surface (Newbrun, 1982), creating a hole which finally reaches the pulp chamber and may eventually lead to abscess formation which, in turn, induces resorption of the neighboring bone and/or tooth exfoliation.

Several factors are involved in the etiology of dental caries. Poor dental hygiene leads to bacterial overgrowth: the amount of bacteria in the dental plaque reaches 10^{11}/ml in individuals with poor dental hygiene, which is a risk factor for caries development (Vanobbergen et al., 2001) . Oral flora, particularly Gram-positive anaerobes such as several kind of *Streptococcus*, mainly of the *viridans* group, and especially *Streptococcus mutans*, metabolize sugars leading to the production of lactic acid, which facilitates dental erosion. The most important dietary factor contributing to caries risk is fermentable carbohydrates (Touger-Decker and van Loveren, 2003), especially sucrose, which not only serve as substrate for bacterial metabolism, but also modulate bacterial growth in the dental plaque. Therefore, consumption of sugars, especially when refined or when contained in sticky food, leads to a marked increase in the prevalence and intensity of carious lesions. In addition, enamel defects and/or developmental dentine defects (Cook and Buikstra, 1979; Duray, 1990; Larsen et al., 1991; O'Sullivan et al., 1992) may also predispose to caries. Finally, the composition of saliva may confer greater or lower protection against the development of caries.

The island of Gran Canaria was inhabited in pre-Hispanic times by people of North African origin who arrived on the island towards the second half of the first millennium BC (Navarro Mederos, 1983), a hypothesis which was reinforced in recent times by data provided by genetic

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TABLE 1. Some of most important archaeological sites of Gran Canaria, with number of individuals analyzed and proportion of carious teeth per individual

Site	Individuals	Proportion of carious teeth	
		Median (mean ± SD)	Interquartile range
Guayadeque	376	14.3% (20.3 ± 22.0)	0–33.3%
E1 Hormiguero	15	15.8% (18.0 ± 18.9)	5.6–28.6%
Other caves	272	18.2% (24.9 ± 28.1)	0–36.1%
E1 Agujero	48	6.3% (12.5 ± 18.9)	0–17.0%
Crucecitas	22	17.7% (23.0 ± 28.0)	0–33.3%
Los Caserones	15	7.7% (18.0 ± 15.0)	0–31.6%
Other tumuli	43	0.0% (11.5 ± 20.4)	0–14.9%

studies (Pinto et al., 1996; Rando et al., 1999; Maca-Meyer et al., 2004). They developed a highly efficient economic system, mainly based on agriculture, which led to a considerable demographic burst. Therefore, when the Spanish conquerors arrived on the island, it was already inhabited by nearly 50,000 individuals with a population density of 30 inhabitants/km^2. However, this demographic pressure could have had a negative counterpart. The economy was mainly based on agriculture and some cattle raising and fishing. Agricultural surplus of the good years was kept in huge silos to be distributed by the landlords in years of bad yield (Morales Padrón, 1994). The subdesertic climate led to irregular and scarce rainfall, and proximity to the Sahara Desert and Sahel facilitated the arrival of locust plagues which almost certainly devastated the fields (repeatedly documented since shortly after Spanish conquest; Cola Benítez, 1996). This would almost certainly have been followed by widespread malnutrition. In support of this, we showed a high prevalence of osteopenia among the inhabitants of this island, in both the pelvis (González-Reimers and Arnay-de-la-Rosa, 1992) and tibiae (Velasco-Vázquez et al., 1999), possibly explained by poor nutritional status. Also, the proportion of adult individuals who died at young ages is strikingly high (Velasco-Vázquez et al., 1999).

Two very different burial types are observed. The inhabitants of the central highlands placed their dead in huge collective burial caves; the dead were not interred, but deposited on stony or plant layers. However, on the coast, although not exclusively, interments are in tumuli. The significance of these two types of interments is unknown. It was proposed that individuals interred in tumuli belonged to a higher social class that those interred in caves. Radiocarbon dating studies showed that most individuals (but not all) buried in tumuli are more recent than most of those buried in caves.

