DIALOGO ANDINO N° 14/15, 1995-1996
Departamento de Antropología, Geografía e Historia
Facultad de Educación y Humanidades
Universidad de Tarapacá, Arica-Chile.

CAN COCA-LEAF CHEWING CAUSE PREMATURE TOOTH LOSS?

by

ODIN LANGSJOEN

RESUMEN

Se estudia la dentición de los Maitas Chiribaya, población de agricultores que ocupó el valle de Azapa cerca de la costa del Pacífico del extremo norte de Chile entre los años 1100 a 1300 d C.

La observación demostró un menor porcentaje de desgaste de lo normal, un gran porcentaje de caries dentales de las cuales un 80% se ubican en la base del diente, así como una alta cantidad de pérdida de dientes posteriores (premolares y molares).

La pérdida dentaria se correlaciona positivamente con la práctica de masticar coca. Se postula que el contacto de la hoja de coca con la gingiva y el periodontium de los dientes posteriores, da como resultado la pérdida de los mismos, sin embargo, no presenta relación con la presencia de caries dentales. El enigma de la etiología permanece, aunque podría estar relacionada con la alta proporción que presenta la mala conformación de los dientes. Se enfatiza la importancia de considerar las caries de la corona como un proceso etiológicamente diferente al de la raíz de los dientes.

ABSTRACT

We studied the dentition of the Maitas Chiribaya, an agricultural population that occupied the Azapa valley near the Pacific coast of extreme northern Chile between A.D. 1100 to 1300. The distinctive findings included an attrition score less than normal, a high rate of dental caries, 80 percent of which was located on the tooth roots and a high rate of antemortem loss of posterior teeth (premolars and molars). The tooth loss correlated positively (relative risk 22.4) with coca-leaf chewing practices (the latter estimated by chemical detection of cocaine and its metabolites in the hair of Chiribaya mummies). We postulate that contact of the coca-leaf quids with the gingiva and periodontium of the posterior teeth resulted in local destruction of these tissues by an as yet undetermined mechanism with resulting tooth loss. The extensive tooth root caries, however, bore no correlation to the coca-leaf chewing practices, nor does it correlate with attrition. Hence its etiology remains enigmatic, though it could be related to the high rate of tooth malposition. The importance of viewing dental crown caries as an etiologically different process from that of dental root caries is emphasized.

The extreme north of Chile is one of the most arid locales in the world. Sandwiched between the Pacific Ocean and the 6000 meter peaks of the Andes, this narrow strip of land representing the Atacama Desert receives virtually no precipitation below about 3000 meters. Steep-walled valleys, cut by glacial meltwater at the end of the last ice age, transect the area. An occasional one of these conducts melted snow from the mountain peaks back to the sea in the form of a diminutive stream. Near the sea these valleys are partially filled with alluvium whose flat surface can be irrigated from these small streams. Between about A.D. 1100 to 1300 the mouth of one of the largest of these, the Azapa Valley at about 23° south latitude, was the home of an indigenous group of agriculturalists called Maitas Chiribaya.

This segment of the coast had been occupied since the early Archaic period. A shell midden radiocarbon dated to about 7500 B.C. near Antofagasta marks the first

appearance of human presence on this coastal strip—the Chinchorro people based at the river mouths in small bands, they were a largely maritime people who derived most of their sustenance from the area's marine resources. Their lifestyle changed little over a period of more than 5000 years until the first migrants from the highlands, the Alto Ramirez people, left their highlands home around Lake Titicaca and settled on this part of the Pacific coast about 1000 B.C., bringing their agropastoral practices with them. During the first millennium of the Christian era the valley provides abundant evidence of Tiwanaku influence (locally called Cabuza), with more prominent integration of pastoralism into an increasingly agriculture-related subsistence. Collapse of the Tiwanaku empire between A.D. 900 and 1000 provided opportunity for local and regional development of communities. In this environment we encounter the efflorescence of the cultural group known as the Maitas Chiribaya who are the focus of this report . Their unique pottery and textiles become recognizable by about A.D. 1100 and archaeological evidence identifies a rapid population expansion during the subsequent century. Their tombs contain agricultural tools and products including maize and beans, though chemical dietary reconstruction indicates that the nearby sea continued to contribute at least a minor fraction of their diet.

