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Patterns of Association Between Oral Health Status and Subsistence: A Study of Aboriginal Skeletal Populations from the Tennessee Valley Area

Maria Ostendorf Smith
University of Tennessee - Knoxville

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To the Graduate Council:

I am submitting herewith a dissertation written by Maria Ostendorf Smith entitled "Patterns of Association Between Oral Health Status and Subsistence: A Study of Aboriginal Skeletal Populations from the Tennessee Valley Area." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Anthropology.

William M. Bass, Major Professor

We have read this dissertation and recommend its acceptance:

Richard Jantz, Charles Faulkner, Richard Jendrucko

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

PATTERNS OF ASSOCIATION BETWEEN ORAL HEALTH STATUS AND SUBSISTENCE: A STUDY OF ABORIGINAL SKELETAL POPULATIONS FROM THE TENNESSEE VALLEY AREA

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Maria Ostendorf Smith
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ABSTRACT

The purpose of this study is to identify subsistence associated differences in caries, periodontal disease and attrition between two aboroginal skeletal samples from the Tennessee Valley area. The hunter/gather sample employed in this study dates from the Archaic period (6000-500 B.C.) and is composed of individuals from the Eva (6BN12), Cherry (84BN74) and Anderson (40WM9) sites. The Mississippian Dallas focus (1300-1500 A.D.) site of Toqua (40MR6) practiced maize agriculture.

Contrasts in caries frequency, location on the tooth, and distribution along the tooth row were readily apparent. Cervical caries in the posterior tooth row characterized the Archaic sample. The pattern is attributed to the combined effects of food impaction and attrition exposing the vulnerable cervix to bacterially produced demineralyzed acids. The Mississippian sample is charaterized not only by a greater caries frequency, but a wide range of locations on the tooth and in the tooth row. Attrition rates differ dramatically between the two samples. This is attributed to the difference in the amount of food processing undertaken between the two subsistence systems. Contrasting anterior to posterior wear gradients were not identified between the Archaic and Mississippian samples. It was hypothesized that in a varied physical environment, such as that inhabited by the Archaic sample, the selective pressure was to use the anterior teeth as a tool. Anterior tooth wear forms indicative of tooth use, differentiated the two samples. A unique wear form in the Mississippian sample was identified.

Periodontal disease involvement between the two subsistence systems showed patterned differences. Bone loss and calculus accumulation are progressive in the Mississippian sample. The accumulation of oral debris concomitant with reduced rate of bone loss is characteristic of the Archaic sample. The about-face is attributed to the mediating influence of attrition in eliminating the sites of food impaction.

Antemortem tooth loss, the ultimate consequence of each of the above mentioned processes, is the significant difference between the loss in the molars only. This higher rate of molar loss in the Mississippian sample is attributed to the combined effects of caries and periodontal disease.

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CHAPTER I

INTRODUCTION

The objective of this dissertation is a descriptive, comparative and interpretive study of caries, periodontal disease, attrition, and antemortem tooth loss on samples of aboriginal skeletal remains from the Tennessee Valley area which represent two different subsistence strategies. In recent years, a select number of studies focusing on patterns of interpopulational differences of caries, periodontal disease, and attrition between human skeletal samples have yielded much useful information, not only in a descriptive capacity, but also as informative auxiliary tools in the reconstruction of diet and subsistence (Hillson, 1979; Smith, 1972; Elzay et al., 1977; Koritzer, 1977). The utility of these three processes in this latter capacity is based on the demonstrable association with the texture and/or carbohydrate content of the diet. Although the anthropological literature is filled with subsistence associated data, especially with respect to caries, the recent research initiatives are novel in their collective examination of the three above-mentioned processes and in their objective of identifying specific subsistence associated patterns. This particular research orientation reflects the current biocultural approach to anthropological data analysis which acknowledges the relationship between biological, cultural, and environmental variables and maintains that biocultural inquiry yields more meaningful information about populations and the nature of their physical and cultural environment than the information gleaned from a traditional descriptive approach (Brown and Streuver, 1973; Buikstra, 1976; Blakely, 1977).

With few exceptions (e.g., Leigh, 1925, 1929), the orientation of the anthropological research specific to caries, periodontal disease, and attrition has favored their examination separately, and although attention paid to these processes displays a long history, their treatment over the years has not been equal. Caries, apart from being readily identified and easily quantified, benefits from a well-established interpretive framework. There is also a large body of epidemiological and anthropological data demonstrating subsistence associated prevalence and incidence. Therefore, the prominence of caries in the anthropological literature is understandable.

Attrition and periodontal disease are progressive and multifactorial processes. These qualities have obscured diet and subsistence associations. Both attrition and periodontal disease have also yet to benefit from the adoption and employment of standardized quantification techniques to facilitate interpopulational comparisons. The focus of attrition studies has only recently included comprehensive evaluation of interpopulational differences (e.g., Hinton, 1981; Molnar, 1968, 1971a). Therefore a modest body of subsistence associated wear rates and patterns is only now becoming available. Unfortunately, in spite of the potential periodontal disease analysis possesses, a feature which will subsequently be elaborated upon, its role in the anthropological literature has been peripheral and will likely remain so until problems associated with its quantification and its relationship with diet and subsistence are evaluated and presented.

Apart from their associations with aspects of diet, the collective examination of caries, periodontal disease and attrition is warranted from their individual and combined capacity to affect masticatory efficiency. Each process is ultimately responsible for antemortem tooth loss, which certainly alters the masticatory environment as well as the environment of each of the disease processes. These are also some data to suggest that alterations in the masticatory environment may have far-reaching consequences for the general health of the individual (Mumma and Quinton, 1970; Kapur and Okubo, 1970; Gejvall, 1972).

Independent of any overall health consequences, the pattern, rate, and etiology of tooth loss certainly can be an important oral health status parameter that may profitably be included in an interpopulation study of the kind here described. Especially since loss has demonstrated interpopulational differences relative to subsistence strategy (Macgregor, 1972; Mayhall, 1977; Anderson, 1965; Elzay et al., 1977).

The comparisons to be made are between a hunting and collecting subsistence strategy from the Archaic Period (6000-500 B.C.) represented by the combined Eva (6BN12) and Cherry (84BN74) sites samples from the western Tennessee Valley and the Anderson (40WM9) site sample from Middle Tennessee (Williamson County) and an agricultural subsistence economy from the Dallas phase Mississippian Period (1300-1550 A.D.) represented by the Toqua site (40MR6) in the eastern Tennessee Valley. The results of these comparisons will serve as a data base for future comparisons with other samples from the Tennessee Valley area as well as provide a data base for hunting/collecting samples and agricultural samples in general.

CHAPTER II

BACKGROUND

Data relevant for a collective examination of caries, periodontal disease, and attrition need to be articulated and evaluated. This includes elaboration and substantiation of statements and problems introduced in the preceding chapter. The present chapter will address these problems as well as undertake a traditional survey of the literature necessary for any descriptive and interpretive study. This includes a brief summary of the orientation of the literature, since these processes have been assessed separately for the greater part of their history; a definition and description of the processes, inclusive of a review of the etiological factors (especially for attrition and periodontal disease, since they are multifactorial); and an examination of the role of diet in the etiology and expression of these processes. The chapter will also include a survey of the patterns of association between subsistence, oral pathology and attrition.

Caries

Definition and Etiology

Dental caries is a progressive demineralization and destruction of the tooth enamel which is the result of local fermentation of retained food sugars by particular bacterial constituents of plaque (Mandel, 1979). It is one of the most widely studied diseases of mankind. Although the modern era of caries research was ushered in by the contributions of W. D. Miller (1883-1904, cited in Mandel, 1979), who demonstrated that the initial lesion was a demineralization brought on by glycolytic fermentation of soluble food carbohydrates by oral bacteria, it was not until the middle of the 1950's that the bacterial etiology of caries was irrefutably established. Orland and associates (1954), using germ-free animal experiments, demonstrated that caries does not occur in the absence of microorganisms. Repetition of germ-free animal experiments verified these findings and now a bacterial etiology is established common knowledge (Keys, 1960; Fitzgerald and keys, 1960). The responsible organism is Streptococcus mutans (Fitzgerald, 1976) although Lactobaccillis and Actinomyces viscosus have been associated in some forms of caries (Mandel, 1979). An impressive body of data demonstrates the caries-conducive properties of S. mutans. This includes the ability to rapidly form demineralizing acids (lactic, formic, and others) from sucrose and glucose (Wood and Critchley, 1966; Critchley et al., 1967; Gibbons and Nygaard, 1968; Newbrun, 1972), the ability to survive in this acid environment (Brown, 1973), the ability to adhere to the tooth surface (Gibbons, 1979), and the ability to store polysaccharides intercellularly for subsequent glycolysis (Gibbons and Socransky, 1962; Gibbons and Van Houte, 1975). Important for a dietary association is the fact that S. mutans appears to be substrate specific. Proliferation and glycolytic activity are dependent on the presence of glucose and sucrose (Bowen and Cornick, 1967; Bowen, 1970; Van Houte, 1964).

The acids produced by glycolytic activity lower plaque pH to at least 5.5 whereupon demineralizing activity becomes possible. The pathogenesis of caries entails the progressive demineralization of the more crystaline components of tooth structure. With the accumulation of intercrystaline voids, mineral loss begins to accelerate. The incipient carious lesion appears as an opaque white or brown spot. In time, the surface enamel loses its hardness and bacterial penetration becomes possible. Eventually a macroscopic cavity becomes apparent (Gray, 1977; Mandel, 1979). The cavity continues to expand as demineralizing activity continues. Ultimately, the pulp cavity is penetrated resulting in necrosis of the tooth.

Diet and Subsistence Associations

The results of epidemiologic and anthropologic studies parallels the laboratory and clinically derived data which demonstrates that caries is associated with the consumption of refined carbohydrates. Epidemiologic studies indicate that the adoption of the Western diet (i.e., a large refined carbohydrate component) universally results in a significant increase in the caries incidence (Barmes, 1977). This pattern is illustrated in the sample in Table 1.

This change has been most vividly illustrated in the various Eskimo data recording the encorporation of processed foods into aboriginal diets. Skeletal data (Pederson, 1949), and data gleaned prior to significant European contact (Stefansson, 1914) indicate that the aboriginal Eskimos were essentially caries free. Data are available from Alaska (Bang, 1964; Collins, 1932; Leigh, 1925; Moorrees, 1957; Rosebury and Waugh, 1939; Waugh, 1930; Costa, 1980), Canada (Mayhall,

TABLE 1

CHANGES IN AVERAGE CARIOSITY PER PERSON WITH THE INTRODUCTION OF REFINED CARBOHYDRATES

Country	% DMFT*/Person for individuals at age twelve by year	
Kenya	.1 (1952)	1.7 (1973)
Uganda	.4 (1966)	1.5 (1972)
Ethiopia	.2 (1958)	1.6 (1975)
Iraq	.7 (1967)	3.5 (1976)
Thailand	.7 (1960)	4.5 (1975)
Vietnam	2.0 (1959)	6.3 (1970)
Fr. Polynesia	.0 (before 1930)	8.0 (1970)
Indonesia	.7 (1973 rural)	3.5 (1972 urban)

*Decayed, missing or filled teeth.

Source: D. E. Barmes, "Epidemiology of Dental Disease," Journal of Clinical Periodontology 4:80-92, 1977.

1975, 1977; Mayhall et al., 1970; Curzon, 1970), and Greenland (Baaregaard, 1949; Pederson, 1938, 1949; Krogh-Lund, 1937) illustrating that the addition of refined carbohydrates to the traditional diets has paralleled the significant increase in caries incidence.

Caries is not unknown among prehistoric peoples; indeed lesions have been identified in various fossil hominids (Brothwell, 1959; Clement, 1956). However, the significance of caries in anthropological studies focuses on its utility as a dietary indicator and as an indicator of subsistence strategy. A high caries incidence has been consistently associated with an agricultural subsistence economy (see Table 2). In marked contrast to the frequencies obtained from agriculturalists (allowing of course for interobserver error), hunting and collecting societies rarely experience caries frequencies greater than 10%. These data are consistent with the hypothesis that an agricultural subsistence strategy makes cariogenic cultigens available in significant enough quantities to effect the caries incidence. The cariogenic cultigen responsible for this increase in the New World is maize (Goldstein, 1948; Buikstra, 1977; Thomas and Larson, 1979).

Other Aspects of Caries Research

The examination of caries in the anthropological literature is of course not limited to documenting incidence. The research orientation has also included the consideration and evaluation of factors which alter the patterns and incidence of caries pertinent to anthropologically meaningful interpretations. For example, relative tooth size,

TABLE 2

REPRESENTATIVE SAMPLE OF CARIES INCIDENCE BY SUBSISTENCE

Population	%/n Teeth	Source
Hunter/Gatherer		
Nubia (Mesolithic)	1.0/-	Armelagos, 1966
Aboriginal (skeletal)	2.3/2653	Steadman, 1939
Aboriginal (skeletal)	1.6/10,561	Campbell, 1925
Aboriginal (living)	4.6/1,844	Campbell, 1938
Aboriginal (Tasmania)	5.3/662	Steadman, 1937
Eskimo (skeletal)	.08/5,920	Pedersen, 1938
Eskimo, Greenland (living)	2.2/17,917	Pedersen, 1938
Eskaleut (skeletal)	.08/2,539	Kaltsky and Kladell, 1943
Aleut (skeletal)	0.0/2,000+	Turner, 1979
Northwest Coast	.42/5,500	Klatsky and Kaldell, 1943
Indian Knoll (3000 B.C.)	.4/912	Herrala, 1961
Old Copper (5600 B.C.)	.4/232	Herala, 1961
Agriculturalists		
Nubia (Meroitic)	12.4/161	Armelagos, 1966
Nubia (X-Group)	11.9/2,526	Armelagos, 1966
Nubia (Christian)	14.8/932	Armelagos, 1966
Egyptian (skeletal)	4.4/2,219	Klatsky and Kaldell, 1943
Europen (skeletal)	96.2/6,104	Klatsky and Kladell, 1943
Neolithic (France)	4.2/6,869	Brabant, 1969
Mongoloid (skeletal)	4.1/826	Klatsky and Kladell, 1943
Mexico (skeletal)	4.64/3,298	Klatsky and Kladell, 1943
Maoris (living)	25.14/887	Saunders and Taylor, 1938

TABLE 2 (CONTINUED)

Population	%/n Teeth	Source
Neolithic Danes	14.2/3,612	Christopherson and Pedersen, 1939
Greek (3,000 B.C.)	12.0/267	Angel, 1944
Greek (2000-150 B.C.)	6.2/2,585	Angel, 1944
Greek (1300 A.D.)	26.5/3,821	Angel, 1944
Greek (living)	15.9/932	Angel, 1944
Gran Quivira NM (skeletal)	15.2/1,817	Swanson, 1974
Mancos Canyon Pueblo (1200 A.D.)	6.5/353	Nickens, 1974
Mancos Canyon Peublo (1200 A.D.)	4.9/266	Robinson, 1976
Midieval England	12.0/790	Tattersall, 1968
Puebloan (Pueblo II)	7.1/225	Ryan, 1977
Puebloan (Pueblo III)	15.0/1,027	Ryan, 1977
Hopi (Pueblo IV)	6.3/1,707	Ryan, 1977

Adapted with modifications after: Christy G. Turner II, "Dental Anthropological Indications of Agriculture among the Jomon People of Central Japan X. Peopling of the Pacific. American Journal of Physical Anthropology 51:619-636, 1979.

cusp number, and the complexity of occlusal fissure patterns has been linked to caries susceptability. Smaller simpler teeth appear to be more caries resistant (Van Reenen, 1966; Grainger et al., 1966; Anderson and Popovich, 1977; Greene, 1972). An evolutionary trend for more caries resistant teeth has been proposed from the trends observed in skeletal samples (Greene, 1972). Other anthropologically meaningful utilization of caries data includes a hypothesis of division of labor among agriculturalists in light of sex difference in caries incidence couples with ethnographic accounts of maize cultivation activity defined by gender (Larson, 1981a, 1981b). Circular caries, a form of caries associated with enamel hypoplasia, has been profitably utilized in a biocultural examination of the interaction of pathology and mortality (Cook and Buikstra, 1979).

Although the articulation of caries data with other data sets has, as illustrated, yielded culturally meaningful results, little attention has been paid to the interaction of caries with processes of the oral cavity like attrition and periodontal disease. This is unfortunate because what data there are concerning the interplay of caries, attrition and periodontal disease suggest that they affect incidence and the relative cariosity of parts of the mouth (e.g., Burns, 1979). This is important because the location of the carious lesion on the tooth surface has altered over time as demonstrated in the fairly complete skeletal series from Britain (Corbett and Moore, 1971, 1973, 1975; Hardwick, 1960; Brothwell, 1959). Prior to the regular consumption of large quantities of refined carbohydrates, the cavity was found almost exclusively interstitially at the cemento-enamel junction. This cervical caries is considered a consequence of periodontal disease by the dental profession because the loss of alveolar support experienced by periodontally involved teeth exposes the vulnerable cervix to demineralizing acids (Carranza, 1979). Continuous eruption experienced by teeth without antagonists as well as teeth experiencing attrition (Taylor, 1963) also exposes the cemento-enamel junction to caries. The suggestion that periodontal disease and attrition affect the pattern and incidence of caries serves to further demonstrate the value of their collective examination.

Periodontal Disease

Definition and Introduction

Properly, the term periodontal disease refers collectively to diseases of the mouth as well as specifically to the common form, periodontitis. Pyorrhea, periclasia, alvealoclasia, and periodontoclasia also refer to periodontitis, but for the sake of clarity and simplicity, as well as by convention, the term periodontal disease will be used here to refer to periodontitis and its synonyms.

Periodontal disease is an inflamatory disease of local origin, caused by plaque, which begins as gingivitis (chronic marginal gingivitis) and progresses to involve the supporting tissues. Bone loss is a late stage in periodontal destruction, accomplished by either alveolar recession or by vertical osseous defects (Carranza, 1979; Prichard, 1965). Both result in the loosening and exfoliation of teeth.

Based on clinical observation, the destruction is slow and cumulative, taking as much as twenty years or more before tooth loss is actualized (Kelly and Van Kirk, 1966).

Apart from simply acknowledging the universal distribution of periodontal disease (Russell, 1960, 1967), some appreciation of its importance as an oral health problem should be established since it is not as well known as caries. Although on a world-wide basis the United States ranks low in prevalence (Russell, 1967), some statistics concerning the dynamics of periodontal disease in America serves to illustrate its importance. According to Kelly and Van Kirk (1966), 75% of American adults, aged 18 to 79, are effected by periodontal disease; of these, one-third experience advanced (i.e., osseous) destruction. The incidence increases with age. According to data gleaned by the National Health Survey, the proportion of adults experiencing periodontal disease at age twenty is 67%; increases to 70% at age thirty-five; and affects a full 80% by age fifty (Kelly and Sanchez, 1972; Kelly and Van Kirk, 1966; Sanchez, 1974). The percentages are even greater in other countries where the onset of periodontal disease apparently occurs at younger ages (Russell, 1971; Sanchez, 1974). This phenomenon is illustrated in Table 3. It has also been shown that periodontal disease is a significant factor in tooth loss after age fifteen. Specifically, approximately half of extractions in the U.S. are due to periodontal disease compared to 38% for caries (Pelton et al., 1954). In fact, Carranza (1979) maintains that all adults will at some time in their lifespan experience periodontal disease induced

TABLE 3

AVERAGE PERIODONTAL INDEX SCORE FOR INDIVIDUALS AGED 40-49[a]

Population	Mean P.I. Score[b]
Baltimore, Md. (white)	1.03
Colorado Springs, Colo. (ages 40-44)	1.04
Alaska, Eskimos (males), aboriginal	1.17
Equador	1.85
Ethiopia	1.86
Baltimore, Md. (blacks)	1.99
Uganda (aged 40-plus)	2.50
Vietnam	2.18
Colombia	2.21
Chile	2.74
Burma	3.58
Jordan	3.96
Trinidad	4.21

[a] Score for an individual is the sum of the per tooth severity scores divided by the number of teeth examined.

[b] Score ranges: Beginning destructive periodontal disease: .7-1.9; established destructive periodontal disease: 1.6-5.0; terminal disease: 3.8-8.0.

Source: A. L. Russell, "The Periodontal Index," Journal of Periodontology 38:585-593, 1967.

destruction. These statistics are significant in light of the concern in America for controlling caries, plaque, for the value of oral health, and in the importance of dental therapeutics.

Unlike caries, periodontal disease does not have a large and readily available interpretive framework upon which to assess the condition of the alveolar bone in a skeletal series vis-à-vis diet and subsistence. There are several reasons why this is true. First, there is acknowledged to be no satisfactory system for scoring periodontal disease (Glickman, 1964; Marshall-Day, 1956). This is true for soft tissue involvement as well as for measures of bone loss. A not inconsequential factor is that the nature of the disease process makes quantification difficult. However, the most important factor appears to be a lack of standardization. A number of systems may and have been employed which vary not only in the assessment of levels of gingival inflammation, but also in the number of variables included in the scoring system. By far, the most epidemiological data have been assembled using the Periodontal Index (Russell, 1956). The National Health Survey data were scored with the PI. Although the Periodontal Index does correspond to the progress of the disease, it tends to underestimate the level of involvement. The focus of the scoring system is the soft tissue component and does not include scoring for oral debris. Only a mouth mirror is used so the bone destruction is not recorded unless roentgenograms are available. The data concerning bone loss are incidental and additional to the scoring system. Therefore, the PI is not a useful scoring system for skeletal samples and the epidemiologic data collected using it is not directly comparable.

Roentgenograms are an important data source for periodontal involvement because they are a permanent objective record of the alveolar support. Although they are the only method available for obtaining crown and root measurements for the clinical sample, they have several serious limitations in utility. First, they are not routinely taken, particularly in the field; and second, improper angulation renders the roentgenogram useless, although techniques to overcome this difficulty have been developed (Bjorn et al., 1969; Schei et al., 1959; Bjorn and Holmberg, 1966). By far the most important difficulty with roentgenograms is the type of bone loss it is intended to measure. The bone loss measurement is the distance between the cemento-enamel junction and the alveolar crest. This quantification of bone loss is reliable in conjunction with soft tissue data and among clinical samples (Schei et al., 1959; Davies and Picton, 1969). However, the extrusion of the worn tooth from the alveolus in order to occlude with its antagonist (Taylor, 1963) may indicate periodontal involvement where none is present. Therefore, for samples characterized by heavy occlusal wear, this measurement by itself is inappropriate. This measurement has been translated to skeletal samples as the Tooth Cervical Height (TCH) (Davies et al., 1969) and is often the only parameter used to measure periodontal destruction (e.g., Lavelle, 1973; Lavelle and Moore, 1969; Davies and Picton, 1969; Curzon, 1976; Koritzer, 1977; Turner, 1979). The use of this measurement without controlling for the other factors contributing to bone loss is ill-advised. Results obtained from this parameter have not always been satisfactory (e.g., Koritzer, 1977;

Turner, 1979). The factors which contribute to loss of alveolar support need to be described and accounted for before reliable interpretation of periodontal disease can be accomplished.

The second reason periodontal disease does not have an adequate interpretive framework is because the focus of epidemiological studies has been on sociological variables affecting periodontal disease rate rather than diet or subsistence relationships or correlations (e.g., Chung et al., 1970; McCombie and Chua, 1957; Green, 1960; Jamison, 1968; Bossert and Marks, 1956; Benjamin et al., 1957; Marshall-Day and Shourie, 1949, 1950; Marshall-Day, 1951, 1961; Marshal-Day et al., 1956). Therefore, the statistics reflect a multiplicity of factors and are not specifically linked to subsistence.

The third reason is that the relationship of periodontal disease and diet has not been clearly defined and established. Therefore the limits of interpretability have not been outlined. The following sections serve to present the needed descriptive and interpretive background data upon which to derive an effective quantification system and upon which to base interpretation of the patterns of periodontal disease involvement.

Etiology and Pathogenesis

Although there are problems inherent in determining the specific etiology of periodontal disease such as: the complexity of the human oral biota, technical limitations related to the identification, location, and culturing of oral bacteria (specifically anaerobic), and the limits of comparability of animal models (different oral biota), the collective evidence from the profusion of literature available on the subject is that the primary etiologic agent responsible for periodontal disease is bacterial plaque (e.g., Bowen, 1976; Ellison, 1970; Genco et al., 1969; Hutchins, 1973; Kelstrup and Theilade, 1974; Keyes, 1970; Listgarten, 1976; Socransky, 1970; Theilade and Theilade, 1976). This has also become established common knowledge.

Briefly, the evidence which implicates bacteria revolves around several key lines of investigation. These include: the success of the topical administration of antiobiotics in controlling gingivitis (Davies et al., 1970; Gjermo et al., 1970; Johnson and Kenney, 1972; Volpe et al., 1969), the success of human oral bacteria in producing gingivitis in germ-free animal experiments (Fitzgerald and McDaniel, 1960; Crawford et al., 1977; Gustaffson and Krasse, 1962), the demonstration of the bacterial prerequisite in the initiation of gingival inflammation (Fitzgerald and McDaniel, 1960; Waerhaug, 1956a, 1956b, 1957), and, by demonstrating the pathogenic potential of bacterial plaque itself. This last point merits elaboration.

The bacterial constituent of plaque is indigenous to the oral cavity (Prichard, 1965; Gordon and Jong, 1968), and these plaque bacteria have been shown to initiate infections when introduced into other parts of the body (Fritzell, 1940; McMaster, 1939). Plaque bacteria produce a wide variety of by-products from glycolytic activity (carbohydrate metabolism) (Brown, 1973) which are demonstrably toxic. These include endotoxin and peptidoglycans, which have been shown to be inflammatory stimulants (Schultz-Haudt et al., 1954; Schultz-Haudt and Scherp, 1955, 1956). Substances which are toxic to cell body components such as ammonia (Macdonald and Gibbons, 1962), protases (Carranza, 1978), hydrogen sulfide (Macdonald et al., 1960), indole (MacDonald et al., 1960), amines (Socransky et al., 1964), and organic acids (Dewar, 1958; Newman et al., 1974) are produced as well as enzymes toxic to the intercellular matrix (Dewar, 1958). Bacterial cell-wall mucopeptides and fatty acids are toxic to osseous tissue either independently or as a cofactor in the inflammatory process (Mergenhagen et al., 1967; Hausmann, 1974). In sum, oral bacteria possesses sufficient ammunition to initiate pathogenic response.