In previous studies, we reported that the prevalence of auricular exostoses is higher among the population interred in coastal tumuli compared with the inland population (Velasco-Vázquez et al., 2000). This finding may be explained by the practice of marine activities, something supported by chroniclers' reports, by archaeological data (Rodríguez-Santana, 1996), and by bone trace-element analysis. Interestingly, the bone Ba/Sr ratio of individuals buried in the coastal regions is significantly lower than that of individuals buried in inland caves, although both groups showed a high bone strontium content (González-Reimers and Arnay-de-la Rosa, 1992). High bone strontium may be interpreted as derived from either plant food or marine sources; however, in contrast with the terrestrial environment, the marine environment is very poor in barium, so a low Ba/Sr ratio may indicate a diet based on marine products (Burton and Price, 1990). Thus, differences may exist with respect to dietary habits between the population buried in caves (which probably consumed a mainly vegetal-based diet, something which may be cariogenic) and the population buried in tumuli (which, perhaps, consumed more fish and seafood than the former, a situation which may be cariostatic). Therefore, analysis of the prevalence of caries among these people may lend further support to current knowledge about the dietary habits of these people.

There are, however, other variables which should be kept in mind. The pre-Hispanic inhabitants arrived at Gran Canaria nearly 2,500 years ago, and the Spanish conquest took place 2,000 years later. Probably, in those 2,000 years, social and economic conditions suffered changes which are largely unknown, although there are no clear-cut differences in the archaeological context between the more ancient and more recent burial sites. In any case, time depth should be considered in the analysis of the archaeological and anthropological remains of the Canary Islands.

Therefore, taking these considerations into account, the aim of this study is to assess the prevalence and intensity of caries among the pre-Hispanic population of Gran Canaria, in order to increase our knowledge about their diet. We also compare the prevalence and intensity of carious lesions, and the proportion of carious teeth between the population interred in tumuli and that buried in caves. Finally, we also analyze the possibility of an association between the prevalence of caries and time depth.

MATERIALS

The sample analyzed in this study is part of the anthropological collection of the Museo Canario (Las Palmas). Maxilla, mandibles, or complete crania of a total of 791 individuals buried either in the central highlands (as Guayadeque) of Gran Canaria or in coastal burial sites were included in the study (Table 1; Fig. 1). Guayadeque, an archaeological site located in the eastern mountains of the island, is by far the most important funerary site of Gran Canaria. It consists of several collective burial caves in which hundreds of individuals were deposited on plant or stony layers. Absolute dates for some remains from Guayadeque yield time depths ranging from 1,213 ± 60 to 1,410 ± 60 BP, as shown in Table 2 (Martín-Rodríguez, 2000). El Agujero is the most important tumular interment from Gran Canaria, containing the remains of several dozen well-preserved individuals. Dates available for the samples from El Agujero yield a time depth of 875 ± 60 BP. Hormiguero is another coastal interment, from which 12 individuals have been recovered, with a time depth of 1,740 ± 90 BP. Caserones is another coastal burial site, from which remains of 15 individuals were recovered, with a time depth of 1,700 ± 100 BP. According to radiocarbon dating, we further classified our sample in

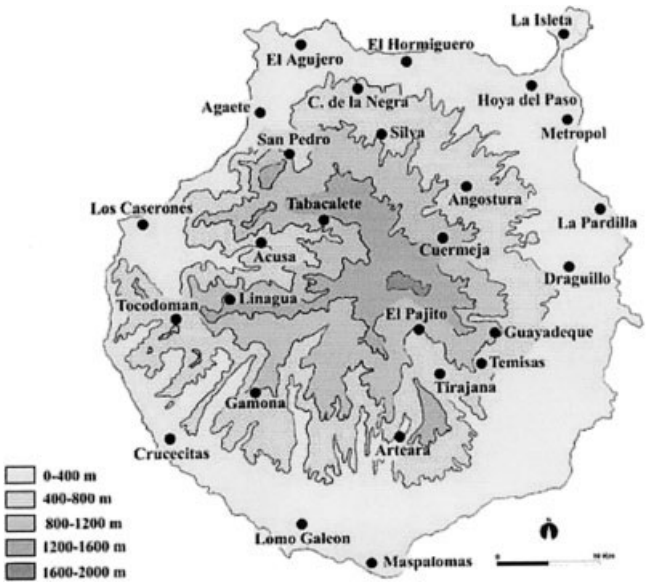

Fig. 1. Map of Gran Canaria with main burial sites.

TABLE 2. Available radiocarbon dates

Subsample	Dates (BP ± SD)
Guayadeque	1,120 ± 60
Guayadeque	1,410 ± 60
Lomo Granados	1,700 ± 100
Cuevas del Rey	1,665 ± 60
Acusa	1,380 ± 60
Acusa	1,520 ± 45
Agujero	875 ± 60
Caserones	1,140 ± 100
Metropole	540 ± 70
Guayedra	700 ± 50
La Restinga	1,030 ± 110
Túmulos Agaete	950 ± 40
Hormiguero	1,740 ± 90

three degrees of antiquity: those who died more than 1,500 years ago, those who died between 1,000–1,500 years ago, and the most recent ones, who had died between 500–1,000 years ago.

