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THE DISTRIBUTION OF CALCULUS DEPOSITS IN DENTITIONS FROM ANCIENT ECUADOR

ABSTRACT: This paper presents new findings on dental calculus distribution obtained from archaeological samples collected since the 1970s in Ecuador, South America, from sites encompassing a time span of more than 7000 years (6250 BC to AD 1940), including Preceramic to Late Historic Periods. The patterns observed are in marked contrast with those reported from modern clinical samples. Results show a temporal shift in calculus deposition patterns in the highlands, possibly reflecting changes in oral hygiene and diet over time. No evidence was detected of an association between location patterns of dental calculus and coca use in these ancient Ecuadorian samples.

KEY WORDS: Dental calculus distribution – Buccal – Lingual – Ancient Ecuador – Prehistoric – Historic – Oral hygiene – Diet – Coca

INTRODUCTION

Dental calculus results from deposits of inorganic salts on the teeth, which are mixed with epithelial cells, food debris and bacteria. Composition includes apatite with small amounts of whitlockite (Forsberg *et al.* 1960). Clinicians usually distinguish between supragingival calculus, located on the occlusal side of the gingival margin, and subgingival calculus, located on the apical side of the gingival margin (Nguyen 1992). It has been suggested that the quantity and location of dental calculus in some cultures correlates with the use of an alkali such as lime in chewing coca leaves (Klepinger *et al.* 1977, Leigh 1937) or betel nut (Leigh 1929, Mehta *et al.* 1955), although the process by which alkali use leads to such deposits has not been defined. In Ecuador, Klepinger *et al.* (1977) reported an increased occurrence of dental calculus in a late Chorrera (Engoroy) cemetery human sample (dated to about 840 BC) from coastal Ecuador in South America, relative to that detected in an earlier Valdivia sample from the nearby Real Alto site (dated to about 3000–1500 BC). These authors attributed the increase in dental calculus to coca use, basing their interpretation on both the quantity and distribution of deposits within the dentition. This essay examines patterns of calculus distribution in large samples from many different sites from Ancient Ecuador in light of some issues identified in the literature on calculus formation.

FACTORS IN CALCULUS FORMATION

Although calculus formation is complex (Driessens, Verbeeck 1989, Hodge, Leung 1949, Leach 1973, Schroeder 1969, Zander *et al.* 1960) and not entirely understood, most agree that it involves initial plaque deposition (Newman, Poole 1974) and the presence of microorganisms (Friskopp, Hammarström 1980, Scheie 1989). Factors influencing plaque and calculus formation include the amount of starch hydrolysates in the saliva (Lingström *et al.* 1993), silicon (Damen, ten Cate 1989) and other factors in saliva content. Dawes and Macpherson (1993) document variability within the mouth in salivary film velocity and suggest a correlation with calculus formation. They further propose that calculus forms in areas of the dentition where plaque exists in a microenvironment of low concentrations of carbohydrates, relatively high concentrations of urea and high salivary film velocity (Dawes, Macpherson 1993). Saliva content is quite heterogeneous within the mouth, presenting distinct microenvironments with varying potential for plaque and calculus formation. Adding to the complexity, Mandel (1973, 1974) reports chemical differences in plaque between samples of individuals with light and heavy formations of calculus. Calculus formation is also enhanced by rough dental surfaces, especially enamel defects and pits (Jones 1972).

Research has suggested differences in sodium and calcium between samples of subgingival and supragingival calculus (Lundberg *et al.* 1966), as well as variations of fluoride levels within calculus deposits (Huang *et al.* 1996). The strong clinical interest in dental calculus has led to thoughtful recording standards (Barnett *et al.* 1989, White 2000) and research documenting its presence in ancient humans as well as non-human animals (Dobney, Brothwell 1986). Although dental calculus is generally associated with poor dental hygiene and overall poor dental health, the specific association with dental caries is not clear (Pattanaporn, Navia 1998). Teeth recovered from Peruvian archaeological samples indicated correlation between large calculus deposits and periodontal disease (Moodie 1931). Martinez-Canut *et al.* (1999) reported that smokers have less subgingival calculus but more supragingival calculus than non-smokers.

DIET AND DENTAL CALCULUS

Experimental studies on laboratory rats suggest that diet is a factor in calculus formation. Research reported by Baer and White (1966) indicates that high protein/high fat diets lead to increased calculus formation compared to high carbohydrate diets (sucrose or cornstarch in the experiments). Although studies of human calculus deposits in archaeological samples have led to dietary interpretations (Evans 1973), the many other factors involved in formation create interpretive complexity (Lieverse 1999). The literature summary presented by Lieverse (1999) illustrates the diversity of dietary interpretations from calculus occurrence and the need to consider multiple factors, including curatorial and taphonomic processes.