In recent years, a better understanding of plaque composition has been realized through improvements in analytic techniques (Socransky, 1979, 1971, 1977). Apparently a sequential colonization of the supragingival and subgingival ecological niches occurs and this coincides with the progression of gingival inflammation. The major groups of bacteria which initiate supragingival plaque are gram-+ rods and cocci (Ritz, 1976; Loe, Theilade and Jensen, 1965) which attach to the salivary glycoprotein of the acquired pellicle (the protective coating of the tooth surface) and proliferate. According to Carranza (1979), "the initial insult to the periodontal structures in gingivitis may be associated with noxious elements of large masses of the gram-+ bacteria associated with this supragingival plaque."

The bacterial toxins present in bacterial plaque invade the intact epithelial lining of the gingival sulcus initiating inflammation of the marginal gingiva and interdental papilla. The toxins dissolve the free gingival fibers that attach the gingiva to the cementum and the junctional epithelium migrates apically and detaches from the root. The net result is a deepened gingival sulcus or "periodontal pocket" which is a chronic inflammatory lesion and an important clinical feature of periodontal disease (Carranza, 1979; Prichard, 1965).

Maturing gingival plaque, besides becoming more dense, experiences population shifts (Loe, Theilade, and Jensen, 1965). The protected, stagnant and oxygen poor enclosure of the developing pocket permits proliferation of subgingival plaque characterized by anaerobic and motile forms (spirochete and fusiform) which thrive on the nutrients present in the sulcular fluid (Carranza, 1979). As the pocket deepens, inflammation progressively involves more tissue elements, ultimately including the bone itself.

Degenerative changes in the surrounding tissue accompany pocket formation. The histologically observed initial tissue response to bacterial plaque include the classic features of acute inflammation. These include an increase in vascularity accomplished by capillary dilation and increased blood flow (Thilander, 1968). Leucocytes from blood vessels are found in increasing number not only in the expanding sulcus and epithelial lining, but also in the underlying connective tissue (Page et al., 1975). In severely inflamed tissues, the inflammation has spread into the deep connective tissue which surrounds the blood vessels and into the tissue between the bundles of collagen fibers (Thilander, 1968). Observed initially by Weinmann (1941), *and* now concensus (Goldman, 1957) the pathway of inflammation from the site of pocket formation to the bone spreads in the loose connective tissue surrounding the blood vessels along the transeptal gingival fibers (located in the area between the epithelium at the base of the sulcus and the crest of the interdental bone). Inflammation reaches the bone through vessel channels which perforate the cortex.

Inflammation spreads most rapidly through vascular cancellous bone (Goldman, 1957) because cancellous bone is more reactive, that is, it has a more rapid turnover rate than cortical bone (Amprino and Marotti, 1964). These observations substantiate Weinman's (1941) initial observation that resorption of the alveolar crest from the gingival side leads to destruction, first, of the supporting bone, then the lamina dura. This pattern has been demonstrated roentgenographically (Grant et al., 1963; Akiyoshi and Mori, 1967).

The result of this pattern of osseous destruction is the progressive denuding of the roots resulting in tooth mobility and, ultimately, the exfoliation of the tooth. This pattern of bone loss proceeds slowly and is accompanied, not unexpectedly, by massive accumulations of plaque (Carranza, 1979). This loss in the horizontal plane is characteristic of periodontal disease and is often the only, if not the primary, pathological consequence recorded in anthropologic literature. But, basically there are two types of bone loss associated with periodontal disease. The expression of one or the other is dependent on the location of the apex of the periodontal pocket. When the base of the pocket is coronal to the alveolar crest, or suprabony pocket, the bone loss is horizontal. When the base of the pocket is apical to the alveolar crest, or infrabony, the defect is vertical. The infrabony pocket is always located between the root and the bone, or in alveolar bone proper. It is important to establish that the suprabony pocket is not an early phase of osseous destruction (Carranza, 1979). Vertical bone loss is rapid and is therefore not associated with significant accumulations of plaque (Carranza, 1979).

Horizontal bone loss is not restricted to periodontal disease. In fact, in order to describe and discuss the form and pattern of bone loss, it is necessary to be aware of the contour of normal bone and the physiological deviations from it so that these deviations are not misinterpreted as being part of the pathological process.

Pattern of Osseous Destruction

Normal Bone Contour

In nondiseased bone, the alveolar plate parallels the shape of the dental arch (Hirschfeld, 1939; Kraus et al., 1969) and the external contour normally conforms to the prominence of the roots (Carranza, 1979). The crests are well-defined and exhibit a sharp angle around the base of the tooth (Leigh, 1925; Phillipas, 1952). The crests follow the margin of the cemento-enamel junction (Orban et al., 1953). The lingual border is higher than the labial (Hirschfeld, 1939). The outline of the normal alveolar plate is illustrated in Figure 1.

Irregularities of the alveolar border are a consequence of the lability of alveolar bone; the most unstable of the periodontal tissues

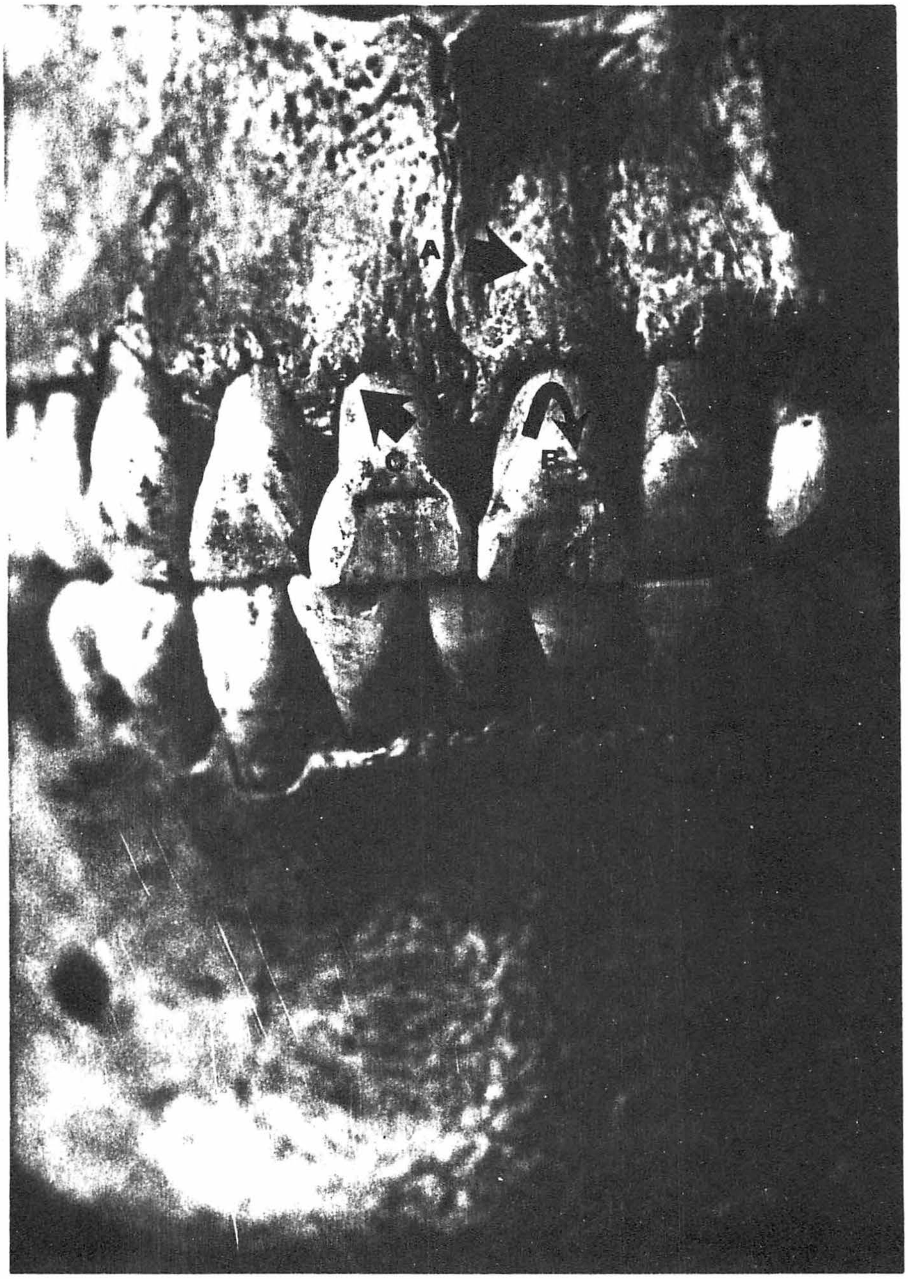


Figure 1. Normal Bone Contour.

The external contour conforms to the prominence of the roots (a) and the margin of the cemento-enamel junction (b). The crests are well-defined and exhibit a sharp angle around the base of the tooth (c).

(Carranza, 1979). Deviations are affected by (1) the alignment of the dentition, (2) the root-to-bone angulation, and (3) the amount and direction of occlusal forces as well as (4) individual, dimorphic, and populational differences in robusticity.

The alignment of teeth can be a factor in the expression of deviation from the ideal. Excessive departure from the curve of the ideal dental arch results in the denuding of the roots known as dehiscence (Elliot and Bowers, 1963; Nabers, 1960). Dehiscence can be identified by the knife-edge border of the bone along the denuded root surface. A gracile tooth-bearing portion of the facial skeleton is a predisposing factor because the more spongy bone present in robust skulls tolerates a greater amount of movement before perforation of the cortical plate occurs (Orban et al., 1957; Wheeler, 1958). The amount of cancellous bone also seems to be a factor in the distribution of defects along the tooth row (Elliot and Bowers, 1963). A higher frequency of dehiscences occurs along the anterior tooth row and more often facially than lingually.

Dehiscences apparently are not isolated phenomena, although their frequency is not known. They occur in approximately 20% of dental patients requiring mucogingival surgery (Elliot and Bowers, 1963). The presence of dehiscences in these particular patients may influence the outcome of this type of surgery. It is difficult to ascertain from these data what the frequency of dehiscence may be in the population in general.

Although the etiology of dehiscence has never been thoroughly examined, it appears to be related to occlusal stress. Apart from the predisposing factors mentioned above, it seems that fewer incidences of dehiscence are found in edge to edge bite (Elliot and Bowers, 1963). This agrees with the observation that the labile alveolar bone is less tolerant of lateral (i.e., facio-lingual) stress (Kraus et al., 1969; Ramfjord and Kohler, 1959). Dehiscence is also strongly associated with attrition (Stahl et al., 1963) and hyperfunction (Ramfjord, 1959). Osteoclastic resorption has been observed at the margins of dehiscences (Ramfjord and Kohler, 1959; Kakehashi et al., 1963) indicating that, according to the principles which govern the remodeling of bone, the site is experiencing compression (Carranza, 1979).

If indeed dehiscence is related to occlusal stress, then it seems reasonable to predict that hunter-gatherers will experience a greater frequency than western clinical samples. This is based on the universal pattern of excessive tooth wear found among hunter-gatherer groups and the associated stress related deterioration of the temporomandibular joint (Hinton, 1981). With an anticipated high frequency of physiologic deviation from the ideal alveolar border, the quantification of periodontal disease induced loss of bone height needs to be carefully considered. The buccal or labial margins should be avoided as landmarks from which to measure bone loss. The Tooth Cervical Height measure introduced by Davies and Picton (1969) uses the mid-root facial alveolar border to measure cervical height.

Loss of Bone Height

The most prominent destructive consequences of periodontal disease is the loss of bone height (Carranza, 1979). However, root exposure appears to be multifactorial. Age, periodontal disease, and attrition are all progressive and cumulative processes. Age has been associated with a reduction in bone height (Froelich, 1965). However, whether this loss actually represents senescent change or advancing attrition (Taylor, 1963) is indeterminate. Consistently observed in the literature considering age, attrition, and periodontal disease is the primary association of bone loss with attrition (Lavelle, 1973; Holmer and Maunsbach, 1956; Davies and Picton, 1969; Mellquist and Sandberg, 1939; Barker, 1975). This is significant particularly in the examination undertaken by Davies and Picton (1969) because the sample was not characterized by appreciable amounts of wear. In an attempt to correct for extrusion related to attrition, Lavelle and Moore (1969) selected individuals from an Anglo-Saxon sample and a 17th-century British sample possessing minimal amounts of wear. However, changes in the rates of attrition were not considered and the possibility that the later sample may be older (on the average) than the Saxon sample cannot be dismissed. Since periodontal disease incidence and severity increases with age, the increase in periodontal disease incidence over time as observed by Lavelle and Moore may have been skewed by the likely older mean age of the 17th-century sample.

Periodontal disease has also been shown to localize (Fleming, 1926). This means that certain areas of the mouth are more susceptible to periodontal disease involvement. It has been shown that mandibular premolars are more resistant to periodontal disease than any other area of the oral cavity (Marshall-Day and Shourie, 1949). The areas which are most susceptible are the mandibular molars followed closely by the incisors (ibid.). This regional distribution of periodontal involvement can also prove to be useful in identifying periodontal disease in skeletal samples. Tooth classes should therefore be evaluated separately in order to detect differences in periodontal disease involvement between samples.

The Vertical Osseous Defect

The infrabony pocket represents local infections which experience conditions favorable for rapid extension into the bony tissues. They are therefore not accompanied by significant accumulations of plaque, and are, as already established, not manifestations of advanced horizontal destruction (Carranza, 1979). Literature on the incidence of infrabony defects is limited. What studies there are suggest that osseous defects do indeed represent significant clinical problems and are therefore not infrequent phenomena. A study of the frequency of specifically three-walled defects, amenable to therapy, from a clinical sample of adults aged 30 to 59 indicates that 38 to 40% are affected (Laranto, 1970). Since three-walled defects are only one form of the geometrically variable periodontal pocket, and since the sample was restricted to defects amenable to therapeutic intervention, it is certainly reasonable to assume that the frequency for all pockets is much higher. In a separate study, 231 intrabony defects were observed from 148 skulls each possessing no less than 28 teeth (Saari et al., 1968). Since the sample represents the orally healthier spectrum of the population, it is again reasonable to assume that we are dealing with an underestimate of the frequency of the infrabony pocket. In sum, what these few statistics do reveal is that infrabony pockets represent an important variable in oral health and a clinically significant indicator of periodontal disease.

The incidence of osseous defects conforms with what we know about periodontal disease: that severity increases with age (Saari et al., 1968; Marshall-Day, 1955; Sandler and Stahl, 1959). The number of defects also increases with age (Saari et al., 1968).

The literature which focuses on the infrabony pocket is concerned with detection and geometry of the defect. The pocket is classified by various combinations of short/deep and narrow/broad, and may be located on single or multiple surfaces around the involved tooth. Familiarity with, and identification of, the geometry of the defect is necessary for successful surgical therapy.

What the literature on the infrabony pocket reveals, not unexpectedly, is that the geometry of the osseous defects closely follows the geometry of the bone (Prichard, 1965; Manson, 1976). specifically, crater-shaped defects occur wherever trabeculated bone occurs, most often in the interproximal bone of the posterior teeth (Larato, 1970; Prichard, 1960; Saari et al., 1968). The highest frequencies of inconsistent margins is found on the facial surface of anterior teeth owing to the thinness of the facial cortical plate and the absence of cancellous bone (Manson and Nicholson, 1974; Saari et al., 1968). High frequencies of inconsistent margins also occurs where the maxillary and mandibular margins conform to the presence of the roots (Manson and Nicholson, 1974).

Although it is clear that bone geometry is the disposing factor in the form of the defects, this certainly should not be taken as an explanation for their occurrence and frequencies. As is true of all pockets, the etiologic agent responsible for the infrabony pocket is bacterial plaque and the impacted food substrate. The thickness and flatness of the posterior interdental area apparently encourages food impaction and the retention of proliferating bacterial plaque (Larato, 1970; Saari et al., 1968; Sibley and Prichard, 1963). Therefore, it is not entirely coincident that the highest frequency of infrabony defects occurs in the interproximal area of the posterior teeth, specifically, mesial to M2 and M3 (Larato, 1970; Saari et al., 1968). Another possible factor offered by Cohen (1959) is that the interdental col may be especially vulnerable to inflammation, although this has been disputed (McHugh, 1971).

Apart from bone geometry and retained plaque, another factor may influence whether or not a pocket will become infrabony. Although the presence of plaque is demonstrably essential to the development of infrabony defects, the rapidity with which these defects migrate apically requires more explanation. Excessive occlusal force may play a role in pocket migration. Since hunting and collecting peoples in particular routinely exhibit responses to occlusal stress such as root shortening and pulp stones (Hylander, 1977), and degenerative changes in the temporomandibular joint (Hinton, 1981), this association needs to be examined.

Essentially, the periodontium exists to support the tooth, and *the* integrity of the periodontal structures depends on the functional activity of the dentition (Carranza, 1979). Following the principles of bone remodelling, the periodontium accommodates itself to alterations in the occlusal demands of the tooth. Insufficient stimulation therefore will result in atrophy, just as increased functional demand results in the strengthening of the support structure. The adoptive remodelling of the alveolar socket to occlus stress consists of permanent widening (Wentz et al., 1958; Ramfjord and Kohler, 1959; Macapanpan and Weinmann, 1954). This is a consequence of both bone loss in the area experiencing pressure as well as thickening of the periodontal ligament (Ramfjord and Kohler, 1959; Macanpanpan and Weinmann, 1954). In excess, occlusal trauma can damage the periodontal structures. This includes vascular damage and hemorrhage, hyalinization, and necrosis of the periodontal membrane (Macapanpan and Weinmann, 1954).

A causal relationship between trauma induced by occlusal stress and periodontal disease was hypothesized by Karolyi in 1901 (as cited in Waerhaug, 1955; and Stahl, 1975) and was subsequently accepted by a number of others in the ensuing decades (e.g., Ames, 1903; Quedenfeld, 1908; Stillman, 1917; Linghorne, 1938; McCall, 1941; Beyron, 1952; Emslie, 1952; Granger, 1950). Recent research devoted to the etiology of periodontal disease and the role of occlusal trauma has universally negated a trauma etiology (Waerhaug, 1955; Waerhaug and Hansen, 1966; Stahl, 1975). However, it has been suggested that trauma from occlusion in the presence of periodontal disease may be a factor in the pathogenesis of infrabony pockets. This hypothesis has been challenged in the literature and in order to assess the presence of pockets in samples characterized by occlusal stress, the literature concerned with this issue should be examined.

Macapanpan and Weinmann (1954) observed deviation from the normal pathway of inflammation in the environment of periodontal disease and experimentally induced trauma. The inflammation followed the fibers of the periodontal ligament experiencing tension rather than passing into cancellous bone. Experiments subsequently conducted by Glickman and Smulow on rhesus monkeys (1962; 1968) and observations on autopsy specimens (1965) confirmed a ligamental pathway, but via the fibers of the pressure surface of the involved tooth. These experiments confirm results obtained earlier by Box (1935) who found more pocket deepening and migration of the junctional epithelium in teeth experiencing trauma from occlusion. The results of the above studies suggest that the alteration of the alignment of the gingival (specifically transseptal) fibers experienced in occlusal stress encourages deviation of periodontal disease inflammation to the periodontal ligament. This interpretation corresponds well with the observation that infrabony pockets are characterized by alteration in the alignment of the gingival (transseptal) fibers (Larato, 1970).

Based on the results of their experiments and observations, Glickman and Smulow offer an interpretive hypothesis (1969). Besides encouraging the deviation of inflammation, they maintain that stress weakens the periodontal fibers encouraging the apical migration of the junctional epithelium of the proliferating pocket. They also maintain that damage incurred by stress during the destructive phase of occlusal stress (i.e., thrombosis, osteoclastic activity, and ultimately necrosis) aggravates tissue destruction resulting from periodontal disease. Together these factors encourage the development of infrabony pockets.

Acknowledging the variability in the response of the periodontium to insult, Glickman and Smulow have also indicated that not all infrabony defects are necessarily the result of the combined effect of trauma and periodontal disease (1969). They do maintain, however, that this combination increases the likelihood that a pocket will become infrabony.

Glickman and Smulow (1965) conclude from their experiments that:

> As long as the inflammation remains in the marginal gingiva, within the confines of the gingival and transseptal fibers, it is unaffected by the presence of trauma from occlusion. However, when the inflammation spreads beyond the marginal gingiva, it and trauma from occlusion combine to become interrelated codestructive factors in periodontitis.

The focus of opposition to a role for trauma in the genesis of infrabony pockets has been the strict adherence to the demonstrable and acknowledged independence of the two processes. It appears that for a role for trauma to be accepted, an association between it and periodontal destruction should be demonstrated. Data which have been used (Stahl, 1975) to argue against a role include the demonstrable stability of the periodontal structure to excessive experimentally induced occlusal stress (Ramfjord, 1959; Comar et al., 1979). In fact, with one exception (Waerhaug, 1955), trauma from occlusion has failed to produce apical migration of the junctional epithelium (Bhaskar and Organ, 1955; Breitner, 1942; Ostrum et al., 1950; Wentz et al., 1955; Muhlemann and

Herzog, 1961; Safari et al., 1974). The reason given by Polson and associates (1976) for the inability of trauma to affect migration of the junctional epithelium is that trauma affects the subcrestal periodontal structures without therefore, involving the supracrestal marginal gingival inflammation. It appears that the etiologic role of trauma from occlusion is emphasized by the opponents, rather than the codestructive role as outline by Glickman and Smulow (1965).

The results obtained by Glickman and Smulow have not universally been reproduced. Stahl's (1968) examination of four autopsy specimens exhibiting both periodontal disease and trauma from occlusion yielded no deviation from the expected pathway of inflammation. Experimentally induced trauma from occlusion on rhesus monkeys experiencing active gingivitis did not produce migration of the junctional epithelium (Comar et al., 1979). It was concluded from this experiment that trauma alone is not responsible for the genesis of infrabony pockets, but that like all periodontal pockets, the etiologic factor is bacterial toxins.

This focus on demonstrating an etiologic relationship for trauma from occlusion by its opponents appears to consider irrelevent the subcrestal penetration of inflammation into the area affected by trauma. Lindhe and Svanberg (1974) did demonstrate deepening of pockets in dogs exhibiting advanced periodontal disease. These results were considered exceptional (Stahl, 1975), which is in keeping with the opposition's etiologic hypothesis. This exception, however, conforms to the codestructive hypothesis proposed by Glickman and Smulow.

This lack of agreement regarding the role of trauma from occlusion has resulted in some confusion. Adding to this confusion, the definition of trauma has apparently been extended to include mechanical irritation. The experimental wedging of an irritant (toothpick) into the gingiva of squirrel monkeys did not result in the apical migration of the junctional epithelium (Polson, 1974). These findings, however inappropriate, have been utilized to further indicate that trauma does not factor in periodontal disease pathogenesis (Stahl, 1975).

An explanatory hypothesis introduced by Sattosanti (1977) has recently been included in evidence for a codestructive role for trauma (Carranza, 1979). A synopsis of the major features of the hypothesis merits presentation at this time.

Histologically observed resorption concavities or bays, formed on the pressure side of cemental surfaces of teeth, have been identified and associated with sustained lateral forces of orthodontic tooth movement (Jones and Boyde, 1972; Kvam, 1972). This form of root resorption appears to have a considerable frequency, occurring in over 80% of clinical samples in at least three separate studies (Massler and Malone, 1954--incidence 100% in 700 persons; Henry and Weinmann, 1951--90% of 261 teeth from 15 cadavers; Harvey and Zander, 1959--90% of the Indian sample of indeterminate size). From an examination of resorption bays and plaque (calculus) distribution and from Zander's (1953) observation that calculus "locks into" areas of cementum resorption, Sattosanti (1977) suggests that the exposure of resorption bays during the apical migration of the junctional epithelium in chronic periodontal disease creates a favorable local niche or pocket for the proliferation of plaque bacteria and therefore a favorable environment for rapid vertical osseous destruction. In lieu of substantiation, this particular hypothesis correlates the two processes in a logical way, and therefore strongly recommends a role for trauma in the progress of periodontal disease.

Plaque, Calculus, and Dietary Carbohydrates

Apart from bacteria and their toxic by-products, plaque is composed of an organic matrix of saliva derived protein (salivary glycoprotein) and extracellular polysaccharides (Carranza, 1979). The inorganic constituent of plaque is primarily calcium and phosphate salts. The proportion of these salts in early plaque is insignificant, but becomes considerable when plaque becomes calculus (Carranza, 1979). The process of this transformation will be considered later in this section.

Since plaque is the etiologic agent responsible for periodontal disease, it follows that it has diagnostic potential. The classic experiments undertaken by Lœ and associates involving the cessation and resumption of oral hygiene (i.e., mechanical plaque removal) among samples of dental students convincingly demonstrated that plaque accumulation both preceded and initiated gingivitis, and that symptoms abated with the resumption of oral hygiene (Lœ et al., 1965; Theilade et al., 1966; Lœ et al., 1967). More significantly, the severity of inflammation appears to vary directly with the amount of bacterial plaque (Arno et al., 1958; O'Leary and Shannon, 1962; Ash et al., 1964; Sanchez, 1974, 1975). Specific to bone loss, the amount (as measured by alveolar recession observed and measured on roentgenograms) is also correlated with the amount of plaque in humans (Schei et al., 1959; Courant et al., 1965; Suomi et al., 1971) and animals (Baer, 1968). These consistently observed patterns will prove to be most useful in assessing the status of oral hygiene in the skeletal samples employed in this study.