MATERIALS

The examined skulls and their contained dentition were originally excavated from the burial site AZ-140 located about eight km up the Azapa Valley from the port city of Arica. They were transferred to the files of the Archaeological Research Institute of the University of Tarapaca where they were kindly made available to me by the professional staff of that unit. I examined 46 adults of which 27 were females and 19 males. Only one skull lacked a mandible.

METHODS

Data were collected for all tooth sites: sites with teeth present, empty sockets due to postmortem tooth loss, and healed sockets representing teeth lost antemortem. Data from each site is recorded by tooth type, class, quadrant and dental arch. Dental pathology frequency is calculated as a percent of the total number of tooth sites available for examination for the feature studied. The total number of tooth sites is the sum of: a) fully erupted teeth present, b) partially erupted teeth present, c) impacted teeth present, d) teeth congenitally missing, e) teeth lost antemortem, and f) teeth lost postmortem (Table 2).

Attrition

Attrition is *scored* in progressive stages from 0-9. Stages 0-4 describe increasing degrees of wear that fall within the physiologic limits of unimpaired function. Stages 5-9 describe stages of advanced wear sufficient to cause loss of tooth vitality through pulp exposure or loss of proximal tooth contact due to wear past the proximal crest of convexity of a tooth crown. Dental pathology occurs when attrition exceeds the body defenses ability to respond to these excesses. Attrition rates are determined by dividing attrition score by age at death corrected for tooth eruption date.

Caries

Caries data is classified as crown, root or indeterminate, according to the location of its site of origin, for reasons defined in section Caries below.

Data is recorded by surface features for each tooth type within the following classification:

Crown caries: a. developmental pit and fissure
b. smooth surface, enamel

Root caries: a. cementoenamel junction
b. smooth surface root

Large lesions of indeterminate origin involving major areas of both crown and root were recorded as one crown and one root. No smooth surface lesions were identified for either crown or root.

Alveolar Osteitis

Periapical and periodontal abscesses were recorded by type:

- periapical abscess: pulp exposure with or without fistula;
- periapical abscess: postmortem socket with periapical fistula;
- periodontal abscess in root furcation;
- interproximal bone crater formation of varying severity by tooth aspect location.
- combination of periapical and periodontal abscesses were recorded as periodontal and one periapical.

Numerical differences between group comparisons were evaluated by anova, Students t-test and relative risk estimate with 95 percent confidence limits. The term statistically significant, as used in this study, indicates that the chance probability of the demonstrated differences is less than 5 percent.

RESULTS

The frequency of the various lesions identified during the analysis are listed in Tables 1-3 and Figures 1-5. Of special interest for this report are the high frequencies of antemortem loss of posterior teeth (premolars and molars), high frequency of root caries and the low levels of attrition. These are elaborated below.

Antemortem Tooth Loss

Approximately 15 percent of the alveoli (sockets; tooth sites) available for examination demonstrated loss of the tooth before death. This is a very high frequency. Furthermore about 80% of the teeth lost antemortem were posterior teeth (premolars and molars). A central question of interest, therefore, is the cause of loss of all these posterior teeth. Since the tooth is absent, the answer can not be obtained by examination of the tooth itself. Clues must be sought in the patterns of the tooth loss and in lesions of remaining teeth. Figure 3 demonstrates a clear, age-related pattern of tooth loss, and one in which dramatic acceleration of the process occurs after age 29 years. A lesion in the remaining teeth that might possibly be related to tooth loss is the substantial frequency of caries. Seventy percent of the Chirbaya's adults had evidence of carious teeth. This possibility is discussed in the next section.

Dental Caries

Dental caries is a necrotizing process brought about through the mechanism of acid dissolution of the bone mineral and proteolysis of the organic matrix. Because of the relatively small amount of organic matrix in dental enamel, acid dissolution is probably the dominant process in at least the earlier part of enamel decay, while the much larger organic fraction in dentine and other root components results in a more major role for protein hydrolysis of this organic matrix when these areas are the target of a carious lesion. The source of the acid and proteolytic enzymes is , of course, oral fluids including their bacterial content.