DISTRIBUTION OF DENTAL CALCULUS WITHIN THE DENTITION

Most studies of calculus formation report saliva to be an important factor, but recognize variability in saliva content and flow within the oral cavity (Lecomte, Dawes 1987, Weatherell *et al.* 1986). The clinical literature firmly suggests that greatest concentrations of supragingival calculus are concentrated near the openings of the major salivary glands on the lingual surfaces of the anterior mandibular teeth and the buccal surfaces of the maxillary posterior teeth (Alexander 1971, Baelum 1987, Canis 1978, Corbett, Dawes 1998, Davies *et al.* 2000, Deshmukh 1995, Macpherson *et al.* 1995, Nguyen 1992). White (1997) agrees with others cited above in the distribution of calculus but notes that in populations lacking oral hygiene and professional care, calculus is distributed throughout the dentition. Sledzik and Moore-Jansen (1991) found calculus distribution differed between early Historic military samples (Snake Hill) in North America and later ones (Civil war and Indian war soldiers).

Blank *et al.* (1994) further suggest higher concentrations in males than females in their central Maryland, U.S. sample. Strohm and Alt (1998) note that calculus increases with age.

MATERIAL AND METHODS

Dental calculus in ancient Ecuador

Since the early 1970s, the first author has systematically collected data on dental calculus from archaeologically recovered samples of human remains from Ecuador in South America (Ubelaker 1980a, 1980b, 1981, 1983a, 1983b, 1988a, 1988b, 1988c, 1988d, 1990a, 1990b, 1993, 1994, 1997, 2000, 2003, Ubelaker, Newson 2002, Ubelaker, Ripley 1999, Ubelaker, Rousseau 1993). If present, calculus deposits were classified as to size (small, medium or large) and location (buccal or lingual) on all teeth that were present from both the mandible and maxilla. The samples (summarized in *Table 1*) range temporally from Preceramic to modern Historic and originate from both highland and coastal areas. The Prehistoric samples represent the indigenous populations and span the transition to agriculture and increased population density. The Historic samples largely originate from religious establishments in Quito and may include some indigenous peoples but mostly represent individuals of European ancestry.

To examine the issues of calculus distribution framed above in the Ecuadorian data, calculus deposits when present for each tooth were classified as being greater on the buccal side, greater on the lingual side or equal on both sides. Only the 10,351 teeth with calculus present were included in this study. Summary statistics were then generated for each site sample and also for samples grouped by various time periods and geographical locations.

RESULTS

Although some variation was present, the overall pattern of calculus distribution within the Ecuadorian samples was mostly equal on both sides with a slight tendency for larger deposits on the buccal surfaces of most teeth (see *Figures 1a* through *12b*). *Table 1* lists the sample sizes, location and chronology.

The present discussion focuses on those calculus deposits that were unequal on the buccal and lingual sides. In the coastal samples, most of these deposits were larger on the buccal than on the lingual surfaces in both the Preceramic (samples dated 6250–4600 BC, *Figures 1a* and *b*) and the

Late Precontact (samples dated 500 BC–AD 1532, *Figures 4a* and *b).* Coastal samples dated from 3400 to 1500 BC (Early Formative, *Figures 2a* and *b*) and 900 BC to AD 400 (Intermediate Precontact, *Figures 3a* and *b*) displayed greater concentrations on the buccal sides of the maxillary teeth and the lingual sides of the mandibular teeth.

In the highland samples, calculus distribution was about equal on both sides for those dating to the Early Formative (*Figures 5a* and *b*). Inequality was observed in other highland periods (*Figures 6a* through *9b)*. Calculus was greater on the buccal surfaces of maxillary samples (anterior and posterior) and lingual surfaces of the anterior mandibular samples dated between 1000 BC to AD 100 (Intermediate Precontact, *Figures 6a* and *b*). Samples from AD 340 (Late Precontact, *Figures 7a* and *b*) and those from AD 1500 to 1725 (Early Historic, *Figures 8a* and *b)* predominantly displayed a higher frequency of buccal calculus on the maxillary teeth. The mandibular teeth of the Early Historic samples showed a mixed pattern but more buccal deposits on the anterior teeth. Larger deposits were observed on the lingual surfaces of the mandibular teeth in the Late Historic samples (AD 1535–1940, *Figure 9b*). For the maxillary teeth in the highland Late Historic samples, lingual calculus was predominant on the anterior teeth, while buccal calculus was prevalent on the posterior teeth (*Figure 9a*).

Figures 10a through *12b* present summary data for mandibular and maxillary teeth from coastal, highland Prehistoric and highland Historic samples. These figures reveal that for most teeth, calculus was approximately equally present on both tooth surfaces. In those teeth that displayed variation, calculus was present predominantly on the buccal surfaces of the maxillary teeth from the coastal samples (*Figure 10a*), buccal surfaces of the maxillary teeth from the Prehistoric highland samples (*Figure 11a*) and the lingual surfaces of the mandibular teeth from the Historic highland samples (*Figure 12b*).

DISCUSSION

The overall pattern of calculus distribution on the teeth from ancient Ecuador contrasts with that suggested from the modern clinical literature, which reports greater prevalence on lingual than on buccal surfaces of mandibular anterior teeth, but is consistent with the suggestion by White (1997) that in populations of deficient dental hygiene and professional care, calculus is distributed throughout the dentition. While the data presented here show some variation, both temporally and geographically, the overall pattern is not consistent with that observed in the modern clinical record. The predominant pattern on all Ecuadorian samples is equal distribution between the buccal and lingual surfaces. Teeth which show some inequality in calculus distribution reveal a slight preference for the buccal surface in most samples but higher frequencies on the lingual surface in posterior mandibular teeth in prehistoric coastal samples, and maxillary anterior teeth and mandibular canines, premolars and molars in the Historic highland samples. The stronger buccal maxillary pattern of calculus deposition in the coastal samples may reflect dietary influences (higher protein diet due to consumption of fish).