The nutrient substrate for energy generation upon which bacterial life functions (including proliferation) depend are dietary carbohydrates (Brown, 1973). The carbohydrate content of the diet has been specifically correlated with bacterial growth (Winkler and Dirks, 1958). It follows that carbohydrate metabolism is intimately associated with the amount of bacteria, which constitutes four-fifths of solid plaque. It is tempting to predict that the severity of periodontal disease is a consequence of the amount of carbohydrates in the diet. However, the specific role of food in periodontal disease etiology is not well-established as in caries, a pathology also associated with bacterial plaque. The periodontal disease process involves a multiplicity of factors including tissue response to inflammation, host response to bacterial antigen, as well as hormonal and other systemic features (Carranza, 1979). The specific influence of these factors is as yet unknown. But since the relationship between the consumption of appreciable amounts of refined carbohydrates and the proliferation of the caries-conducive _S. mutans_ is well established, it follows that an association between other oral bacteria and carbohydrate consumption is likely.

At present, only generalizations about carbohydrate metabolism and plaque proliferation with respect to periodontal disease are possible.

This is because the roles of a wide range of carbohydrates have not been fully explored (Brown, 1973) and because the roles of specific organisms in the disease process are not clearly established. In spite of these restrictions, some important associations may be made.

The initial colonization of the tooth surface is accomplished by Streptococcus sanguis and gram rods (Loe et al., 1965). Apparently, dietary sucrose is not the preferred metabolic substrate for S. sanguis because proliferation has been observed in a restricted sucrose environment where S. mutans expectedly decreases (Gibbons and Van Houte, 1971, 1973; Gibbons and Banghart, 1967). The opposite was observed when sucrose was replaced with sorbitol (Gibbons and Van Houte, 1973). Certainly while the preferred substrate cannot be implied from the limited scope of these experiments, it is important to note that the bacteria which pioneer the supragingival tooth area proliferate in a carbohydrate medium which is not specifically cariogenic.

As plaque matures, coincident with progressing gingival inflammation, the proliferating pocket, and the opening up of new niches with respect to the deepening pocket, a different suite of organisms characterizes dental plaque (Loe et al., 1965). The most prominent forms now are the species of the genus Actinomyces. This genus demonstrates adaptability by producing polysaccharides from a wide variety of carbohydrates and therefore, significantly, does not depend on dietary sucrose (Jordan et al., 1969; Hageage et al., 1970; Rosan and Hammond, 1974). This ability to metabolize various substrates may account for the fact that the growth of supragingival plaque is associated with an increase in absolute number and percentage of *Actinomyces* species (Loesche and Syed, 1975; Syed et al., 1975). Since the development of gingivitis is a consequence of the increase of this supragingival plaque, the *Actinomyces* constituent of plaque takes on etiologic significance. Not only is their presence coincident with the level of periodontal involvement, but (although the data on specific bacterial forms associated with periodontal disease are limited), it can be shown that as much as 40% of the pocket plaque is composed of *Actinomyces* species (Williams et al., 1976) in contrast to a <11% proportion in the nonperiodontally involved oral cavity (Gordon and Jong, 1968). More significantly, experiments conducted using pure *Actinomyces* strains have specifically implicated them as an etiologic agent (Jordon and Keyes, 1964; Jordon et al., 1965; Jordon et al., 1972).

The metabolic versatility of *Actinomyces* suggests that bacteria associated with periodontal disease may not be limited to a single substrate. This realization introduces new complexity into an already intricate situation. Until the specific roles of the individual bacterial strains found in dental plaque are identified and their metabolic requirements ascertained, the importance of specific extracorporeal carbohydrates in the periodontal disease process cannot be determined. It can only be concluded that carbohydrates are demonstrably important for plaque proliferation and therefore significant for the initiation of periodontal disease.

Studies focusing on the consequence of carbohydrate consumption vis-a-vis periodontal disease are unfortunately few in number. What data there are corroborate the hypothesis that carbohydrates are a significant factor in plaque proliferation. Laboratory hamsters fed a fine-textured high carbohydrate diet for a three month period were observed to experience significant destruction of the periodontal tissues in conjunction with the consequent accumulation of plaque (Mitchell, 1954). Laboratory chow (protein enriched) of equally fine texture did not produce equivalent results (ibid) suggesting that the carbohydrate constituent of the experimental diet was the disposing factor. Subsequent animal experiments also demonstrated significant plaque and calculus proliferation in a high carbohydrate diet (Mitchell and Johnson, 1956; Baer et al., 1961; Plumbo et al., 1963).

The carbohydrates employed in the above-mentioned experimental diets were refined. In this form, metabolism is more readily accomplished. In non-Western diets, particularly aboriginal diets, the form of the carbohydrate is complex, that is, unrefined. In order for these dietary carbohydrates to be available for bacterial metabolism, they must be retained in the oral cavity long enough for the starches to be broken down to simple sugars. Soft texture encourages retention. This factor has become important in caries research in recent years (Bowen, 1977; Alfano, 1981). It appears that the form and frequency of cariogenic carbohydrate consumption are more significant in the initiation and progress of caries than the actual amount (Bowen, 1977). It has also been demonstrated experimentally that retained complex carbohydrates are equally effective metabolic substrates for bacterial plaque as simple sugars (Caldwell, 1970). In sum, retentive carbohydrates provide a favorable nutrient substrate for plaque biosynthesis.

One of the earliest experiments (Ivy et al., 1931) to indicate an association between texture and periodontal disease was performed on young gastrectomized dogs who were fed a nutritionally adequate but texturally soft diet. The animals acquired significant levels of calculus and four out of the seven dogs showed clinical evidence of periodontal disease. A similar experiment, also employing young dogs, produced comparable results including food impaction, stasis of gingival circulation and observable proliferation of the junctional epithelium (Burwasser and Hill, 1939). More recently Egelberg (1965) compared the oral tissue of dogs fed hard and soft diets. His results confirmed previous experimental work by demonstrating that more plaque occurs on soft diets than on hard.

Krasse and Brill (1960) observed distinct differences in the oral bacterial composition between the dogs fed on soft and hard diets. The dogs subsisting on the tough diet exhibited predominently rod-shaped bacteria, while the dogs subsisting on the soft-textured diet exhibited plaque composed of predominantly spirochete and fusiform types. As indicated in an earlier section of this chapter, the latter suite of bacteria are characteristics of advanced periodontal involvement.

The results obtained from experiments on dogs have been duplicated for the ferret (King, 1954; Baer, 1956) and for rats and hamsters (Sognnaes, 1947; Mitchell, 1950; Mitchell and Johnson, 1956; Cohen, 1960; Stahl and Dreizen, 1964).

There has been difficulty in reproducing the results obtained from the animal experiments in human subjects. The situation is not remedied by the fact that there are few studies to deal with making interpretations and assessments difficult. Several investigators have indeed observed significant differences in the oral health status in subjects whose diets differed from the control population only with the introduction of a particular coarse food item (Haber, 1940; King and Gunison, 1947; Slack and Martin, 1958). But other experimentors have failed to observe any differences (e.g., Venning, 1965; Bergenhaltz et al., 1967; Lindhe and Wicen, 1969; Arnim, 1963). Reasons why human subject experiments have not yielded results obtained from animal experiments includes the difficulty of using humans as experimental subjects. The omnivorous human diet includes food variables not controlled for in the experiments which produce gustatory stimulation similar to those obtained during vigorous mastication. An example of such a food variable is tartness. Humans are also not passive subjects. Lindhe and associates (1966) have criticized Slack and Martin (1958) for not controlling oral hygiene because subjects who are aware of their advantaged position in the experiment have been observed to be more fastidious about oral hygiene. This is especially true of children (Lindhe et al., 1966; Koch, 1967). Another difficulty encountered is the undemonstrable effectiveness of abrasives in initiating appropriate results in even the most ideal of experimental situations. Celery, apples, and carrots for example do not reproduce the same results for humans as dietary abrasives introduced in animal experiments do (e.g., Lindhe and Wicen, 1969; Bergenholtz et al., 1967). Too many variables have not been controlled in human experiments. Therefore the inconsistency of results obtained from experimentation should in no way negate the findings of oral health status differences among animals whose diets differ only in texture. It may still be concluded that texture does indeed play a role in the manifestation of periodontal disease.

Basically, calculus is mineralized plaque (Carranza, 1979). It occurs supra- and subgingivally, the latter reflecting presence in the periodontal pocket. Calculus is the form of oral debris encountered on skeletal samples. Since it will represent the etiologic agent responsible for periodontal disease, the formation of calculus and its relationship to the consumption of dietary carbohydrates are of considerable importance.

The transformation of soft plaque into calculus entails the binding of calcium ions to the carbohydrate-protein complex of the organic matrix and the precipitation of crystalline calcium phosphates (Mandel, 1960). The ions are found in suspension in saliva and also in crevicular fluid. These fluids therefore, are the sources for the minerals (Stewert and Ratcliff, 1966), and plaque has the ability to concentrate these ions from two to twenty times the level in saliva (Davies and Jenkins, 1962).

Seventy to 90% of the calculus is inorganic precipitate which is composed primarily of calcium and phosphorus. Various metals are present in trace amounts. About 76% of this inorganic calculus is calcium phosphate; 31% is calcium carbonate and trace amounts of magnesium phosphate are also found (Carranza, 1979). The organic portion of calculus is of course the constituents of plaque: bacteria, leucocytes, desquamated epithelial cells and the protein-polysaccharide complex of the matrix (Hamper et al., 1961).

There is a general lack of agreement concerning the mechanism or mechanisms by which calcification occurs because of the difficulty in factoring out etiological events from those which are coincident. According to Carranza (1979), theories regarding the mechanisms whereby calcification occurs fall into what he calls two principal concepts.

The first concept focuses on the mechanisms of calcium and phosphorus precipitation from their normally saturated state in the saliva. It is hypothesized that factors operating to increase the saturated state of the saliva with respect to the above-mentioned ions will result in precipitation. Supersaturation has been suggested to occur in three ways. Saliva may be characterized as a colloidal solution owing to the presence of glycoproteins (mucins) produced by the mucus glands of the salivary glands (Carranza, 1979). These salivary proteins have the ability to bind calcium and phosphate ions, and operates to maintain them in suspension. However, the proteins settle out in stagnant saliva causing calcium phosphate to precipitate (Hamper et al., 1961; Prinza, 1921). It appears that calculus formation may be accomplished by a simple physical-chemical process, but it is not the only factor.

Calculus formation appears to be sensitive to salivary pH levels, preferring a more alkaline environment to a cariogenic one (Ginwalla et al., 1968), a feature which further serves to distinguish the two diseases. Mechanisms which operate to modify pH include the rapid release of CO_2 which occurs at the interface of saliva with the oral cavity where the latter experiences low CO_2 tension (Leung, 1961). Initial calculus formation has been observed to form at this interface (Leung, 1951; Hodge et al., 1950). Also, the metabolism of the above-mentioned salivary proteins by plaque microorganisms releases ammonia which elevates pH, making plaque precipitation favorable (Hodge et al., 1950). A higher content of mucin would increase the metabolic activity of plaque bacteria and would favor a higher rate of calculus formation (Ginwalla et al., 1968).

The third mechanism by which precipitation may be facilitated is through enzyme activity. The saliva, the gingival epithelium, blood from gingival hemorrhage and/or the oral bacteria are the sources of the enzymes phosphatase and enterase (Leung, 1951). Phosphate hydrolyzes organic phosphate compounds in saliva freeing phosphate ions. This type of increase would favor precipitation (Leung, 1951; Citron, 1945; Wilkindon, 1935). Esterase hydrolizes fatty esters into free fatty acids which combine with calcium and magnesium to form soaps which are later converted to less soluble calcium and phosphate salts (Baer and Burston, 1959).

The second concept of calculus formation, often called the epitactic concept, focuses on deriving an etiologic mechanism from the observed pattern of calcification. Calculus forms by the gradual coalescence of small foci to form a calcified mass (Mandel, 1960). It is postulated that seeding agents are responsible for the foci, although specific seeding agents have not been identified. The carbohydrate-protein complex of the plaque matrix is a suspected seeding agent because it bonds with the salivary calcium to form nuclei that encourages further mineral deposition (Von der Fehr and Brudevold, 1960; Muhlemann and Schroeder, 1964).

The bacteria themselves have been postulated as possible seeding agents because, as outlined above, they encourage precipitation by producing phosphates, altering the pH, or otherwise inducing matrix mineralization (Mandel, 1960). Others feel, however, that bacteria are only passively involved (Gonzales and Sognnaes, 1960; Rizzo et al., 1962; Wasserman et al., 1958). Since the polysaccharide portion of the matrix is largely produced by the bacteria, and the amount of plaque per se is a result of bacterial proliferation and metabolism, the bacteria are certainly intimately involved in calculus formation. It should also be pointed out that calculus is always overlain by bacterial plaque; therefore, its presence (at least) as a nidus for plaque proliferation would also strongly implicate it as an etiologic factor and therefore a significant indicator of periodontal disease involvement.

Epidemiology

In the preceding sections, the comparative data available to potentially aid in evaluating the Tennessee skeletal material has been systematically dismissed. The apparent and acknowledged shortcomings of the skeletal quantification techniques now available render data gleaned by them untenable. The epidemiological data, based on soft tissue involvement, is obviously not directly comparable. This lack of comparability has also been confounded because the samples utilized, as outlined earlier in this section, have been gleaned exclusively from economic and sociological subgroups of otherwise complex societies. The statistics, therefore, reflect a multiplicity of factors and are not specifically tied to subsistence. Since it is important for the Tennessee data to be evaluated within some sort of interpretive framework, the present section will attempt to articulate the epidemiological data with data available from hunting and collecting societies. It is anticipated that a comparison between these samples will establish a range for the incidence of periodontal disease (specifically, gingivitis). The incidence of gingival involvement among hunter/collector societies will be contrasted against available data on the condition of the alveolare support and the presence of calculus in these same societies. The net result of such a comparison will be an estimate of periodontal disease involvement for hunter/gatherer subsistence strategies potentially applicable to skeletal data. Whereas frequency statistics will never be comparable as long as variation in quantification techniques exist, an appreciation for the differences in periodontal experience between subsistence systems can indeed be useful.

Since the epidemiological data will serve as an estimate of the upper limits of periodontal involvement, it is important that the data reflect equivalent parameters. The survey data found in Table 4 represent data collected by the same or similar quantification techniques. This is important to establish because different standards of quantification have proven to yield widely disparaging results. A particularly notable example from early epidemiological data illustrates this point. Data gleaned on children in the U.S. by Messner et al. (1938) and Brucker (1943) and data on children in the U.K. by Campbell and Cook (1942) report a less than 10% frequency for gingivitis in groups ranging in age from 4 to 16 years. These figures are almost the antithesis of subsequent observations on children of similar background (see Table 4). These differences in the reported frequencies have been attributed to differences in diagnostic criteria (Marshall-Day, 1956). Allowing for interobserver error, the data found in Table 4 are internally consistent (Marshall-Day, 1956).

Owing primarily to the ease with which school children may be sampled, the bulk of epidemiological data is based on subadults. Since the quantification techniques employed in epidemiological surveys focuses on incidence and not level of involvement, subadult cases are also appropriate because advanced involvement is rare and qualitative assessment is unnecessary. It is important to restate at this point that incidence increases with age. Therefore children reflect the lower range of the adult frequency of periodontal disease in the populations from which they were gleaned. Keeping this in mind, an important fact is readily apparent from reviewing the data in Table 4. With few exceptions (notably, higher socioeconomic groups), the incidence of

TABLE 4

INCIDENCE OF GINGIVITIS AMONG SUBADULTS

Sample	%/n	Investigator(s)
Middle class boys Labore, India ages 6-15	68/756	(Marshall-Day and Tandan, 1940)
Isle of Lewis ages 6-16	90/2280	(King, 1940)
Males, poor nutritional status, Kangra, India aged 13	81/200	(Marshall-Day, 1944)
Lower-middle class, Kangra, India, aged 13	80.613	(Marshall-Day and Shourie, 1944)
English boys, ages 11-14	77.4-87.6/403	(King, Franklin, and Allen, 1944)
Gibralter, ages 10-14	85.2/135	(King, Franklin, and Allen, 1944)
Dundee, Scotland ages 12-14	90/103	(King, 1945)
Low to middle-class males Lahore, India ages 9-17	99.4/1054	(Marshall-Day and Shourie, 1947)
Upper class girls, Lahore, India ages 9-17	73.4/179	(Marshall-Day and Shourie, 1947)
Puerto Rico, ages 6-18	60-79/1648	(Marshall-Day et al., 1948)
Suburban school children ages 5-14	63.4/804	(Massler, Schour, and Chopra, 1950)
Virgin Islands, (Negro) ages 6-18	57/823	(Marshall-Day and Schourie, 1950)
Virgin Islands, (Negro) ages 5-13	26.9/860	(Marshall-Day and Schourie, (1950)
Massachusetts, ages 13-17	29/1300	(Stahl and Goldman, 1953)
Lower class males, India ages 11-17	96.9/1613	(Greene, 1960)

gingivitis is greater than 70%. Referring now to Table 3, p. 14, the severity of periodontal disease among adults from samples throughout the world indicates that adults (not only experience periodontal disease in higher frequency but), universally possess damage to the periodontal structures. This damage includes bone loss as well as soft tissue inflammation. This status quo, mindful again of the multiplicity of factors they represent, is in stark contrast to what has been observed to occur among various hunter/gatherer societies. A review of this data is appropriate at this point.

Australian Aborigines

Campbell and Gray (1936) examined 54 individuals from Macdonald downs in eastern Central Australia. Of these, 27 were assessed as exhibiting good oral health. Definite evidence of marginal gingivitis was found on 23 individuals. Only seven of these exhibited calculus, and then only in slight amount. No signs of advanced infection were discerned. Commenting on how representative these particular results were, the authors stated that "relatively few instances [of calculus] occur[ing] in the several hundred living natives and the many hundreds of skulls which have been examined . . . ." A particularly large (350) sample of aborigines was subsequently examined by Campbell (1939). Although these were also from Central Australia, not all of them lived in purely aboriginal conditions. In spite of some external contacts, over 50% (175/171) showed disease free gums. Of the 171 with periodontal problems, 121 had only mild inflammation. Only 10% of the adults in the 30 to 49 age range exhibited unhealthy gingiva, while two-thirds of the over-50 age range did. Campbell (ibid) also reports that of 354 individuals examined, only 11 had calculus. Three males exhibited "slight" amounts, and all three were over age 50. Two females exhibiting this thin perimeter of calculus were aged 40 and 50. Six females possessed calculus in "medium" amounts and all were middle-aged or older (ages 50, 60, 45, 35, 75, 40).

Cran (1955) also observed good oral health among the Yuendumu of South Australia. Deep pockets were rare, even in old subjects. Calculus was never found in large quantities, and was always supragingival. Of 118 subjects, 58.5% experienced what Cran called "slight marginal gingivitis." Cran offhandedly remarked that changes from a natural to a civilized lifestyle resulted in a gradual increase in both caries and periodontal disease (ibid). This situation may be exemplified by a sample from Haasts Bluff, Central Australia (Heithersay, 1959). Of the 33 adults over the age of forty that were examined from this gradually detribalizing group, 8 had advanced periodontal disease as evidenced by tooth mobility. Fifty-four younger adults were examined. Two showed advanced periodontal disease (one having 4 mm deep pockets throughout the mouth). Apparently, the shift away from a hunting and collecting subsistence strategy is associated with oral health problems.

The skeletal data are equally indicative of good oral health. Campbell (1939), reporting on an earlier examination of aboriginal skeletal material, indicated that calculus, when it occurs, is nearly always expressed as a thin ridge of deposit following the gingival margin. The buccal surface of maxillary molars is the most frequent location for calculus; less frequently, it is found on the buccal margins of the lower molars. Of the 140 crania he reported to have examined, 35 showed this level of calculus on the posterior teeth and "practically all these occurrences concerned aged individuals (ibid)." Although Nicholls (1914) based his diagnoses of periodontal involvement on the amount of root exposure, he reported that marked periodontal "destruction" was limited to aged individuals. Apparently firm alveolar processes are characteristic up until advanced age. Calculus was detected in only 19 individuals, and only in small amounts. These observations correspond to what has been observed for living aborigines.

Wilkinson and associates (1929) observed calculus in 20 of 56 skulls drawn from the collection of the Anatomy Department, University of Melbourne. Of these 20, 15 possessed "only slight" amounts; two moderate, and only three marked in amount. The age of the sample was not available, but it suffices to say that it was not characterized by significant accumulations of calculus. Tasmanians appear to be equally characterized by periodontal health up until advanced age. Steadman (1937) reports that of 53 skulls examined, only one experienced "periodontal breakdown."

The pattern that is emerging from a brief examination of the Australian material is that the incidence of gingivitis is low in comparison to the epidemiological data, especially since the aboriginal samples are composed of adults. The associated calculus accumulations are insignificant and represent a trend for hunting and collecting samples.

Bushmen

Although the Bush sample examined by Clement et al. (1956) was unique in possessing a significant calculus accumulation as a consequence of the unusually high mineral content of the drinking water, they too were characterized by good oral health conditions. Fifty individuals of indeterminate age from the western Kalahari were examined. Only four individuals did not possess gingivitis (three were children, one adult female). Of these, 8 were "mild" cases; the rest were "advanced." The elevated inflammatory status was not doubt the results of the calculus presence because most of the adults had full complements of teeth. Teeth were missing in only seven individuals; five of these due to broken teeth. If we accept the premise that tooth loss among hunters and collectors is primarily a consequence of periodontal disease (Ramfjord, 1966; Moore and Corbett, 1973; Moore and Corbett, 1975), then it may be assumed that the Bush sample here reported is not characterized by advanced periodontal destruction. Therefore this data does not contradict the pattern indicated from the aboriginal data.

East Africa

Dodds (1955) states, "Parodontal disease is prevalent among the inhabitants of Africa, but among East African natives it is less prevalent than among the other races." The East African pastoralists, most notably the Maasai, are characterized by infrequent cases of periodontal disease (Schwartz, 1946; Schwartz, 1952; Upton, 1945). This finding is all the more significant in light of the fact that oral hygiene among these people is universally neglected (Schwartz, 1952;

Upton, 1945). Although the East Africans are not hunter/gatherers in the strictest sense, they have been included in this survey because of their unique high protein diet (Orr and Gilks, 1931) which makes them essentially the equatorial counterpart of Eskimos.

Eskimos

Although periodontal disease detection among Eskimos has been of peripheral interest, enough data exist to indicate that periodontal disease is also uncharacteristic of aboriginal Eskimos. Exemplary of this pattern is Baarregaard's mention of the results obtained from his extensive examination over a six year period of some 1300 North Greeneland Eskimos (1949). He observed that although plaque was common among adults, it was always supragingival. Mild gingivitis was common, and more importantly, severe periodontitis was rare.

Baarregaard reported that among the civilized Eskimo (that is, those with extensive contact with European goods), gingivitis is experienced a full 100% (ibid). More importantly, although no breakdown according to incidence, severity and age were presented, periodontal disease with pocketing and bone loss was common in this group. Hilming and Pederson (1940) have also reported similar results.

McEuen's (1937) examination of oral hygiene in 84 adults from Baffin Island revealed only six had even a slight amount of calculus. Only three individuals experienced advanced periodontal disease.

Mayhall (1970) examined the oral hygiene among four groups of Igloolik Eskimos varying only in the amount of the nonnative components in their diets. He concluded that generally, those on the predominantly native diet had less calculus than those on the purchased diet, although the differences were not statistically significant. The reason for this may be due to the lack of sensitivity of the Oral Hygiene Index used. In all groups, less than half the crown was covered by debris. The debris score, when weighted against the unaffected teeth in order to obtain a score per individual, was diluted in its ability to illustrate differences between groups. Nevertheless, it was still apparent that Eskimos on aboriginal diets were characterized by good oral hygiene.

Less specific, but also indicative of this trend are the observations made by Waugh (1928; 1931) on the differences in the oral health of precontact and postcontact Eskimos of Labrador. The Eskimos experiencing extensive contact with European goods possessed teeth "in a deplorable condition; and they appeared to be getting worse in each succeeding generation" (1928). He further reports that Eskimos from further north in the more remote Port Burwell region possessed teeth that were "practically free from decay" (1928). Mild gingival disturbance was apparently common in this group among individuals twelve years of age and older. This was attributed to the presence of calculus. Tooth loss was restricted to the aged, and that was attributed to the encroachment of calculus on the supporting tooth structures (Waugh, 1928). Specific breakdown of frequency and incidence by age was not presented. Since no specific mention of chronic gingivitis was made for any individual, it may be assumed that periodontitis was rare, if not absent. It can therefore only be implied from the statements made by Waugh that periodontal disease was not a major oral health problem among the outlying Eskimo of Labrador.

Precontact skeletal material also seems to suggest that good oral health vis á vis periodontal disease was the rule. Ritchie (1923), in his examination of 34 skulls of the Western and Central Eskimo recovered from the Canadian Arctic Expedition of 1913-1918 observed, "salivary calculus, even in the oldest skulls, is entirely absent, as is any trace of pyorrhea, or resorption of the alveolar margins."

Although Curzon (1976) examined the periodontal condition of museum collection Eskimo skulls using the Tooth Cervical Height measure, he made passing reference to the presence of calculus in the 100-plus skulls used in this analysis. Calculus was identified on "some" skulls indicating, although indirectly, that calculus was by no means widespread. Since the example consisted of museum specimens, some having been collected as early as 1823, it is possible that postmortem loss of calculus deposits resulted in an underestimate of calculus incidence.

With respect to the results obtained from using the Tooth Cervical Height measure, Curzon (1976) reports that periodontal disease is widespread (80%) even among the young. These results parallel Davies and Picton 91969) and Lavelle (1970) who, to some extent, utilized the same museum samples. The conclusion arrived at from these particular results is that periodontal disease has always been severe for the Eskimo. This is in contrast with the epidemiological information we have gleaned so far. If we conclude that the amount of root exposure is more a function of attrition that periodontal disease, and if we acknowledge the high degree of attrition characteristic of Eskimos (e.g., Hylander, 1977), then we may assume that the Eskimo, like the other hunter/collector groups surveyed are essentially characterized by good oral health status with respect to level of periodontal involvement.