Although a moment's reflection will make this obvious, it is important to call attention to the etiologic or mechanistic difference between carious lesions of a tooth crown and those of a tooth root. While all the details of the exact relative roles of acid dissolution and protein hydrolysis in the initiation and extension of a carious lesion are not yet completely resolved, dental caries can only affect the tooth parts that are exposed to oral fluids. The enamel-covered tooth crown, of course is exposed to oral fluids when it is in its normal position and thus is vulnerable to caries as soon as it erupts. Hence, crown caries in adults is primarily a condition found during the first half of adult life. Furthermore, this process usually reaches and exposes the tooth pulp well before the entire crown is destroyed, such pulp involvement gives the bacteria access to the root tip where an abscess will form. A very common result of such an untreated abscess is fistulization through the bone with spontaneous drainage into the oral cavity (or sometimes into a paranasal sinus in the case of and upper or maxillary tooth). While such a tooth is no longer vital, its fixation to the periodontium often remains intact. In this circumstance the tooth is quite frequently retained in position and can be useful for mastication for many years. Finally because endproducts of bacterial carbohydrate metabolism are acid, a high carbohydrate diet enhances initiation of a carious enamel lesion by acid dissolution.

The tooth root, however, normally is covered by gingival soft tissues and attached to the periodontium. Oral fluids can gain access to it only if these overlying tissues are destroyed by some pathological process. While root exposure to oral fluids can also occur in some other occasional circumstances (gradual extrusion of an unopposed tooth, angulated tooth growth such as impaction, etc.), by far the most common cause is loss of proximal contact. This term refers to the fact that the crown of a molar tooth is wider than its neck. If tooth wear (attrition) gradually lowers the chewing ("occlusal") surface to the point that the crowns of two adjacent teeth no longer touch each other (proximal contact loss), then the space between the teeth is exposed to the food being chewed. Vigorous mastication will first fill this space with food and then subsequent chewing pressure will tend to put sufficient pressure on this food that the underlying gingival soft tissue ("dental papilla") becomes damaged. Commonly food particles eventually become wedged between the gingival soft tissues and the adjacent teeth and bone. Oral fluids frequently gain access to the tooth root surface in this manner, initiating a carious lesion there. Soft tissue inflammation in this area is called "periodontitis." Any extension of this inflammation into the adjacent alveolar bone (alveolar osteitis) resulting in bone loss is termed "periodontal abscess." It will be evident from this description that this occurs after sufficient time has passed to accommodate the degree of attrition that underlies the development of this lesion. Thus, root caries is usually a condition found prominently in the latter half of adult life and occurs in individuals with an advanced state of dental attrition.

Given the above, Fig. 5 makes it clear that the bulk (80 percent) of the carious lesions involve the tooth root (most at the cemento-enamel junction), not the crown. In addition, this is an age-related process as evidence in Fig. 6.

Initially it appeared that the observed pathology could be explained easily by assuming that the high carbohydrate diet of this agricultural group caused the high caries rate, and that the carious lesions were responsible for the extensive antemortem loss of teeth (Kelley et al., 1991). However, this facile scenario becomes less plausible when considered in greater detail. Most carious lesions occurred on the roots in older individuals. Carbohydrate foods may have contributed to the crown lesions, but this was a minor (only 20%) problem for the Chiribaya. A high carbohydrate diet plays a minor, if any, role in root caries. Interpretation becomes even more complex when we remind ourselves that by far the most common cause of root caries is periodontitis and that this is usually the result of advanced attrition—sufficient to destroy proximal contact. Yet, the Chiribaya presented less, not more attrition than usual. Indeed, only about six percent of their teeth demonstrated a pathological degree of attrition.

Our inability to integrate these features into a plausible chronology strongly implied the operation of some other, not yet considered factor. Our search for such a factor that could have been responsible for the gingival destruction that exposed the teeth roots to caries and played a role in the high tooth loss rate led us to consideration of the only other substance that made contact with the gingiva—the common use of coca-leaf quids.