The lingual shift of calculus distribution in the highland Historic samples may be linked to the rise of modern dental hygiene and professional care among these church affiliated groups, or possibly to a change in diet, although the predominant pattern was equal deposition on both sides, even in these samples.

Clearly, any argument for the use of coca in ancient Ecuador based on calculus distribution must consider the pattern documented above rather than the modern clinical data. Although many individuals in this Andean sample likely used coca, it is not clear that such use had any effect on the accumulation and distribution of dental calculus.

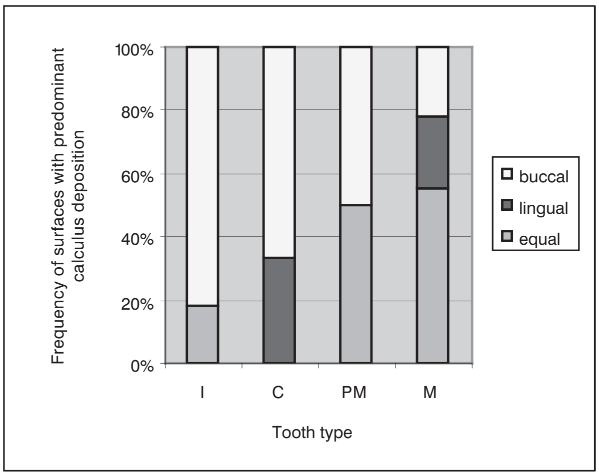

FIGURE 1a. Maxillary teeth from coastal Santa Elena site, Preceramic.

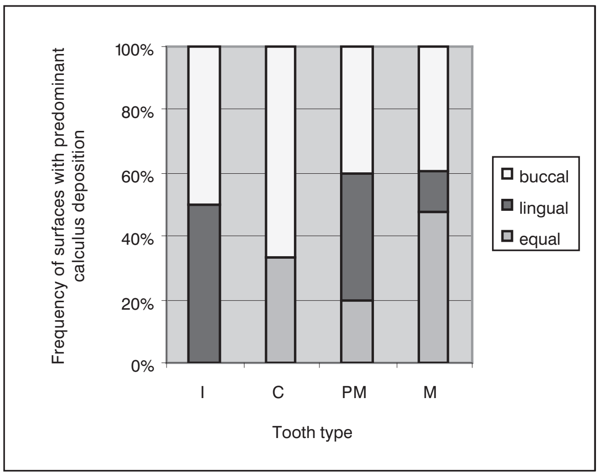

FIGURE 1b. Mandibular teeth from coastal Santa Elena site, Preceramic.

TABLE 1. Chronological sequence of dental samples by period and culture (* coastal sites).

Site	Date	Location	Culture	Number of teeth
	Preceramic			
Sta. Elena	* 6250 – 4600 B.C.	Guayas	Vegas Complex	181
	Early Formative			
Real Alto	* 3400 – 1500 B.C.	Guayas	Valdivia	464
Challuabamba	2100 – 1780 B.C.	Manabi	Bahía	57
	Intermediate Precontact			
Cotocollao	1000 – 500 B.C.	Pichincha	Cotocollao	38
La Libertad (OGSE-46)	* 900 – 200 B.C.	Guayas	Valdivia/Machalilla	155
La Tolita	* 600 B.C. – A.D. 400	Esmeraldas	La Tolita	683
Cumbayá	400 B.C. – A.D. 100	Pichincha	Cumbayá	246
Early Guangala (OGSE-MA-172)	* 100 B.C.	Guayas	Guangala	67
El Azucar	* 200 – 300 B.C.	Guayas	Guangala	67
	Late Precontact			
Chirije	* 500 B.C. – A.D. 500	Manabi	Bahía	28
Ayalán (non-urn)	* 500 B.C. – A.D. 1155	Guayas	Milagro	2,456
La Florida	A.D. 340	Pichincha	Chaupicruz	2,232
Vuelta Larga	* A.D. 700 – 1500	Guayas	Yaguachi	912
Agua Blanca	* A.D. 800 – 1500	Manabi	Manteño	32
Ayalán (urn)	* A.D. 700 – 1730	Guayas	Milagro	481
San Marcos	* A.D. 1200 – 1532	Colonche	Manteño-Guancavilca	745
Mar Bravo	* A.D. 1400 – 1532	Colonche	Manteño-Guancavilca	287
	Early Historic			
Convento de San Francisco				
hallway	A.D. 1500 – 1570	Pichincha	Historic	218
Santo Domingo	A.D. 1500 – 1650	Pichincha	Historic	99
Convento de San Francisco				
strata cut, upper level	A.D. 1540 – 1650	Pichincha	Historic	
strata cut, lower level	A.D. 1580 – 1700	Pichincha	Historic	138
atrium	A.D. 1600 – 1725	Pichincha	Historic	43
	Late Historic			
San Juan de Dios	A.D. 1565 – 1800	Quito	Historic	99
Convento de San Francisco				
church	A.D. 1535 – 1858	Pichincha	Historic	350
superficial collection, lower level	A.D. 1670 – 1709	Pichincha	Historic	92
main cloister	A.D. 1730 – 1858	Pichincha	Historic	56
superficial collection, upper level	A.D. 1770 – 1890	Pichincha	Historic	22
boxes	A.D. 1850 – 1940	Pichincha	Historic	103