Attrition

Definition and Review of the Literature

Dental attrition is an ongoing dynamic process of the wearing away of tooth structure (enamel and dentin) over the lifespan of an individual. Apart from the texture of the diet, possible factors which are known to contribute to the attritioning of teeth include food preparation techniques, artificially introduced mechanical abrasives (grit), and cultural activities which employ the dentition. The level of attrition analysis possible at the present time does not permit reliable discrimination between all of these factors, so it is not known how important toughness of the food bolus or grit content is in contributing to the pattern of attrition. Current analysis of tooth microwear however anticipates discrimination between certain attrition variables (e.g., Walker et al., 1978).

Apart from the above-mentioned factors, biological variables also affect the rate of erosion of the tooth surface. These factors include the size and shape of the teeth and the hardness of the dental tissues. This latter factor includes the difference in hardness between enamel and dentin (Kraus et al., 1969). Timing and sequence of eruption will affect the duration a particular tooth experiences attrition, and the malpositioning of teeth will certainly influence the pattern and degree of wear.

Mindful of the many variables which factor in attrition, the main variable which specifically affects rate of wear appears to be the physical consistency (including abrasive contaminants) of food (Ruffer, 1920; Leigh, 1925; Goldstein, 1948; Smith, 1972). Although methods of quantification vary from study to study and from observer to observer, the accumulated data from individual case studies have shown that tooth wear rates show patterned variation between groups practicing different subsistence strategies. This association may be anticipated because a shift in food procurement strategies to subsistence strategies based on food production is concomitant with an increase in cultural sophistication in, among other things, food preparation techniques (Steward, 1968). A rapid rate of attrition is characteristic of hunting and collecting societies (e.g., Campbell, 1925; Shaw, 1931; Pederson, 1938; 1949; Snow, 1948; Hylander, 1977; Anderson, 1965). Other studies have demonstrated that attrition has decreased with increasing urbanization (Davies and Pederson, 1955; Brothwell, 1963; Greene et al., 1967; Moorrees, 1957).

Although rate differences have become apparent from the accumulation of attrition data, most of attrition research has focused on the description and interpretation of specific or unique patterns of wear (e.g., Cybulsky, 1974; Anderson, 1965; Hylander, 1977). Little comprehensive comparative analysis has been undertaken. This has resulted, as Hinton (1981) maintains, in intuitive interpretations of attrition patterns. Molnar's (1968, 1971b, 1972) evaluation of the status of attrition studies has demonstrated a need for cross-cultural comparisons of wear parameters. His success (1971b) in elucidating subsistence related differences has been the model for the recent focus on cross-population analysis.

It has been observed that relative anterior to posterior wear varies between populations (Steensby, 1910; Merbs, 1968; Brothwell, 1972), and within specific fossil hominid groups (Smith, 1976, 1977; Stewert, 1959; Trinkaus, 1978; Brace, 1962). Based on ethnographic analogy (Gould, 1968; Lous, 1970; Hylander, 1977), it has been suggested that hunter/gatherers use their anterior dentitions more extensively than food producers. This pattern has been observed in certain skeletal samples (Smith, 1972; Anderson, 1965; Molnar, 1971a, 1971b). An actual interpopulational examination of this type of wear was also only recently undertaken (Hinton, 1981). Therefore an interpretive framework is now beginning to become established.

Rounded anterior tooth wear observed for hunters and gathers (such as Eskimos, for example) has been evaluated as indicative of the extensive nonmasticatory uses the anterior dentition is subject to in these populations. Cupping of the incisor teeth has been observed for certain agricultural populations (Molnar, 1968, 1971b). A cross-populational study of anterior tooth form has indicated that a dichotmous relationship exists between these two forms of anterior tooth wear (Hinton, 1981).

An interpopulational examination of observations made on particular populations serves to corroborate the hypotheses about the meaning of these patterns and establishes the features as representative of particular subsistence strategies. The few cross-populational studies that exist (namely, Molnar, 1968, 1971b; Smith, 1980; Hinton, 1981) represent the establishment of an interpretive framework with which to evaluate other samples against. What is now needed is a wider base to further corroborate these patterns, and to determine the range of variability within subsistence strategies in order to detect regional differences in attrition patterns. It is anticipated that the growing body of comparative data will be paralleled by data from extant groups where patterns of tooth wear may be associated with specific cultural activities.

Quantification

The most significant limiting factor in the establishment of a comparative data base is the lack of an adequate and universally applied quantification system. This situation is far from being remedied because of the complex nature of the tooth attrition process. Differences in the hardness of the dentin and enamel affect the rate of wear once dentin has become exposed. The difference in the shape of the anterior and posterior teeth makes equivalent attrition levels difficult to ascertain. Therefore, the intervals within and between teeth cannot be said to be equal. Apart from problems inherent in the attritioning process, there are numerous quantification systems indicted from the literature, each with inadequacies difficult to resolve. In lieu of a universal system, a scoring system which best conforms to the goals of the present analysis has been adopted. A description of the scoring system is undertaken in Chapter IV.

CHAPTER III

THE SAMPLE: DESCRIPTION AND CONTEXT

The data which constitute the basis for the generalizations made concerning the diet of the prehistoric hunter/gatherers and agriculturalists of the Tennessee Valley area are derived from a variety of sources. These include the actual food remains recovered from the site as well as food processing technology, appropriate ethnographic information, and the identification of the exploitable resources of the environment and their economic potential. Together these data provide a necessary interpretive framework for the oral health status results. A review of these generalizations follows the description of each sample.

The Archaic Sample

The hunter/gatherer sample consists of the combined skeletal material from the Eva (6BN12) and Cherry (84BN74) sites, located in the Western Tennessee Valley, and the Anderson (40WM9) site in the Nashville Basin. The combined samples yielded 121 individuals suitable for analysis.

The Eva and Cherry sites, located in Benton County, Tennessee, are now inundated by the Kentucky Lake Reservoir (see Figure 2). The Cherry site was the last site excavated by the combined effort of The University of Tennessee, the Tennessee Valley Authority, and the Works Progress Administration prior to the flooding of the reservoir (1941). The Eva site was excavated in the previous year (Lewis and Kneberg, 1947; Lewis and Lewis, 1961).

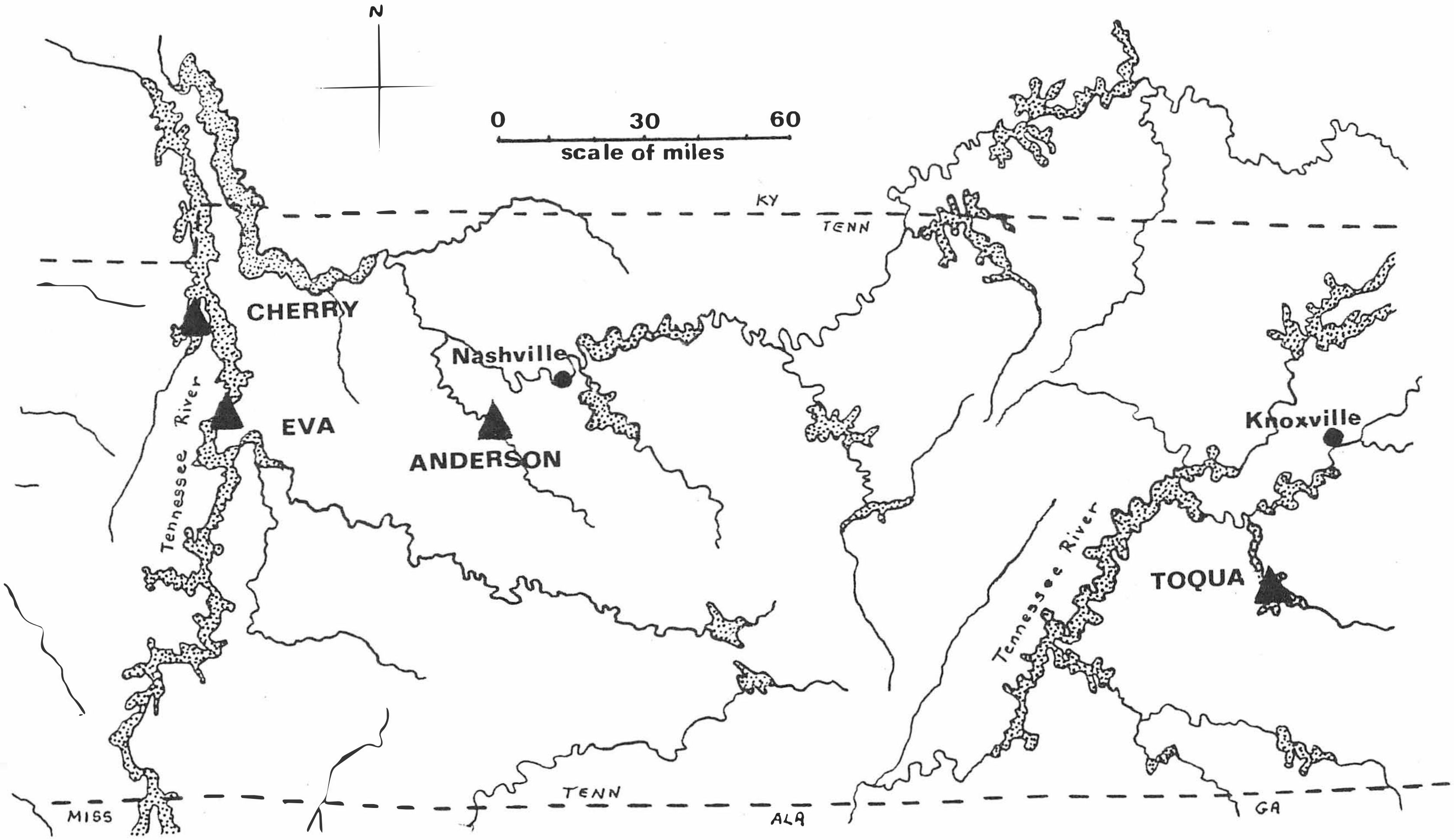


Figure 2. Map of the Site Locations Mentioned in the Text.

The Eva site was located on the broad floodplain of the Tennessee River approximately twelve miles above the confluence of the Duck River. The site was a stratified midden which yielded fire-cracked rock, animal bone and shell, and implement clusters (Lewis and Lewis, 1961). The Cherry site was a remote upland site located between two tributary streams of the Big Sandy River approximately twenty-two miles above its confluence with the Tennessee River. Unlike Eva, the Cherry site was characterized by subsurface features such as storage pits and post holds (Lewis and Kneberg, 1947; Bowen, 1975, 1977).

The Anderson site is a stratified site located in Williamson County, Tennessee (Dowd, 1981). The site is located on the Harpeth River approximately two miles north of the city of Franklin (see Figure 2). The excavation of the site was initiated in 1979 by the Middle Cumberland Archeological Society (Dowd, 1981).

The combined skeletal sample dates from the Middle to Late Archaic periods. The Anderson site, where a total of 73 individuals has been recovered, produced Middle Archaic projectile points such as Eva, Morrow Mountain, Stanly, and Big Sandy (Dowd, 1981). Two Carbon-14 dates are available for the site. A sample of wood charcoal from the base of the site yielded a date of 6495 ± 205 B.P. and a date of 6720 ± 220 was derived from a sample of charcoal fragments in ash (Joerschke, personal communication). The lower two-thirds of the Eva II component, which yielded the remains of 161 individuals, also appears to be Middle Archaic in age (Lewis and Lewis, 1961; Magennis, 1977). Dates for the Middle Archaic range between 4000-5000 B.C. (Chapman, 1976; DeJarnette et al., 1975). The Eva I component yielded 17 interments and also the only Carbon-14 date for the Eva site of 5200 ± 500 B.C. (Lewis and Lewis, 1961). The data corresponds well with the early Middle Archaic dates for the Little Tennessee Valley (Chapman, 1976). Magennis (1977) makes an estimate for the base of Eva of 6000-5000 B.C.

Cherry and Eva III appear to be Late Archaic (Bowen, 1975, 1977; Lewis and Kneberg, 1959). Carbon-14 dates for the Late Archaic indicate a time range of 3500-1000/500 B.C. (Lewis and Kneberg, 1959; Schroedl, 1975; Morse, 1967; Winters, 1969; Faulkner and McCollough, 1973, 1974). Therefore, 128 of the total 246 individuals are specifically Late Archaic.

The individuals utilized in the present analysis will represent a general Archaic adaptation and cover a time span of (approximately) 6000 to 1000 B.C.

Subsistence Strategy and Diet

Hunters and gatherers characteristically exhibit seasonal shifts, often cyclic, in food procurement activities (Lee and Devore, 1968). This pattern, established for extant groups, is being routinely tested and identified for archeological cultures. A prominent example for the Archaic is the analysis of the Riverton Culture (Winters, 1969). The reevaluation of the subsistence/settlement system in the Western Valley undertaken by Bowen (1975, 1977) has identified a hunter/gatherer pattern for the Archaic in that area. Originally, Lewis and Kneberg (1959) identified two cultures, but justification for this distinction was subsequently questioned (Phelps, 1964). It now appears evident from the pattern of the tool assemblage that a single cultural phase, the Ledbetter, is warranted (Bowen, 1975).

The contrasts between sites, originally interpreted as a cultural distinction, appear to indicate differences in the exploitation of local resources. The sites may be distinguished on the basis of location, midden content, and subsoil features. The Eva site, along with other shell midden sites located on the main river channel appears to represent a summer occupation (Bowen, 1975). The upland sites, of which Cherry is representative, are located away from main channel resources. These sites also demonstrate storage facilities and substantial dwellings which, along with environmental data, indicate winter occupation. These results, though in agreement with the pattern derived for the Riverton Culture, do indicate a local variation of the generalized hunter/gatherer pattern in that the seasonal occupations were more extensive (Bowen, 1975, 1977).

Evaluation of the Late Archaic in the Normandy Reservoir, located in the Nashville Basin, reaffirms the appropriateness of the generalized hunter/gatherer model for that area as well. Although only a fragment of the total settlement pattern can be determined at the present time, the pattern for the Normandy area appears to be site location intermediate between the upland resources and the main channel resources. This site location appears to be convenient for exploiting resources at the extremes of the range (Bowen, 1979).

Since the carbohydrate content of the diet is of etiological significance for oral pathology, the plant food content of the Archaic diet is of particular interest. The pattern which emerges from the ethnobotanical data both from the Tennessee Valley area and outside of it is the singular importance of arboreal seed crops (e.g., Asch et al., 1972; Shea, 1978; Crites, 1978; Chapman and Shea, 1981). Hickory nuts constitute by far the largest proportion of the ethnobotanical remains. Asch, Ford, and Asch (1972) maintain that hickory nuts are a first-line food resource both because of their nutritive quality (high protein content) and the abundance and ease with which they may be harvested and stored.

Other nuts routinely identified include acorns and, in lesser proportions, pecans, black walnuts, butternuts, and hazelnuts (Asch et al., 1972; Watson, 1974; Shea, 1978; Watson, 1969; Chapman and Shea, 1981). According to ethnographic data, the southeastern Indians harvested nuts for their oil (Hudson, 1976). The importance of acorns is inferred from the ethnographic accounts of acorn soup being consumed when the maize harvest was poor (Hudson, 1976). According to the archeobotanical record, hickory nuts and acorns decrease in importance with the adoption of maize (Chapman and Shea, 1981). A return to the exploitation of the resource superseded by maize may be indicative of its former importance.

Other plant food resources appear to play a minor role in the diet of Archaic populations (Chapman and Shea, 1981). In spite of their implied minor roles, certain plants are routinely identified in an archeological context and therefore constitute a regular addition of the plant food spectrum. Seed plants recovered in the Archaic Period include goosefoot (*Chenopodium sp.*), knotweed (*Polygonum sp.*), pokeweed (*Phytolacca americana*), bedstraw (*Galium sp.*), maygrass (*Phalaris caroliniana*), pigweed (*Amaranthus sp.*), and purslane (*Portulaca oleraca*) (Asch et al., 1972; Watson, 1969; Yarnell, 1974; Marquardt and Watson, 1976; Shea, 1978; Chapman and Shea, 1981). In the Little Tennessee Valley, goosefoot and maygrass increase in importance in the Late Archaic, and pigweed is considered to be of no economic value (Chapman and Shea, 1981). Wildrice (*Zizania aquatica*) was recovered in a Late Archaic context at the Bacon Bend and Iddens sites (Chapman and Shea, 1981). Sunflower (*Helianthus annuus*) is a Late Archaic addition to the plant food spectrum as is squash (*Cucurbiticeae*) (Chapman and Shea, 1981). Fruit remains are also identified in the Archaic. Some of the fruits recovered include blackberry, strawberry, grape, persimmon, and elderberry (Marquardt and Watson, 1976; Yarnell, 1974; Watson, 1969; Chapman and Shea, 1981). Roots and tubers appear to be important from the ethnographic accounts of the southeastern Indians (Hudson, 1976). These have been identified in a Late Archaic context at Salts Cave (Yarnell, 1974), but the importance of these as a food source is unknown. The general pattern (with some variation) which emerges from the spectrum of plant foods utilized in the Archaic is that the range of plant species exploited was narrow. The focus of exploitation appears to be the foods which yielded the maximum economic value with the least amount of procurement effort.

Of equal importance for an interpretive framework upon which to assess the oral health of Archaic populations are data indicating the texture of the food bolus. The most important variable in considering texture is the amount of extracorporeal preparation of the food prior to consumption. For the Archaic, this appears to be minimal. The paleofecal remains recovered from Salts Cave and Mammoth Cave generally parallel the plant food spectrum identified from archeological sites. The fecal specimens contained hickory nutshell fragments, goosefoot and maygrass seeds, and sunflower achenes (Marquardt, 1974; Robbins, 1971; Yarnell, 1974). Other constituents of the fecal remains included fish scales, small bones, rock fragments, and bits of charcoal (Yarnell, 1974). Interestingly, the nutshells found in significant quantity included fragments which could easily have been discarded prior to consumption (Yarnell, cited in Chapman, 1973:125). The inclusion of these large nut shell fragments as well as the other nondigestable items in the paleofecal samples indicate a pattern of consumption rather than accidental ingestion. It appears that food received minimal preparation prior to consumption. The seed remains exhibit evidence of roasting or parching (Yarnell, 1977), but no evidence of grinding or pounding which appears to have been done from the ethnographic accounts of the Indians of the Southeast (Hudson, 1976; Swanton, 1946). The mastication of such rough unprocessed foods anticipates significant attrition levels as well as low incidences of both caries and periodontal disease.

The Mississippian Sample

The site of Toqua (40MR6) is located in the Little Tennessee Valley of East Tennessee (see Figure 2, p. 62). Specifically, the site was situated on the south bank of the Little Tennessee River approximately thirty-two miles south of Knoxville. Excavation of the site began in 1975 by The University of Tennessee in cooperation with the Tennessee Valley Authority. The excavation was part of an extensive archeological salvage operation which preceded the completion of the Tellico Dam (Schroedl and Polhemus, 1977). The site is now inundated by the resultant reservoir.

The value of Toqua for the present analysis was owed to the large sample of human material (500 individuals) yielded by the site. The site ultimately contributed 73 individuals for analysis. Although the sample for the Mississippian is smaller than the Archaic sample, it is much better preserved and therefore yields equivalent numbers of individual teeth.

Toqua belongs to the Dallas Phase, a geographically confined culture of the Great Valley physiographic province (Hatch, 1974), and ranges in time from 1250-1600 A.D. (Hatch, 1976).

Subsistence Strategy and Diet

The Mississippian period is defined by an agricultural subsistence economy (Griffin, 1967). Features associated with the Mississippian include fortified villages containing a central plaza flanked by truncated or flat-topped mounds, social stratification, and location in rich agricultural soils (Griffin, 1967).

The focus of cultivation for the Mississippian agriculturalists was maise (*Zea mays*), beans (*Phaseolus sp.*), and squash (*Cucurbita pepo*).

Other plants cultivated include sunflower (Helianthus annuus), gourd (Largenaria siceraria) and marsh elder (Iva sp.) (Chapman and Shea, 1981; Shea, 1978; Smith, 1978). Hunting and collecting continue to be important (Faulkner et al., 1976; Shea, 1978; Kline and Crites, 1979). The trio of herbaceous seeds which appear to be of particular importance are goosefoot, knotweed, and maygrass (Chapman and Shea, 1981). Maygrass apparently disappears from the archeological record after Dallas times (Chapman and Shea, 1981). Arboreal seed crops (hickory nut, acorn, walnut) are supplanted by maize, as indicated in the previous section (Chapman and Shea, 1981). Chestnut is infrequent in the archeological record although the ethnographic data suggest that it was an important food item (Hudson, 1976; Swanton, 1946). In contrast to the Archaic, the Mississippian spectrum of plant food varieties is much broader (Asch et al., 1972; Chapman and Shea, 1981). This appears to have been a trend over time and may be related to the increased nutritional needs of a larger base population.

Data from ethnographic accounts as well as independent biological data indicates that agriculturalists of the Mid South engaged in extensive preparation of food prior to consumption. For example, goosefoot seeds, eaten whole in the Archaic, are apparently pounded into a meal by the Indians of the Southeast from the ethnographic accounts available (Hudson, 1976). Acorns, also pounded to a meal, were used to make bread (Swanton, 1946) or soup (Hudson, 1976). Persimmons, found in significant quantity at Toqua (Chapman and Shea, 1981), were used by Indians of the Southeast to make bread, cakes, and candy (Hudson, 1976).

A staple among the Creek Indians was a corn much which consisted of hulled corn meal boiled for several hours (Swanton, 1946). soft texture was apparently not limited to vegetables, which were apparently rarely eaten raw, because meats were apparently shredded or pounded as well (Swanton, 1946). The collective assessment of the ethnographic accounts suggests that the Indians of the Southeast preferred foods of a soft or mushy consistency (Swanton, 1946; Hudson, 1967; Chiltoskey, 1975). These conclusions suggest that the Mississippian agriculturalists possess caries and periodontal disease at a significantly higher incidence and severity than the Archaic hunter/gatherers. The soft texture also predicts less attrition.

Patterns of tooth size reduction exhibited for the same populations used in the present analysis suggest that selection to maintain large tooth size (as a response to masticatory stress) was much reduced between the Archaic and Mississippian times (Hinton et al., 1980; Smith et al., 1980). This conforms well with the ethnographic data reviewed above and the pattern of reduction which has exhibited for other hunter/gatherer to agricultural subsistence strategy shifts (e.g., LeBlanc and Black, 1974; Brace, 1978). Concomitant with tooth size reduction in the same samples is a reduction in the size of the temporo-mandibular joint (Hinton, 1981). This size change is very much indicative of reduction in masticatory stress. Equally corroborative of reduced masticatory stress was Hinton's (1981) observation that the size of interstitial wear facets changes between the Archaic and the Toqua samples. Interstitial wear is apparently directly related to the amount of masticatory stress experienced by the mesially inclined teeth (Wolpoff, 1971). The reduction in wear facet size experienced by the Toqua sample indicates a reduction in the magnitude of occlusal stress experienced by the teeth. Taken collectively, the biological data also strongly indicates a soft-textured diet for the Mississippian agriculturalists.

It appears that the variable which has altered the most between the diets of the two samples, apart form the inclusion of the primary domesticates in the latter sample, is the amount of food processing which is performed on the plant foods before it is ingested. In sum, an interpretive framework upon which to assess the oral health data predicts a significant difference in the oral health status between the two samples under evaluation.

CHAPTER IV

QUANTIFICATION AND ANALYTICAL PROCEDURES

Aging and Sexing

The determination of age and sex for the samples used in this study represent the concensus of several observers inclusive of the author (Magennis, 1977; Parham, 1982; Hinton et al., 1980). The methods by which age and sex were determined are outlined below.

Sex Determination

Sexual dimorphism can be detected in many parts of the human skeleton, but nowhere is discrimination more reliable than in the pelvis. Female pelves, apart from being more gracile, exhibit accommodation features to fascilitate parturition. They are characterized by a low and flaring ilium, a less curved sacrum, a wide and shallow sciatic notch, a wide subpubic angle, a prominent preauricular sulcus, and a smaller acetabulum, obturator foramen, and sacroiliac articulation (Bass, 1971; Krogman, 1962; Stewert, 1979). The dual role of the female pelvis is also seen in the parturation pits found in the symphyseal region (Stewert, 1957; 1970).

Phenice's (1969) visual method of sexing pelves, shown to be highly reliable (Kelly, 1978), focuses on criteria on the pubic bone. Apart from the subpubic angle, the subpubic concavity, the medial aspect of the subpubic ramus, and the ventral arc are used.

The human skull is also very diagnostic, but is a less reliable sex discriminator than the pelvis. The dimorphic features which serve to distinguish male from female are largely related to differences in robusticity. Since populations vary in robusticity the sexes must be evaluated within the confines of their respective populations. Because of interpopulational variability with respect to robusticity, a sexing bias has been observed in favor of males (Weiss, 1972, 1973). Sexing on the basis of the skull alone was avoided when possible. When it was undertaken, the skulls were assessed against skulls sexed by pelvic features. The characteristics of the skull which were employed include: the size of the supraorbital ridge, the sharpness of the superior orbital border, the size of the mastoid process, the size and shape of the mandible, and the rugosity of the nuchal area (Bass, 1971; Krogman, 1962).

The femur is also very useful in sexing. The size of the bicondylar angle and the size of the femoral head are the two most notable features. Because of the fragmentary condition of the samples, metric techniques were not employed.

Age Determination

Since only adults were employed in the present study, aging techniques were limited to nongrowth related phenomena. Attrition may be used to age specimens but was not used to age the sample in the present study because attrition was to be used in other contexts and it was important to eliminate an age bias. Specimens were considered adults when the third molars were in occlusion. This was the only aspect of the dentition employed to age the sample.

The most reliable aging technique again uses the pelvis, specifically the pubic symphysis. The symphyseal surface deteriorates over time in a predictable fashion and comparison of the surfaces in the sample to standards established for males and females served as the aging technique. The standards for males are based on the work of McKern and Stewert (1957). However, the standards are only reliable for males under the age of forty. Older males were aged using Todd's standards (1920; 1921). Brooks (1955) has indicated that Todd's method tends to overage. This has been compensated for by making the age intervals large enough to absorb error.

