# Prevalence of Carious and Non-carious Cervical Lesions in Archaeological Populations from North America and Europe

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## ABSTRACT

*Purpose:* The purpose of this study was to report the prevalence of carious and non-carious cervical lesions in the teeth of five archaeological populations. A secondary purpose was to report the association between age, gender, diet, tooth wear, carious cervical lesions, and non-carious cervical lesions.

*Materials and Methods:* One hundred and four archaeological specimens from subjects originating from five distinct geographical areas were examined to detect the presence of carious cervical lesions, non-carious cervical lesions, and tooth wear. Data were tabulated and statistics used to describe prevalence and non-causal associations.

*Results:* Carious cervical lesions were prevalent in all populations except among Labradoreans, while non-carious cervical lesions were found predominantly in Mexicans. The authors found no association between non-carious cervical lesions and age, gender, and diet in any of the populations. Tooth wear was noted in all populations, but the highest rates of severe wear were noted among the Labradoreans and New Mexicans. Age was associated with tooth wear in all populations except Ohioans. There was no association between tooth wear and non-carious cervical lesions.

*Conclusions:* The prevalence of carious cervical lesions among the five archaeological populations studied ranged from 0 to 65%. Non-carious cervical lesions were not prevalent among these populations, being found predominantly in Mexicans (26%).

## CLINICAL SIGNIFICANCE

Historically, carious and non-carious cervical lesions can be found in individuals with no access to modern oral hygiene tools. The findings of this study are not conclusive, however, as the associations described are not causal.

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## INTRODUCTION

Although many studies have described dental pathologies among archaeological populations, only a few report specifically on the prevalence of carious and non-carious cervical lesions.[1–7] The etiology of carious lesions is relatively well-established. Dental caries, one of the most prevalent chronic diseases of people worldwide, is primarily caused by a complex interaction over time between acid-producing bacteria and fermentable carbohydrates on the dental surface. Many host factors, including dental biofilm (plaque) and saliva, also play a role in the establishment and progression of dental caries. Risk for caries includes physical-, biological-, environmental-, behavioral-, and lifestyle-related factors such as high numbers of cariogenic bacteria, inadequate salivary flow, insufficient fluoride exposure, carbohydrate-rich diet, poor oral hygiene, and poverty.[8–11] Additionally, the presence and rapid progression of caries in the cervical area of teeth implicate occlusal loading forces which, during function and parafunction, create stress concentration in the cervical region, thus becoming an important mechanism and cofactor in the etiology and progression of root caries.[12–15]

The etiology of non-carious cervical lesions is controversial. Similarly to dental caries, most evidence points to a multifactorial etiology.[13,16–31] Perhaps because of conflicting terms used in key dental publications of the early 20th century,[32,33] many clinicians still adhere to the dated concept that toothbrush/dentifrice abrasion is the sole cause of the formation of non-carious cervical lesions. Others contend that non-carious cervical lesions are caused by what has been incorrectly called *erosion*.[19,31,34] *Corrosion* would be a more accurate term to describe the physical mechanism defined as chemical degradation.[15,35]

Unfortunately, until the 1960s, dentistry had neglected the mechanism of stress from occlusal loading forces during function (mastication and deglutition) and/or parafunction as contributing factors in the etiology of non-carious cervical lesions.[12,14,15,36–50] It is now believed that these lesions can also result from cyclic occlusal loading whereupon the resulting stress produces microfracture of the hydroxyapatite crystals in the cervical region of teeth where stress is most frequently concentrated. The progression of these multifactorial lesions is frequently exacerbated by toothbrush/dentifrice abrasion and by corrosion.[20,36,38,40,42,45,51–53]

This investigation was prompted by a lack of information on the presence of carious and non-carious cervical lesions among early Neolithic and more recent archaeological populations. Information on the presence of such conditions among these populations may provide insight into their etiology. Therefore, the purpose of this article was to report the prevalence of non-carious and carious cervical lesions in the teeth of archeological specimens from humans dating from AD 650 to the late 19th century. A secondary aim of the article was to report on the association between age, gender, diet, tooth wear, carious cervical lesions, and non-carious cervical lesions.

## MATERIALS AND METHODS

### Archaeological Sample

The data collection phase of this study was conducted in the Peabody Museum of Archaeology and Ethnology at Harvard University, Cambridge, MA, USA. Founded in 1866, the Peabody Museum is one of the oldest museums in the world devoted to anthropology and houses one of the most comprehensive records of human cultural history in the Western Hemisphere. With the approval of the museum curator, human crania and mandibles of subjects from five distinct geographical regions were screened. These specific populations were selected because, among the many osteological collections housed by the museum, they contained at least 10 well-dated adult skull specimens. Specimens with a total of 10 or more teeth were included in this study.

