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# Dental Trauma and Antemortem Tooth Loss in Prehistoric Canary Islanders: Prevalence and Contributing Factors

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ABSTRACT Differential diagnosis of the aetiology of antemortem tooth loss (AMTL) may yield important insights regarding patterns of behaviour in prehistoric peoples. Variation in the consistency of food due to its toughness and to food preparation methods is a primary factor in AMTL, with dental wear or caries a significant precipitating factor. Nutritional deficiency diseases, dental ablation for aesthetic or ritual reasons, and traumatic injury may also contribute to the frequency of AMTL. Systematic observations of dental pathology were conducted on crania and mandibles at the Museo Arqueologico de Tenerife. Observations of AMTL revealed elevated frequencies and remarkable aspects of tooth crown evulsion. This report documents a 9.0% overall rate of AMTL among the ancient inhabitants of the island of Tenerife in the Canary Archipelago. Sex-specific tooth count rates of AMTL are 9.8% for males and 8.1% for females, and maxillary AMTL rates (10.2%) are higher than mandibular tooth loss rates (7.8%) Dental trauma makes a small but noticeable contribution to tooth loss among the Guanches, especially among males. In several cases of tooth crown evulsion, the dental root was retained in the alveolus, without periapical infection, and alveolar bone was in the initial stages of sequestering the dental root. In Tenerife, antemortem loss of maxillary anterior teeth is consistent with two potential causal factors: (a) accidental falls while traversing volcanic terrain; and (b) interpersonal combat, including traditional wrestling, stick-fighting and ritual combat. Steep-walled valleys (*barrancos*) and lava fields (*malpaís*) required agile locomotion and occasional vaulting with the aid of a wooden staff. Accidental falls involving facial injury may have contributed to AMTL. Traditional conflict resolution involved competitive wrestling (*lucha canaria*), stick-fighting (*juego del palo*), and ritualised contests involving manual combat. These activities made a small but recognisable impact on anterior dental trauma and tooth loss. Inter-personal behaviours of such intensity leave their mark on skeletal and dental remains, thereby providing insight into the lives and cultural traditions of the ancient Guanches. 

*Key words:* dental palaeopathology; dental trauma; antemortem tooth loss; tooth fracture; manual combat; accidents; Tenerife; Canary Islands

## Introduction

Loss of teeth from the jaws is a complex and multi-causal process (Brothwell, 1963:277; Lukacs, 1989:271; Scott *et al.*, 1991:194). Despite the valuable insights that can be derived from the careful study of antemortem tooth loss patterns, dental palaeopathologists seem to have neglected this potentially rewarding area of investigation. Four primary causal factors contribute to premature loss of teeth: (1) variations in dietary consistency (Leigh, 1925; Alexandersen, 1967a; Frayer, 1987, 1989; Beckett & Lovell, 1994; Nelson *et al.*, 1999; Bonfiglioli *et al.*, 2003);

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(2) nutritional deficiency diseases (Stuart-Macadam, 1989); (3) cultural or ritual ablation (Merbs, 1989; Pietrusewsky & Douglas, 1993; Tayles, 1996); and (4) trauma (Leigh, 1929; Merbs, 1989: 171; Lukacs & Hemphill, 1990). Variations in diet may be especially complex since AMTL can result from recognisably distinctive aetiological pathways (see Lukacs, 1989, Fig. 1). Firstly abrasive foods may cause severe attrition, resulting in pulp exposure, dental abscess, and ultimate tooth loss (Lukacs & Pal, 1993). Secondly, soft foods and refined diets, high in carbohydrates, may encourage development of large caries lesions, producing pulp exposure, abscess formation, and finally tooth loss (Lukacs, 1992). Thirdly, large calculus accumulations may serve as gingival irritants, resulting in periodontal disease and alveolar recession, the ultimate outcome being tooth loss (Koritzer, 1968; Clarke & Hirsch, 1991a, b; Diaz & Tayles, 1997). This report, however, will focus on the role of dental trauma as a non-dietary factor contributing to patterns of AMTL among the Canary Islanders.

My interest in dental trauma was initially stimulated by two remarkable cases from prehistoric Pakistan (Lukacs & Hemphill, 1990). The first is an adult male from aceramic levels at Neolithic Mehrgarh, Baluchistan. The left central incisor crown suffered a complicated fracture in life (Andraesen, 1982), as indicated by wear on the incisal edge of the broken crown and development of a medium-sized periapical dental lesion. The force causing this trauma is indicated by the orientation of the fracture plane and suggests forceful pulling of an unknown material outward from the oral cavity. The second case comes from the Bronze Age urban centre of Harappa, in Punjab Province, where a robust adult male exhibits a traumatic root fracture of the right lateral incisor and antemortem loss of URI1. Consequently, as I began my investigation of the dental anthropology of prehistoric human remains from the Canary Islands, in Santa Cruz de Tenerife, I had some acquaintance with and interest in evidence of dental trauma.

## Materials and methods

This study was conducted from April to October 1991, at the Museo Arqueologico de Tenerife, with the collaboration of Conrado Rodríguez-Martín. The antiquity of specimens included in this study ranges from the 6th to the 14th century AD. While 90% of the specimens are from the island of Tenerife (Figure 1), the remainder are from other islands in the Canary archipelago. The original inhabitants of Tenerife, known as Guanches, had close physical and linguistic

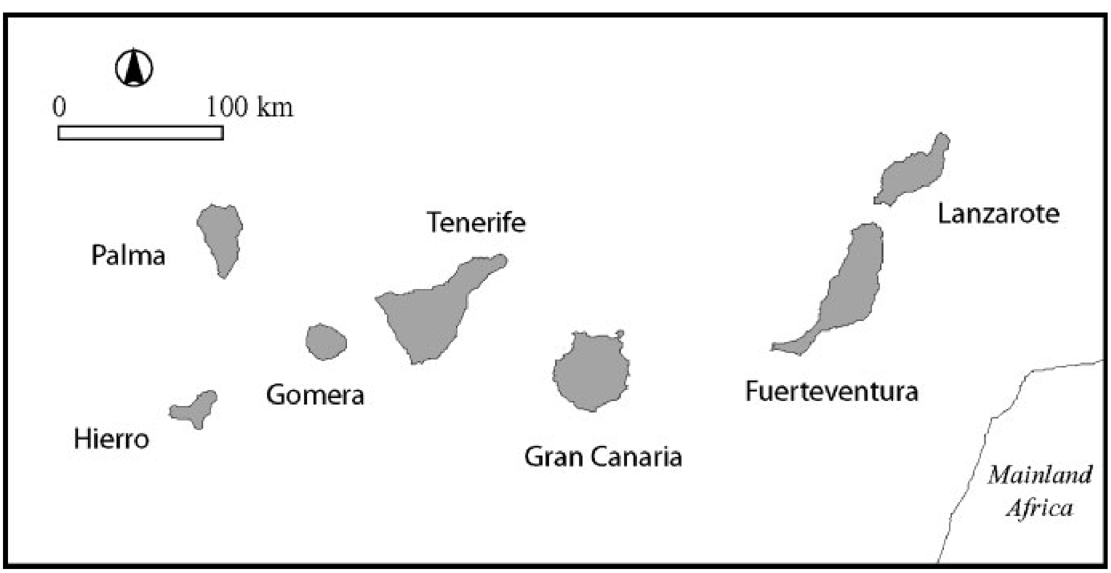


Figure 1. Location map of the Canary Island archipelago.

similarities with the Berbers of northwest Africa. This relationship was initially documented by well-known 19th century anthropologists and natural historians (Blumenbach, 1808; von Humboldt & Bonpland, 1819; Vernaux, 1891). The origins and biological diversity of Guanches were subsequently approached from a typological racial paradigm based on craniometry (Hooton, 1916, 1925; Schwidetsky, 1957). Multiple independent studies of dental morphology confirm the close affinities between Guanches and Berbers observed by earlier investigators (Bermudez de Castro, 1985; Irish, 1993; Guatelli-Steinberg *et al.*, 2001).