The female pubic symphysis experiences trauma during the birth process which results in a different pattern of age-related change. An aging method comparable to the method used for males was developed by Gilbert and McKern (1973). This standard was used to age the females in the present sample in spite of the criticism leveled at it. Suchey (1977) maintains that the sample size used to generate the standards was too small and that the interobserver error is fairly significant.

Suture closure may also be used to age skeletal specimens. However, there is considerable variability in the timing and pattern of suture closure. For this reason, it was avoided. The utility of suture closure in the present sample was restricted to distinguishing the young from the old.

Attrition

There is no widely accepted standard for quantifying attrition so a system which seemed to best suit the purposes of the present study was employed. The scale adapted is after Hinton (1981) and is reproduced in Table 5. The intervals are based on the pattern of enamel loss. The system was adopted because the criteria for each level was clear, precise and reproducible.

The limits inherent in any attrition scoring system have been reviewed elsewhere. To summarize, the problem is that attrition levels are not equivalent within and between teeth. Therefore, elaborate statistical manipulations of the data are ill-advised.

Some scoring systems have included pulp exposure as an advanced stage of attrition (e.g., Leigh, 1925; Davies and Pederson, 1955) and these systems have been employed in recent attrition analyses (e.g., Koritzer, 1977; Lavelle, 1973). Pulp exposure is the result of attrition overtaking the production of secondary dentin. Therefore, pulp exposure is a factor of rate of wear rather than the amount. Since antemortem tooth loss includes necrotic tooth loss, the identification of pulp exposure independent of attrition was desirable. The presence of exposed pulp was an independent variable in the present analysis. Pulp damage incurred by caries was not included in this variable.

The form of anterior tooth wear was adapted with modifications from Hinton (1981). Five categories were identified and scored. The natural face or a slight blunting was an independent category. The forms of the attritional surface were flat, rounded, cupped and lingually sloped.

TABLE 5

ATTRITION SCORING SYSTEM

Incisors and Canines

1. No dentin exposure
2. Hairline dentin exposure
3. Line of dentin of distinct thickness
4. Moderate dentin exposure still in m-d direction
5. Enamel rim
6. Half of enamel rim gone
7. No enamel rim ("nub")
8. Severe loss of crown height ("nublet")

Premolars

1. No dentin exposure
2. Significant loss of cusp height
3. Full cusp removal and/or moderate dentin patches
4. Minimum of one large dentin patch on one cusp
5. Two large dentin exposures (may be slight coalescence)
6. Enamel rim
7. Half of enamel rim gone
8. Severe loss of crown height

Molars

1. No dentin exposure
2. Significant loss of cusp height
3. Full cusp removal and/or moderate dentin patches
4. Several large dentin exposures, still discrete
5. Two areas coalesce
6. Three areas coalesce or four areas coalesce with enamel island
7. Enamel rim
8. Rim more than half gone and severe loss of crown height

Source: R. J. Hinton, "Form and Patterning of Anterior Tooth Wear among Aboriginal Human Groups." American Journal of Physical Anthropology 54:555-564, 1981.

Wear was considered rounded when a labio-lingual slope could be detected (see Figure 3). The more rapid eroding of dentin at the expense of the surrounding enamel rim results in a cup-shaped depression. This cupped wear was identified as present when the occlusal surface exhibited a distinct basin (see Figure 4). Where no depression was apparent, the occlusal surface was flat (see Figure 5). A unique anterior tooth form was discerned for the Tennessee sample and was included in the scoring system. Erosion of the tooth surface from the lingual aspect results in the exposure of dentin along the lingual margin, emphasizing the incisal form of the anterior teeth. Teeth were scored as possessing incisal wear when dentin was differentially exposed on the lingual surface. The form was obvious wherever it was observed and has been identified in the tables as lingual wear (see Figure 6).

Antemortem Tooth Loss

Antemortem tooth loss was identified on the basis of at least some evidence of alveolar absorption. If no signs of resorption were apparent, the tooth was scored as postmortem loss. The teeth which were not clear as to the etiology of their absence were scored as missing data.

Caries

The carious lesion was scored present by tooth and by booth surface involved. If a tooth had more than one lesion, the larger of the two was scored. The tooth surface categories were cervical, interproximal,

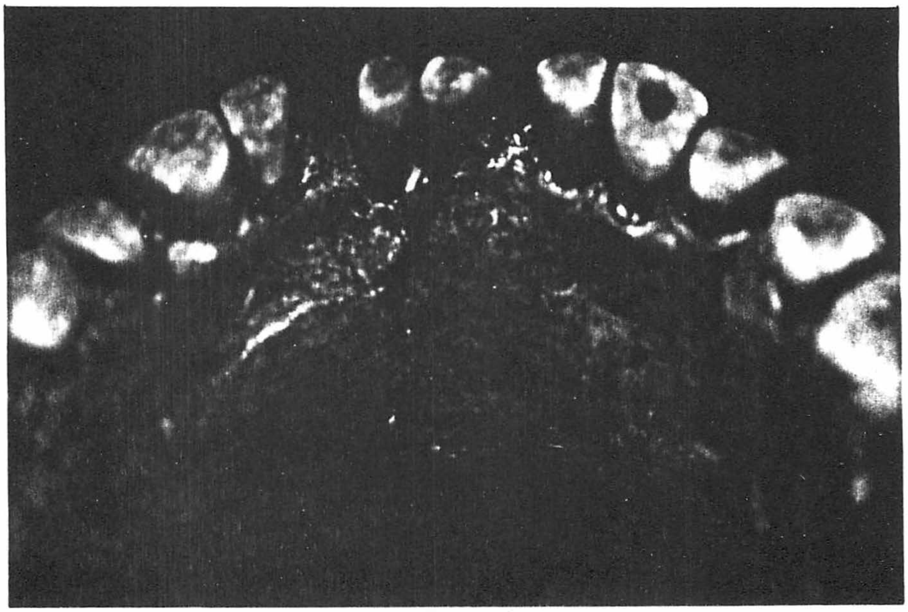


Figure 3. An Example of Rounded Wear from the Archaic Sample.

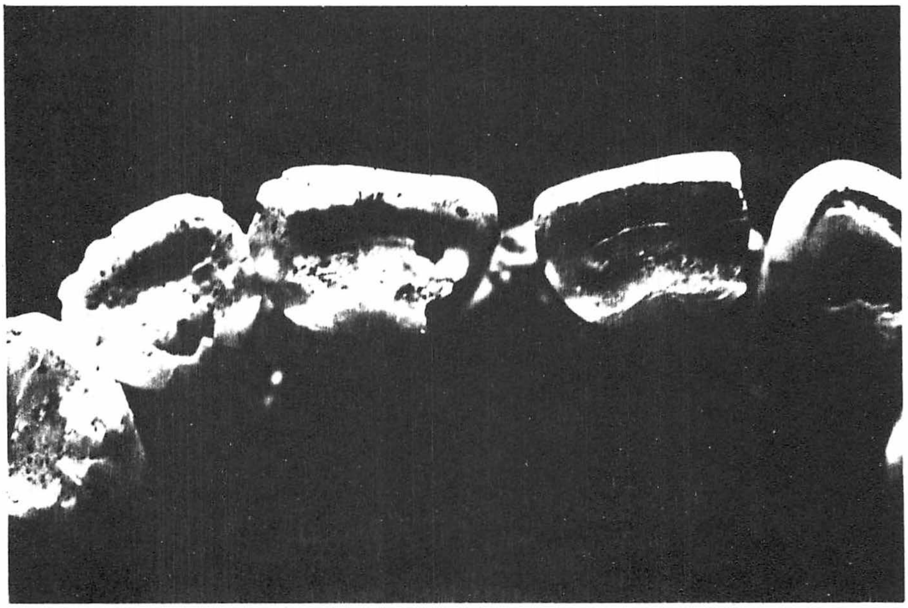


Figure 4. Cupped Wear on an Individual from the Mississippian Sample.

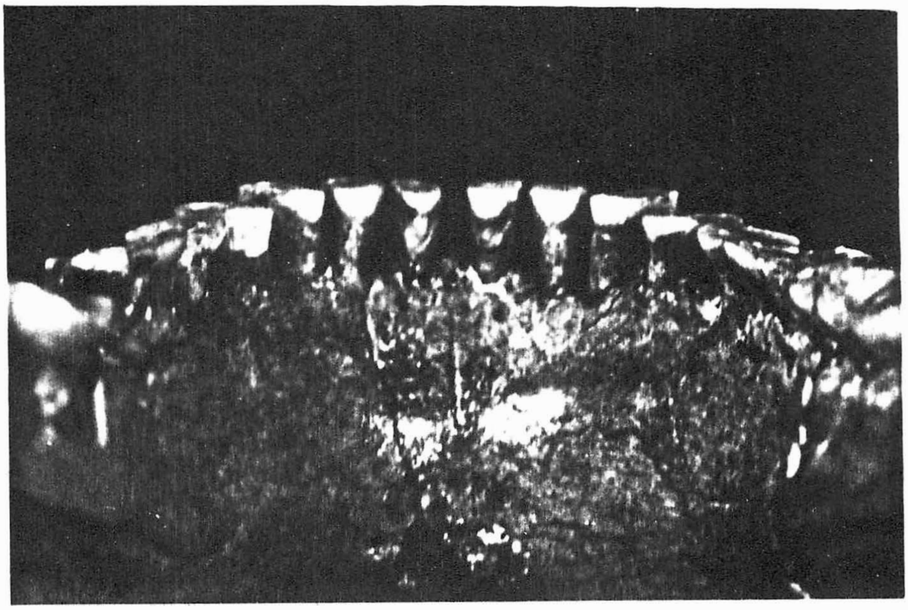


Figure 5. An Example of Flat Wear from the Archaic Sample.

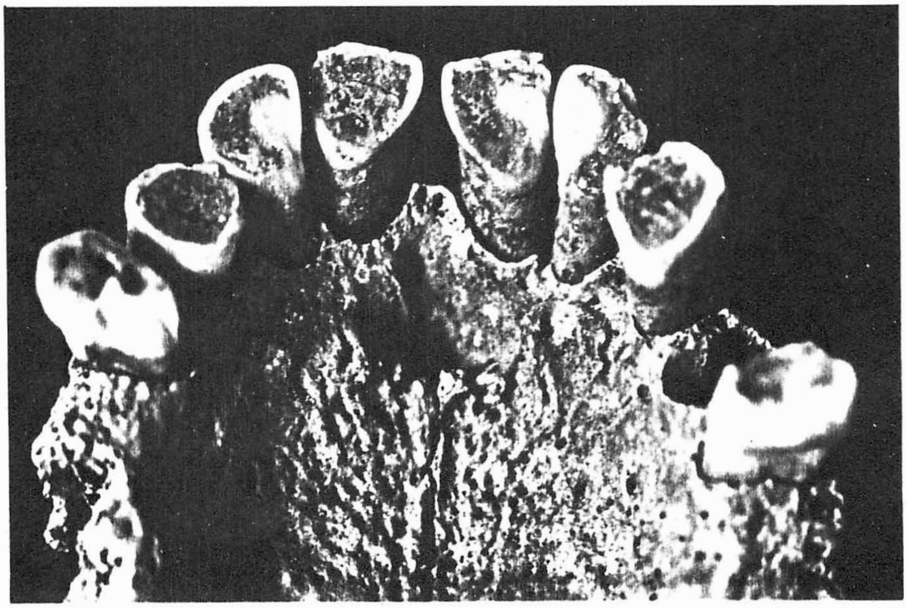


Figure 6. Lingually Worn Teeth from the Mississippian Sample.

buccolingual and occlusal. The identification of lesions was facilitated by the use of a probe and hand lens. Some of the interproximal surfaces were difficult to examine, therefore the possibility that some cavities remained undetected must be considered. Where possible, teeth were removed from their sockets in order to detect lesions which would otherwise have gone unnoticed.

Periodontal Disease

Calculus and two forms of bone loss were scored for periodontal disease detection. The system for scoring calculus was adopted from the epidemiological literature (Greene and Vermillion, 1955). The levels of calculus accumulation are described in Table 6.

TABLE 6

CALCULUS SCORING SYSTEM

Score	Criteria
1.	None
2.	Trace--flecks and perimeter
3.	Slight--less than 1/3 of surface or perimeter with thickness
4.	Moderate--greater than 1/3 of surface and less than 1/2 or considerable thickness
5.	Heavy--greater than 1/2 of surface and of considerable thickness

The infrabony pocket, variable in form and depth, is nevertheless discrete and not difficult to detect where bone texture is good (see Figure 7). Vertical osseous defects were scored for presence and individual tooth affected.

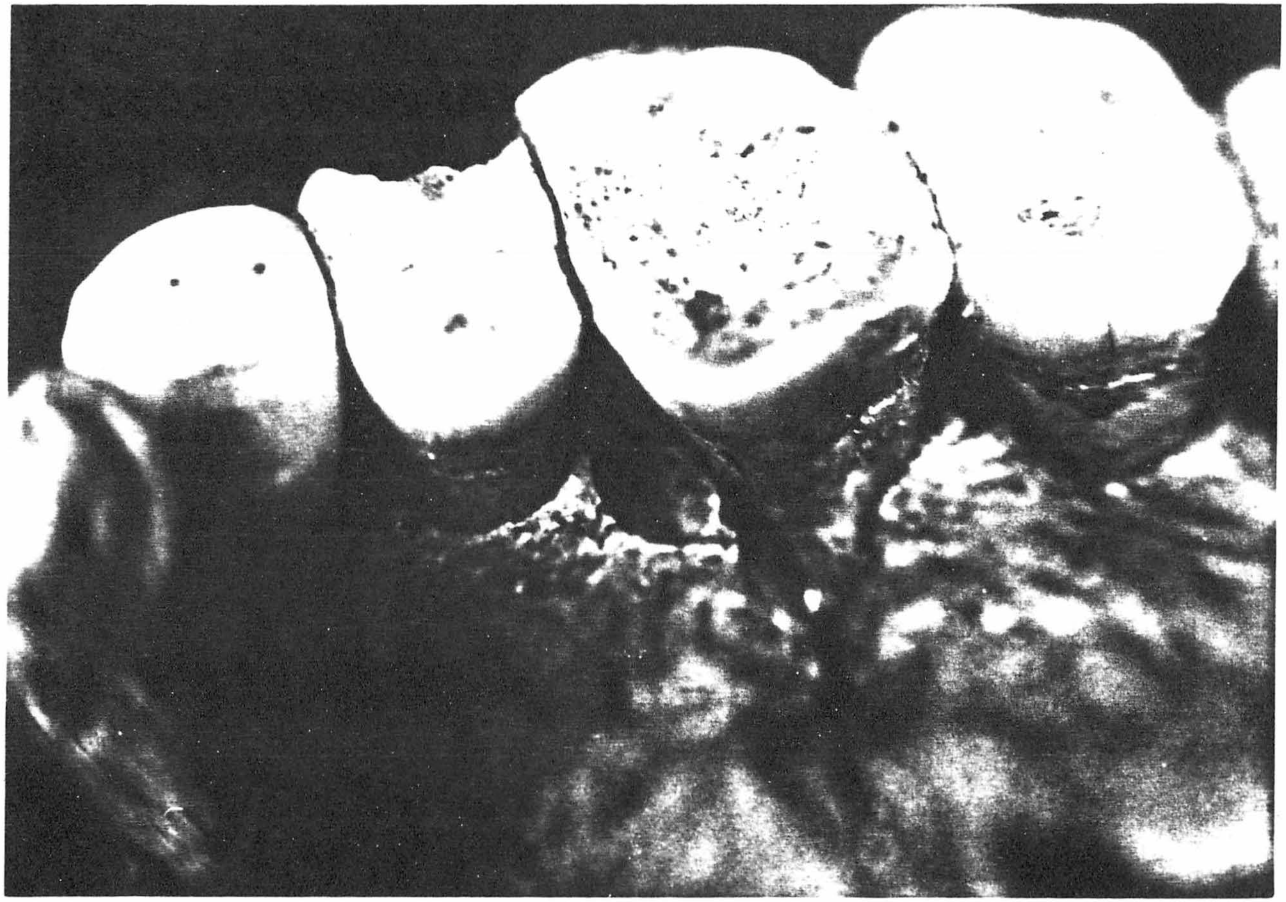


Figure 7. An Example of the Infrabony Pocket from the Archaic Sample.

A form of the Tooth Cervical Height measure (Davies and Picton, 1969) was used to determine the amount of root extrusion present. Buccal and lingual surfaces were avoided because possible physiological deviations in the alveolar crest contour (i.e., dehiscences) would introduce error. The mesial and distal root extrusion was measured instead. The average of the two measurements constituted the estimation of cervical height.

Analytical Techniques

The bulk of the data is composed of either discrete variables or continuous variables arbitrarily divided into contiguous classes. These data sets are appropriately analyzed by statistical techniques which specifically deal with frequencies and distributions.

The statistic employed to analyze the frequency data is the log-likelihood ratio test or G-test for goodness of fit. The test is similar to chi-square, the traditional method of analyzing frequency data, but has several advantages over it, among them being ease of computation (Sokal and Rohlf, 1981). The basic computational formula for the G-test for a calculator with a natural log function is

$$G = 2 \sum^{a} fi \ln \left(\frac{fi}{fi}\right)$$

of "the sum of the independent contributions of departures from expectation [ln (fi/fi)] weighted by the frequency of the particular class (fi)" (Sokal and Rohlf, 1981). The derived score is compared to the tabular chi-square value for the desired significance level and appropriate degrees of freedom (Sokal and Rohlf, 1981).

The particular value of the G-test is its capacity to test complex patterns of association. The three-way contingency table was desirable for many of the variables examined in the present study. This hierarchical test was most frequently employed because it facilitated probing of the interactions of several dimensions whenever significance was achieved at the more complex level. In a three-way test, the computational formula is

$$G = \sum^{aba} fijk \ln (fijk/\hat{f}ijk)$$

where $\hat{f}ijk$ is the product of the row (i), column (j), and depth (k) divided by the square of the total sample size (n) (Sokal and Rohlf, 1969).

The G-test is appropriate when the sample size is greater than fifty. But for samples of less than 200, in 2 × 2 tables, the Yates' correction for continuity was applied (Sokal and Rohlf, 1981).

For many of the variables employed in the present analysis, the differences in the entire distribution of frequencies between two samples required statistical evaluation. For this purpose, the Kolmogorov-Smirnov two-sample test was employed. The null hypothesis is an isomorphic distribution between the two samples and thus the test is "sensitive to differences in location, dispersion, skewness, and so forth" (Sokal and Rohlf, 1981). The test is essentially the significance of the largest unsigned difference between two cumulative percent distributions divided by the product of the sample sizes measured against expected critical values found in the K-S table (Kosal and Rohlf, 1981). The Kolmogorov-Smirnov tests is appropriate for small sample sizes and was thus most appropriate for the data in the present study. For the few samples which exceeded the critical sample size for the application of the K-S test, a correction factor was employed (Sokal and Rohlf, 1981).

CHAPTER V

THE DATA

Antemortem Tooth Loss

Antemortem tooth loss may be caused by one or more of several factors. Caries, periodontal disease, and attrition may be conceded to be primary agents which actively participate in tooth loss, but trauma and the cultural practice of intentional tooth extraction are also possible causes. Trauma is of undeterminable importance. A pattern of intentional tooth extraction is not observed for either the Archaic Period sample or the Mississippian Period sample. The etiology of antemortem tooth loss, therefore, focuses on the above-mentioned processes.

The large and varied body of data which demonstrates subsistence associations for caries, periodontal disease and attrition anticipates patterned differences in antemortem tooth loss between the Archaic and Mississippian samples. Patterns which emerge from population samples examined for tooth loss further anticipate subsistence associated contrasts. Anderson (1965) describes a dramatic difference in tooth loss between hunting and collecting populations and agricultural populations of the Tehuacan Valley. With the transition to agriculture, the percent of antemortem tooth loss drops from 41.2% to a modest 6.2%. The difference has been attributed to a different etiology between the two samples. Anderson states, "in the early phases the cause is attrition leading to the exposure of the pulp chamber. With the adoption of agriculture and its concomitant softer diet high in carbohydrate, caries replaces attrition as the prime cause" (1965). This proposed etiological difference has been inferred from the results of the oral health status examination of five pre-Columbian Peruvian agricultural samples (Elzay et al., 1977). The variations in tooth loss between these samples parallels caries incidence differences.

Antemortem loss frequencies are not always simple to interpret, however. A pattern of antemortem tooth loss was not readily discernible for three pre-European contact Alaskan Eskimo Skeletal populations examined by Costa (1980). The frequency statistics revealed the uniqueness of each sample with respect to rate loss and age and sex differences.

A cursory examination of the summary data for antemortem loss in Table 7 for the Archaic sample and Table 8 for the Mississippian sample suggests that antemortem tooth loss associates with age. Sample size differences both between teeth and between age classes obscures patterned differences, in rate of loss between subsistence systems. Therefore, if patterns of antemortem tooth loss are to be discerned and interpreted, the frequency statistics need to be evaluated by statistical tests of significance appropriate for discontinuous traits. A significance test will differentiate between meaningful and spurious differences in the pattern of antemortem tooth loss.

The log likelihood ratio test was employed to test the associations between age and antemortem tooth loss and to determine whether the rates of tooth loss are isomorphic or not between the Archaic and Mississippian

TABLE 7

SUMMARY DATA OF ANTEMORTEM TOOTH LOSS: ARCHAIC SAMPLE

		Males						Females					
		Age				Total		Age				Total	
Tooth		<20	20-30	30-40	40-50	50+	N	<20	20-30	30-40	40-50	50+	N
Maxilla													
I_1	N[a]	0	2	5	6	9	111	0	0	3	4	9	85
	%	00.00	8.33	13.16	26.10	56.25		00.00	00.00	10.00	22.22	52.94	
I_2	N	0	0	4	8	9	109	0	0	1	7	9	79
	%	00.00	00.00	10.53	36.64	56.25		00.00	00.00	3.33	33.33	56.25	
C	N	0	1	1	7	10	111	0	1	2	4	8	93
	%	00.00	4.16	4.88	30.43	58.82		00.00	16.67	6.90	19.05	42.11	
P_3	N	0	2	3	10	6	111	0	1	3	8	12	97
	%	00.00	8.33	7.32	45.45	42.86		00.00	16.67	10.00	36.36	57.14	
P_4	N	0	0	5	11	7	113	0	0	3	7	13	97
	%	00.00	00.00	12.20	47.82	60.00		00.00	00.00	10.34	30.43	61.90	
M_1	N	0	0	8	13	10	113	1	0	5	7	12	93
	%	00.00	00.00	19.51	56.52	62.50		55.55	00.00	17.24	35.00	60.00	
M_2	N	0	0	4	15	6	110	0	0	3	5	9	93
	%	00.00	00.00	9.75	71.43	40.00		00.00	00.00	10.00	25.00	45.00	
M_3	N	0	0	8	17	6	96	0	0	2	3	9	85
	%	00.00	00.00	22.86	85.00	46.15		00.00	00.00	7.14	13.63	50.00	
Mandible													
I_1	N	0	0	0	4	4	102	0	0	0	9	14	100
	%	00.00	00.00	00.00	18.18	28.57		00.00	00.00	00.00	40.90	51.85	
I_2	N	0	0	1	2	7	110	0	0	1	7	9	105
	%	00.00	00.00	2.70	8.70	43.75		00.00	00.00	3.33	29.16	33.33	
C	N	0	1	3	1	5	111	0	0	1	3	8	109
	%	00.00	4.16	7.90	4.16	33.33		00.00	00.00	3.23	11.11	27.58	
P_3	N	0	0	0	1	5	113	0	0	2	5	10	113
	%	00.00	00.00	00.00	4.16	31.25		00.00	00.00	6.25	17.24	34.48	
P_4	N	0	0	2	2	5	118	0	0	2	7	6	115
	%	00.00	00.00	4.88	7.69	29.41		00.00	00.00	6.25	23.30	20.00	
M_1	N	0	0	5	7	5	122	1	0	3	8	8	114
	%	00.00	00.00	11.36	26.92	27.78		5.88	00.00	9.38	26.67	27.59	
M_2	N	0	0	7	13	5	122	1	0	3	7	11	115
	%	00.00	00.00	15.91	50.00	27.78		5.55	00.00	9.38	23.33	37.93	
M_3	N	0	0	2	8	4	110	0	0	3	8	10	97
	%	00.00	00.00	4.79	30.77	22.22		00.00	00.00	11.11	27.59	34.48	

[a] Number of teeth missing per age category

[b] Percent of teeth missing per age category

TABLE 8

SUMMARY DATA OF ANTEMORTEM TOOTH LOSS: MISSISSIPPIAN SAMPLE

Tooth		Males						Females					
			Age			Total			Age			Total	
		<20	20-30	30-40	40-50	50+	N	<20	20-30	30-40	40-50	50+	N
Maxilla													
I_1	N[a]	0	0	5	0	2	70	0	0	0	2	0	67
	%	00.00	00.00	15.63	00.00	100.00		00.00	00.00	00.00	15.63	00.00	
I_2	N	0	0	5	0	2	66	0	0	0	0	2	64
	%	00.00	00.00	16.13	00.00	100.00		00.00	00.00	00.00	00.00	100.00	
C	N	0	2	1	1	2	70	0	0	0	0	0	70
	%	00.00	8.00	3.13	14.29	100.00		00.00	00.00	00.00	00.00	00.00	
P_3	N	1	2	4	1	2	64	0	0	1	1	0	69
	%	25.00	8.70	13.79	16.67	100.00		00.00	00.00	8.33	16.67	00.00	
P_4	N	0	2	6	1	2	66	0	0	1	2	2	70
	%	00.00	8.33	20.00	16.67	100.00		00.00	00.00	8.33	33.33	100.11	
M_1	N	0	4	8	3	2	71	0	0	1	1	2	65
	%	00.00	16.00	24.24	42.86	100.00		00.00	00.00	8.33	25.00	100.00	
M_2	N	0	3	6	2	2	65	0	2	2	0	1	65
	%	00.00	14.29	19.35	28.57	100.00		00.00	6.06	20.00	00.00	100.00	
M_3	N	0	1	5	1	2	49	0	3	3	0	1	52
	%	00.00	6.67	21.74	20.00	100.00		00.00	11.11	37.50	00.00	100.00	
Mandible													
I_1	N	0	0	2	0	1	65	0	1	0	2	1	64
	%	00.00	00.00	6.45	00.00	100.00		00.00	3.13	00.00	25.00	100.00	
I_2	N	0	0	2	0	1	68	0	1	0	0	1	69
	%	00.00	00.00	6.45	00.00	100.00		00.00	3.03	00.00	00.00	50.00	
C	N	0	0	1	0	1	69	0	0	0	0	2	69
	%	00.00	00.00	3.23	00.00	50.00		00.00	00.00	00.00	00.00	100.00	
P_3	N	1	1	2	1	1	68	0	0	1	2	2	69
	%	25.00	4.17	6.25	16.67	50.00		00.00	00.00	8.33	25.00	100.00	
P_4	N	1	1	3	1	1	70	0	0	0	4	2	71
	%	25.00	4.17	9.09	14.29	50.00		00.00	00.00	00.00	50.00	100.00	
M_1	N	0	2	15	5	2	72	0	7	3	6	2	70
	%	00.00	8.00	14.18	71.43	100.00		00.00	21.86	25.00	75.00	100.00	
M_2	N	0	6	13	7	2	72	0	8	7	4	2	72
	%	00.00	24.00	39.39	87.50	100.00		00.00	23.53	58.33	50.00	100.00	
M_3	N	0	6	11	5	2	66	0	3	4	5	1	62
	%	00.00	27.27	36.67	62.50	100.00		00.00	11.11	33.33	71.43	50.00	

[a] Number of teeth missing per age category

[b] Percent of teeth missing per age category

samples. Age was an important parameter in the present analysis because the age distribution between the two samples is known to be different based on demographic data available for the populations. The Archaic sample, specifically the Eva and Cherry material, is over-represented by the older aged individuals (Magennis, 1977). The Toqua sample is younger (Parham, 1982) and considerable difficulty was encountered in acquiring a large enough sample of older individuals for the purpose of the present research initiative. Therefore, it was important to establish an association for antemortem loss with age to eliminate the bias which it introduces. The results of the G-test on age and tooth loss are reproduced in Table 9. For the purpose of this particular test, tooth types were collapsed to increase the sample size. As for all tests, the sexes were pooled. Five age classes were evaluated (<20, 20-30, 30-40, 40-50, and 50+). The arches were examines separately. As Table 9 indicates, tooth loss is significantly associated with age for all teeth in both samples in both arches except for the maxillary canines in the Mississippian sample. This strong association with age argues in favor of analysis by age class rather than total frequency differences between populations.