Sex was estimated by considering the classic macroscopic aspects of the skull (Ubelaker, 1989). Following this method, 365 individuals were men, and 196 were women. In another 115 cases, sex could not be accurately estimated from the macroscopic features, whereas in the remaining 75 cases, preservation of remains did not allow sex estimation. Age at death was established following the criteria of Brothwell (1972) on dental attrition, classifying the sample into four stages according to age at death (17–25, 25–35, 35–45, and 45+ years). Skulls with advanced molar loss were assigned ages of 45+. This parameter could be recorded in 549 individuals. However, in order to assess the validity of the method of Brothwell (1972) for the population of Gran Canaria, we analyzed the intensity of wear affecting the first (M1) and second (M2) molars in 35 individuals with intact third molars (M3).We observed that the wear rate on molars from Gran Canaria resembled that reported for the British sample of Brothwell (1972), since individuals with an intact M3 surface showed M1 and M2 wear patterns similar to those reported by Brothwell (1972). The intensity of attrition observed on M1 and M2 helped us establish roughly how much attrition had taken place over a fixed period of years, since M2 usually erupts 6 years after M1, and M3 about 8 years later. Based on the intensity of wear on the third molar, we calculated the age at death of individuals in our sample. Using this last approach, three cases classified following the system of Brothwell (1972) as dead at 17–25 years (one man, and two with undefined sex) died at older ages; four cases dead at 25–35 years following the system of Brothwell (1972) (three men, and one with undefined sex) died at older ages, and one (woman) at a younger age; one female classified as dead at 35–45 following Brothwell (1972) should have died at a younger age following intensity of dental wear, and one individual of undefined sex classified by Brothwell (1972) as dead at an age greater than 45 would have died at a younger age. Thus, the degree of concordance of both methods in the estimation of age at death is acceptable. However, the intensity of wear was not always uniform in the individuals analyzed, leading to some degree of uncertainty. In any case, when we compared the proportion of carious teeth with age at death we did not find differences when age at death was estimated following the method of Brothwell (1972), following dental wear on the third molar, or excluding individuals whose ages at death gave disparate results with both methods, so we chose the method of Brothwell (1972) to allocate age.

The total number of teeth analyzed was 5,197 from individuals buried in caves, with 1,508 belonging to women, 2,800 to men, and 889 to individuals with undefined sex, and 1,442 from individuals buried in tumuli, with 994 belonging to men, 254 to women, and 194 to individuals with undefined sex.

METHODS

The following criteria were recorded: number of observed teeth; number of carious teeth; intensity of the carious lesion, following Metress and Conway (1975) (classifying the carious lesion into four degrees: 1) pitting of enamel; 2) destruction of less than one half of the crown; 3) destruction of more than one half; and 4) complete destruction of the tooth, with pulp exposure); and location of the carious lesion, considering location in crown, cervix, root, or crown and root, and also if caries were observed in the occlusal, buccal, lingual, mesial, or distal surface of the teeth. We considered a lesion destructive when it was big enough to affect two or more areas of the tooth.

We calculated the proportion of individuals with at least one carious lesion, the proportion of carious teeth in relation to the observed teeth for each individual, and the proportion of carious teeth for each tooth type (incisors, canines, premolars, and molars).

Dental carious lesions can easily be detected by the naked eye and a dental probe. Indeed, it was shown that visual methods show little interobserver variation, yielding reliable results (Rudney et al., 1983), which we also tested in this study. In 40 individuals, the presence of caries, the number of carious lesions, and their intensity were assessed by two independent observers. Perfect concordance existed in selecting individuals (27) with at least one carious lesion. Both observers found 72 carious lesions in 27 individuals, although in one case the first observer counted 4 carious lesions instead of 5, and in another case, the first observer counted 6 instead of 5 carious lesions. Regarding the intensity of carious lesions, there was discordance in only 2 cases out of 72 (in both cases, grade 2

carious lesions were overscored as grade 3 carious lesions).