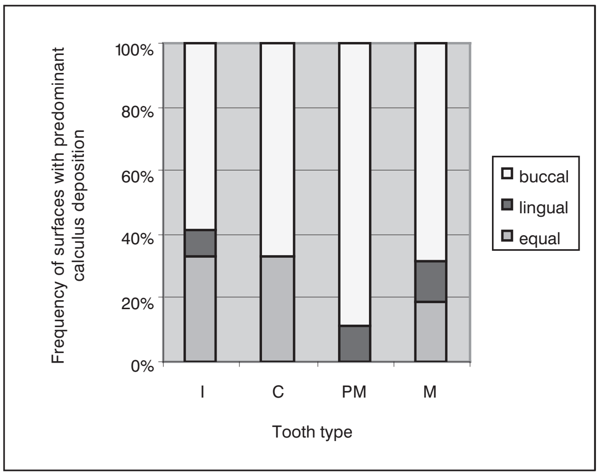

FIGURE 2a. Maxillary teeth from coastal Real Alto site, Early Formative.

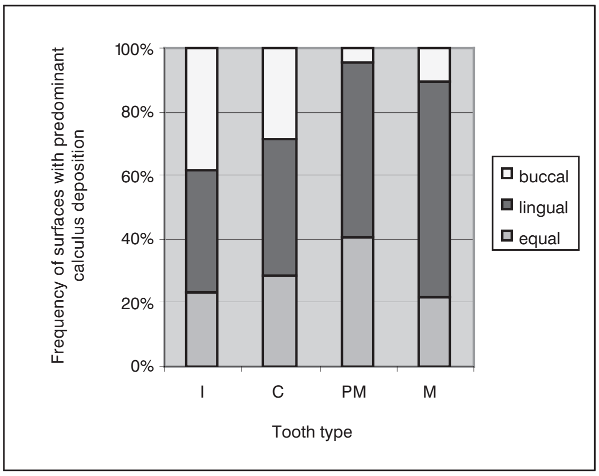

FIGURE 2b. Mandibular teeth from coastal Real Alto site, Early Formative.

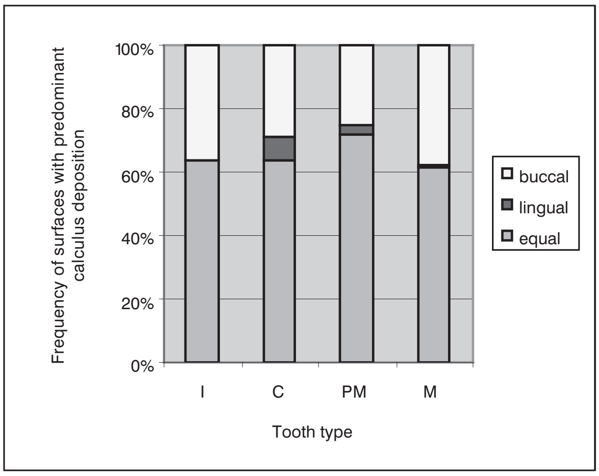

FIGURE 3a. Maxillary teeth from coastal La Libertad, La Tolita, Early Guangala, and El Azucar sites, Intermediate Precontact.

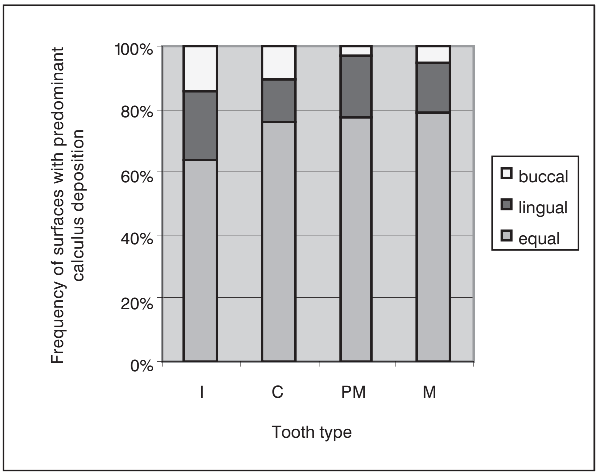

FIGURE 3b. Mandibular teeth from coastal La Libertad, La Tolita, Early Guangala, and El Azucar sites, Intermediate Precontact.

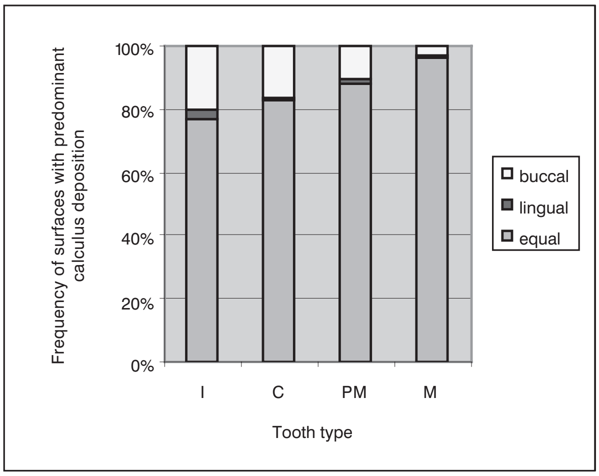

FIGURE 4a. Maxillary teeth from coastal Chirije, Ayalán, Vuelta Larga, Agua Blanca, San Marcos, and Mar Bravo sites, Late Precontact.