Recent analysis of mtDNA and Y chromosome polymorphisms reveal three sources for the modern Canary Islander gene pool: a major Iberian contribution (62–78%); a substantial northwest African component (23–38%); and a minor sub-Saharan African component (3%; Maca-Meyer *et al.*, 2004a). The documentation of mtDNA diversity among prehistoric Guanches implies significant founder effects and multiple migration events (Maca Meyer *et al.*, 2004b). Y chromosome variation suggests that the aboriginal genetic contribution to the modern Canarian gene pool exhibits a strong sexual bias (Flores *et al.*, 2001, 2003). A colonisation scenario with three primary components can be derived: (a) northwest Africans settled the islands from east to west following a stepping-stone model; (b) this aboriginal population was subsequently augmented by slave trade immigration from sub-Saharan and northwest Africa; and (c) in the 15th century the islands experienced extensive European immigration associated with the Norman conquest and Iberian colonisation (Rando *et al.*, 1999; Flores *et al.*, 2001). These genetic estimates suggest that initial colonisation of the islands occurred around 600 BC, significantly earlier than the 1st century BC, as previously believed (Mercer, 1980).

The provenance of most specimens in the study collection is known. Many were recovered from ossuaries in caves located in isolated *barrancos* that are difficult to enter. Stratigraphic and chronological status of individual specimens is not always precise, and crania and mandibles included in this study are isolated specimens not associated with one another or with complete skeletons. Standardised morphological indicators of sex were used in diagnosing specimens as male or female (Stewart, 1979; Brothwell, 1981; Bass, 1987; Steele & Bramblett, 1988; Ubelaker, 1989).

The following procedure was used in assessing sex of Guanche skeletal specimens. Criteria to be used in sex determination were selected; cranial indicators included variation in prominence of the supra-orbital torus and nuchal lines, sharpness of the superior lateral margin of the orbit, frontal and parietal bossing, size of the mastoid process and supra-mastoid eminence, and the sagittal contour of the frontal bone from glabella to bregma. Features of mandibular morphology used were prominence and shape of the mental and lateral eminences, angulation of the ascending ramus at gonion, rugosity and eversion of the gonial margin, and symphyseal height. Using these criteria, Lukacs and Conrado Rodríguez-Martín conducted independent assessments of sex on a sample of 36 skulls with associated crania and mandibles. A high degree of concordance (88.9%) was achieved, with agreement on sex determination in 32 of 36 specimens. Since sex determination of isolated mandibles is more difficult than estimates based on complete skulls, an osteometric analysis of 15 male and 15 female mandibles from the previous experiment was completed. In an attempt to identify sex dimorphic size variations of the mandible, nine variables were recorded following procedures described in Bass (1987). These variables included the gonial angle, bicondylar and bigonial breadth, height and breadth of the corpus at M2, height of the ascending ramus, minimum and maximum width of the ascending ramus, and height of the ascending ramus. A simple *t*-test of sample means was used to test for significant sex differences in size ($\alpha = 0.05$), using the PROC TTEST function in SAS PC ver. 8. Four variables were found to exhibit significant sex dimorphism: bicondylar breadth ($P = 0.000$), bigonial breadth ($P = 0.001$), and ascending ramus width: maximum ($P = 0.049$) and minimum ($P = 0.006$). Sex difference in symphyseal height was not significant ($P = 0.074$), although a larger sample may have resulted in a significant sex difference for this variable. This exercise proved useful and enhanced the ability to estimate accurately the sex of isolated mandibles. Dental status was recorded as part of a systematic anthropological analysis of the dentition of each specimen. Each tooth was graded as either present or absent, and if absent, loss was recorded as either antemortem or postmortem. Notes were made regarding the degree to which alveoli were damaged postmortem, resorbed following antemortem tooth loss, or damaged in life by trauma. Statistical analysis used the PROC FREQ procedure in SAS PC ver. 8. Chi-square tests were used to identify significant differences in AMTL frequency by side, sex and jaw. Fisher's exact test was used when any cell had a sample size of five or fewer (Zar, 1999).

## Results

The overall rate of AMTL for the study sample is 9.0%. Figure 2a shows variation in tooth loss by side, for males and females separately (Table 1). The dark vertical dashed lines represent the mean sex-specific tooth loss rates (9.8% males; 8.1% females). Noteworthy patterns include: (1) side to side differences in AMTL are largely non-significant, the one exception being the lower third molar among females; (2) most molar and some premolar teeth exceed mean values; (3) loss of anterior teeth is generally less than the mean; and (4) among males, there is a slight tendency in lower anterior teeth for the left side to exceed the right side. Tooth-specific AMTL rates are presented separately for each sex in Figure 2b (Table 2). Only five of 16 comparisons show a significant difference, and four of these occur in the maxilla where male rates exceed female rates. In the mandible, sex differences in AMTL are mostly non-significant and, except for the first molar, male and female values display more similarity than in the maxilla.

Sex differences in AMTL were also analysed by determining the percentage of individuals that lost one or more teeth from a specific tooth class (Table 3). Individual tooth classes and composite tooth classes are listed along the horizontal axis for the maxilla and mandible separately in Figure 3a. The category **ANY** includes individuals with antemortem loss of one or more teeth from any tooth class. Several points are remarkable: (1) no significant differences occur between the sexes for individual tooth classes, or for any of the mandibular teeth; (2) significant differences are evident in two composite categories in the maxilla–Incisor and Canine combined (abbreviated as I & C in Table 3), and Incisor, Canine and Premolar combined (I, C & P in Table 3), where male rates exceed female rates. The final comparison evaluates differences in AMTL rates between maxillary and mandibular isomeres (Figure 3b). In this graph the upper dotted line represents the mean AMTL rate for maxillae (male and female, 10.2%), and the mean AMTL rate for mandibular teeth (sexes combined, 7.8%) is portrayed by the lower dotted line. Five of the 16 comparisons (31%) are significant, and in four of these maxillary teeth show higher loss rates than lower teeth. In males, higher maxillary rates are evident for P3, P4 and M1, while in females only P3 follows this pattern. By contrast, the female I1 shows significantly greater loss of the lower vs. the upper central incisor.