The results obtained from a log likelihood test of significance for the between sample evaluation of antemortem tooth loss by age are found in Table 10. Most of the calculated G statistics are not statistically significant, but significant differences do occur in the molar region. The rate of molar loss is significantly different for most of the mandibular age classes. Three maxillary age classes exhibit a rate

TABLE 9

ASSOCIATION OF ANTEMORTEM TOOTH LOSS WITH AGE: CALCULATED G-STATISTIC

	Archaic		Mississippian	
Tooth	Maxilla	Mandible	Maxilla	Mandible
Incisors	78.70*	100.91*	50.76*	27.90*
Canines	43.38*	31.04*	7.19	20.02*
Premolars	92.68*	55.38*	33.52*	38.40*
Molars	156.79*	86.04*	67.46*	109.70*

*p < .001

TABLE 10

G-TEST OF INDEPENDENCE OF ANTEMORTEM TOOTH LOSS WITH AGE: ARCHAIC BY MISSISSIPPIAN SAMPLE

		Age Class				
Tooth Class	Arch	<20	20-30	30-40	40-50	50+
Incisors	maxilla	00.00	1.36	00.02	4.01*	1.41
	mandible	00.00	00.06	1.63	3.82	1.66
Canines	maxilla	00.00	00.04	00.17	1.02	00.00
	mandible	00.00	00.11	00.37	00.29	00.72
Premolars	maxilla	00.003	00.004	1.22	2.37	00.70
	mandible	00.95	00.08	00.37	1.83	3.64
Molars	maxilla	00.91	11.90***	2.27	6.09*	8.69**
	mandible	00.37	28.57***	43.41***	24.20***	18.50***

***p < .001

**p < .01

*p < .05

difference. Since the molar tooth class collapsed the tooth loss data for all three molars, another log likelihood test was undertaken to determine whether fluctuations in the pattern of tooth loss between teeth within each sample might contribute to the between sample differences. These results are found in Table 11. No significant differences were detected for either arch, for any age, or for either sample. This implies that molar loss is largely due to factors which differ between the subsistence systems.

TABLE 11

PATTERN OF ANTEMORTEM MOLAR LOSS: CALCULATED G-STATISTIC

		Age				
Sample	Arch	<20	20-30	30-40	40-50	50+
Archaic	maxilla	00.00	00.00	02.32	00.04	02.50
	mandible	00.00	00.00	00.29	01.12	00.49
Mississippian	maxilla	00.00	00.26	00.48	01.62	00.00
	mandible	00.00	01.12	00.72	00.59	00.00

*p < .001

The examination of the mandibular molar loss frequencies in Tables 7 and 8 (pp. 88 and 89) will quickly reveal that the rate of molar loss is higher for the Mississippian sample. This argues for the role of caries and periodontal disease as the agent or agents responsible for the rate differences. A more detailed evaluation of the contribution of caries, periodontal disease and attrition to antemortem tooth loss is undertaken subsequent to presentation of the descriptive and comparative statistics for these parameters.

Caries

In the Archaic sample, 25 out of 62 males, or 40.32%, exhibit at least one carious lesion. The Archaic females showed a similar incidence, 20 out of 59, or 33.9%. The difference between males and females is not statistically significant (Table 12). In the Archaic male sample, a total of 1805 individual teeth were examined for caries. Only 46 carious teeth were detected, constituting 2.55% of all male teeth. The results were similar for Archaic females. A total of 47 carious teeth were identified out of a sample of 1609. These affected teeth represent 2.9% of the female sample. There is no statistically significant difference between the sexes for the incidence of caries in the total tooth sample (Table 12). The percent of carious teeth agrees well with the pattern for hunter/gathers illustrated in Table 2, p. 9.

TABLE 12

CARIES INCIDENCE: CALCULATED G-STATISTIC

Test	Archaic	Mississippian
Male/female for frequency of carious teeth	.444	2.188
Male/female for frequency of carious individuals	.295	.0034

$^*p < .001$

A mean cariosity per person score was calculated for males and females in order to illustrate the incidence of caries for the Archaic sample. The mean cariosity score is computed by dividing the number of carious teeth by the number of individuals. Archaic males exhibit an average of 1.35 caries per person and females possess the equivalent per person average of 1.25 caries.

As expected, the Mississippian sample exhibits a greater frequency and incidence of caries. For the males, 29 individuals out of 37 exhibited at least one carious lesion. This represents 78.4% of the sample. The female sample yielded a similar incidence of 29 individuals out of 36 or 80.5% of the sample. As with the Archaic sample, the difference in incidence of caries between males and females was not statistically significant (Table 12). The Mississippian male sample yielded 1083 teeth appropriate for caries detection. Of these, 121 were carious or 11.2% of the sample. Similarly, Mississippian females yielded 13.26% carious teeth or 142 out of 1071 individual teeth. The proportion of carious teeth also proves not to be statistically significant for the Mississippian sample (Table 12).

A higher incidence of caries in females has been reported for the agricultural sample from St. Catherine's Island on the Georgia coast (Larson, 1981a, 1981b). The sex difference in frequency parallels the ethnographic records for Indians of the Southeast of female responsibility for maize cultivation (Hudson, 1976). If the data from the Georgia coast anticipates a pattern for populations who historically relegate the cultivation of maize to women, then the Toqua sample should have shown similar sex differences in caries frequency. That they do not should not mean that division of labor cannot always reliably be mirrored in caries incidence. Status differences were not accounted for in the present analysis and other diet/nutrition parameters have segregated according to presumed rank differences (Hatch and Willey, 1974; Parham, 1982). It is possible that caries incidence may also be distributed by status based on proposed food redistribution responsibilities for higher status individuals (Hatch and Willey, 1974). If this is true, then sex differences, if indeed there are any, may have been obscured by bias introduced by status (particularly if biased toward high status). The frequency of carious teeth for the Mississippian sample agrees well with the frequencies derived for other agricultural samples (Table 2, p. 9). Mean cariousity scores were also calculated for the Mississippian population as an illustrative device. The score for males is 3.27 and females is 3.94. The average score values show a sex difference, but as indicated earlier, the caries experience between males and females is not statistically significant.

The summary data of caries location are presented in Table 13. Since sex differences in incidence were not statistically significant, the male and female data were pooled to facilitate statistical evaluation.

Even a superficial examination of the frequency distribution of caries by location reveals that for the Archaic sample, cervical caries is the predominant form. These data wholeheartedly agree with those gleaned from similar populations in Britain (Moore and Corbett, 1973, 1975). Over 91% of maxillary caries are cervical. Other locations are sporadically represented and not patterned in location along the tooth row. In the mandible, cervical caries shares its importance with

TABLE 13

SUMMARY DATA OF CARIES LOCATION

	Archaic Sample									Mississippian Sample								
	Tooth									Tooth								
Location	I_1	I_2	C	P_3	P_4	M_1	M_2	M_3	Row Totals (%)	I_1	I_2	C	P_3	P_4	M_1	M_2	M_3	Row Totals (%)
Maxilla																		
cervical	1	1	4	3	0	7	19	18	53 (91.38)	6	7	6	9	12	17	21	9	87 (56.13)
interproximal	0	0	1	1	0	0	0	0	2 (3.39)	9	2	1	7	7	5	2	0	33 (21.15)
buccolingual	0	0	0	0	0	1	0	0	1 (1.69)	2	3	2	1	1	4	3	1	17 (10.90)
occlusal	0	0	0	0	1	0	0	1	2 (3.39)	0	1	0	0	1	6	3	7	18 (11.54)
column totals	1	1	5	4	1	8	19	19	58 (100.00)	17	13	9	17	21	32	29	17	155 (100.00)
Mandible																		
cervical	0	0	1	0	1	6	5	2	15 (39.47)	2	1	6	9	4	7	9	6	44 (40.37)
interproximal	0	0	1	1	0	0	0	1	3 (7.89)	1	1	3	0	2	3	1	4	15 (13.76)
buccolingual	0	0	1	0	0	0	1	2	4 (10.53)	0	0	0	0	3	6	1	3	13 (11.93)
occlusal	0	1	2	2	1	1	1	8	16 (42.11)	0	0	0	0	0	13	12	11	36 (33.33)
column totals	0	1	5	3	2	7	7	13	38 (100.00)	3	2	9	9	9	29	23	24	108 (100.00)

occlusal surface caries. Interproximal and bucco lingually located lesions also occur sporadically.

More carious lesions occur in the maxilla than the mandible. This observation was tested for significance using the G-test and was revealed to be significant at the .025 level (Table 14). Caries incidence seems to concentrate in the posterior tooth row and the contingency table analysis was again employed to test the association of caries incidence with location along the tooth row. The results are recorded in Table 15. Caries incidence is not independent of location along the tooth row for maxillary and mandibular cervical caries and mandibular occlusal surface caries. Therefore, caries, where it occurs in the Archaic sample, is seen in a higher frequency in the posterior teeth. The high incidence of caries in this portion of the tooth row may be attributed to the results of food impaction, for which the molar region is particularly vulnerable (Larato, 1970; Saari et al., 1968).

The interpretive framework proposed for the British series is appropriate for the Archaic sample and merits reporting. According to Mandel,

> Caries usually (does) not develop until wear of the occlusal (biting) surfaces, recession of the gums, and loss of some bony support of the teeth (periodontal disease) encourage(s) food impaction at the gum line between the teeth. Given enough time, starch molecules are enzymatically degraded to glucose and can enter the bacterial cells and be converted by glycolysis to lactic and other organic acids. (1979)

The Mississippian sample is not only characterized by a larger number of carious teeth, but also a wider range of location and distribution along the tooth row. A substantial percentage of carious

TABLE 14

ARCH DIFFERENCES IN CARIES FREQUENCY: CALCULATED G-STATISTIC

Sample	Statistic	P	df
Archaic	8.39*	.025	1
Mississippian	16.89*	.001	1

*p < .05

TABLE 15

ASSOCIATION OF CARIES LOCATION BY TOOTH TYPE: CALCULATED G-STATISTIC

Sample	Arch	Test	Statistic	P	df
Archaic	maxilla	cervical	15.70*	.05	7
	mandible	cervical	17.92*	.025	7
	mandible	occlusal	9.59*	.5	7
Mississippian	maxilla	cervical	6.97*	.5	7
	maxilla	interproximal	36.20*	.001	7
	maxilla	buccolingual	4.66	-	-
	maxilla	occlusal	23.03*	.005	7
	mandible	cervical	25.74*	.001	7
	mandible	interproximal	.307	-	-
	mandible	buccolingual	12.08*	.05	7
	mandible	occlusal	33.99*	.001	7

*p < .05

lesions is still located at the cervix. In the maxilla, cervical caries is 56.41% of all lesions and in the mandible, 40.37% of all lesions. The distribution of cervical caries in the maxilla is not strongly associated with location in the arch. The derived G-statistic is significant at only the .5 level (Table 15). In the mandible, cervical caries is very highly associated with the posterior teeth. The level of significance of the derived G-statistic for the mandibular cervical caries is significant at the .001 level (see Table 15).

Crown lesions located in the bucco-lingual surface in the maxilla are not statistically significant with respect to position along the tooth row. However, caries on the occlusal surface for the same arch do preferentially segregate in the posterior tooth area. Interproximal caries distribute preferentially in anterior tooth row (Table 15) at a .001 level of significance. The opposite is true in the mandible; interproximal caries are not located preferentially in any portion of the tooth row. Caries in the bucco-lingual dimension do occur more frequently in the molar region, but the significance level of this association is not great (.05). The occurrence of occlusal surface caries in the molar region of the mandible is significant at the .001 level (Table 15).

Like the Archaic sample, more caries are located in the maxilla than the mandible and this association is statistically significant (Table 14). The agreement of caries distribution by arch may indicate the susceptibility of the maxilla to carious involvement, presumably as related to food impaction and inaccessibility to natural mechanisms of oral hygiene (i.e., vigorous mastication). The shift in caries location from predominantly cervical forms to forms located on the crown agrees with the shift in location for carious lesions reported for other agricultural samples (Moore and Corbett, 1973, 1975; Hardwick, 1960).

Basically, the incidence and location of caries on the tooth agrees with data derived from other sources.

Attrition

Rate of Attrition

Differences in attrition rates between hunter/gatherer populations and agricultural groups have become apparent from years of accumulated attrition data. It has also been introduced in an earlier chapter that the main variable affecting rate of wear is the physical consistency of the food (including the abrasive contaminants). The archeological data for the Archaic and Mississippian samples suggests that food preparation techniques and therefore, texture of the food bolus, have undergone dramatic change. This change is also seen in independent biological data (Hinton, 1981; Hinton et al., 1980). Therefore, a cohesive interpretive framework is firmly established for attrition rate evaluation.

The summary data for attrition level frequencies are located in Table 16 for the Archaic sample and Table 17 for the Mississippian sample. The attrition levels have been collapsed to four classes in order to increase the sample size and to maximize the frequency changes incumbant with age. Likewise, parts of the tooth classes data and males and females have been collapsed for the same reason. From the

TABLE 16

ATTRITION FREQUENCIES FOR THE ARCHAIC SAMPLE

		Maxillary Dentition					Mandibular Dentition				
		Attrition Level				Maxillary Row Totals	Attrition Level				Mandibular Row Totals
Tooth	Age	Slight	Intermediate	Significant	Severe		Slight	Intermediate	Significant	Severe	
I_s	<20	34	15	4	0	53	39	11	4	0	54
	20-30	11	27	12	0	50	11	29	8	3	51
	30-40	2	36	33	27	98	0	40	40	23	103
	40-50	0	3	12	27	42	0	8	18	32	58
	50+	0	0	4	17	21	0	0	9	27	36
C_s	<20	21	6	0	0	27	22	0	2	0	24
	20-30	9	14	6	0	29	5	19	4	0	28
	30-40	2	15	31	17	65	0	14	31	15	60
	40-50	0	1	8	23	32	0	2	16	25	43
	50+	0	0	1	14	15	0	0	8	22	30
P_s	<20	30	20	2	2	54	30	20	2	2	54
	20-30	6	35	17	0	58	6	35	17	0	58
	30-40	0	12	85	28	125	0	12	85	28	125
	40-50	0	0	41	44	85	0	0	42	44	86
	50+	0	0	9	55	64	0	0	5	37	42
M_1	<20	0	19	7	0	26	0	19	7	1	27
	20-30	0	4	16	10	30	0	4	16	10	30
	30-40	0	2	10	54	68	0	2	10	54	66
	40-50	0	0	0	41	41	0	0	0	41	41
	50+	0	0	0	33	33	0	0	0	33	33
M_2	<20	17	8	0	2	27	17	8	0	2	27
	20-30	3	13	10	4	30	3	13	10	4	30
	30-40	0	6	17	40	63	0	6	17	40	57
	40-50	0	0	2	34	36	0	0	2	34	36
	50+	0	0	0	31	31	0	0	0	31	31
M_3	<20	10	0	0	0	10	10	0	0	0	10
	20-30	9	14	0	0	23	9	14	0	0	23
	30-40	11	27	10	14	62	11	27	10	14	62
	40-50	5	11	7	15	38	5	11	7	15	38
	50+	0	6	3	22	31	0	6	3	22	31

TABLE 17

ATTRITION FREQUENCIES FOR THE MISSISSIPPIAN SAMPLE

		Maxillary Dentition					Mandibular Dentition				
		Attrition Level					Attrition Level				
Tooth	Age	Slight	Intermediate	Significant	Severe	Maxillary Row Totals	Slight	Intermediate	Significant	Severe	Mandibular Row Totals
I_s	<20	34	3	0	0	37	32	0	0	0	32
	20-30	45	46	1	0	92	47	43	0	0	90
	30-40	8	29	25	1	63	10	53	7	0	70
	40-50	0	3	7	6	16	5	6	9	4	24
	50+	-	-	-	-	-	-	-	-	-	-
C_s	<20	19	0	0	0	19	14	0	0	0	14
	20-30	24	16	2	0	42	22	18	0	0	40
	30-40	7	14	13	1	35	3	31	4	0	38
	40-50	0	2	4	0	6	0	6	6	0	12
	50+	-	-	-	-	-	-	-	-	-	-
P_s	<20	36	0	0	0	36	36	0	0	0	36
	20-30	75	14	3	0	92	83	17	5	0	105
	30-40	34	19	5	1	59	40	31	10	0	81
	40-50	6	6	3	0	15	6	4	6	1	17
	50+	-	-	-	-	-	-	-	-	-	-
M_1	<20	18	0	1	0	19	14	0	1	0	15
	20-30	13	25	16	0	54	12	27	5	0	44
	30-40	4	13	14	0	31	4	9	10	2	25
	40-50	1	1	5	0	7	0	0	3	0	3
	50+	-	-	-	-	-	-	-	-	-	-
M_2	<20	20	0	0	0	20	20	0	0	0	20
	20-30	31	16	0	0	47	27	14	1	0	42
	30-40	20	8	2	0	30	7	11	5	0	23
	40-50	3	4	3	0	10	0	2	0	0	2
	50+	-	-	-	-	-	-	-	-	-	-
M_3	<20	6	0	0	0	6	9	0	0	0	9
	20-30	32	3	0	0	36	32	1	0	0	33
	30-40	16	3	0	0	19	15	8	0	0	23
	40-50	5	1	0	0	6	2	1	0	0	3
	50+	-	-	-	-	-	-	-	-	-	-

frequency distributions available in Tables 16 and 17, it is easy to discern a rate difference in attrition levels between the two samples. A more effective method of demonstrating rate differences is the application of a suitable significance statistic. Since detection of differences in the total frequency distribution between sites was the objective, the Kolmogorov-Smirnov test for two samples was employed. In an earlier chapter, it was noted that the equivalency of attrition scores between tooth types cannot be assumed. Therefore, in order to avoid any score distribution bias which may be incurred by the lumping of teeth of different sample size, each tooth was tested separately. The results of the Kolmogorov-Smirnov tests between Archaic and Mississippian females are found in Table 18. The male comparisons are found in Table 19. With only a few exceptions, the total frequency distributions are significantly different between the samples. This means that for all teeth, both in the maxilla and the mandible, and for at least four age classes, and the Archaic sample are characterized by a more rapid rate of tooth wear than the Mississippian.

Pulp Exposure

When attrition of the dentin procedes at a faster rate than the deposition of secondary dentin, the pulp cavity becomes exposed resulting in the necrosis of the tooth. Pulp exposures are common in heavy attrition environments (e.g., Hylander, 1977; Pederson, 1949; Campbell, 1925), and are often accompanied by abscesses. The environment of rapid attrition is not the only variable which causes pulp

TABLE 18

ATTRITION RATES: KOLMOGOROV-SMIRNOV TEST PERFORMED ON FEMALE SAMPLES

	Maxillary Dentition						Mandibular Dentition				
			Age						Age		
Tooth	1	2	3	4	5	Tooth	1	2	3	4	5
I_1	210***	.80**	216***	20*	-	I_1	204***	1.0**	126***	52***	-
I_2	240***	1.0**	1.0**	30**	-	I_2	252***	1.0**	1.0**	90***	-
C	270***	1.0**	1.0**	32*	-	C	180***	132***	1.0**	132***	-
P_3	252***	1.0**	1.0**	70***	-	P_3	255***	.96**	1.0**	92***	-
P_4	270***	1.0**	250***	64***	-	P_4	255***	1.0**	1.0**	63***	-
M_1	255***	1.0**	360***	39**	-	M_1	221***	144***	1.0**	44**	-
M_2	240***	1.0**	1.0**	75***	-	M_2	272***	150***	1.0**	46**	-
M_3	60***	115***	100***	34*	-	M_3	63***	110***	161***	-	-

*$p < .05$

**$p < .01$

***$p < .001$

TABLE 19

COMPARISON OF ATTRITION RATES BETWEEN MALE SAMPLES: KOLMOGOROV-SMIRNOV TEST

	Maxillary Dentition						Mandibular Dentition				
			Age						Age		
Tooth	1	2	3	4	5	Tooth	1	2	3	4	5
I_1	40**	380***	460***	75***	-	I_1	18*	300***	1.0**	91***	-
I_2	36**	306***	.81**	65***	-	I_2	40**	440***	1.0**	119***	-
C	-	-	-	-	-	C	9.0	296***	1.0**	126***	20*
P_3	30**	418***	.94**	24	-	P_3	40**	552***	1.0**	76***	22*
P_4	40**	480***	95.2**	48**	-	P_4	255***	.96**	1.0**	92***	-
M_1	30**	483***	81.8**	36**	-	M_1	14	480***	.87**	-	-
M_2	40**	391***	1.0**	30**	-	M_2	40**	408***	1.0**	-	-
M_3	-	216***	360***	-	-	M_3	-	216***	1.0**	34*	-

*p < .05

**p < .01

***p < .001

damage. Carious lesions ultimately invade the pulp cavity and periapical abscessing, a consequence of periodontal disease, may also destroy the pulp cavity. Pulp exposure, because of its intimate association with the process of attrition, has often been included as a diagnostic feature of advanced attrition for attrition scoring systems. Pulp exposure, however, is actually a feature of rate of wear rather than severity. The inappropriateness of pulp exposure in attrition scoring systems has been reviewed in Chapter IV. The value of pulp exposure as a separate variable illustrating attrition rates has yet to be exploited. The present section undertakes just such an examination in order to demonstrate its value as a descriptive and comparative parameter.

The rate of attrition for the Mississippian sample is as we have seen predictably and demonstrably lower than the Archaic. This situation anticipates a significantly different frequency of pulp exposures for the two samples. This predicted contrast between the two subsistence strategies is borne out by briefly reviewing the summary statistics found in Table 20. For both Mississippian males and females and in both dental arches, the occurrence of pulp exposure is essentially sporadic. Only four pulp exposures were observed for the total maxillary tooth sample of 386 teeth for males and only two pulp exposures were detected in the female maxillary tooth sample of 451 teeth. The incidence of pulp exposure in the Mississippian mandibles was equally sporadic. Five pulp exposures were observed in the male mandibular sample of 406 teeth. The mandibular tooth sample for females yielded three pulp exposures from a possible 413 teeth. This is in striking contrast with the Archaic sample. Archaic males exhibited a frequency of 66 pulp exposures out of 696 maxillary teeth and 71 pulp exposures out of 752 mandibular teeth. Archaic females are equally characterized by a large proportion of pulp exposures in contrast to the Mississippian females. A total of 84 pulp exposures was detected out of a total sample of 636 maxillary teeth and 66 out of 740 mandibular teeth possessed exposed pulps.

TABLE 20

PULP EXPOSURE: SUMMARY DATA

	Archaic				Mississippian			
	Male		Female		Male		Female	
	max.	mand.	max.	mand.	max.	mand.	max.	mand.
incidence:	66	71	84	66	4	5	2	3
total N:	696	752	636	740	386	406	451	413
%:	9.48	9.44	13.2	8.92	1.04	1.23	0.44	0.73

Application of the G-statistic in a three-way analysis, evaluating pulp exposure presence (i.e., incidence) against age and tooth class parameters, was not statistically significant for any of the arches in both the male and female Mississippian samples (Table 21). Tooth types were collapsed into three classes representing the front, middle and back of the tooth row. The results of the G-statistic for the Archaic sample reveal patterns in the distribution of pulp exposures in the tooth row and by age.

TABLE 21

THREE-WAY TESTS OF INDEPENDENCE FOR PULP EXPOSURE IN THE MISSISSIPPIAN SAMPLE: CALCULATED G-STATISTIC

	Mississippian Sample			
	Males		Females	
Test	Maxilla	Mandible	Maxilla	Mandible
incidence/class/age	11.17	34.39	12.72	1.17

*p < .005 (22 d.f.)