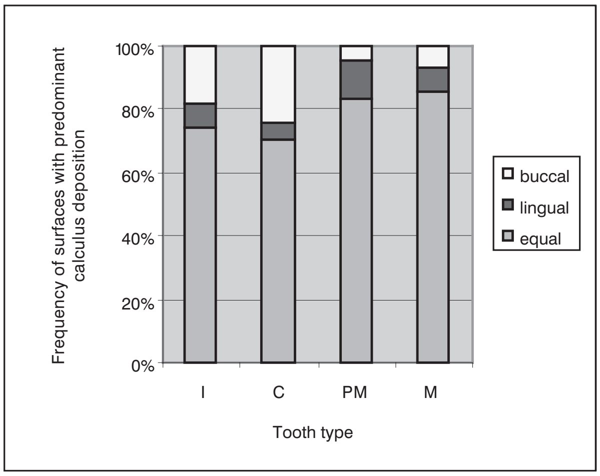

FIGURE 4b. Mandibular teeth from coastal Chirije, Ayalán, Vuelta Larga, Agua Blanca, San Marcos, and Mar Bravo sites, Late Precontact.

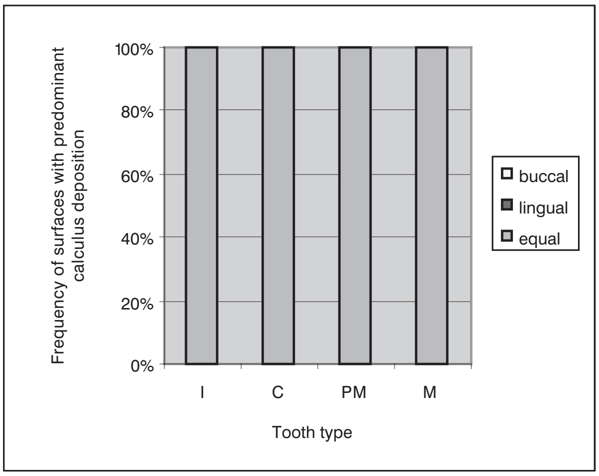

FIGURE 5a. Maxillary teeth from Prehistoric Highland Challuabamba site, Early Formative.

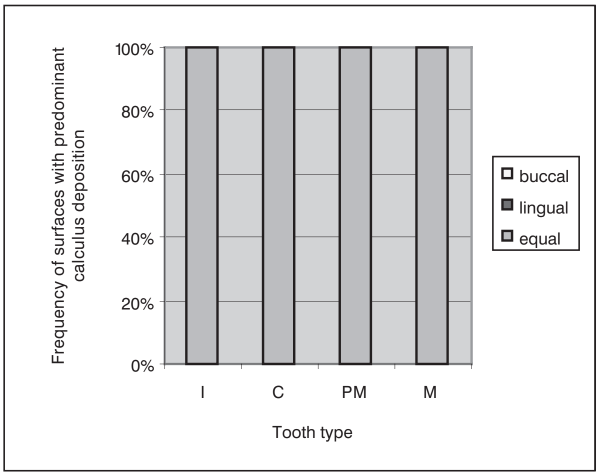

FIGURE 5b. Mandibular teeth from Prehistoric Highland Challuabamba site, Early Formative.

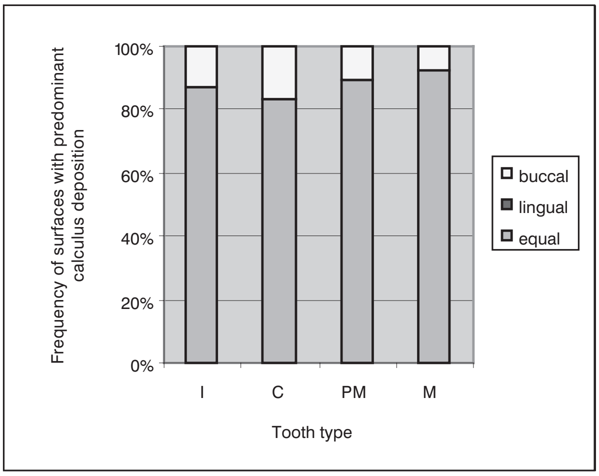

FIGURE 6a. Maxillary teeth from Prehistoric Highland Cotocollao and Cumbayá sites, Intermediate Precontact.