It is important to bear in mind that not every pit in the enamel is caused by caries, since diagenetic changes can produce similar lesions in archaeological samples. However, as mentioned earlier, the preservation of samples analyzed in this study is excellent, due to a combination of factors, which include the fact that corpses were not interred, but deposited on stony or plant layers avoiding direct contact with soil, and the subdesertic climatic conditions of Gran Canaria. Nonetheless, in 15 cases we needed the aid of a binocular microscope to distinguish carious lesions from diagenetic changes. A brownish color and the general aspect of enamel destruction strongly suggest that a lesion is carious and not a postmortem alteration.

Methods of statistical analysis

Proportions of individuals with at least one carious lesions were compared between men and women, between individuals buried in coastal and inland sites, and in caves or in tumuli, by means of chi-square test (with Yates correction in 2×2 tables). This test was also used, in general, when two qualitative parameters were compared. Since the probability of having carious lesions is directly related to the number of teeth observed, we previously analyzed if there were differences in the number of teeth observed between men and women, between individuals buried in coastal and inland sites, and in caves or in tumuli, or with different ages at death or of different antiquity.

We calculated the proportion of carious teeth in relation to observed teeth. This proportion showed a non-normal distribution, so nonparametric tests such as Kruskall-Wallis (KW) and Mann-Whitney U (Z) were used to compare differences in the proportions of carious teeth (in relation to observed teeth) in individuals with different ages at death or with different antiquity, in men and women, individuals buried in caves or tumuli, or in coastal or inland burials. Stepwise logistic regression analyses were also performed in order to discern which parameters (age at death, gender, burial site (coastal or inland), burial type (cave or tumuli), or antiquity) are significantly and independently associated with a high proportion of carious teeth, with which odds ratio (OR) and 95% confidence interval (95% CI), comparing the first and second quartiles of the proportion of carious teeth with the third and fourth ones, and also the 75th percentile with the 25th. This kind of analysis was performed on the whole population, and separately on those buried in caves and in tumuli. Since several cases were recorded in which the number of observed teeth was low, we also performed all these analyses including only those cases with at least eight teeth available for analysis.

All statistical tests were performed using the SPSS (Statistical Package for Social Sciences, Chicago, IL) program.

RESULTS

Prevalence of individuals with carious lesions

The prevalence of individuals with at least one carious lesion among the population analyzed reached 65.2%. A similar prevalence was observed in both sexes (65.8% among men and 65.8% among women, $\chi^2 = 0.013$, $P = 0.98$). The number of observed teeth was similar in both sexes (10.3 ± 7.3 in men, and 9.3 ± 6.5 in women)

We failed to find any differences between the prevalence of individuals with at least one carious lesion from coastal regions (62.3%) and those from inland sites (66.5%; $\chi^2 = 1.00$, $P = 0.37$). A trend toward a higher prevalence of individuals with carious lesions was observed among those buried in caves (67%) than among those buried in tumuli (58.9%); although differences were not statistically significant ($\chi^2 = 2.75$, $P = 0.061$), it is important to keep in mind that the number of observed teeth was higher among individuals buried in tumuli (12.2 ± 9.6 teeth per individual) than among those buried in caves (8.7 ± 6.2). Data regarding prevalence of individuals with at least one carious lesion according to age intervals are given in Tables 3 and 4. It seems that the prevalence of individuals with caries decreases with age, but it is important to consider that the number of observed teeth is quite a lot lower among individuals who died at 45+ years (5.9 ± 5.3) than among those who died between 35–45 years (9.2 ± 5.8), between 25–35 years (10.6 ± 6.3), and before 25 years (12.0 ± 7.9), so the probability of finding one carious teeth is lower among the oldest than among younger individuals.

Proportion of teeth with carious lesions per individual

Differences in the proportion of teeth with carious lesions (in relation to the observed teeth) between the population buried in caves and that buried in tumuli are statistically significant (Z = 3.36, $P = 0.001$). The median proportion of teeth with carious lesions is much lower among the population buried in tumuli (6.3%; interquartile range (IR) = 0–20%) than among that buried in caves (median = 15.7%; IR = 0–33.3%). Most of the caves are in the central highlands, but tumuli, although mostly located in coastal areas, are also present in inland areas. Differences in the proportion of teeth with carious lesions are also statistically significant between individuals buried in inland sites (median = 15.4%; IR = 0–33.3%) and those near the coast (median = 7.6%; IR = 0–28.1 %; Z = 2.00; $P = 0.045$).