A small but important component in producing this pattern of AMTL is the contribution made by loss due to traumatic fractures. Eleven specimens, five maxillae and six mandibles, display evidence of traumatically fractured teeth (Figure 4). These compound fractures are characterised by a list of several shared features. The fractures consistently occur at the alveolar margin; reparative dentinogenesis maintains root integrity, and thereby prevents sequelae such as focal destruction of periapical or alveolar bone due to infection. In most instances, some degree of proliferative alveolar bone growth is evident (Figure 5). This forms over the broken root and represents an early stage in the sequestration and ultimate resorption of the tooth root. Incisor and premolar teeth are primarily affected, canines rarely and no molar fractures were observed. Three maxillary and three mandibular specimens (a total of nine teeth) exhibit evidence of proliferative bone growth over the broken root surface (3 incisor and 2 premolars in the maxilla, and 3 incisors and 1 premolar in the mandible). Others display evidence of dental trauma such as broken alveolar walls or septa in association with remodelling, and only two specimens yield indications of associated periapical infection.

The fact that these fractures are found toward the anterior region of the mouth, that six of nine

 

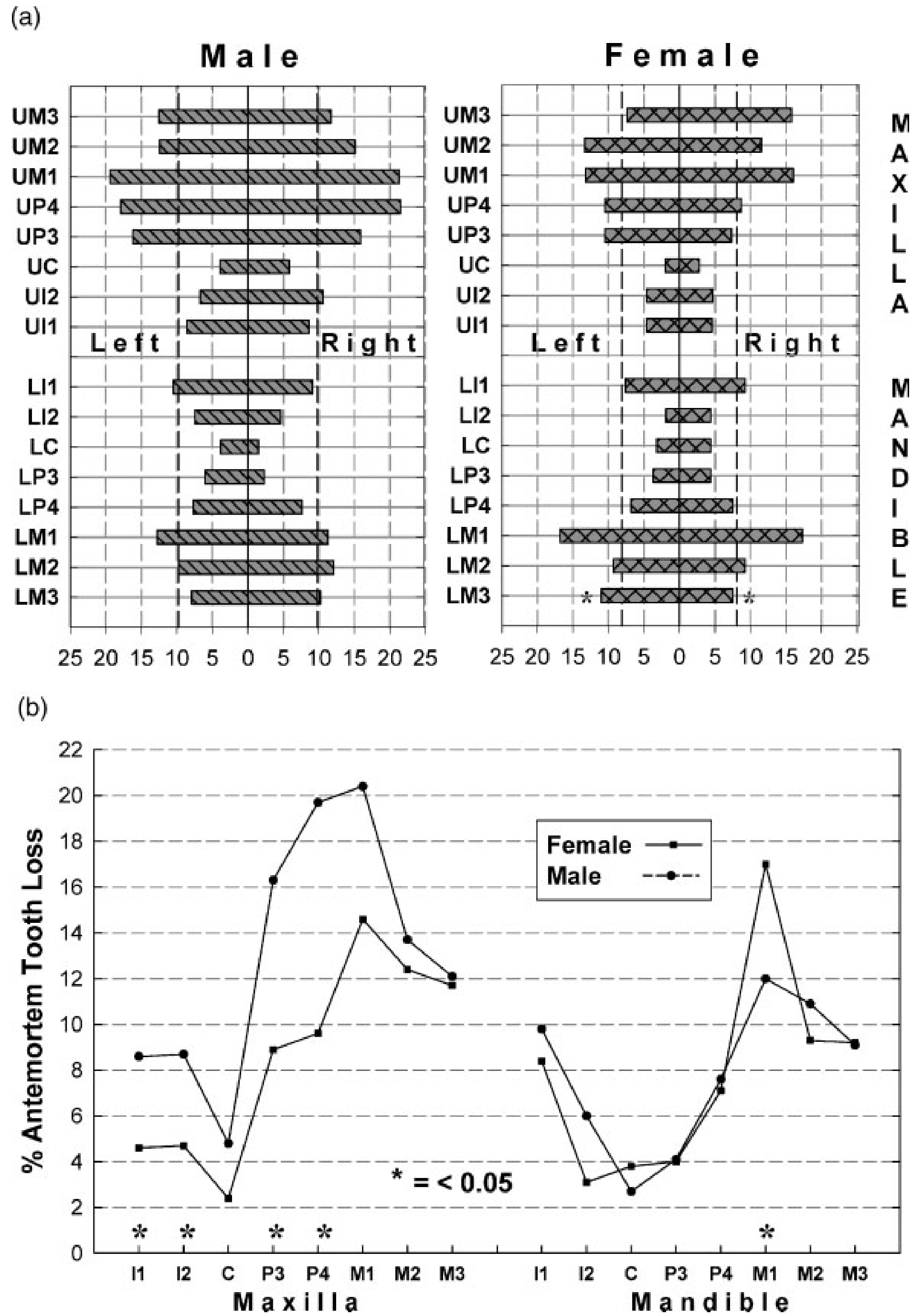


Figure 2. (a) Percentage antemortem tooth loss by side; (b) frequency of antemortem tooth loss by sex.

teeth with proliferative bone development are left incisor teeth, and that other forms of alveolar bone damage and repair are evident, leads to the conclusion that traumatic injury of incisors, canines and premolar teeth contributed to the observed rates of antemortem tooth loss documented for the Guanches. Two explanatory hypotheses can be offered for the patterns of antemortem tooth loss