A total of 104 subjects (crania and mandibles) were included in the study. There were 23 subjects from Labrador, Canada; 23 from the region of Merida, Mexico; 13 from the Mimbres Valley sites in New Mexico; 23 from Madisonville, OH, USA; and 22 from Mistihalj, Montenegro. Three trained and calibrated examiners independently inspected the dentitions of each of the 104 subjects. The primary outcomes were the presence of occlusal and incisal wear (tooth wear) as well as carious and non-carious cervical lesions. As secondary outcomes, information on the subjects' age, gender, and diet was also obtained (see criteria below).

Each cranium and mandible was handled with latex gloves and examined with a handheld magnifying lens. A small, pointed wooden stick was used to explore hard tissue lesions. Guidelines established by the museum prevented any markings or debridement of the dental and osseous hard tissues being made on any of the skeletal remains by the dental examiners. Photographs were obtained with a Yashica II Dental Eye Camera from representative specimens.

**Age Criteria**

The age of each subject was determined based on the stage of tooth eruption, degree of epiphyseal fusion of long bones, condition of the pubic and sacroiliac joints, degree of occlusal wear of both posterior and anterior teeth, and degree of fusion of the cranial sutures following protocols previously described.[54] Age data were tabulated in three categories: (1) subjects younger than 20 years, (2) adult subjects between 20 and 35 years, or (3) adult subjects older than 35 years.

**Time Period Criteria**

The time period of each skeleton was established based on the archaeological context from these various sites, strata of the soil in which the burials were interred, and locations of the excavation sites. In the population from Labrador, it is estimated that the Native American subjects were precontact and therefore more than 500 years old. All of the Mexican samples came from a cemetery in Merida, Northern Yucatan, Mexico, which dates back to the late 19th century. Evidence suggests that these individuals were likely of mixed ethnic background and were at least partially Mayan in heritage.[55] The New Mexican Native American human remains were from the Mimbres Valley sites of the Swarts Ruin and Harris Village dating to the Late Pit House period of AD 650–950. The Ohio Native American human remains from Madisonville were attributed to the "Fort Ancient Tradition" date to AD 1275–1640. The European subjects from the site of Mistihalj, Montenegro dated back to the 15th and 16th centuries.

**Diet Criteria**

Diet information was thoroughly collected from the literature, which considered, among other factors, that the climate and environment of the various regions dictated the composition of their diet. The studied populations were classified as: (1) hunter–gatherers, (2) agriculturists, or (3) consumers of domesticated animals. Corn (maize) was present in the diet of the populations from Mexico, New Mexico, and Ohio.[56–58] Frozen meat, "stinking meat," powdered eggs, and storage caches were means of nutritional insurance among the population from Labrador.[59] The preparation of the food was a significant factor, as the New Mexican, Mexican, and very likely the Ohio populations used mortar and pestle to grind their maize (corn). This method of food preparation could result in severe abrasion of the teeth from particles of stone which became incorporated into the corn as it was prepared.

**Tooth Wear Classification**
Occlusal and/or incisal wear was based on Broca's classification, which divides wear into four categories:[60] (1) early tooth wear, (2) mild tooth wear, (3) advanced tooth wear, or (4) severe tooth wear. A fifth category was also noted when wear was not detected (no wear). The first stage of occlusal and incisal wear was designated as "early wear" when the incisal edges of maxillary and mandibular incisors were found worn and the incisal mamelons were absent. The second stage of wear, termed "mild wear," occurred when the incisal edges of the anterior teeth and the occlusal surfaces of the posterior teeth became affected, thus exposing the dentin. As abrasion/attrition progressed to the third stage of wear, termed "advanced wear," the loss of incisal and occlusal enamel was found with a remaining peripheral rim of enamel. Subsequent wear progressing to the neck of the crown was termed "severe wear."