Differences in the proportion of teeth with carious lesions were also statistically significant between the population buried in tumuli and that buried in caves when only men were considered (Z = 2.77, $P = 0.006$), but not when women were analyzed separately (Z = 1.53, $P = 0.13$, Table 5). Globally, differences in the proportion of carious teeth between men (median = 12.5%; IR = 0–27.3%) and women (median = 16.7%; IR = 0–33.3%) were not statistically significant (Z = 1.77, $P = 0.076$). There were also no differences in the proportion of carious teeth among the four groups of ages at death (KW = 2.80, $P = 0.42$), but there were indeed differences among individuals according to antiquity (KW = 10.09, $P = 0.006$; median proportion of most antique individuals = 18.5%; IR = 0–30.8%; median proportion of most recent individuals = 4.7%; IR = 0–15.4%). Logistic regression analysis revealed that burial type (cave or tumuli) was the only parameter which was significantly, independently related to the proportion of carious teeth (OR = 3.01, 95% CI = 1.63–5.54, $P = 0.005$). Sex, antiquity, and age at death were all excluded.

We analyzed separately those individuals buried in caves and those buried in tumuli. With respect to the latter, no differences were observed between men and women (Z = 0.87, $P = 0.39$, Table 5), older and younger individuals (KW = 5.68, $P = 0.13$, Table 6), and more ancient (median = 6.3%, IR = 0–24%) and more recent (median = 4.7%, IR = 0–15.4%; KW = 0.18, $P = 0.92$)

TABLE 3. Prevalence of men and women with at least one carious lesion according to age at death

	Males			Females		
Age at death	With caries	Without caries	%	With caries	Without caries	%
17–24 years	66	40	62.3	45	16	73.8
25–35 years	73	25	74.5	41	20	67.2
35–45 years	27	15	64.3	13	4	76.5
45+ years	24	20	54.6	6	11	35.3

TABLE 4. Prevalence of individuals buried in caves and in tumuli with at least one carious lesion according to age at death

	Individuals buried in tumuli			Individuals buried in caves		
Age at death	With caries	Without caries	%	With caries	Without caries	%
17–24 years	29	8	78.4	111	61	64.5
25–35 years	13	14	48.2	122	40	75.3
35–45 years	4	9	30.8	40	11	78.4
45+ years	5	8	38.5	30	32	48.4

TABLE 5. Proportion of carious teeth (median and interquartile range) in individuals buried in caves or in tumuli

	Caves		Tumuli	
	Males	Females	Males	Females
Proportion of carious teeth	13.6 (0–28.6)	16.7 (0–37.5)	5.6 (0–17.2)	13.0 (0–33.3)

individuals regarding the proportion of carious teeth. Differences were also not statistically significant among individuals buried in caves. Men and women showed a similar proportion of carious teeth ($Z = 1.36$, $P = 0.18$), and no differences existed among individuals of different ages ($KW = 4.69$, $P = 0.20$) or different antiquity ($KW = 1.15$, $P = 0.25$).

We also performed the same comparisons considering only individuals with at least eight preserved teeth. The results obtained were similar: there were striking differences between individuals buried in caves and in tumuli ($Z = 4.34$, $P < 0.001$), and coastal areas and inland burials ($Z = 3.10$, $P = 0.002$), nearly statistical differences between sexes ($Z = 1.93$, $P = 0.054$), and a lower proportion of carious teeth in the more recent population ($KW = 17.07$, $P = 0.001$). However, by stepwise logistic regression analysis comparing the first and second quartiles of the proportion of carious teeth with the third and fourth, only type of burial (cave or tumulus) was independently related (OR for presenting a proportion of carious teeth in the third or fourth quartile when an individual is buried in cave = 9.79, 95% CI = 2.70–35.46, $P < 0.001$) to the proportion of caries. Sex, age at death, and antiquity were all removed from the final formula. When the analysis was repeated excluding type of burial, antiquity was the only parameter which showed an independent relation with the proportion of carious teeth, with an OR associated to more antique individuals = 9.01 (95% CI = 2.48–32.79, $P < 0.001$). Similar results were obtained when the 75th percentile was compared with the 25th. No parameter showed an independent relation when individuals buried in caves and tumuli were analyzed separately.

Proportion of teeth with carious lesions per tooth type

In Table 7 we show the proportion of teeth affected by carious lesions for each tooth type. Following Larsen et al. (1991), we lumped all mandibular and maxillary incisors, canines, premolars, and molars into these four respective categories. As shown, molar teeth show carious lesions in the highest proportion (33.4%), both in men (33.6%) and women (33.2%). The prevalence of premolars with carious lesions was 7.3% among women and 5.8% among men. Both men and women showed a very low proportion of anterior teeth affected by carious lesions (Table 8).