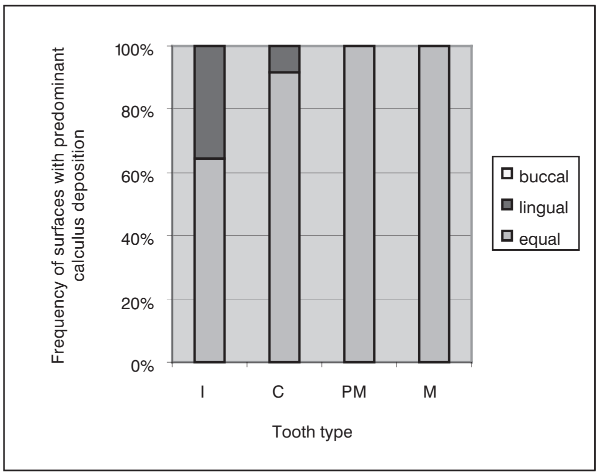

FIGURE 6b. Mandibular teeth from Prehistoric Highland Cotocollao and Cumbayá sites, Intermediate Precontact.

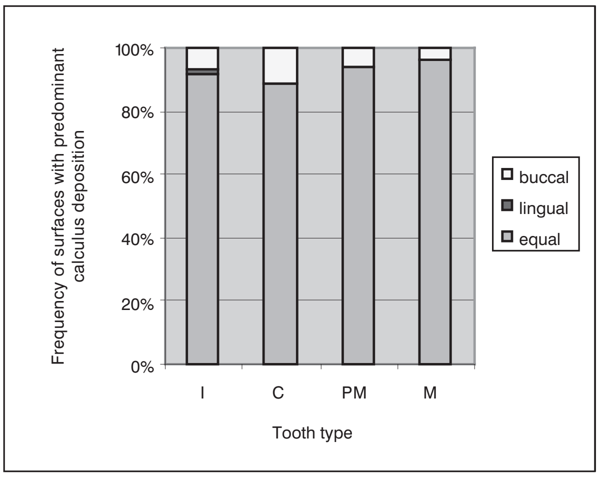

FIGURE 7a. Maxillary teeth from Prehistoric Highland La Florida site, Late Precontact.

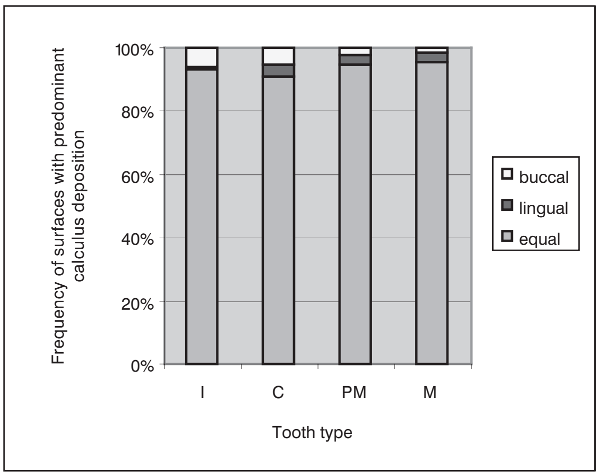

FIGURE 7b. Mandibular teeth from Prehistoric Highland La Florida site, Late Precontact.

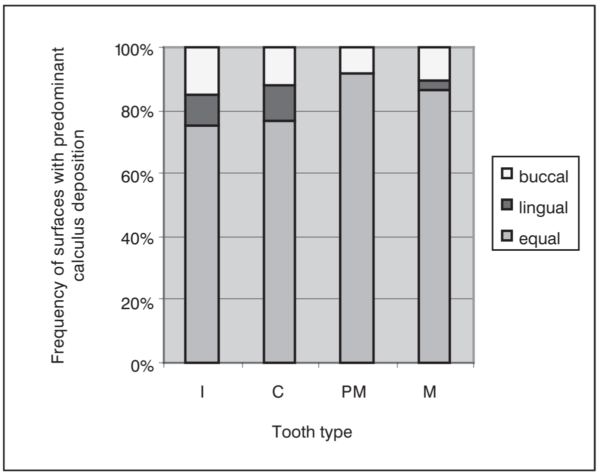

FIGURE 8a. Maxillary teeth from Historic Highland Convento de San Francisco and Santo Domingo, Early Historic.

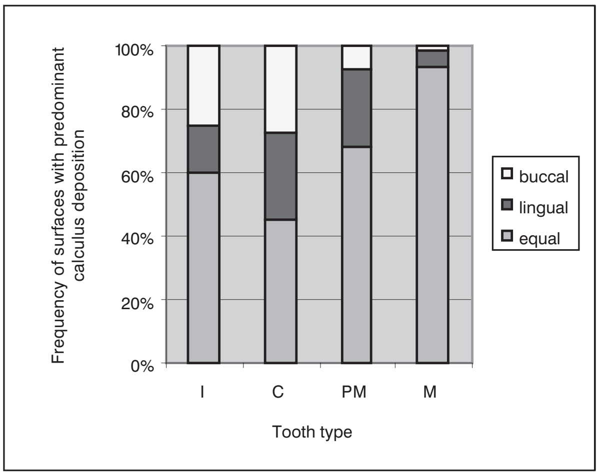

FIGURE 8b. Mandibular teeth from Historic Highland Convento de San Francisco and Santo Domingo, Early Historic.