Chewing of Coca Leaves

The "chewing" of coca leaves is an ancient Andean practice. Four to six leaves of the coca plant are rolled into a quid and placed between the gingiva and the cheek in a manner similar to that of tobacco today. The quid is allowed to soak up saliva passively; i.e., it is not actually chewed. When saturated it is alkalinized by the addition of powdered limestone or ashes, that enhances extraction of the cocaine and other alkaloids. The amount of alkaloid extracted is low—usually producing only a minimal, if any, mood alteration. It usually remains in place for less than an hour, but multiple daily applications are common. It appears to be primarily a cultural custom rather than a hedonistic practice. While there is both archaeological and ethnographic evidence of its pre-Hispanic use, we did not have detailed knowledge of this practice in prehistoric times. Using both gas chromatography—mass spectrometry and radioimmunoassay techniques—we studied hair samples from 163 individuals from seven successive cultures between about 500 B.C. to A.D. 1500 that lived in the Azapa valley. Ninety-seven of these were Chiribaya people, of which 54 had positive reactions. Clearly the practice was common among these people.

Since the presence of an oral coca-leaf quid was a common finding in mummies of this group, and since the position of the quid caused it to be in direct contact with the buccal periodontium of the posterior teeth, and since it was precisely these teeth that were lost antemortem, we tested the correlation between the presence of cocaine in the hair of a Chiribaya mummy and the antemortem loss of posterior teeth. The result indicated a statistically significant ($p < .05$) positive correlation and a relative risk of 4.3 (overall) rising to 21.3 for the older age group. This leaves little doubt that a relationship exists between coca-leaf chewing and the antemortem loss of posterior teeth.

The nature of that relationship is not obvious. Conceivably some element in the quid may be toxic to gingival tissues—perhaps one of the alkaloids other than cocaine or, more plausibly the alkalinizing agent. The latter might exert its effect by altering the oral pH at that site perhaps enhancing the local bacterial action or by creating an adverse cellular environment. Alternatively, it is conceivable that merely by applying the quid directly to the gingiva for hours every day could enhance bacterial action in the same way that applying carbohydrate food to teeth does. What remains clear is overwhelmingly high correlation between the practice of chewing coca leaves and the loss of posterior teeth. A literature search revealed that Turner (1993) had suggested such a possible relationship in a different population, but in his specimens no soft tissues were available for cocaine analysis.

Peculiarly, no statistically significant correlation could be established between coca-leaf chewing and cemento-enamel junction root caries. We are pursuing, but have not completed further correlations to evaluate the possibility that this is related to tooth extrusion secondary to causes other than opposing tooth loss. Since neither the low level of attrition nor the chewing of coca leaves can explain the gingival loss that led to the cemento-enamel junction root caries, this feature remains enigmatic.

Table 1. The number of tooth sites available for examination.

Number of Teeth Present:	M. Chiribaya
-in functional position	948
-partially erupted	22
-impacted	4
Total Present	974
Number of Teeth Missing:	
-congenitally missing	37
-lost antemortem	222
-lost postmortem	226
Total Missing	485
Total Teeth Sites Possible	**1459**

Table 2. Number of posterior teeth lost antemortem (AMTL) by age decade.

MAITAS CHIRIBAYA		
Age Decade	Number of Individuals	Posterior AMTL
0-20	8	0
20-29	11	12
30-39	11	24
40-49	8	58
50+	8	85
Total	**46**	**179**

Table 3. Frequency and antiquity of prehistoric coca-leaf-chewing practices in northern Chile, abstracted from Table 1, Cartmell et al. (1991).

Culture	No. Tested	No. Positive	Time Period of Sampled Sites	%+
Chinchorro	26	0	3000 BC - 1250 BC	0
Alto Ramirez	3	1	1000 BC - A.D. 350	33
Cabuza	16	10	AD 400 - AD 1000	62
Maitas Chiribaya	97	54	AD 1100 - AD 1300	56
San Miguel	8	2	AD 1200 - AD 1350	25
Inca Regional Chiefdom	13	9	AD 1400 - AD 1500	70
Totals	163	76	BC 3000 - AD 1500	47