**Carious and Non-carious Cervical Lesions Classification**
Carious lesions were defined as lesions with rough surface texture, leathery in appearance, with intrinsic dark brown or black dentin discolorations, and obvious cavitation; non-carious lesions were defined as saucer- or notched-shaped lesions with a smooth surface texture, with no obvious cavitation, and occasional extrinsic discoloration from the burial conditions of the subjects, or exogenous stain from food. A precise diagnosis of carious and non-carious cervical lesions would require a complete medical and dental history in addition to a dietary inventory for each individual. Because all of the aforementioned were impossible to determine in the context of this study, assessments of frictional wear manifested as abrasion, the diet based on prevailing indigenous foods, the possibility of ritual mutilation of the teeth, and food preparation common to each geographical group were used as secondary criteria to classify the observed cervical lesions. There was no evidence that any of the groups practiced oral hygiene methods that could have caused abrasion to the dental hard tissues.

**Data Analysis**
As the primary aim of this study was to report on the prevalence and type of carious and non-carious cervical lesions observed in the studied populations, descriptive statistics were used to analyze the data. The unit of analysis for all variables was the subject, as teeth within a subject are not independent observations. Within each population, Pearson's chi-square and Fisher's exact test were used to examine the association between carious cervical lesions, non-carious cervical lesions, tooth wear, gender, age, and diet. Data from the different populations were not pooled for any of the analyses because of the heterogeneous nature of the populations. Data were managed and analyzed using Stata 10 (College Station, TX, USA).

## RESULTS

Representative examples of specimens are shown in Figures 1–6. Demographic, descriptive, and prevalence data are presented in Table 1.

Most of the subjects were males in all populations except for the Labradoreans, which were predominantly (70%) females. The subjects' age distribution was not significantly different across populations ($p = 0.473$), with most subjects being adults between 20 and 35 years. Cervical carious lesions were common, and found in all groups except in the high-latitude population of Labrador. Cervical caries prevalence was low among the Montenegro subjects (18%), but high among the populations from Mexico (52%), New Mexico (54%), and Ohio (65%). These caries rates were significantly different, with the populations from Mexico, New Mexico, and Ohio having significantly higher caries rates than the populations from Labrador and Montenegro. Montenegro subjects also had significantly more caries rates than

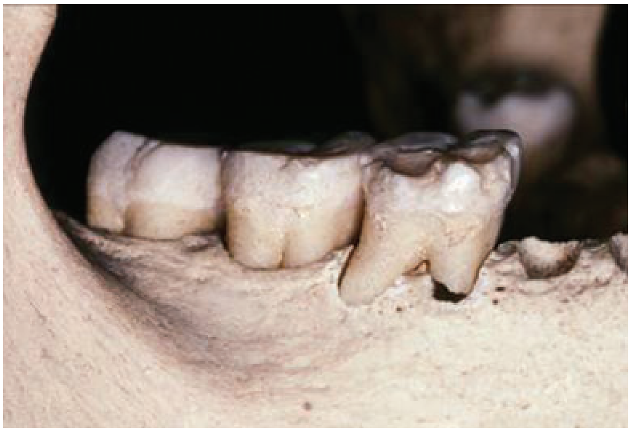

*Figure 1. Advanced tooth wear in a typical Labradorean dentition with neither carious nor non-carious cervical lesions. Copyright 2009 President and Fellows of Harvard College PMAE Number 92-2-10/47992.0.*

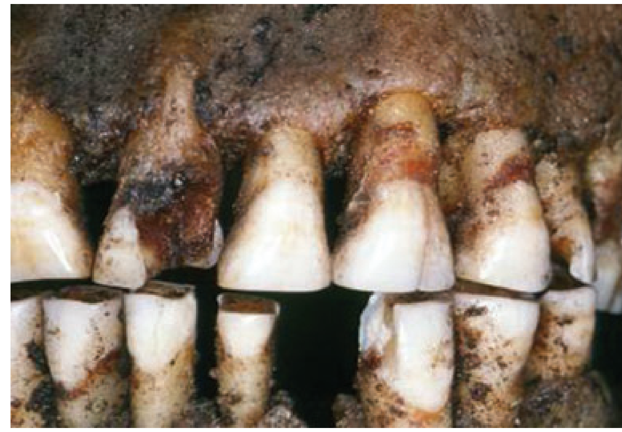

*Figure 2. Non-carious cervical lesions on the maxillary left canine and first premolar, and cervical caries lesion on the maxillary left central incisor (extending to distoincisal line angle) in a New Mexican male dating to AD 650–950. Copyright 2009 President and Fellows of Harvard College PMAE Number 27-11-10/96495.0.*

*Figure 3. Non-carious (mesial aspect) and carious (distal aspect) cervical lesions on a maxillary right first molar in a New Mexican male. Copyright 2009 President and Fellows of Harvard College PMAE Number 27-11-10/96495.0.*