A three-way G-test was undertaken for the male maxilla and mandible and the female maxilla and mandible (Table 22). The results were statistically significant for all arches at the .005 level of significance. This significant association between age, tooth class and pulp exposure merited further probing in order to determine the specific role of age and tooth class on the distribution of pulp exposures. The examination of pulp exposure by tooth class (Table 22) yielded a statistically significant association in the mandible for both the Archaic males and females. No such significance was apparent for either of the maxillae. In the male sample (Table 23), incisors and premolars were not statistically significant from each other in their incidences of pulp exposures. Both tooth classes were, however, significantly different from molars. Therefore, for males, the molar teeth are more vulnerable to pulp necrosis than teeth in the anterior and mid tooth row. The pattern for females appears to be different. Incisor incidence (Table 23) is not statistically significantly different from premolars

TABLE 22

TESTS OF INDEPENDENCE FOR PULP EXPOSURE IN THE ARCHAIC SAMPLE: CALCULATED G-STATISTIC

	Archaic Sample							
	Males				Females			
Test	Maxilla	df[a]	Mandible	df	Maxilla	df	Mandible	df
Incidence/class/age	74.59*	22	82.32*	22	64.13*	22	71.02*	22
Incidence/class	9.72	2	216.63*	2	1.84	2	17.94*	2
Age/class	15.64	8	5.54	8	4.97	8	6.73	8
Incidence/age	45.53*	4	49.18*	4	40.71*	4	16.75*	4

[a] df = degree of freedom

*p < .005

TABLE 23

PULP EXPOSURE BY TOOTH CLASS: CALCULATED G-STATISTIC FOR ARCHAIC MANDIBLES

Test	Males	Females
Incisors/Premolars	0.60	4.23
Incisors/Molars	15.17*	5.31
Premolars/Molars	8.15*	17.11*

*p < .005 (1 d.f.)

and molars but the premolars are different from the molars. This does not so much represent a difference in pattern between the males and females as it does represent difference in the pulp exposure proportion for the females sample. Molars represent the class with the largest incidence of pulp exposures (41 out of 300) but the intermediate size of the incisor sample operated to render it statistically insignificant to the other two classes.

The next parameter examined was the relationship of pulp exposure to age. The association of pulp exposure with tooth class merited a preliminary examination of tooth class to age in order to detect any bias in tooth type for any age class. No statistically significant association between tooth class distribution and age was detected for any of the arches (Table 22). As might be expected, pulp exposure was significantly associated with age for all arches. Table 24 for males and Table 25 for females presents the G-statistic calculations for each individual age class comparisons. The patterns of distribution for the mandible in both the male and female samples are identical. Incidence

TABLE 24

TEST OF INDEPENDENCE OF PULP EXPOSURE TO AGE: ARCHAIC MALE SAMPLE

	Calculated G-Statistic Age				
Age	<20	20-30	30-40	40-50	50+
<20	-	8.44[a]*	16.31[a]*	12.02[a]*	21.63[a]*
20-30	1.99[b]	-	22.77[a]*	12.17[a]*	48.62[a]*
30-40	6.88[b]	4.46[b]	-	0.14[a]	3.17[a]
40-50	14.78[b]*	16.34[b]*	6.09[b]	-	3.14[a]
50+	24.09[b]*	30.63[b]*	18.36[b]*	3.49[b]	-

[a] Maxillary score.

[b] Mandibular score.

*p < .005 (1 df)

TABLE 25

TEST OF INDEPENDENCE OF PULP EXPOSURE TO AGE: ARCHAIC FEMALE SAMPLE

	Calculated G-Statistic Age				
Age	<20	20-30	30-40	40-50	50+
<20	-	0.17[a]	11.80[a]*	11.80[a]*	35.46[a]*
20-30	1.06[b]	-	2.97[a]	4.48[a]	15.15[a]*
30-40	2.95[b]	4.81[b]	-	0.66[a]	14.49[a]*
40-50	8.77[b]*	8.24[b]*	2.58[b]	-	7.44[a]
50+	21.18[b]*	14.45[b]*	13.47[b]	3.95[b]	-

[a] Maxillary score.

[b] Mandibular score.

*p < .005 (1 df)

of pulp exposure is not statistically significant between adjacent age classes but becomes so over two age class intervals. The only exception for both sexes is the incidence between the 30-40 age class and the class of individuals less than age twenty. The general pattern indicates a steady frequency increase in pulp exposure over time.

Anterior Tooth Form

If we acknowledge that the form of tooth wear is a reflection of patterns of tooth use and jaw movement (Brace, 1967, 1975; Smith, 1976; Cybulski, 1974; Taylor, 1963; Roydhouse and Simonsen, 1975), then subsistence associated contrasts in anterior tooth form suggest differences in tooth use activities.

Distinct differences in the form of advancing wear for incisal teeth have been identified between hunter/gatherers and agriculturalists (Hinton, 1981; Molnar, 1968). The former are characterized by a high frequency of labiolingual rounding of the occlusal surface. The agriculturalists may be typified by a high frequency of cupping of the occlusal surface. In the present sample, another type of wear was identified and scored. This form, identified as lingual wear, has been defined and illustrated in the previous chapter. Basically, lingual wear is the selective attritioning of the lingual tooth surface resulting in an exaggeration of the incisal form of the anterior teeth. The distribution of these forms by tooth, age and sex are presented in Table 26 for the Archaic and Table 27 for the Mississippian. The frequency by percent of the wear forms is graphed in Figure 8 for females and in Figure 9 for males. The incidence of cupping and

TABLE 26

AGE DISTRIBUTION OF ANTERIOR TOOTH FORMS FOR THE ARCHAIC SAMPLE

		Males					Females					
				Age					Age			
Tooth	Shape	<20	20-30	30-40	40-50	50+	<20	20-30	30-40	40-50	50+	N Teeth
Maxilla	unworn	7	10	3	0	0	12	0	1	0	0	
	flat	3	10	16	11	0	4	4	17	4	4	
I_1	rounded	0	0	2	4	1	0	0	5	6	3	
	cupped	0	0	0	0	0	0	0	0	0	0	
	lingual	0	0	0	0	2	0	0	1	0	0	129
	unworn	7	10	3	0	0	13	0	2	0	0	
	flat	2	10	20	10	3	3	5	16	6	2	
I_2	rounded	0	0	4	3	1	0	0	6	3	4	
	cupped	0	0	0	0	0	0	0	0	0	0	
	lingual	0	0	0	0	0	0	0	1	0	0	134
	unworn	7	14	3	0	1	16	0	2	0	0	
	flat	2	10	30	7	3	2	3	17	8	2	
C	rounded	0	0	4	7	2	0	0	6	8	2	
	cupped	0	0	0	0	0	0	0	0	0	0	
	lingual	0	0	0	0	0	0	0	0	0	0	163
Mandible	unworn	7	6	0	0	0	11	0	0	0	1	
	flat	2	14	20	5	3	6	3	13	3	2	
I_1	rounded	0	0	5	8	7	0	1	8	10	3	
	cupped	0	0	0	0	0	0	0	0	0	0	
	lingual	0	0	0	0	0	0	0	0	0	0	137
	unworn	4	5	0	0	0	12	0	0	0	1	
	flat	2	17	29	7	4	6	5	16	4	2	
I_2	rounded	0	0	2	9	5	0	1	12	11	9	
	cupped	0	0	0	1	0	0	0	0	0	0	
	lingual	0	0	0	0	0	0	0	0	0	0	167
	unworn	7	8	0	0	0	13	0	0	0	1	
	flat	2	14	24	12	6	2	1	20	3	5	
C	rounded	0	0	6	8	4	0	2	7	17	12	
	cupped	0	0	0	0	0	0	0	0	0	0	
	lingual	0	0	0	0	0	0	0	1	0	1	176

TABLE 27

AGE DISTRIBUTION OF ANTERIOR TOOTH FORMS FOR THE MISSISSIPPIAN SAMPLE

		Males					Females					
		Age					Age					
Tooth	Shape	<20	20-30	30-40	40-50	50+	<20	20-30	30-40	40-50	50+	N Teeth
Maxilla I_1	unworn	4	3	0	0	0	8	2	0	0	0	
	flat	0	16	6	3	0	4	19	7	1	0	
	rounded	0	0	0	0	0	0	0	0	0	0	
	cupped	0	0	6	0	0	0	0	2	0	0	
	lingual	0	0	6	2	0	1	7	0	2	0	99
I_2	unworn	4	7	0	0	0	11	7	3	0	0	
	flat	0	16	6	3	0	3	11	3	0	0	
	rounded	0	0	0	0	0	0	0	0	0	0	
	cupped	0	1	3	1	0	0	0	2	0	0	
	lingual	0	0	5	2	0	1	9	1	2	0	99
C	unworn	3	5	1	0	0	11	12	0	0	0	
	flat	1	14	10	3	0	2	14	5	0	0	
	rounded	0	0	0	0	0	0	0	0	0	0	
	cupped	0	1	8	0	0	0	0	0	0	0	
	lingual	0	0	4	0	0	0	0	2	1	0	97
Mandible I_1	unworn	2	0	2	0	0	4	1	1	0	0	
	flat	0	15	23	7	0	8	25	5	4	0	
	rounded	0	0	1	0	0	0	0	0	0	0	
	cupped	0	0	0	0	0	0	0	0	0	0	
	lingual	0	0	0	0	0	0	0	0	0	0	98
I_2	unworn	2	2	1	0	0	5	0	1	0	0	
	flat	2	17	25	7	0	9	29	5	3	1	
	rounded	0	0	0	0	0	0	0	0	0	0	
	cupped	0	0	0	0	0	0	0	0	1	0	
	lingual	0	0	0	0	0	0	0	0	0	0	110
C	unworn	1	4	1	0	0	10	7	1	0	0	
	flat	1	7	24	4	1	2	15	4	5	0	
	rounded	0	0	0	0	0	0	0	0	0	0	
	cupped	0	0	0	0	0	0	0	0	0	0	
	lingual	0	1	2	1	1	0	0	1	0	0	84

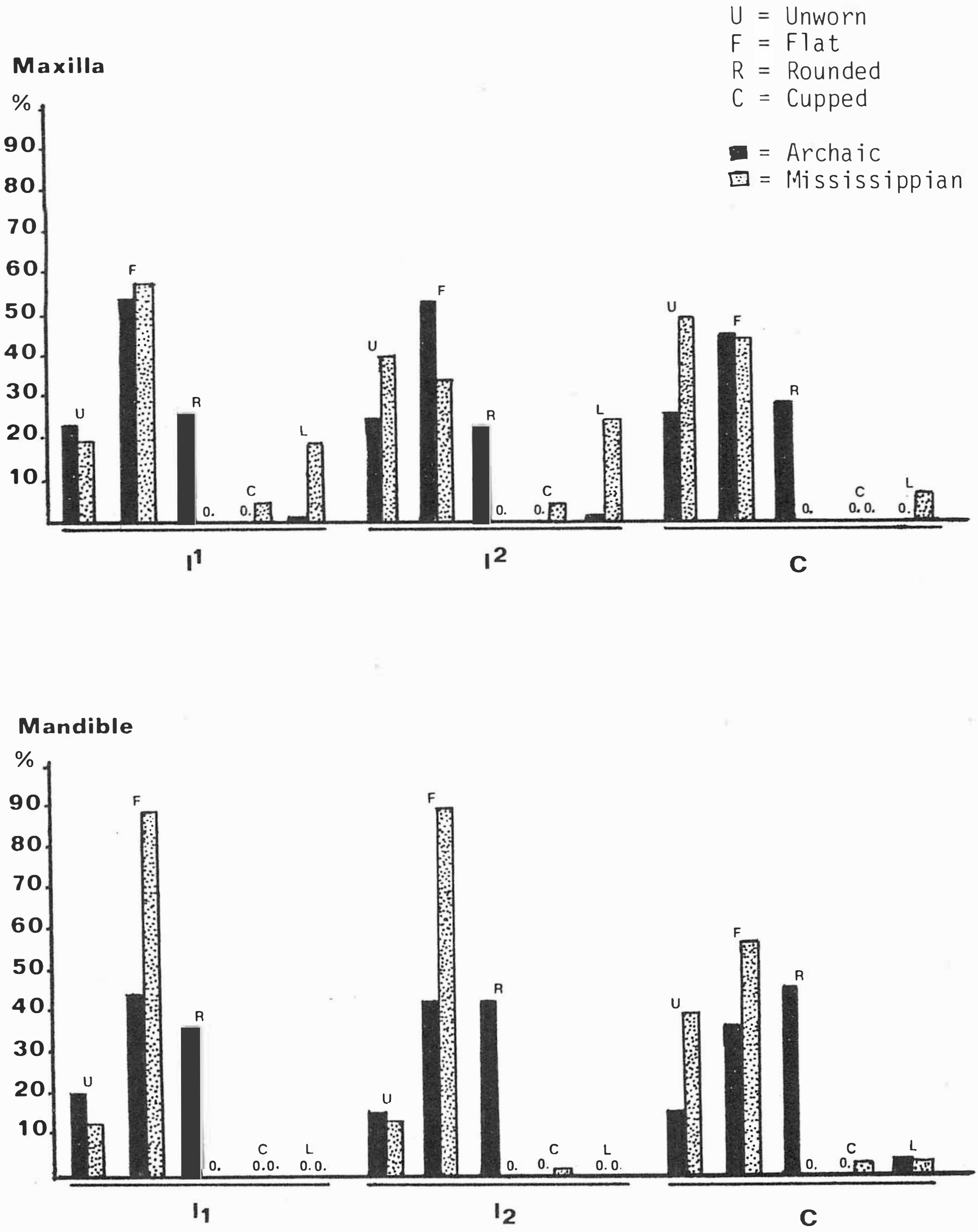


Figure 8. Percent Distribution of Anterior Tooth Forms for Archaic and Mississippian Females.

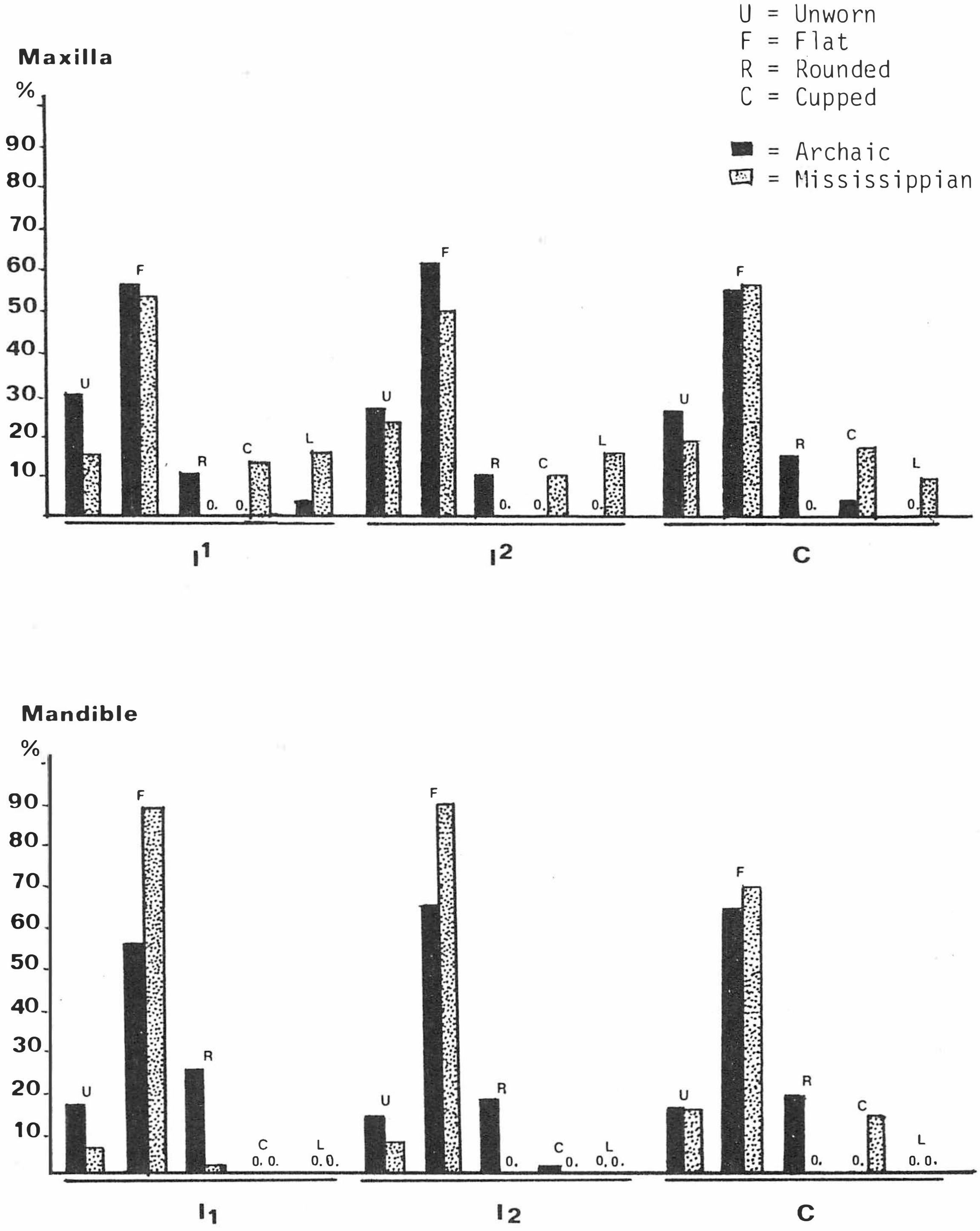


Figure 9. Percent Distribution of Anterior Tooth Forms for Archaic and Mississippian Males.

lingual slope are not large for the Mississippian sample because of the small number of aged individuals sampled from the Toqua site. The low frequencies, therefore, do not indicate insignificance of the tooth form as a diagnostic tool.

The data from the Archaic and Mississippian Periods mirror the results obtained from previous research initiatives. Cupped wear is the exclusive domain of the agricultural Mississippian population. As expected, the hunter/gatherer Archaic sample is characterized by rounded wear. With one exception, rounding is not found in the agricultural sample. Therefore, the frequencies of the diagnostic wear forms are, basically, mutually exclusive.

Lingual wear appears to overwhelmingly distribute in favor of agriculturalists. Only 6 cases of lingual wear were observed in the Archaic sample; the Mississippian sample yielded 51 cases. The Archaic cases represent less than 1% of the total anterior tooth form sample. The lingual form represents 8.7% of the Mississippian anterior tooth form sample. The percentage would most likely have been higher had the agriculturalists had an age distribution isomorphic with the Archaic. The lingual wear form is a significant diagnostic wear form for the Mississippian sample. The incidence is more than twice that of cupped wear (i.e., 4.26%). The frequency at which lingual wear is observed suggests the importance of some particular tooth activity which may not necessarily be masticatory.

The advanced wear forms for the Mississippian sample exhibit a segregated distribution over the six incisiform teeth. The mandibular and lateral incisors in both sexes exhibit no deviations from flat wear. For the whole Mississippian sample, only one case of cupped wear is found in the mandible. Cupped wear as found in the maxilla is fairly evenly distributed in the sample between the central and lateral incisors and the canine. The lingual wear form is most commonly found in the maxillary central and lateral incisors. For the central incisors, 18.2% of the total sample of teeth exhibit lingual wear. The lateral incisor is lingually worn 20.2% in the total sample. The maxillary and mandibular canines exhibit lingual wear 7.2% and 7.1% respectively. The pattern of lingual tooth wear segregation is paralleled in the Archaic sample, small as it is. The teeth exhibiting lingual wear are the mandibular canines and the maxillary central and lateral incisors. The particular distribution of the lingual form may also relate to the size of the occlusal surface. The mandibular incisors are small teeth in contrast to the other four incisal teeth. The interplay of tooth use and tooth size among other factors on the pattern and distribution of anterior tooth form is indeterminable at the present time.

Anterior to Posterior Wear

Subsistence contrasts with respect to attrition also include differences between relative anterior to posterior wear. Teeth are understood to be employed in activities other than mastication and distinct patterns in anterior tooth use between the Archaic and Mississippian samples have already been identified. Apparently reliance on segments of the tooth row also vary between subsistence systems. A pattern of extensive anterior tooth wear relative to the molar teeth has been identified for hunter and gatherers. This pattern has been described and highlighted in Australian aborigines (e.g., Campbell, 1925; Gould, 1968) and Eskimos (e.g., Pedersen, 1938; Hylander, 1977; Merbs, 1968). The extensive use of the anterior teeth has been attributed to the habit, in these populations, of using the incisal teeth as tools. The anterior teeth are used as a "third hand" as a vice, for cutting and tearing, and other manipulative functions (Brace, 1964, 1967; Bailit et al., 1968).

The pattern of extensive anterior tooth use has been identified in fossil hunter/gatherers (specifically, the Neandertals) and the pattern is being attributed to the use of anterior teeth as tools (e.g., Brace, 1964; Smith, P., 1976; Wallace, 1975). Therefore, data from various hunter/gatherer samples indicate that extensive anterior tooth use is a pattern in the subsistence system.

The reverse pattern has been identified in agriculturalists (Smith, 1972). Molar wear appears to be more extensive relative to the anterior teeth. The molar wear is attributed to food trituration.

An interpopulational comparison of these patterns has been undertaken to Hinton (1981) and the subsistence-related contrasts appear to be substantiated. The results obtained by Hinton (1981) provide an important interpretive framework within which to evaluate the present samples. For this reason, the anterior to posterior wear for the Archaic and Mississippian samples was similarly evaluated.

The problems involved in examining attrition levels between teeth were addressed in an earlier chapter. Attrition levels, it was stated, can in no way be considered equivalent between teeth and between levels for a single tooth class. The levels of attrition are based on readily identifiable horizon markers which are not equidistantly separated. The obvious differences in the size of the occlusal surfaces between the anterior and the posterior teeth also effectively argue against equivalency of one wear level across tooth class. Therefore, elaborate statistical manipulations of the data are imprudent and are not attempted here. An effective illustrative device, and the one employed here, is outlined by Hinton (1981). Relative wear can best be examined by evaluating the wear levels of teeth from the two respective areas of the mouth which come into occlusion at the same time. The tooth pairs which qualify for such an evaluation are the central incisor and first molar and the canine and the second molar. In the present analysis, the I1/M1 and C/M2 attrition level contrasts were evaluated against a reference tooth which served as an anchor around which the anterior and posterior wear levels vary. The reference tooth for the I1/M1 pair analysis was the second molar. The first molar, conversely, served as the reference tooth for the C/M2 pair evaluation. Attrition score means for the respective tooth pairs were plotted against the attrition scores of the reference tooth. The sample employed consists only of arches which contained an abutting M1/M2 pair and a respective canine and/or central incisor. In order to maximize data, the sexes were pooled. The plots of the maxillary pairs are located in Figure 10 and the plots of the mandibular pairs are found in Figure 11.

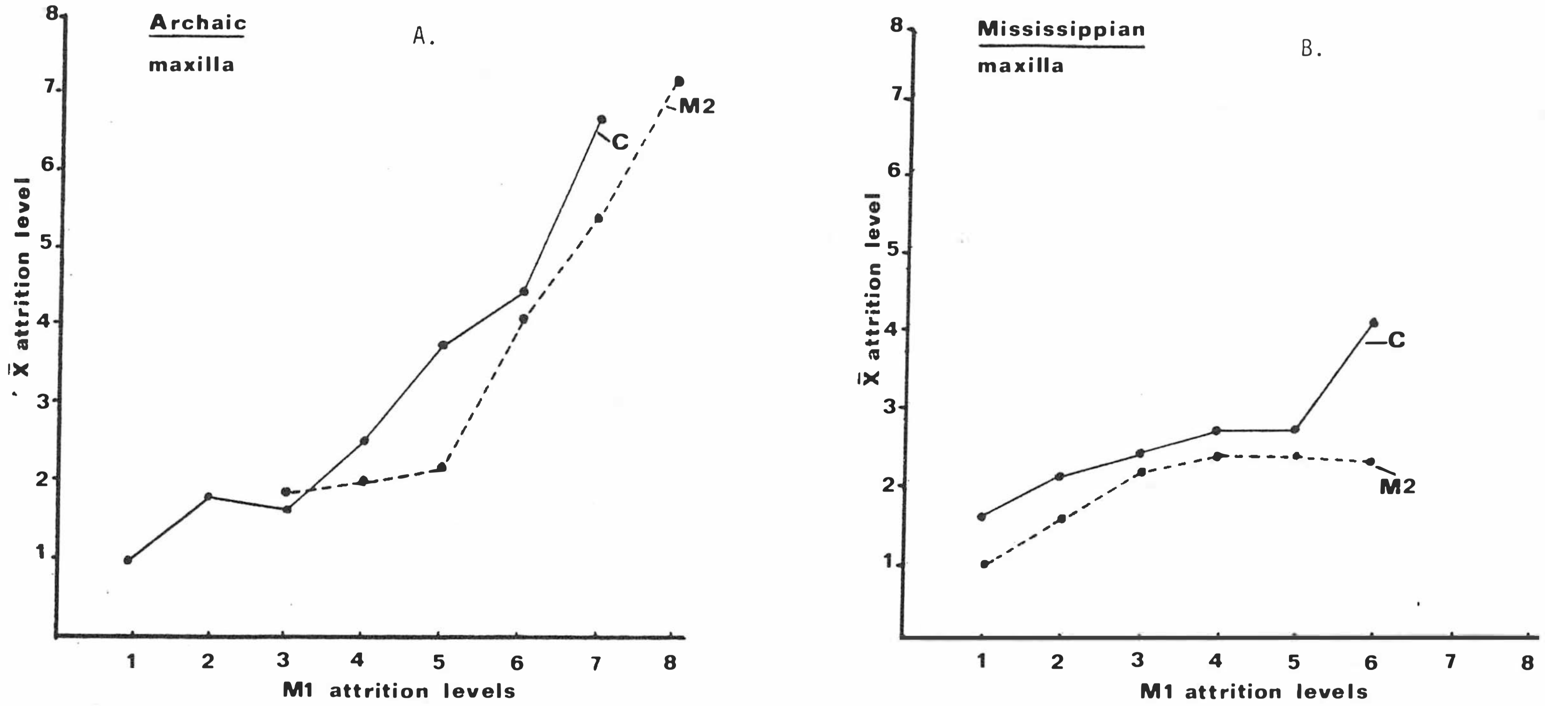


Figure 10. Anterior to Posterior Wear Comparisons between the Archaic and Mississippian Samples: The Maxillary Dentition.