Location and severity of carious lesions

Individuals buried in caves showed more carious lesions located in mesial areas (142 cases out of 394) than individuals buried in tumuli (9 cases out of 68, $\chi^2 = 14.18$, $P < 0.001$). No differences existed when other locations of carious lesions were compared among individuals buried in caves and those buried in tumuli. We also failed to find differences between men and women with respect to location of carious lesions. No differences were observed between intensity of the carious lesion in men and in women, in those buried in tumuli or in caves, or in those from inland or from the coast.

DISCUSSION

Assessment of dental caries may provide useful information with respect to dietary habits of ancient population groups. Consumption of vegetables is generally associated with a high prevalence of caries, whereas consumption of seafood may be cariostatic. Following Turner (1979), hunter/gatherers show a proportion of carious lesions ranging from 0.0–5.3%, consumers of a mixed agricultural economy, between 0.4–10.3%, and individuals whose economy is based on agriculture, between 2.3–29%. In contrast with these latter figures, studies performed on Eskimo populations showed proportions as low as 0.09 carious lesions per teeth and 0.01 per individual, although data are not homogeneous for all Eskimo populations (Costa, 1980). The mean values observed for the pre-Hispanic population from Gran Canaria are much closer to those reported for populations with an agriculture-based economy. Most populations with an agriculture-based economy show a prevalence of carious lesions in greater than 60% of individuals, although in Bronze Age Harappa, the frequency of carious teeth is only 6.8%, and the prevalence of individuals with caries is 43.6% (Lukacs, 1992), and in the agricultural Chinese Yin-Shang period, the frequency of carious teeth was low (2.9–4%;

TABLE 6. Proportion of carious teeth in individuals buried in caves and tumuli according to age at death (median, interquartile range, and number of cases)

Age	Tumuli	Caves
17–24 years	7.1% (3.3–16.0%) (n = 37)	13.4% (0–33.3%) (n = 172)
25–35 years	0.0% (0–18.2%) (n = 27)	16.7% (2.9–30%) (n = 162)
35–45 years	0.0% (0–9.1%) (n = 13)	16.7% (6.9–33.3%) (n = 51)
45+ years	0.0% (0–40%) (n = 13)	0.0% (0–33.3%) (n = 63)

TABLE 7. Carious teeth and observed teeth in men and women for each tooth type

	Males		Females	
Tooth	Observed	Carious teeth	Observed	Carious teeth
Maxilla				
I1	78	0	34	0
I2	121	1	54	0
C	175	7	75	4
P3	285	11	130	13
P4	284	19	129	9
M1	354	55	213	39
M2	315	86	181	61
M3	228	56	108	39
Mandible				
I1	100	0	41	0
I2	145	3	52	2
C	192	3	74	0
P3	265	8	120	6
P4	249	25	103	7
M1	383	77	180	51
M2	357	106	166	54
M3	312	110	126	69

TABLE 8. Number of observed teeth, carious teeth, and proportion of carious teeth (in relation to observed teeth, as %) for each tooth type in individuals buried in tumuli and in caves, in men and in women

	Tumuli	Caves	Males	Females
Incisors				
Carious teeth	1	5	4	2
Observed teeth	272	460	444	191
Proportion	0.4%	1.1%	0.9%	1.1%
Canines				
Carious teeth	2	17	10	4
Observed teeth	172	438	367	145
Proportion	1.2%	3.9%	2.7%	2.8%
Premolars				
Carious teeth	17	113	63	35
Observed teeth	385	1,429	1,083	482
Proportion	4.4%	7.9%	5.8%	7.3%
Molars				
Carious teeth	129	849	490	323
Observed teeth	613	2,814	1,459	972
Proportion	21.0%	30.2%	33.6%	33.2%

Shakashita et al., 1997). Kelley et al. (1991) observed proportions ranging from 0.6–48.1% in five early North Chilean groups, with a prevalence of carious lesions ranging from 4.9–87% of individuals analyzed. The low proportions of carious teeth described by Kelley et al. (1991) for the populations of Morro-1 (0.6%) and El Laucho (2.5%) probably reflect the dependence of these populations on marine resources, whereas the proportion of carious teeth among the highland agriculturalists from Quitor-5 (48.1%) is among the highest observed for prehistoric population groups. In Table 9 we provide some data obtained from the complete compilation by Larsen et al. (1991) on North American hunter/gatherers and agriculturalists, together with a few others derived from populations whose diet was based on fish consumption or on a mixed economy, and with the data derived from the Gran Canarian individuals buried in caves and in tumuli. Some of the geographical areas recorded in Table 9 share some climatic conditions with Gran Canaria, such as Bahrein and Oman or North Chile. It is noteworthy that some populations which inhabited desertic areas, such as Oman, and probably consumed sticky, carbohydrate-rich fruits, such as dates, show a proportion of carious teeth similar to that observed in the pre-Hispanic population from Gran Canaria, who, according to chroniclers, would also have consumed dates and figs (Morales Padrón, 1994).