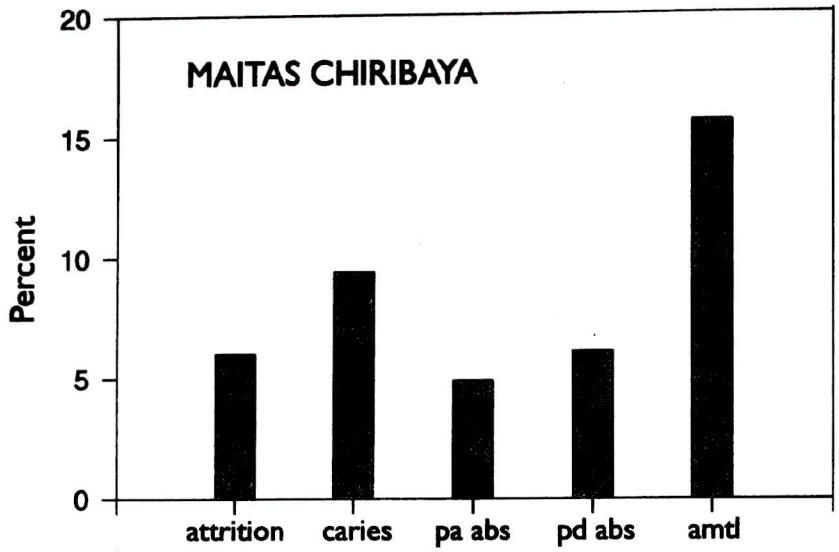

Fig. 1. Caption: Frequencies of pathological dental lesions.

Legend:
pa abs = periapical abscess, pd abs = periodontal abscess., amtl = antemortem tooth loss. Values for attrition and caries are expressed as percent of all teeth remaining and for the remainder as percent of alveolar sockets available for study

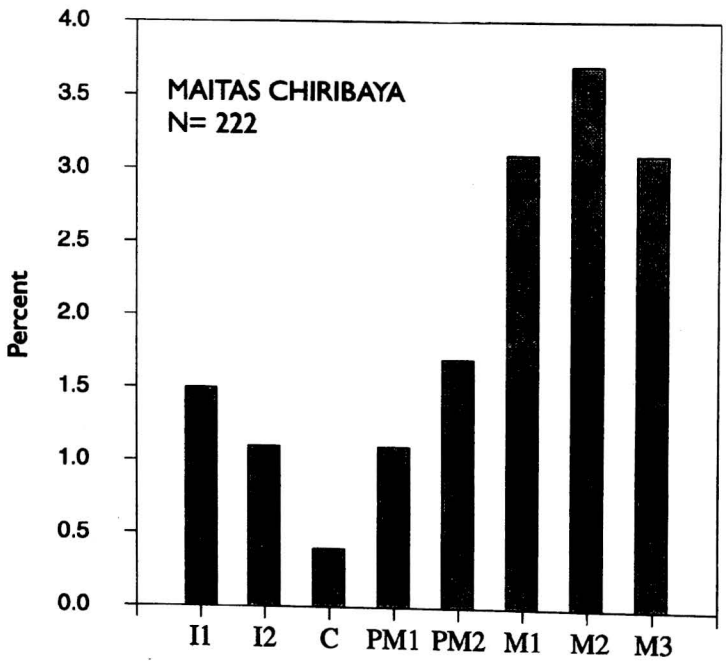

Fig. 2. Caption: Antemortem tooth loss frequencies by tooth type.
Legend: I = incisor, C = canine, PM = premolar, M = molar.
Values are expressed as percent of total number of alveolar sockets available for study.