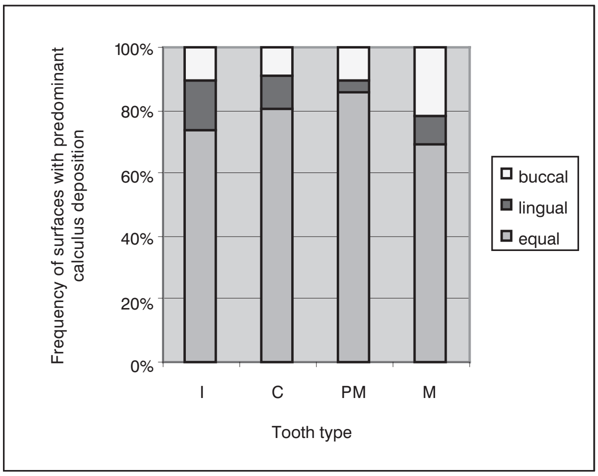

FIGURE 9a. Maxillary teeth from Historic Highland Convento de San Francisco and San Juan de Dios, Late Historic.

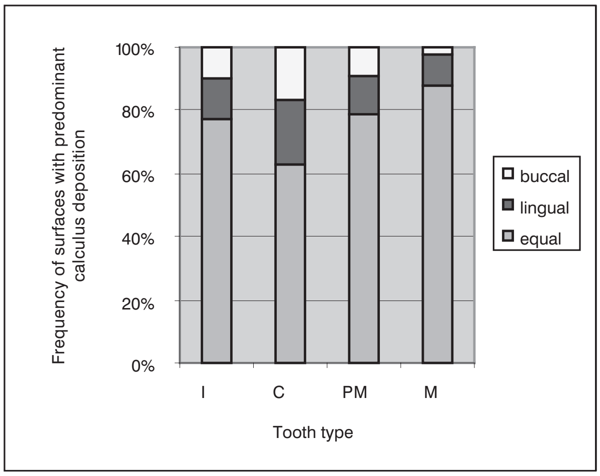

FIGURE 9b. Mandibular teeth from Historic Highland Convento de San Francisco and San Juan de Dios, Late Historic.

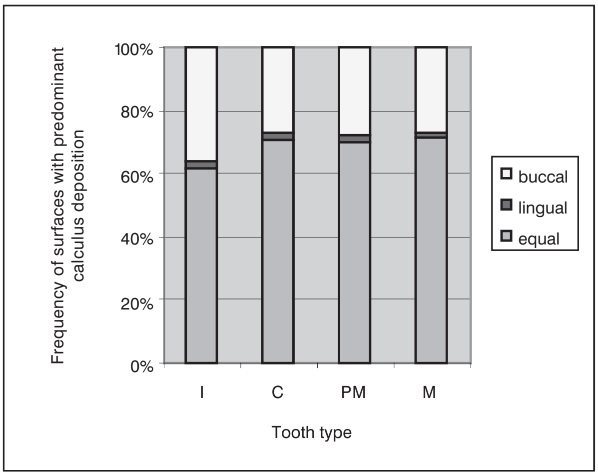

FIGURE 10a. Maxillary teeth from coastal Ecuador, Preceramic to Late Precontact.

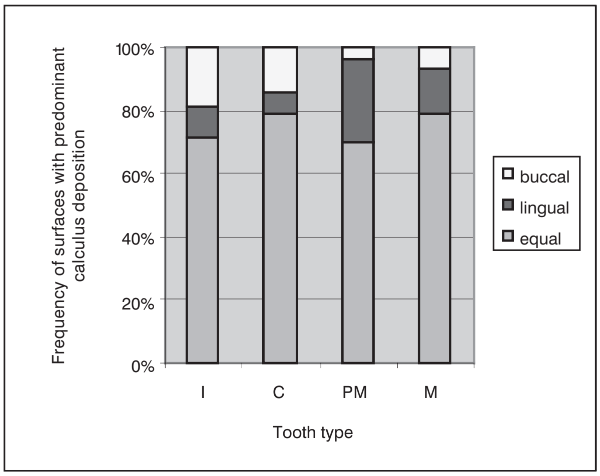

FIGURE 10b. Mandibular teeth from coastal Ecuador, Preceramic to Late Precontact.

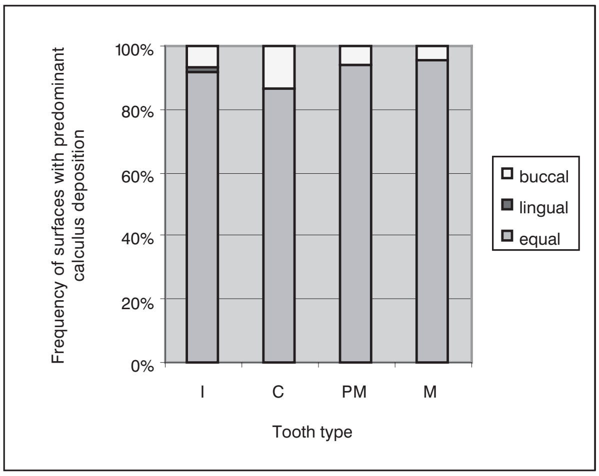

FIGURE 11a. Maxillary teeth from Prehistoric Highland Ecuador, Early Formative to Late Precontact.