All these data do not take into account the proportion of antemortem lost teeth, so they probably underestimate the true prevalence of carious lesions. As seen, the data obtained in this study for Gran Canaria, particularly for the population buried in caves, fit well with other agriculturalist populations, whereas the proportion of carious teeth observed among the population buried in tumuli suggests that their diet was somewhat different: the proportion of carious teeth was below 7%, a figure which, in North America (Larsen et al., 1991), separates the population which consumed maize as a component of diet from hunter/gatherers, who showed a lower proportion of carious teeth. Thus it seems that, globally considered, the data derived from this study suggest that the the diet of the pre-Hispanic population from Gran Canaria who buried their dead in caves was mainly based on consumption of sticky vegetables. Several other data also support the hypothesis that pre-Hispanic inhabitants of Gran Canaria consumed a mainly vegetal-based diet, derived from a strong dependence on agriculture. Besides chroniclers' writings about the importance of agriculture in Gran Canaria at the time of Spanish conquest, in previous reports we observed very high bone strontium values among these people, higher than in any other pre-Hispanic population of the Canary Archipelago (González-Reimers and Arnay de la Rosa, 1988). Thus anthropological, archaeological, and etnohistorical data stress the importance of agriculture in the pre-Hispanic society of Gran Canaria, something which is also strongly suggested by the results of this study.

Dental caries is an age-progressive process. Unfortunately, we do not know age at death of the sample analyzed, only an estimate based on intensity of attrition. As mentioned above, this estimation is only approximate. However, other studies carried out on the same population, using pubic symphysis as the analytical method, yielded ages at death similar to those obtained using the method of Brothwell (1972). Interestingly, the prevalence of carious lesions seems to be lower among the oldest individuals. This finding apparently contradicts the generally accepted statement that dental caries is an age-progressive process, although it may be also interpreted in a different way, i.e., those who suffer dental caries die at younger ages, perhaps because a certain unkown underlying mechanism predisposes both to development of the carious lesion and to premature death. However, it is of

TABLE 9. Proportion of carious teeth in different populations

Population	Proportion of carious teeth
Fourche Malin (Oklahoma), hunter/gatherers (Powell, 1985)	0.07%
Northern Chile (3500–2000), fishers (Kelley et al., 1991)	0.6%
Northern Chile (Quitor-5), agriculturalists (Kelley et al., 1991)	48.1%
Tierra del Fuego, fishers (Pérez-Pérez, 1996)	0.7%
Castellón Alto (Granada), mixed economy (Jiménez Brobeil et al., 1991)	4.1%
Pampa Grande, early agricultural (Kozameh and Barbosa, 1996)	34.3%
Oman, Iron Age, consumption of dates, figs (Nelson et al., 1999)	18.4%
Bahrein, agriculture; fishers? (Littleton and Frohlich, 1989)	14.0%
Maitas (800–1200 AD), agriculture (Kelley et al., 1991)	14.4%
Gran Canaria (caves)	15.7%
Gran Canaria (tumuli)	6.2%
Ancient Hawaiians (Keene, 1986)	9.8%

TABLE 10. Antemortem loss of teeth and estimated prevalence of carious lesions, taking into account correction factor of Lukacs (1992)

Age	Observed teeth (a)	Carious teeth (b)	Antemortem loss teeth (c)	Total (a + c)	Luckacs factor (d)	Total number of caries (b + c × d)	Total prevalence of carious teeth (b + c × d/a)
17–25	2,565	411	144	2,709	20.3%	411 + 29	16.2%
25–35	2,052	335	342	2,394	22.0%	335 + 75	17.1%
35–45	609	79	171	780	14.7%	79 + 25	13.3%
45+	463	85	1,195	1,658	22.4%	85 + 268	15.3%