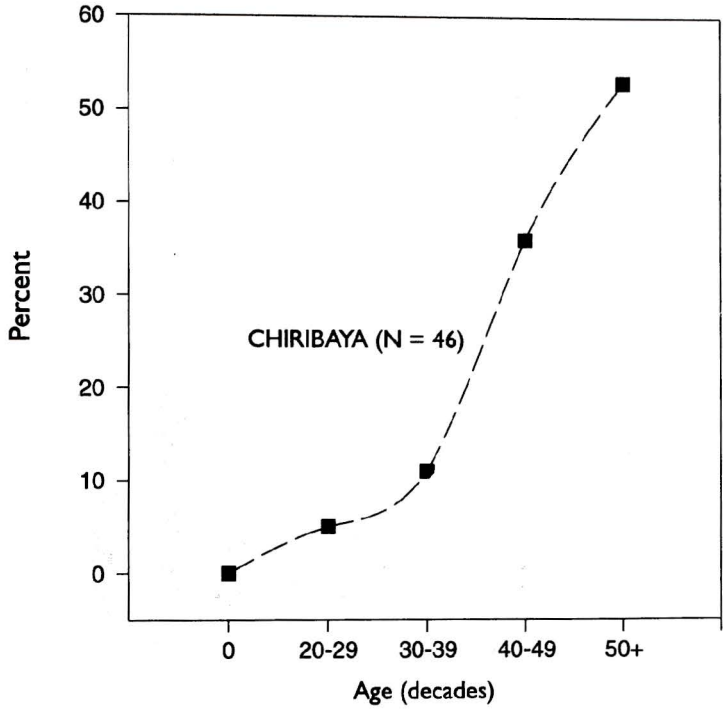

Fig. 3. Caption: Antemortem loss of posterior teeth by age decades.
Legend: Values are expressed as percent of total number of posterior teeth (PM1-M3) alveolar sockets available for study. Differences above age 29 are statistically significant at .05 level.

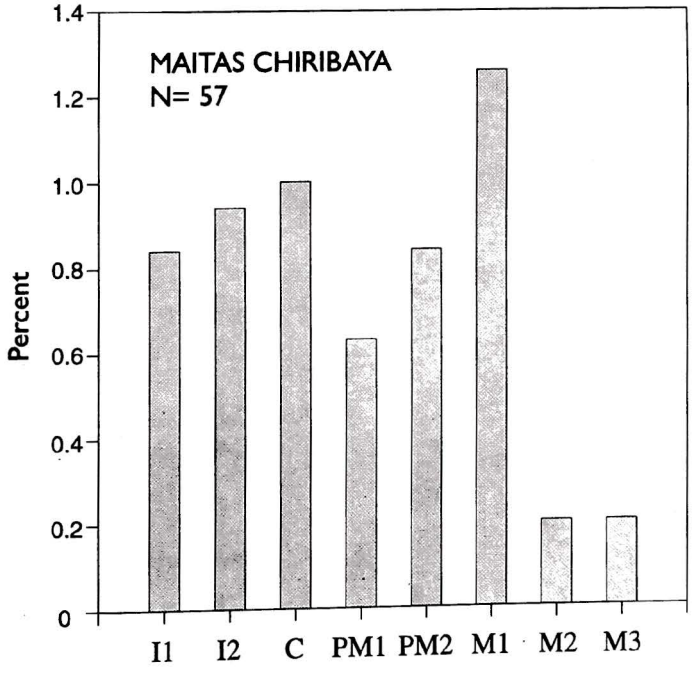

Fig. 4. Caption: Pathologic attrition scores by tooth type.
Legend: Numerical values represent the fraction of teeth showing pathological degrees of attrition expressed as percent of all teeth available for study.