Table 1. Antemortem tooth loss among Guanches by side

| Tooth | Female | | | | | | | Male | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Left | | | $P^*$ | Right | | | Left | | | $P^*$ | Right | | |
| | AMTL | *n* | % | | AMTL | *n* | % | AMTL | *n* | % | | AMTL | n | % |
| UI1 | 7 | 153 | 4.6 | 0.980 | 7 | 151 | 4.6 | 9 | 105 | 8.6 | 1.000 | 9 | 105 | 8.6 |
| UI2 | 7 | 151 | 4.6 | 0.990 | 7 | 150 | 4.7 | 7 | 104 | 6.7 | 0.324 | 11 | 104 | 10.6 |
| UC | 3 | 147 | 2.0 | *0.722* | 4 | 145 | 2.8 | 4 | 104 | 3.9 | *0.748* | 6 | 104 | 5.8 |
| UP3 | 16 | 152 | 10.5 | 0.331 | 11 | 150 | 7.3 | 17 | 105 | 16.2 | 0.952 | 17 | 107 | 15.9 |
| UP4 | 16 | 152 | 10.5 | 0.583 | 13 | 150 | 8.7 | 19 | 106 | 17.9 | 0.513 | 23 | 107 | 21.5 |
| UM1 | 20 | 152 | 13.2 | 0.484 | 24 | 150 | 16.0 | 21 | 108 | 19.4 | 0.735 | 23 | 108 | 21.3 |
| UM2 | 20 | 150 | 13.3 | 0.629 | 17 | 148 | 11.5 | 13 | 105 | 12.4 | 0.567 | 16 | 106 | 15.1 |
| UM3 | 8 | 108 | 7.4 | 0.052 | 18 | 114 | 15.8 | 11 | 88 | 12.5 | 0.884 | 11 | 94 | 11.7 |
| Maxilla | 97 | 1165 | 8.3 | 0.733 | 101 | 1158 | 8.7 | 101 | 825 | 12.2 | 0.319 | 116 | 835 | 13.9 |
| LI1 | 12 | 159 | 7.6 | 0.569 | 15 | 161 | 9.3 | 14 | 134 | 10.5 | 0.709 | 12 | 132 | 9.1 |
| LI2 | 3 | 159 | 1.9 | *0.336* | 7 | 160 | 4.4 | 10 | 133 | 7.5 | 0.310 | 6 | 132 | 4.6 |
| LC | 5 | 158 | 3.2 | *0.770* | 7 | 160 | 4.4 | 5 | 132 | 3.8 | *0.447* | 2 | 131 | 1.5 |
| LP3 | 6 | 161 | 3.7 | 0.777 | 7 | 161 | 4.4 | 8 | 134 | 6.0 | *0.217* | 3 | 133 | 2.3 |
| LP4 | 11 | 161 | 6.8 | 0.829 | 12 | 161 | 7.5 | 10 | 130 | 7.7 | 0.972 | 10 | 132 | 7.6 |
| LM1 | 27 | 161 | 16.8 | 0.902 | 28 | 162 | 17.3 | 17 | 133 | 12.8 | 0.706 | 15 | 133 | 11.3 |
| LM2 | 15 | 162 | 9.3 | 0.986 | 15 | 161 | 9.3 | 13 | 133 | 9.8 | 0.541 | 16 | 132 | 12.1 |
| LM3 | 15 | 137 | 11.0 | 0.321 | 10 | 134 | 7.5 | 9 | 114 | 7.9 | 0.546 | 12 | 118 | 10.2 |
| Mandible | 94 | 1258 | 7.5 | 0.610 | 101 | 1260 | 8.0 | 86 | 1043 | 8.2 | 0.413 | 76 | 1043 | 7.3 |
| Total | 191 | 2423 | 7.9 | 0.548 | 202 | 2418 | 8.4 | 187 | 1868 | 10.0 | 0.829 | 192 | 1828 | 10.2 |

$^*P$ = probability associated with $\chi^2$ values; probabilities in italics associated with Fisher's exact test.

Table 2. Antemortem tooth loss among Guanches, by sex

| Tooth | Female | | | $P$ | Male | | |
|---|---|---|---|---|---|---|---|
| | AMTL | *n* | % | | AMTL | *n* | % |
| UI1 | 14 | 304 | 4.6 | 0.067 | 18 | 210 | 8.6 |
| UI2 | 14 | 301 | 4.7 | 0.067 | 18 | 208 | 8.7 |
| UC | 7 | 292 | 2.4 | 0.143 | 10 | 208 | 4.8 |
| UP3 | 27 | 302 | 8.9 | 0.000* | 34 | 212 | 16.3 |
| UP4 | 29 | 302 | 9.6 | 0.001* | 42 | 213 | 19.7 |
| UM1 | 44 | 302 | 14.6 | 0.083 | 44 | 216 | 20.4 |
| UM2 | 37 | 298 | 12.4 | 0.660 | 29 | 211 | 13.7 |
| UM3 | 26 | 222 | 11.7 | 0.907 | 22 | 182 | 12.1 |
| Maxilla | 198 | 2323 | 8.1 | 0.000* | 217 | 1660 | 13.1 |
| LI1 | 27 | 320 | 8.4 | 0.574 | 26 | 266 | 9.8 |
| LI2 | 10 | 319 | 3.1 | 0.090 | 16 | 265 | 6.0 |
| LC | 12 | 318 | 3.8 | 0.453 | 7 | 263 | 2.7 |
| LP3 | 13 | 322 | 4.0 | 0.960 | 11 | 267 | 4.1 |
| LP4 | 23 | 322 | 7.1 | 0.821 | 20 | 262 | 7.6 |
| LM1 | 55 | 323 | 17.0 | 0.024* | 32 | 266 | 12.0 |
| LM2 | 30 | 323 | 9.3 | 0.506 | 29 | 265 | 10.9 |
| LM3 | 25 | 271 | 9.2 | 0.946 | 21 | 232 | 9.1 |
| Mandible | 195 | 2518 | 7.7 | 0.978 | 162 | 2086 | 7.8 |
| Total | 393 | 4841 | 8.1 | 0.000* | 379 | 3746 | 9.8 |

* = Significant difference at $P < 0.05$.

and traumatic injury of anterior teeth among prehistoric Canary Islanders: (1) accidental falls while traversing steep and uneven volcanic terrain; and (2) injury during traditional forms of interpersonal combat. The latter included both competitive wrestling and stick-fighting, as well as conflict resolution through ritualised hand-to-hand combat. The ways in which these factors

Table 3. Percentage of Guanche specimens with AMTL, by tooth class

| Sex (*n*) | Incisor | | Canine | | Premolar | | Molar | | I & C | | I, C & P | | P & M | | ANY | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| Maxilla | | | | | | | | | | | | | | | | |
| Female (153) | 18 | 11.8 | 6 | 3.9 | 29 | 19.0 | 45 | 29.4 | 20 | 13.1 | 36 | 23.5 | 54 | 35.3 | 55 | 36.0 |
| *P* | 0.194 | | 0.137 | | 0.141 | | 0.532 | | 0.056 | | 0.045 | | 0.592 | | 0.078 | |
| Male (109) | 19 | 17.4 | 9 | 8.3 | 29 | 26.6 | 36 | 33.0 | 24 | 22.0 | 38 | 34.9 | 42 | 38.5 | 51 | 46.8 |
| Total (262) | 37 | 14.1 | 15 | 5.7 | 58 | 22.1 | 81 | 30.9 | 44 | 16.8 | 74 | 28.2 | 96 | 36.6 | 106 | 40.5 |
| Mandible | | | | | | | | | | | | | | | | |
| Female (163) | 19 | 11.7 | 10 | 6.1 | 20 | 12.3 | 52 | 31.9 | 26 | 16.0 | 38 | 23.3 | 58 | 35.6 | 71 | 43.6 |
| *P* | 0.247 | | 0.725 | | 0.784 | | 0.489 | | 0.674 | | 0.943 | | 0.498 | | 0.312 | |
| Male (135) | 22 | 16.3 | 7 | 5.2 | 18 | 13.3 | 38 | 28.2 | 24 | 17.8 | 31 | 23.0 | 43 | 31.9 | 51 | 37.8 |
| Total (298) | 41 | 13.8 | 17 | 5.7 | 38 | 12.8 | 90 | 30.2 | 50 | 16.8 | 69 | 23.1 | 101 | 33.9 | 122 | 40.9 |

Key: I = Incisor; C = Canine; *P* = premolar; M = molar; I & C = incisor and canine combined; I, C & *P* = incisor, canine and premolar combined; P & M = premolar and molar combined; ANY = antemortem loss observed in any tooth class; *P* = probability associated with $\chi^2$ test.

would potentially contribute to dental fracture and AMTL are considered in greater detail below.