paramount importance to consider that the number of observed teeth was also lower in the oldest individuals, a fact which introduces a bias into the results. Indeed, older individuals could have lost more teeth due to carious lesions than younger ones, so we must also take into account the correction factor of Luckacs (1992) and the number of antemortem lost teeth. There are some data regarding antemortem teeth loss for pre-Hispanic inhabitants from El Hierro (Velasco-Vázquez et al., 2003) and Gran Canaria (Delgado Darias, 2001). Adding the already published data for Gran Canaria with those included in this study, the proportion of antemortem lost teeth reaches 3.1% (144 out of 4,690 observed alveoli) among those who died at 17–25 years; 8.1% (342 out of 4,224 observed alveoli) among those who died aged 25–35; 12.5% (171 out of 1,367 observed alveoli) among those who died between 35–45; and 49.8% among those who died at over 45 years. The correction factor of Luckacs (1992) for each of the age groups is 20.3%, 22.0%, 14.7%, and 22.4%, respectively (Table 10). Thus, considering the number of carious teeth, observed teeth, antemortem lost teeth, observed alveoli, and correction factor for each age group, we can be assured that the proportion of carious teeth, considering both observed teeth and antemortem lost teeth, is approximately the same in the four age groups, although the trend toward lower values among the oldest individuals still exists. However, these differences are no longer statistically significant. Nonetheless, the high incidence of carious lesions among a significant proportion of young people is noteworthy, supporting the possibility that, in addition to a mainly vegetarian diet, perhaps these people were also undernourished and more prone to conditions leading to premature death. In this sense, irregular rainfall and other catastrophic events could have provoked disequilibrium between agricultural production and population needs, probably leading to severe, episodic malnutrition. The high prevalence of osteoporosis observed among the pre-Hispanic population from Gran Canaria supports this hypothesis, as well as the relative high proportion of individuals dead at young ages (Velasco-Vázquez et al., 1999).

In our study, marked differences were found between the population buried in caves and that buried in tumuli. Indeed, logistic regression analysis shows that type of burial is the most important factor determining the proportion of teeth with carious lesions. This clearly contains information relative to antiquity, since the significance of the parameter "time depth" is no longer present when the parameter "type of burial" is introduced. Although the proportion of individuals with at least one carious lesion is similar among both population groups, the proportion of carious teeth is by far lower among individuals buried in tumuli.It is not known why some individuals were buried in tumuli and others in caves. Several hypotheses suggest that people buried in tumuli belonged to the leading class of the otherwise strongly hierachized pre-Hispanic society of Gran Canaria. Some anthropological differences may separate both groups of individuals. Prevalence of auricular exostoses is by far higher among the population buried in tumuli (in most cases located near the coast), and the Ba/Sr index suggests an important consumption of marine products (Velasco-Vázquez et al., 2000), in contrast with the mainly vegetarian diet of the inhabitants of the central highlands (González-Reimers and Arnay-de-la-Rosa, 1992). The lower proportion of carious teeth among people buried in tumuli lends further support to the hypothesis that their dietary intake differed from that of individuals buried in caves, suggesting less consumption of sticky vegetables, especially by men. Chroniclers wrote that the social leaders used to fish and performed diving activities (Morales Padrón, 1994.). In Table 9, we compare the results obtained for the population of Gran Canaria which was buried in tumuli with those observed in other populations whose diet was based on seafood consumption, with a very low prevalence of caries. The proportion of carious teeth is higher in the population from Gran Canaria buried in tumuli, suggesting that, in addition to seafood, other dietary products, probably derived from agriculture, were consumed by these people.

Although men in general showed a trend toward less prevalance of caries than women, differences between the sexes are more striking among the population buried in tumuli. The results regarding gender differences agree with those obtained by others (Larsen et al., 1991). Given the absence of physiologic differences between men and women regarding cariogenesis, our results suggest that some differences existed between men and women with respect to dietary intake, and that these dietary differences were more marked in the population buried in tumuli. However, neither the trace-element pattern nor ethnohistorical or archaeological data support the existence of these differences, besides some chroniclers' writings which suggest that women were more involved in agricultural activities (Morales-Padrón, 1994). In any case, there are some data which suggest that salivary cariogenic microorganisms may increase in pregnancy, together with a decrease in salivary pH and buffer effect (Laine, 2002).

CONCLUSIONS

The results obtained in this study fully agree with previous findings. It does seem that both the inhabitants buried in tumuli and those buried in caves consumed plant products as their main food; the high frequency of carious teeth supports this statement. It is also clear that the lower frequency and severity of caries observed in the people buried in tumuli suggest that this group was less "agriculture-dependent" than those buried in caves, something in accordance with other data, such as the high prevalence of auricular exostoses and the low Ba/Sr ratio, which suggest consumption of marine resources.

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