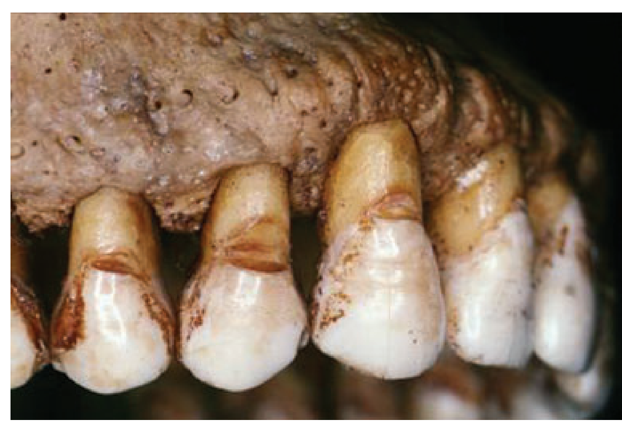

*Figure 4. Non-carious cervical lesions on the maxillary right first and second premolars, and canine from a Mexican male from the late 19th century. Copyright 2009 President and Fellows of Harvard College PMAE Number 27-7-20/61072.0.*

Labrador subjects, which had none. Non-carious cervical lesions were rare in the populations studied, and found only in one subject from New Mexico (8%) and six subjects from Mexico (26%). None of the populations showed association between carious cervical lesions and age or gender, and between non-carious cervical lesions and age or gender ($p > 0.1$). Diet was excluded from this and the other analyses because it was a constant for each sample.

Tooth wear was noted in all populations. Notably, the groups from Labrador and New Mexico

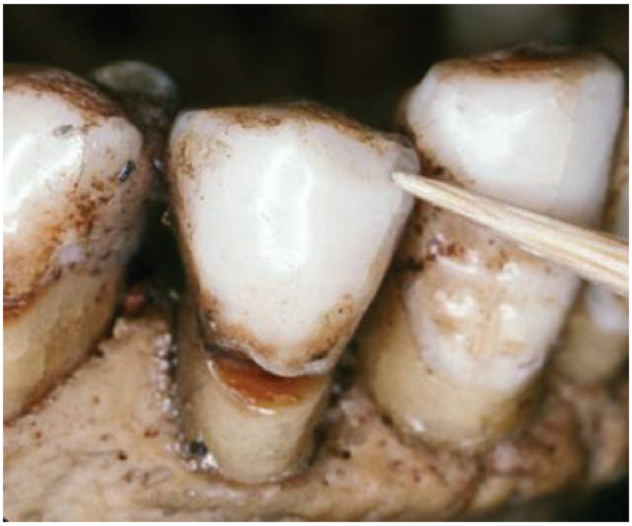

*Figure 5.* *A single non-carious cervical lesion on a mandibular right first premolar of the same Mexican as in Figure 4. The wood pointer designates a wear facet. Copyright 2009 President and Fellows of Harvard College PMAE Number 27-7-20/61072.0.*

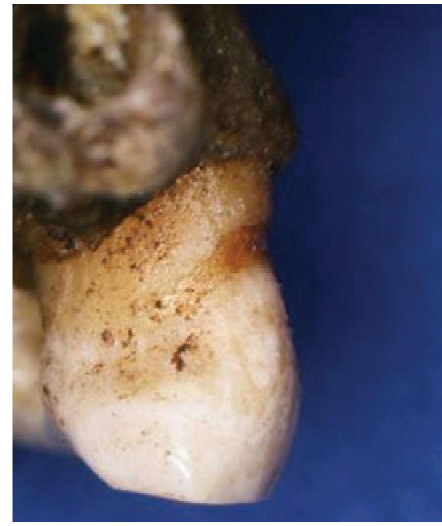

*Figure 6.* *A non-carious cervical lesion and wear facet on a maxillary right canine of a New Mexican male as dating to AD 650–950. Copyright 2009 President and Fellows of Harvard College PMAE Number 27-11-10/96495.0.*