## *Locomotion over hazardous terrain*

The Canary Islands are volcanic and geologically recent in origin. They represent an extremely dry western extension of the Sahara Desert (Mercer, 1980). Active volcanism is evident today on the islands of Fuerteventura, La Palma and Tenerife. All islands have recent lava flows of varying size, landforms such as craters and calderas, and Tenerife presents the magnificent strato-volcano known as El Teide which reaches an altitude of 3718 m (12,199 ft). Lava flows present multiple obstacles to easy bipedal locomotion, including coarsely textured rock with uneven and tenacious surfaces, rocky prominences and crevasses, as well as unstable areas and rock of crumbly composition. These features require constant vigilance during locomotion, if accidental falls are to be avoided. Recently extruded lava beds of all types are referred to by modern Tenerifeños as *malpaís*, and these volcanic badlands may have made key features of Guanche life difficult. Maintaining inter-group contact for social and economic activity, acquiring essential natural resources, and gaining access to hillside caves in which the deceased were placed required travel across lava fields or through *barrancos*. Many island areas not recently blanketed with lava flows are characterised by narrow, steep-sided valleys referred to as *barrancos*. They present many of the same challenges to easy locomotion as *malpaís*.

Navigating volcanic landscapes required skill, diligence and effective use of a staff or stave, which in pre-conquest times was called *magodo* or *amodeghe*. A general, multipurpose tool, staffs were made from branches of the *membrillo* tree, were approximately 1.8 m long and 2.5 cm thick, and after removing the bark were seasoned and treated with pig fat or linseed oil for resiliency. Guanches used staffs for two main purposes: (a) as locomotor aides for support in traversing *malpaís* and *barrancos*; and (b) as weapons, for protecting flocks, for interpersonal defence or combat, and for competitive sporting events (see below). In crossing volcanic landscapes, staffs would have been used in vaulting over crevasses and for support in ascending or descending steep obstacles. Guanche monuments typically depict adult male Guanches with staffs, either at rest—standing with the support of a staff, as in the central plaza of Santa Cruz (Tenerife)—or engaged in actively traversing rocky terrain, as in Las Palmas (Gran Canaria). The latter monument shows Guanches vaulting over, and accidentally falling from, rocky promontories. Accidental falls were probably common occurrences while traversing such a treacherous landscape. Falls during locomotion would undoubtedly have had greater impact on the postcranial skeleton, increasing the prevalence of trauma such as sprains, dislocations and fractures, than on

 

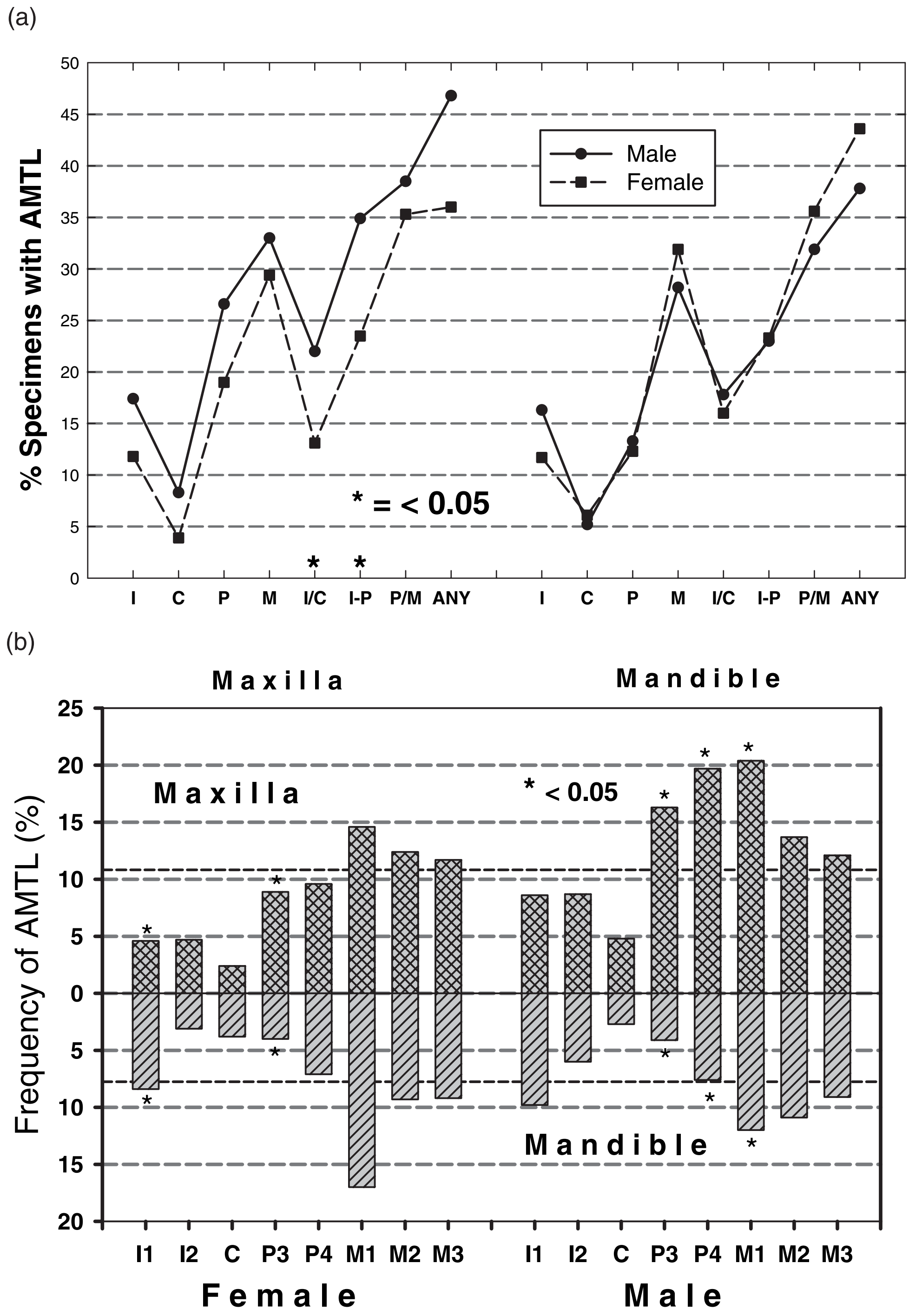


Figure 3. (a) Percentage of specimens with AMTL by tooth class; (b) frequency of antemortem tooth loss by jaw and by sex.