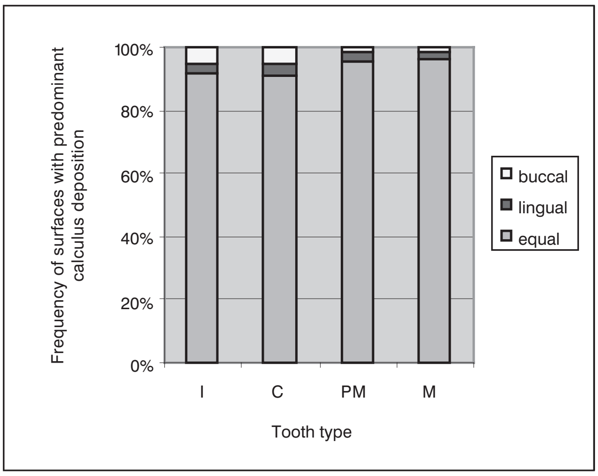

FIGURE 11b. Mandibular teeth from Prehistoric Highland Ecuador, Early Formative to Late Precontact.

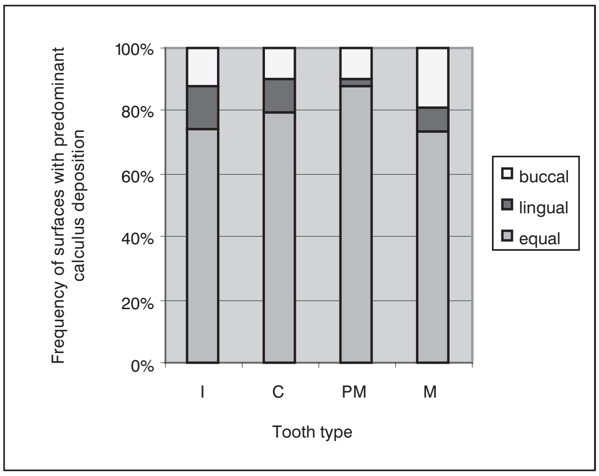

FIGURE 12a. Maxillary teeth from Historic Highland Ecuador, Early Historic to Late Historic (European specimens).

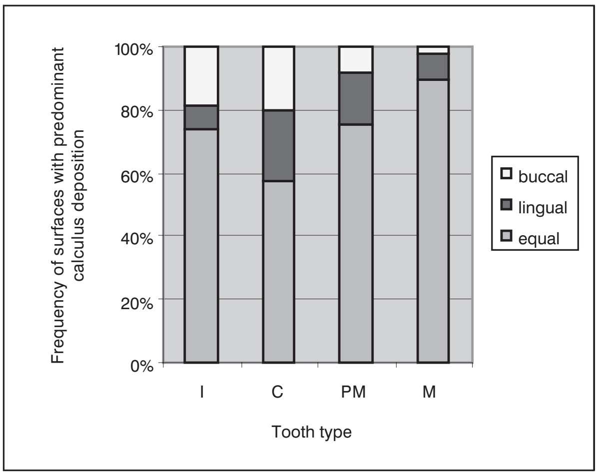

FIGURE 12b. Mandibular teeth from Historic Highland Ecuador, Early Historic to Late Historic (European specimens).

REFERENCES

ALEXANDER A. G., 1971: A study of the distribution of supra and subgingival calculus, bacterial plaque and gingival inflammation in the mouths of 400 individuals. *J. of Periodontology* 42: 21–28.

BAELUM V., 1987: Pattern of periodontal breakdown in adult Tanzanians. *Scandinavian J. of Dental Research* 95, 3: 221–228.

BAER P. N., WHITE C. L., 1966: Studies on experimental calculus formation in the rat IX. The effect of varying the protein and fat content of the diet on calculus deposition and alveolar bone loss. *J. of Periodontology* 37: 113–117.

BARNETT M. L., CHARLES C. H., GILMAN R. M., BARTELS L. L., 1989: Correlation between Volpe-Manhold calculus index scores and actual calculus area. *Clinical Preventive Dentistry* 11, 6: 3–5.

BLANK L. W., RULE J. T., COLANGELO G. A., COPELAN N. S., PERLICH M. A., 1994: The relationship between first presentation and subsequent observations in heavy calculus formers. *J. of Periodontology* 65, 7: 750–754.

CANIS M. F., 1978: A study on modes of calculus attachment to tooth surfaces. School of Graduate Dentistry, Boston University, Boston, Thesis. 58 pp.

CORBETT T. L., DAWES C., 1998: A comparison of the site-specificity of supragingival and subgingival calculus deposition. *J. of Periodontology* 69, 1: 1–8.

DAMEN J. J. M., TEN CATE J. M., 1989: Calcium phosphate precipitation is promoted by silicon. In: J. M. ten Cate (Ed.): *Recent Advances in the Study of Dental Calculus*. Pp. 105–114. IRL Press, Oxford.

DAVIES R. M., ELLWOOD R. P., VOLPE A. R., PETRONE M. E., 2000: Supragingival calculus and periodontal disease. *Periodontology* 15: 74–83.

DAWES C., MACPHERSON L. M. D., 1993: The distribution of saliva and sucrose around the mouth during the use of chewing gum and the implications for the site-specificity of caries and calculus deposition. *J. of Dental Research* 72, 5: 852–857.

DESHMUKH B. P., 1995: Quanticalc assessment of the therapeutic benefits provided by softscale calculus scaling gel and determination of pH changes in the diseased gingival sulcus