**TABLE 1. POPULATIONS' CHARACTERISTICS AND PREVALENCE OF CARIOUS AND NON-CARIOUS CERVICAL LESIONS, AND TOOTH WEAR (NUMBER OF TEETH PRESENT WAS ≥10 PER SUBJECT).**

| Ethnic group | Labrador | Mexico | New Mexico | Ohio | Montenegro | Total |
|---|---|---|---|---|---|---|
| Time period | Older than AD 1500 | Late 19th century | AD 650–AD 950 | AD 1275–AD 1640 | 15th and 16th centuries | AD 650–late 19th century |
| *N* (subjects) | 23 | 23 | 13 | 23 | 22 | 104 |
| Gender (% males) | 30 | 61 | 77 | 52 | 68 | 56 |
| Age *n* (%) | | | | | | |
| <20 years old | 0 | 2 (9) | 1 (8) | 0 | 0 | 3 (3) |
| 20–35 years old | 12 (52) | 14 (61) | 8 (61) | 15 (65) | 12 (56) | 61 (59) |
| >35 years old | 11 (48) | 7 (30) | 4 (31) | 8 (35) | 10 (45) | 40 (38) |
| Diet* | HG | A | A, HG | A, HG | D, A | |
| Carious† *n* (%) | 0[c] | 12 (52)[a] | 7 (54)[a] | 15 (65)[a] | 4 (18)[b] | 38 (36) |
| Non-carious *n* (%) | 0 | 6 (26) | 1 (8) | 0 | 0 | 7 (6.7) |
| Wear *n* (%) | | | | | | |
| None | 0 | 2 (9) | 0 | 0 | 1 (5) | 3 (3) |
| Early | 0 | 2 (9) | 0 | 0 | 1 (5) | 3 (3) |
| Mild | 4 (17) | 9 (39) | 1 (8) | 10 (43.4) | 10 (45) | 34 (33) |
| Advanced | 5 (22) | 9 (39) | 6 (46) | 10 (43.4) | 4 (18) | 34 (33) |
| Severe | 14 (61) | 1 (4) | 6 (46) | 3 (14) | 6 (27) | 30 (29) |

*A = agriculturists (maize, agriculturally grown grains); D = domesticated animals; HG = hunter–gatherers.
†Different superscript letters indicate statistically significant difference between rates.

presented high prevalence of severe wear (61 and 46% of the subjects, respectively). Only a few subjects presented no wear, while the majority of the samples presented mild and advanced wear.

There was no association between tooth wear and gender in any of the populations ($p > 0.05$), but age was significantly associated with tooth wear in most populations ($p < 0.02$). The only exception was the population from Ohio, which showed no significant association between tooth wear and age ($p = 0.25$).

Finally, there was no association between non-carious cervical lesions (dependent variable) and tooth wear in the populations from Mexico ($p = 0.69$) and New Mexico ($p = 0.53$), the only two populations where non-carious cervical lesions were found.

## DISCUSSION

The present study is one of few reporting prevalence of tooth wear, and carious and non-carious cervical lesions among various archaeological populations.[1–3,7] The study of carious and non-carious lesions in early Neolithic and more recent archaeological populations may provide insight into the etiology of these conditions. This study shows that the prevalence of carious cervical lesions and tooth wear was high among the subjects studied, with a few exceptions. Although non-carious cervical lesions were found in two of the five populations, their prevalence was low and they were not significantly associated with tooth wear. These results cannot, however, be interpreted as conclusive, because prevalence can substantially influence the strength of the association.

Cervical caries were found in four of the five groups, whereas non-carious cervical lesions were found in two of the five groups. In the populations studied, modern hygiene practices can be precluded as an etiologic factor in the formation of the detected hard tissue lesions because they were not used among any of these subjects. In order to determine the etiology of non-carious cervical lesions in subjects who had never been exposed to toothbrush/dentifrice abrasion, various factors such as occlusal and incisal frictional wear (which lead to cervical stress), caries, and diet (composition and preparation of food) were noted. All of the aforementioned were considered because they do have an effect, or a relationship, in the formation of these enigmatic lesions. Among the factors, diet and preparation of the food appear to be important because these were similar among the Mexican and New Mexican groups with non-carious cervical lesions.

The differential wear rate of the teeth among the groups could also be an important factor in the etiology of non-carious cervical lesions. Rapid wear would flatten the occlusal table, decrease the crown/root ratio, and distribute forces over a wider area, thus creating less stress to the cervical region of the occluding teeth. This hypothesis has been demonstrated in a study by Wang and colleagues.[61] In this photoelastic study, by applying 2 kg (4.4 lb) of vertical force on a tooth, it was found that the distal inclined planes or slopes of cusps and lingual inclined planes or slopes of the buccal cusps received the greatest force on mandibular molars. The magnitude of the stress increased considerably when the occlusion plane was flat because of a change in the distribution of the force, while the total force is the same. A vertical force contacting an inclined surface is resolved into a force normal to the surface and one parallel to the surface. As the incline becomes horizontal, the normal force increases and the parallel force decreases, but the total force is the same. The change in the direction of the stress from occlusion results in less stress in the cervical region.