 

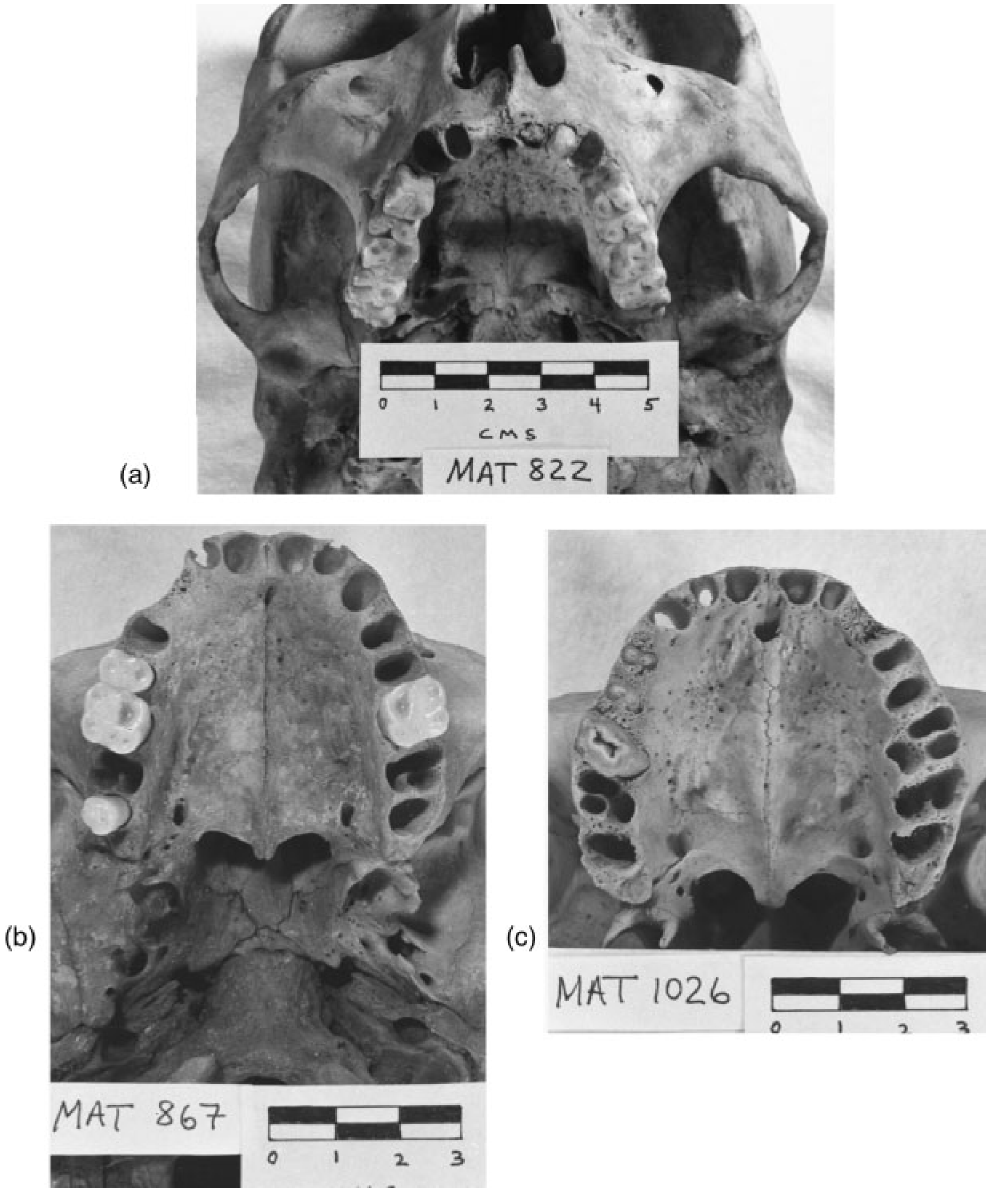


Figure 4. Maxillary antemortem tooth loss and dental trauma. (a) MAT-822 (adult, male): note resorbed alveolus of URI1 and remanent of ULI1 root with crown missing (neg. no. CANIS-2-91-9). (b) MAT-867 (adult, male): complete resorption of the URC alveolus is visible (neg. no. CANIS-2-91-31). (c) MAT-1026 (adult, female): note the roots of URP3 and URP4 are present, but the crowns of these teeth are broken away, and in RP4 proliferative bone growth over the root is visible distally. Also, resorption of the ULC alveolus is in active progress (neg. no. CANIS-2-91-20).

cranio-facial or dental structures. Nevertheless, it is probable that a small yet significant percentage of the antemortem loss of anterior teeth among the Guanches is attributable to accidental falls that resulted in either dental fractures or evulsions.

## *Interpersonal combat: ethnohistory and palaeopathology*

Today, the most common form of Canarian combat is traditional wrestling or *lucha canaria*. In pre-conquest times, wrestling matches assumed

 

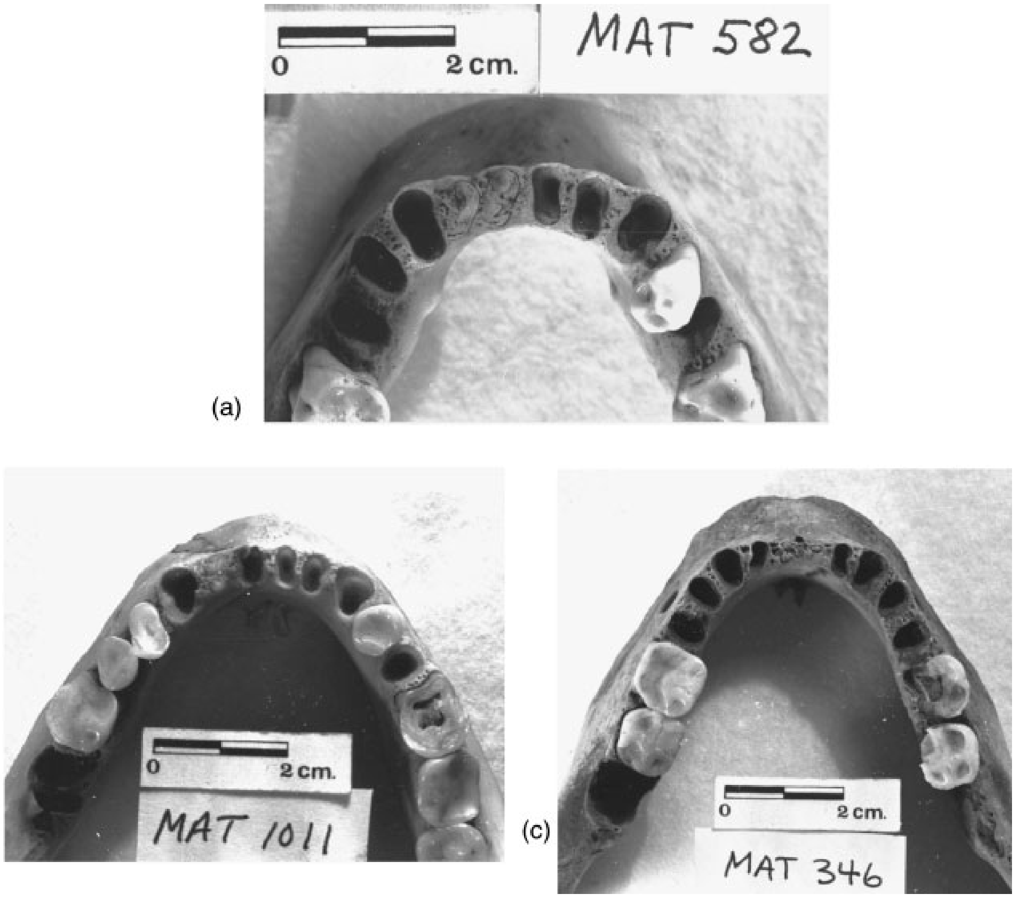


Figure 5. Mandibular antemortem tooth loss and dental trauma. (a) MAT-582 (adult, male): lower left central and lateral incisor tooth crowns are missing, and proliferative bone growth has begun to seal off the roots of these teeth (neg. no. CANIS-1-91-22). (b) MAT-1011 (adult, male): The crown of the lower LI2 is missing and proliferative growth of alveolar bone across the root surface can be observed (neg. no. CANIS-1-91-10). (c) MAT-346 (adult, female): crowns of lower central incisor teeth are missing and root fragments of these teeth are in tahe process of resorption (neg. no. CANIS-1-91-23).

the form of duels or trials of combat, and functioned to settle land disputes or grazing rights between combatants. Wrestling also served as training for war and as entertainment at festivities and weddings. Early European visitors describe large stone circle wrestling areas situated on high ground where conflict was conducted in a hand-to-hand manner without weapons of any kind. While loss of teeth may have occasionally resulted from wrestling bouts, it was probably rather infrequent.