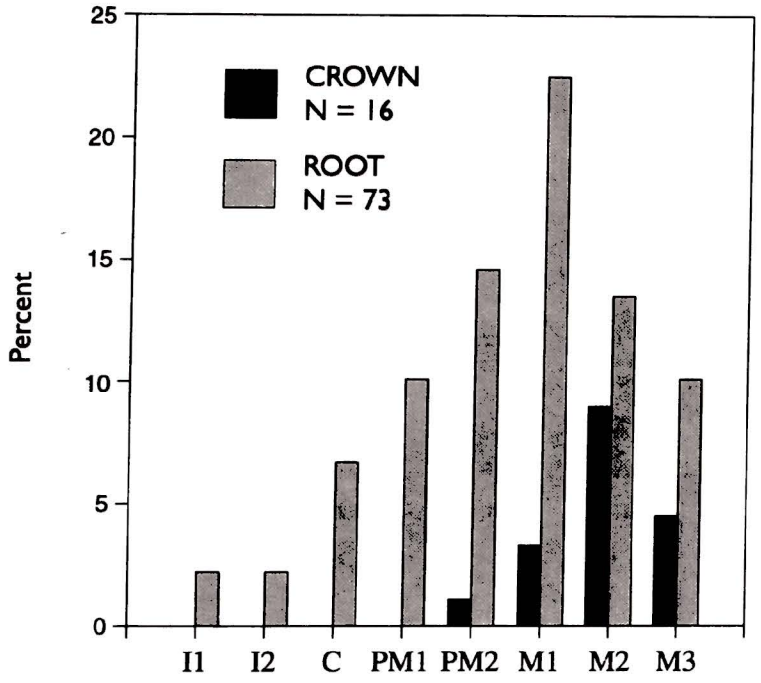

Fig. 5. Caption: Crown and root caries frequencies by tooth type.
Legend: I = incisor, C = canine, PM = premolar, M = molar. Distribution and frequency of Maitas teeth showing crown caries and those with root caries expressed as a percentage of total carious teeth.

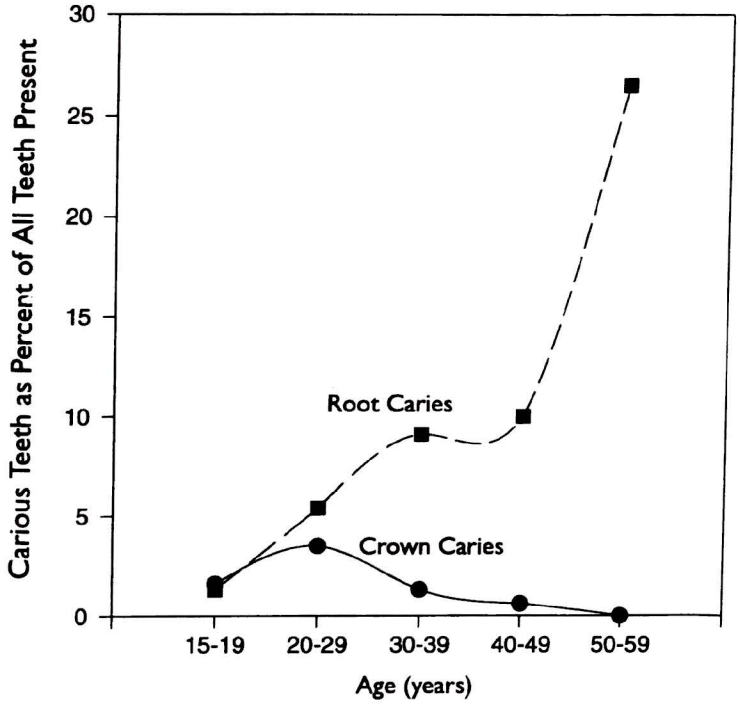

Fig. 6. Caption: Age-related frequencies of dental crown and root caries.

BIBLIOGRAPHY

AUFDERHEIDE, A. C.

1990 Report of field operations during dissections of mummified human remains from Chiribaya Alta and Yaral sites near Ilo, Peru. Manuscript on file in the Department of Anthropology, University of Chicago, and Paleobiology Laboratory, University of Minnesota, Duluth.

AUFDERHEIDE A. C., and Allison M.J.

1992 Chemical dietary reconstruction of north Chile prehistoric populations by trace mineral analysis. Proceedings of the First World Congress on Mummy Studies, Archaeological Museum of Tenerife, Canary Islands, February 3-6, 1992. In press.

CARTMELL LW, Aufderheide AC, Springfield A, Weems C, and Arriaza B

1991 The frequency and antiquity of prehistoric coca leaf chewing practices in northern Chile: radioimmunoassay of a cocaine metabolite in human mummy hair. Latin American Antiquity 2(3):260-268.

KELLEY MA, Levesque DR, and Weidl E

1991 Contrasting patterns of dental disease in five early northern Chilean groups. In M Kelley and C Larson (eds.): Advances in Dental Anthropology. New York: Wiley-Liss, pp. 203-213.

TURNER, Christy G.

1993 A prehistoric Peruvian pathology suggesting coca chewing. Dental Anthropology Newsletter 17(2):10-11.