For most groups, age was significantly associated with tooth wear. It is unclear why age was not significantly associated with tooth wear in the Ohio population, whose subjects had mostly mild and advanced tooth wear. Advanced tooth wear among the precontact subjects from Labrador was likely caused by the cultural practice of chewing hides to soften the skin of seals for clothing, and chewing bones to extract calcium.[62] One possible reason why non-carious cervical lesions were not observed in this group could be because of the short crown/root ratios as aforementioned. The lack of exogenous acidic foods in their diet would prevent the genesis of non-carious cervical lesions (corrosion/abfractions), while the lack of fermentable carbohydrates in their diets appears to be a significant factor in precluding caries (biocorrosion/abfractions) from occurring at these specific sites. Furthermore, the high-latitude Labrador group consumed primarily marine mammals, fish, and shellfish, supplemented by berries, nuts, and perhaps some roots as seasonally available resources.

The higher percentage of advanced and severe wear among the New Mexican population (92%), the oldest group examined, in contradistinction to the lesser wear found in the more recent Mexican population (43%), may have been caused primarily by differences in food production and processing. In particular, the composition of the stone used to make the metates (ground stones used to process foods in Mesoamerican cultures) may be a factor. Sandstone, a more abrasive material, was readily available in New Mexico, whereas limestone and coral were present in the Merida, Yucatan region of Mexico. All of these stones would easily find their way into the cornmeal and render the meal highly abrasive.[63] Because greater tooth wear was more frequently found in the New Mexicans using sandstone, as compared to the Mexicans, then, as observed, one would expect fewer non-carious cervical lesions among the New Mexicans because the crown/root ratio would be rapidly diminished. Furthermore, the loss of occlusal anatomy would also eliminate horizontal forces to the teeth, reducing stress to the cervical region and becoming a protective factor for the development of cervical lesions.[64]

Non-carious cervical lesions were noted in the Mexican and New Mexican populations. The Mexican group had access to citrus fruits that were indigenous to this area as well as acidic tomatoes, which can hypothetically explain the substantially higher number (26%) of non-carious cervical lesions compared with the New Mexican group (8%). Furthermore, fermented grain used by the Mexicans would have produced an acidic environment, thus fostering the formation of the non-carious stress-induced lesions.

The highest caries rate among the studied populations (65%) was inexplicably found among the Fort Ancient population from Ohio who were both hunter/gatherers and agriculturists, and whose primary cariogenic food was corn. Their lack of acidic food appears to have accounted for the absence of non-carious cervical lesions. The New Mexicans from the Mimbres Valley had the second highest caries prevalence (54%), very possibly because of their consumption of sugar cane.[55,65] Of the five groups, only the Labradoreans being primarily hunter/gatherers did not consume any significant quantity of fermentable carbohydrates, which may help explain why they were caries free.

Montenegrans of the 15th century were agriculturists with signs of vigorous mastication indicated by the advanced wear of their teeth. The low carious cervical lesions rate found in this group (18%) suggests the consumption of less cariogenic carbohydrates, such as wheat, barley, and oats. Animal protein was likely also a substantial portion of the diet. The absence of non-carious cervical lesions may be attributed to the lack of highly acidogenic foods.

Although all subjects in this study had at least 10 teeth, this report does not include the exact number of teeth, nor the number of lesions in each subject. In many instances, teeth were missing because of antemortem or postmortem tooth loss. The objective of this preliminary archaeological study was to investigate the presence of carious and non-carious cervical lesions among populations where the use of modern dental hygiene tools was precluded. Because of the cross-sectional nature of the study, causal relationships are precluded from the conclusions. Additionally, archaeological studies may have limited generalizability because: (1) the specific subjects studied might not represent the entire population from which they were a part of, and (2) data on most independent variables (subject's age, time period, diet) are not easy to estimate precisely.

Future studies of larger samples are suggested to further evaluate the mechanisms of stress and corrosion as well as dietary factors involved in the etiology of hard tissue lesions among archaeological populations.

## CONCLUSIONS

Based on the data presented, the following can be concluded:

1. The prevalence of carious cervical lesions among the five archaeological populations studied ranged from 0 to 65%.
2. Non-carious cervical lesions were not prevalent among the populations studied, being found predominantly (26%) in Mexicans from the late 19th century.

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