Although less common than wrestling among modern Canary Islanders, a considerably more dangerous and potentially injurious form of combat, known as *juego del palo* or stick-fighting, was practised in pre-conquest times. Today the technique of stick-fighting varies from island to island, as does the name of the staff used in combat (*garrote*—Gran Canaria; *banot*—Tenerife; *lata*—Fuerteventura). In pre-conquest days, stick-fighting comprised one part of a much more elaborate and ritualised duel, as depicted in 16th century watercolours by the Italian engineer Leonardo Torriani (Heyerdahl, 1952: Plate XXXIII). Challengers met at an arena and initially took positions opposite one another on large flat stones approximately 2–3 metres apart. Each combatant was armed with three stones (for throwing at the opponent), three more stones (for wounding during hand-to-hand combat) and a staff or stave (in pre-conquest times known as *magodo* or *amodeghe*). After throwing three stones from their initial positions, opponents engaged in manual combat using small stones held between the knuckles as a vicious 'brass-knuckle' or 'knuckle-duster'. In the final stage of a match, contestants employed staves in their attempt to defeat the opponent. Contemporary Canary Islanders omit the stone-throwing and manual stone weapons of earlier times, and have retained only the stick-fighting component of this generally hazardous form of sportive combat. Thus ethnohistorical descriptions and artwork of stick-fighting portray the use of stone and wooden weapons as an integral component of the contest, every phase of which displays high potential for bodily injury. The recognition of anterior dental trauma as one contributing factor in the rate of anterior tooth loss among prehistoric Canary Islanders is plausibly explained by the longstanding and injurious traditions of stick-fighting and wrestling. That six out of nine anterior dental fractures are on the left side suggests that interpersonal combat may have been a contributing factor. Further support for this interpretation comes from the prevalence of cranio-facial trauma among the Guanches, a pattern of trauma that has been observed by multiple investigators and is consistent with the idea that anterior dental trauma may result, in part, from interpersonal violence.

## Discussion: the multifactorial nature of AMTL

Anthropological analyses of AMTL are undoubtedly complicated by the difficulty of attributing a particular case of tooth loss to a specific aetiological factor. The purpose of this discussion is to provide a broader context for this analysis of dental trauma and AMTL among the Guanches, to emphasise the multifactorial nature of AMTL, and thereby to encourage the collection and reporting of evidence that bears upon the aetiology of AMTL in prehistoric human skeletal remains (Armelagos & Rose, 1972).

While AMTL provides an important measure of dental status, it is difficult to interpret and cannot be used effectively in isolation of other measures of dental status (Tal & Tau, 1984; Hall *et al.*, 1986). The complex and multicausal nature of AMTL in prehistoric human populations is well illustrated by the native American inhabitants of Texas (Hartnady & Rose, 1991) and by human skeletal series from the Arabian Gulf states (Littleton & Frohlich, 1993). Abnormally early and high AMTL rates were reported among Archaic Period inhabitants of the Lower Pecos Region, Texas, by Hartnady & Rose (1991), who described a two-stage model of dental loss. Firstly, dietary components including grit, bone, nut hulls and fibre contribute to high attrition, and simultaneously, sticky high-carbohydrate foods result in a high caries rates (14% tooth count) for a non-agricultural subsistence pattern. In concert, these two primary factors account for the excessively high rates of AMTL in the Lower Pecos people. These factors are further augmented by non-dietary use of anterior teeth as tools in basket weaving and producing woven goods. Littleton & Frohlich (1993) recognised four basic patterns of AMTL in skeletal series of the Arabian Gulf: (1) absent—low, as in the marine dependent Ras el-Hamra series; (2) low and attrition-induced, at Umm an Nar, Bronze Age Maysar, and Failaka; (3) moderate to severe and influenced by calculus deposition, as at Bronze Age Shimal, Iron Age Galilah, Ras el-Khaimah 5, and Islamic Bahrain; and (4) high, severe, early onset, and caries-related, as at Bronze and Iron Age Bahrain, Iron Age Maysar, and Ras el-Khaimah 3. Pattern 4 AMTL, characterised by high prevalence and early onset, was further documented among Iron Age remains from Oman (Nelson *et al.*, 1999). The association of different AMTL patterns and frequencies with distinctive subsistence strategies and levels of techno-cultural development provides useful insights into the aetiology of AMTL.

### *Cultural and ritual factors in AMTL*

A comprehensive review of tooth ablation by Pietrusewsky & Douglas (1993), focused on variations in type and incidence among

Hawaiians. In north Africa, ablation of maxillary incisor teeth during late childhood or adolescence was reported by Ferembach *et al*. (1962) for remains from Taforalt and Afalou. The pattern of evulsion among these epipalaeolithic cultures focused on removal of maxillary central incisors, and males were affected twice as often as females (Ferembach *et al*., 1962: 60). The diagnosis of ritual ablation is often problematic and subject to controversy. Hrdlička (1940), for example, attributed antemortem loss of front teeth in populations of Siberia and North America to 'ritual ablation'. However, Merbs' (1968:29) review of Hrdlička's work led to the conclusion that Arctic peoples have an extremely high rate of AMTL '. . .not because of any ritual removal of these teeth, but because of trauma occasioned by use of the anterior dentition as a tool'. Cook (1981) documented 12 cases of traumatic loss of deciduous teeth among Koniag Eskimo youth, and favoured purposive ablation. Costa (1980) and Mayhall (1977) have also reported on tooth loss among Arctic peoples.

## *Dietary variations and AMTL*

Dietary factors are a primary causal agent in the aetiology of antemortem tooth loss, and differences in AMTL between groups practising distinctive subsistence patterns are not uncommon. In many regions the rate of AMTL is reported to increase dramatically with the onset and intensification of agriculture. This relationship has been documented for the Arabian Gulf (Littleton & Frohlich, 1993), northern Chile (Kelley *et al*., 1991), prehistoric Iroquois of Ontario (Patterson, 1984), and the Tennessee Valley area (Smith, 1987), for example. The only prior analysis of AMTL among prehistoric Canary Islanders was conducted by Fusté (1961), who found higher rates among skeletal sample from sites in the interior than among coastal sites in Gran Canaria. Since severe dental caries is a major contributing factor to antemortem loss of post-canine teeth, Fusté's observation is in agreement with the recent report of higher dental caries prevalence among skeletal samples from inland sites (15.4%) on Gran Canaria than from coastal sites (7.6%; Delgado-Darias *et al*., 2005).

The pattern of AMTL among five early north Chilean skeletal samples reveals different aetiological pathways (Kelley *et al*., 1991). Attrition-induced pulp exposure contributed to AMTL rates at Morro-1, whereas at Quitor-5 rapid tooth loss in early childhood was probably due to severe caries involvement. These differences were attributed to increased dependence upon agriculture. The pre-intensive agricultural group of Iroquois from Le Vesconte Mound (8.0%), Ontario, displays an AMTL rate less than half that of two neighbouring horticultural groups (Bennett site, 18.7%; Kleinberg Ossuary, 18.5%) (Patterson, 1986). Alternatively, some investigators have reported evidence to the contrary. A dramatic decline in AMTL rates between hunter-gatherers and agriculturalists was described for the Tehuacan Valley, Mexico (Anderson, 1965).

A recent analysis of dental caries and antemortem tooth loss in the northern Petén area of Mexico documented differences in frequency by social status (Cucina & Tiesler, 2003).

In general, AMTL due to heavy attrition or dental caries favours postcanine teeth, and especially molar teeth (Nelson *et al*., 1999). Depending on a group's subsistence system and food preparation practices, heavy masticatory forces or the complexity of occlusal grooves are factors that contribute to higher rates of dental wear or caries, respectively, as agents of antemortem loss in molar teeth. By contrast, the majority of traumatic dental and facial injuries involving accidental falls or interpersonal violence predilect the maxillary anterior teeth (Andraesen, 1982).

## *Sex differences in AMTL*

When AMTL is comparatively evaluated by sex, the most common pattern is for females to display higher rates than males (Al-Shammery *et al*., 1998). Among prehistoric Americans of central California, analysis of completely resorbed alveoli revealed a sex difference, with females affected more than twice as often as males (Jurmain, 1990: 337). Females are reported to display higher rates of AMTL than males in human skeletal samples from prehistoric northern Chile (Kelley *et al.*, 1991); Iron Age, Italy (Gualandi, 1992); and 7th–9th century Pontecagnano, Italy (Fornaciari *et al.*, 1985–86). However, some investigators report results to the contrary (M > F), as in skeletal series from the Middle Ages of Hungary (Frayer, 1984). Merbs (1968:25) described sex differences in the use of anterior teeth as tools among Arctic peoples; however, no sex-specific figures for AMTL rates are provided. Examples of how differences in manipulative and occupational use of the dentition between the sexes and between groups might result in unique patterns of tooth loss are provided. A significant, yet not widely appreciated, factor contributing to higher AMTL among women is the female gender bias in dental caries prevalence due to hormonal fluctuations associated with pregnancy and monthly cycling (Lukacs & Largaespada, 2006). The microbiology of oral ecology is complex, influenced by diet as well as by saliva composition and flow rates, which in turn are influenced by female hormones. These interactions would have a more significant impact on AMTL rates among postcanine teeth, especially the molar tooth class, since caries typically tend to be less prevalent in anterior teeth (Hillson, 2001; Duyar & Erdal, 2003).

## *Variation in AMTL by jaw and tooth class*

Among prehistoric native Americans from different geoecological settings in Oregon, Hall *et al.* (1986) found AMTL to range from 33% to 56% in five regional samples, and to be more frequent in the maxilla than in the mandible. While the greater maxillary frequency of AMTL is significant, no cultural or biological explanation for the difference is offered. Socket resorption is present in 52% of adults from prehistoric central California natives from site CA-Ala-329 (Jurmain, 1990). The average number of sockets resorbed per specimen is 4.6 in the maxilla and 5.0 in the mandible; molars and premolar teeth are primarily affected, and maxillae (93%) display greater involvement than mandibles (71%). Among the Iroquois of Ontario, there is a higher rate of AMTL from mandibles than from maxillae, with rates being from 3.2% to 5.8% greater in the lower jaw.

## *Antemortem trauma and tooth loss*

Reports on dental trauma that may influence AMTL rates are rare in the anthropological literature (Hillson, 1986; Scott & Turner, 1988). While a thorough review of dental alterations included dental fractures (Milner & Larsen, 1991), their impact on AMTL rates was not addressed. A salient early example is Leigh's (1929) observation of 12 fractured teeth (7% of individuals) in a skeletal series from prehistoric Guam. Alexandersen (1967b, 1978:51) and Scott *et al.* (1991: 194) may be counted among those who have recognised the small but important contribution that dental trauma make to AMTL rates. Antemortem tooth trauma, including chipped and fractured teeth, were reported by Patterson (1986) as part of his evaluation of the oral heath of three pre-Iroquoian populations from southern Ontario. The 'pre-maize agriculture' hunting and gathering group from Le Vesconte Mound displayed higher rates of dental chipping and fractures than either of the two horticultural groups (Bennett site and Kleinberg Ossuary), a feature attributed to more extensive use of the dentition in the preparation and consumption of food (Patterson, 1986: 10). Fractured teeth among the Neolithic people of Abu Hureyra, Syria, have been attributed to the failure to remove hard seeds and small stones from grain during processing (Molleson & Jones, 1991; Molleson, 1994).

Dental chipping and enamel microfractures due to hard inclusions in food, such as small stones or bone fragments, have been documented for Aleuts and Eskimo (Turner & Cadien, 1969), and more recently for the Epipalaeolithic sample from Taforalt in eastern Morocco (Bonfiglioli *et al.*, 2004). Small-scale dental damage from dietary inclusions can occur throughout the dentition, and does not differentially affect a specific tooth class. Large-scale trauma, such as complicated fractures that impinge upon the pulp chamber, are more prevalent in the anterior dentition and are not of dietary origin. Rather, traumatic fractures of anterior teeth are more often the result of either occupational use of teeth as tools, accidental falls or unanticipated encounters with stable or moving objects, and violent interpersonal interactions (Pindborg, 1970; Andraesen 1982).

## Conclusions

Antemortem tooth loss (AMTL) is a complex and multifaceted process that involves dietary texture, nutritional deficiency diseases, oral health status, traumatic injury and cultural practices. The frequency and distribution of AMTL is described for the Guanches of the island of Tenerife in the Canary Archipelago. Dental trauma is implicated as a factor contributing to the antemortem loss of anterior maxillary teeth among the Guanches. Antemortem loss of maxillary anterior teeth among the Guanches of Tenerife is consistent with two potential causal factors: (a) accidental falls while traversing volcanic landscapes and gorges; and (b) violent interpersonal combat. The latter includes traditional wrestling and stick-fighting competitions, as well as conflict resolution through ritualised hand-to-hand combat. The left side bias in antemortem fractures of anterior teeth among males is consistent with interpersonal combat as a factor contributing to anterior AMTL among the Guanches. The analysis of oral palaeopathology must go beyond the simple reporting of AMTL rates, and seek to identify the relative significance of multiple aetiological agents responsible for tooth loss patterns in prehistory. Recording and reporting data that permit the partitioning of total tooth loss into its multifactorial aetiological components will result in greater insight into the behaviour of earlier human populations.

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