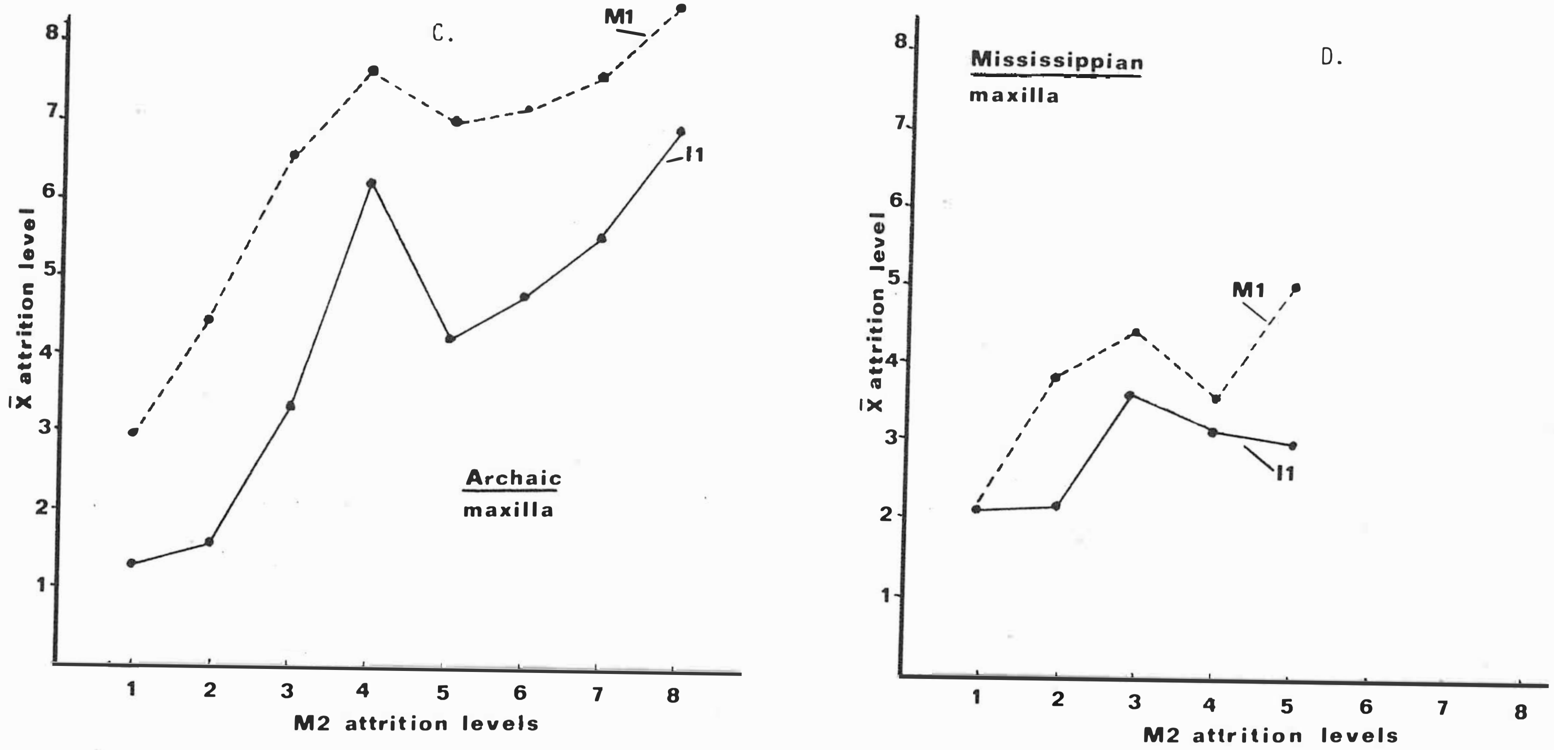


Figure 10 (continued).

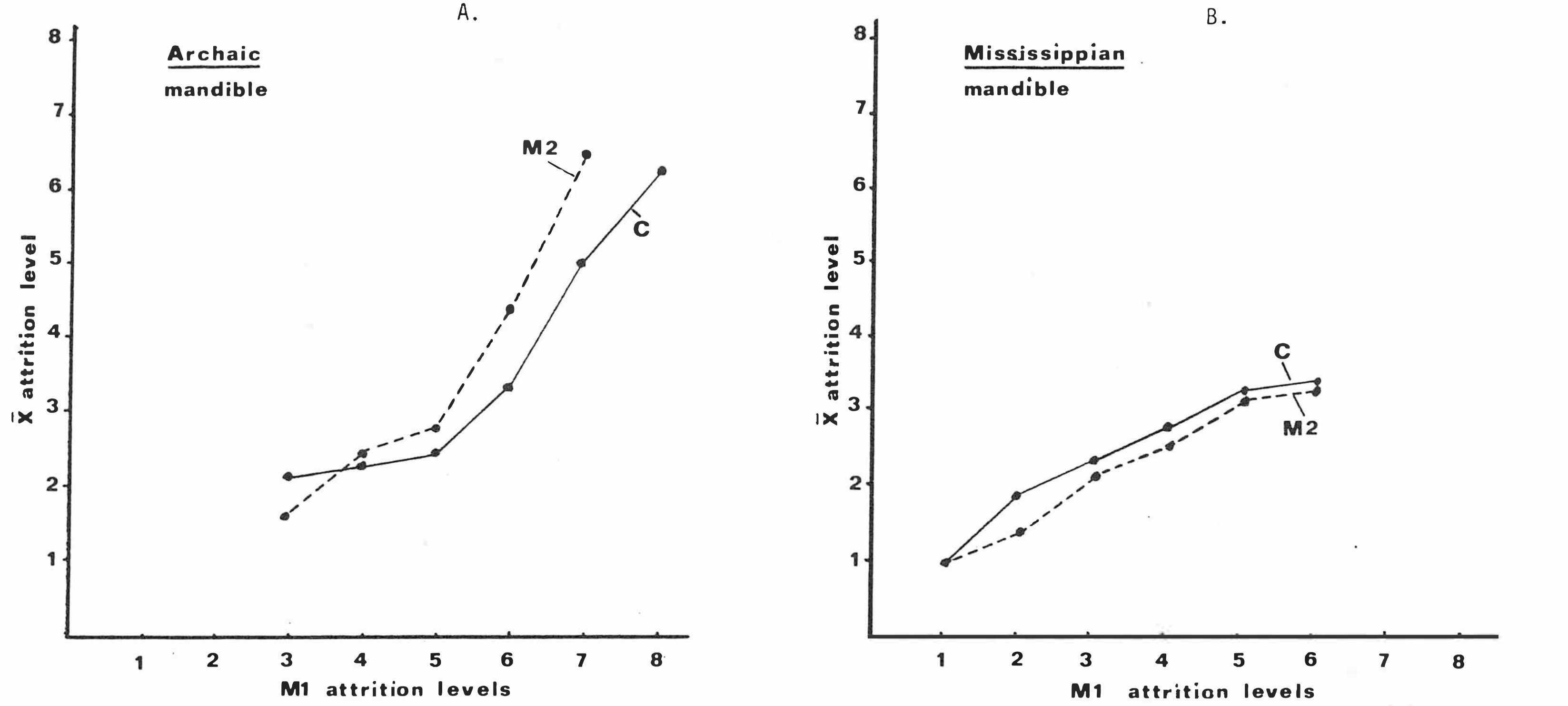


Figure 11. Anterior to Posterior Wear Comparisons between the Archaic and Mississippian Samples: The Mandibular Dentition.

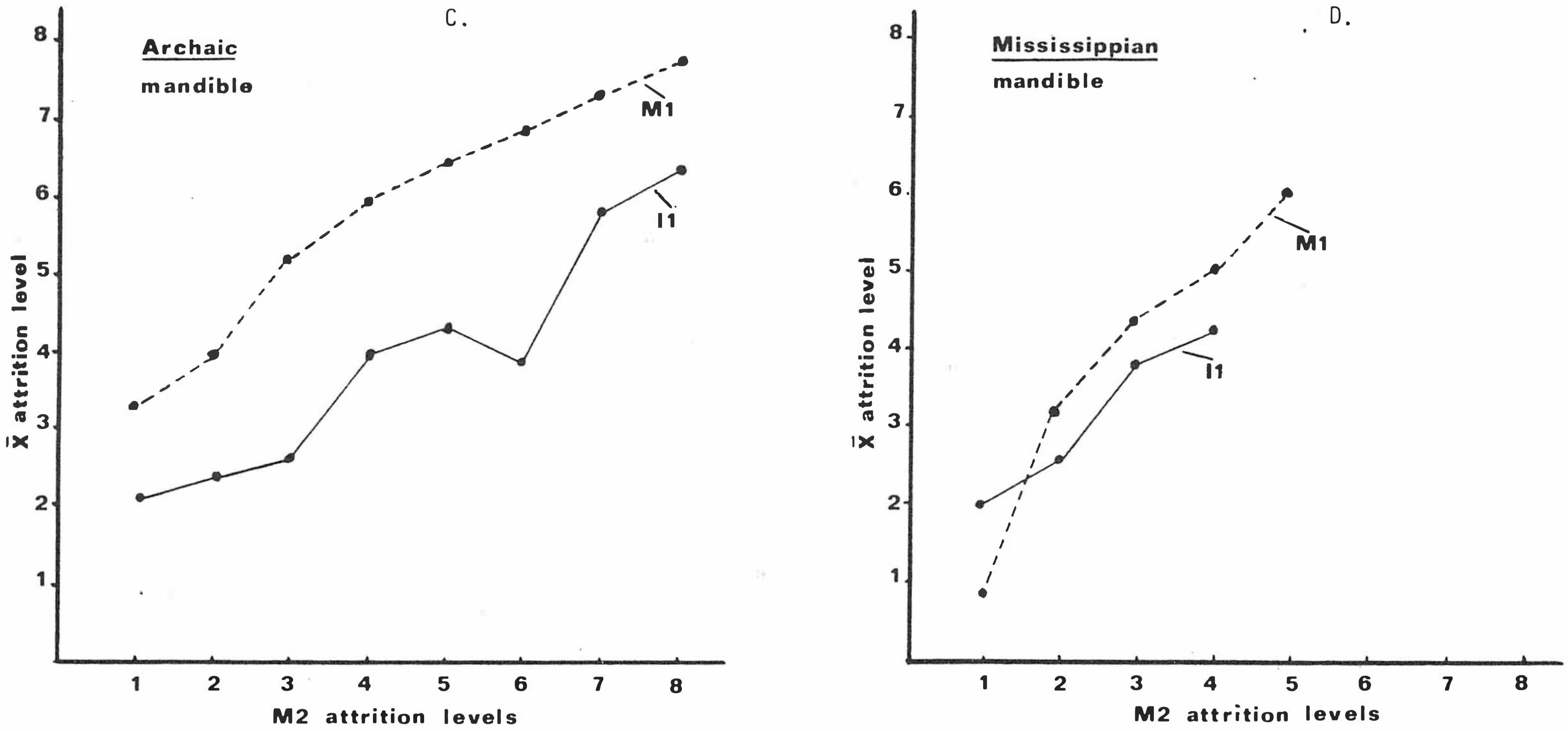


Figure 11 (continued).

In general, the results from the Tennessee Valley area do not conform with patterns established in the literature. The Archaic and Mississippian anterior/posterior wear plots show a between subsistence system agreement in overall pattern. A contrast is seen in the Archaic sample anterior to posterior wear to the patterns derived from the Eskimos and Australian aborigines (Hinton, 1981). The differences between results of the present analysis and the analysis undertaken by Hinton (1981) may, in part, be due to interobserver error. However, the patterns which emerge from the present research initiative exhibit consistency between the tooth pairs and between the arches suggesting that the interpretation of the Tennessee Valley material consider factors specific to the environment of the Archaic and Mississippian populations.

In the maxilla, the pattern of I1/M1 attrition seems equivalent. In both cases, the molar wear exceeds incisal wear. These results are not consistent with what was obtained by Hinton (1981). For the Eskimo and aboriginal samples employed by Hinton, incisal wear exceeded first molar wear in, at least, the early stages of attrition. This was not observed for the agricultural Southwest sample or the mixed-economy Late Woodland Libben sample. Molar wear exceeded incisal wear for the food producers. The maxillary C/M2 plots for the Archaic and Mississippian samples exhibit similar between site equivalency that the I1/M1 plots for the same samples illustrated. The plots are generally isomorphic with canine attrition slightly elevated above the molar plots in both samples. The anterior to posterior pattern for the Southwest and Libben samples are undiagnostic (Hinton, 1981). The canine wear exceeded second molar wear in the Eskimo and aboriginal data in the early stages of attrition. This pattern is reversed in the later attrition stages. The Archaic plots are more similar to the Mississippian pattern than to the pattern apparent for the other hunter/gatherers.

The mandibular comparisons for the Archaic and Mississippian are equally isomorphic. With the exception of the first level of wear, the first molar wear exceeds central incisor wear in the Mississippian sample. This same pattern is apparent for the Archaic, with the disparity between the teeth, surprisingly enough, more pronounced than in the Mississippian. This serves to make the Archaic pattern appear even less hunter/gatherer-like. The mandibular data for the Australian aborigines and the Eskimos indicate that incisal wear, particularly in the early attrition levels, exceeds molar wear. Therefore, the Archaic data is more like the pattern anticipated for the agriculturalists.

The mandibular canine/second molar data show the only contrast for the Archaic/Mississippian comparisons. The pattern exhibited is the reverse of what would be expected. Molar wear largely superceded canine wear in the Archaic. In the Mississippian sample, the canine wear plots, although closely parallel to the molar plots, are consistently larger. The pattern for the Eskimos and aborigines is that molar wear is distinctly exceeded by canine wear (Hinton, 1981). The agricultural samples are again undiagnostic and not helpful in the assessment (Hinton, 1981).

The general pattern appears to be that the Archaic sample is more like the Mississippian sample than it is like any other hunter/gatherer sample. One possible explanation may be the environmental context of the hunter/gatherer populations. Both the Australian and Eskimo populations inhabit environments restricted in the variety of exploitable resources. Given the more hospitable and varied environment of the Archaic populations, there may have been less selective pressure to utilize the anterior teeth as tools.

Periodontal Disease

Periodontal disease is an acknowledged multifactorial process. However, review of the pertinent background information provided in Chapter II indicates the particular importance of dietary carbohydrates in the initiation and progress of the disease and the importance of food texture as a mediating factor affecting disease status. The epidemiological literature strongly suggests that hunters and gatherers universally experience good oral health. Since rate of attrition is attributable to food consistency (inclusive of abrasives), and since the hunter/gatherer Archaic sample experiences 9 statistically significant higher rates of attrition compared to the Mississippian sample it is anticipated that subsistence related differences in periodontal disease involvement will be identified. The following sections review and evaluate the findings of the present research initiative.

The Infrabony Pocket

The infrabony pocket is a periodontal pocket whose base is located apical to the alveolar crest. This osseous defect is located between the root and the bone and is the result of local factors which encourage rapid pocket proliferation. Consequently, the infrabony pocket is not associated with a significant accumulation of oral debris. The depth and contour of infrabony pockets varies. The preservation of the crestal area in both the Archaic and Mississippian samples permitted identification of only the most distinct infrabony pockets. Therefore, the frequency of defects in the present analysis can only be taken to be a conservative estimate of their true frequency in their respective populations. Alveolar crests which were damaged, or unclear as to presence/absence of infrabony pockets, were scored as missing.

The summary data are found in Table 28. The frequency differences were tested for significance between subsistence systems using the G-test. Since pocket incidence has demonstrated a relationship with age, the tests were performed on samples of the same age class. The results are found in Table 29. In the male comparisons for the maxilla, the incisors and molars are statistically significant in the 30-40 age class only. In the mandible, the premolars for the 20-30 age bracket are statistically significant. In these three tests, the Mississippian sample had more infrabony pockets. The female comparisons yielded a greater number of statistically significant scores. In the maxilla, two age classes for the incisors were statistically significant. In the mandible, the incisors were significant at the 30-40 age range only. The mandibular molars were significantly different in the advanced age classes. As with the male comparisons, the Mississippian frequencies were higher.

TABLE 28

INFRABONY POCKETS: SUMMARY DATA

	Archaic				Mississippian			
	Male		Female		Male		Female	
	max.	mand.	max.	mand.	max.	mand.	max.	mand.
Incisors								
incidence	96	112	78	111	71	83	63	65
N	328	325	271	315	184	206	138	202
%	29.3	34.5	28.8	35.2	38.6	40.3	45.7	32.2
Premolars								
incidence	71	41	54	55	41	36	31	24
N	224	129	197	218	129	142	139	140
%	31.7	31.8	27.4	25.2	31.8	25.4	22.3	17.1
Molars								
incidence	147	100	110	122	104	112	47	67
N	320	354	271	332	185	211	176	204
%	45.9	28.2	41.0	36.7	56.2	53.1	26.7	32.8

TABLE 29

BETWEEN ARCHAIC AND MISSISSIPPIAN SAMPLE G-TEST RESULTS FOR INTRABONY POCKET INCIDENCE

		Males					Females				
		Age Class					Age Class				
Tooth Class	Arch	<20	20-30	30-40	40-50	50+	<10	20-30	30-40	40-50	50+
Incisors	maxilla	1.090	0.0004	13.99*	0.386	1.837	10.975*	0.047	2.267	5.921	0.064
	mandible	--	1.255	0.353	0.111	--	0.00	0.940	12.490*	1.156	0.270
Premolars	maxilla	--	0.0023	2.104	0.281	--	0.136	0.082	1.144	0.241	--
	mandible	--	9.563*	0.576	1.349	--	0.0024	0.710	1.726	1.619	3.222
Molars	maxilla	--	0.005	28.995*	0.057	2.756	3.039	2.665	3.331	0.022	0.659
	mandible	--	0.030	2.166	--	--	0.008	0.053	5.492*	5.604*	10.969*

*Significant when greater than $\chi^2_{.005}$ for one degree of freedom or 7.879.

Since vertical osseous defects occur more frequently in molars and incisors, significant subsistence differences should be more readily apparent in these teeth. Differences are apparent, but they are not widespread. This is particularly true for the male sample. Food impaction as outlined in Chapter II is considered an important local factor contributing to the production of these acute periodontal involvements. Since rapid attrition eliminates the small interdental crevaces which encourage food impaction, the lack of a dramatic difference between the Archaic and Mississippian samples is puzzling. A possible intervening factor is occlusal stress which deepens already existing pockets. Interbony stress results in a greater number of infrabony defects. Another possibility is that periodontal involvement is not diagnostically different between the two samples tested.

Calculus

Oral debris, as established in an earlier chapter, correlates well with periodontal disease involvement. Therefore, calculus is an important diagnostic variable in periodontal disease detection.

The data available from the limited hunter/gatherer literature seems to indicate that the presence of calculus is either infrequent (e.g., Campbell, 1939; McEuen, 1937; Ritchie, 1923) or occurs in significant amounts in the older age groups (e.g., Waugh, 1928; Campbell, 1939). The Archaic and Mississippian samples, both scored the same way for calculus, were tested for significant difference in calculus frequency using the G-test. Since the age distribution between the two samples is different, age was controlled for. The results are found in Table 30. No real differences between the subsistence systems were detected. These results contrast what was anticipated from the literature review.

The accumulated oral debris, rather than the frequency of its occurrence, is indicative of periodontal disease involvement. Therefore, proper evaluation of between sample disease status should consider the amount of debris rather than simply its presence.

The calculus scores (1-5) were collapsed into three categories (none, 1; some, 2 and 3; much, 4 and 5) and graphed by age and three tooth classes (incisal inclusive of canines, premolars, and molars). The sexes were collapsed to maximize data. The frequencies of calculus severity for each tooth class were graphed and are displayed in Figure 12 for the maxilla and Figure 13 for the mandible. The percentages are recorded in Table 31. Calculus was evaluated from the cumulative percent graphs.

From even a cursory examination of the graphs, two primary patterns emerge. The first is that the amount of oral debris peaks during the middle age years (30-40) and then tapers off, and second, the incidence and degree of calculus in the earlier age increments is higher in the Archaic sample. The Mississippian sample overtakes the Archaic in the later age classes.

The pattern of age changes in calculus incidence and severity in the Archaic is predictable. With accumulating attrition and antemortem tooth loss, there are fewer inaccessible interproximal niches which

TABLE 30

BETWEEN SAMPLE CALCULUS INCIDENCE FOR MALES: CALCULATED G-STATISTIC

		Males					Females				
		Age Class					Age Class				
Tooth Class	Arch	<20	20-30	30-40	40-50	50+	<10	20-30	30-40	40-50	50+
Incisors	maxilla	—	2.61 n.s.	5.30 n.s.	.009 n.s.	--	.1202 n.s.	.134 n.s.	.075 n.s.	--	--
	mandible	--	.416 n.s.	13.317 sig.	.750 n.s.	--	4.363 n.s.	2.346 n.s.	6.653 n.s.	.505 n.s.	--
Premolars	maxilla	--	.974 n.s.	.002 n.s.	--	--	5.82 n.s.	1.049 n.s.	4.345 n.s.	--	--
	mandible	--	.167 n.s.	4.226 n.s.	--	--	.034 n.s.	4.92 n.s.	1.859 n.s.	--	--
Molars	maxilla	--	2.44 n.s.	3.62 n.s.	--	--	.514 n.s.	.028 n.s.	.063 n.s.	--	--
	mandible	--	16.09 sig.	.008 n.s.	--	--	.042 n.s.	4.36 n.s.	2.14 n.s.	--	--

*Significant when greater than $\chi^2_{.005}$ for one degree of freedom or 7.879.

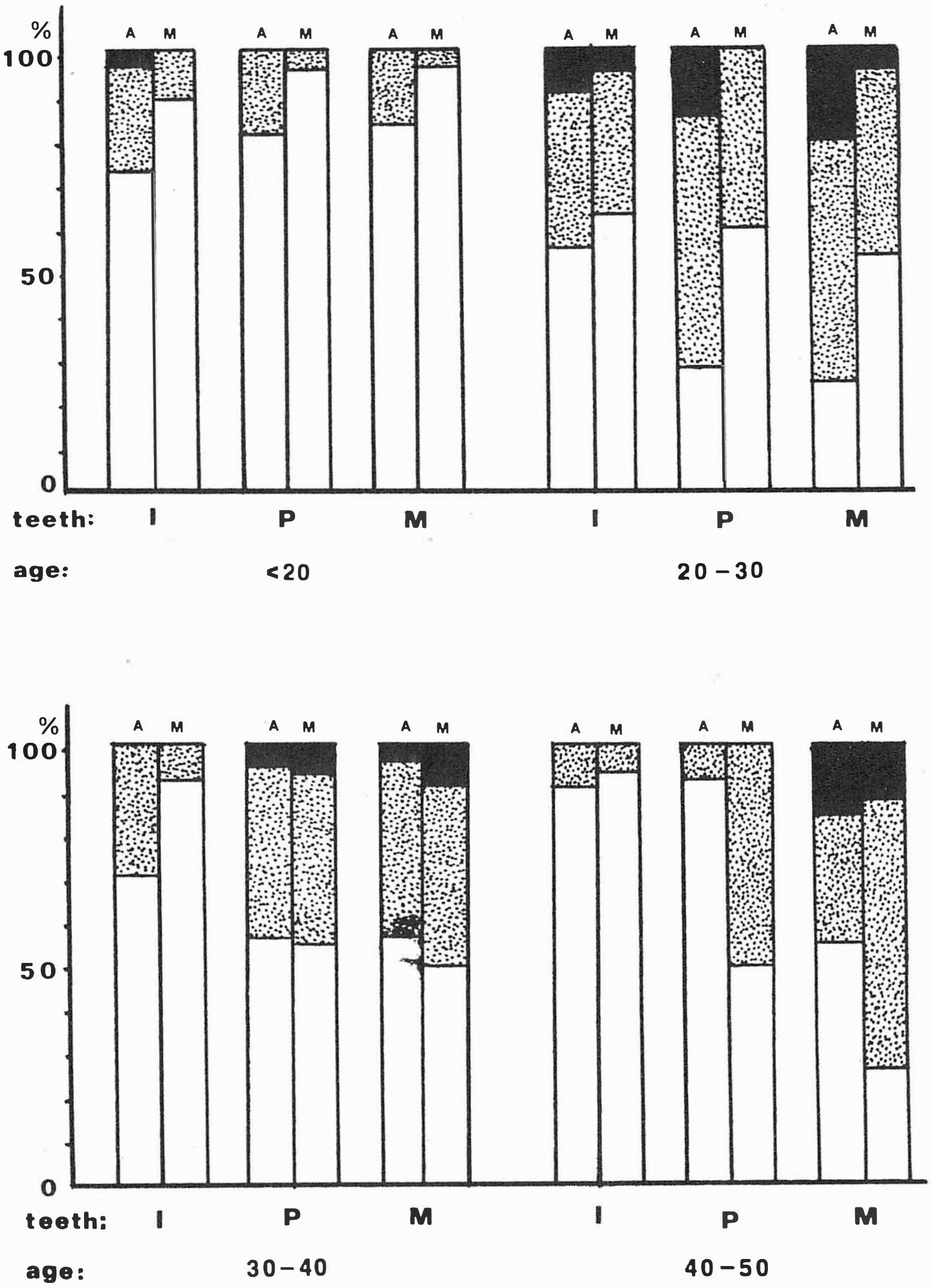


Figure 12. Comparison of Calculus Experience by Age and Tooth Class between the Archaic and Mississippian Samples: The Maxillary Dentition.

Percentages displayed are: white, no (score 1); stipled, some (score 2 and 3); and much (score 4 and 5) calculus. The tooth classes are: incisal (including canines) (I), premolars (P), and molars (M). In each paired comparison, the Archaic data is displayed to the left and the Mississippian, to the right.

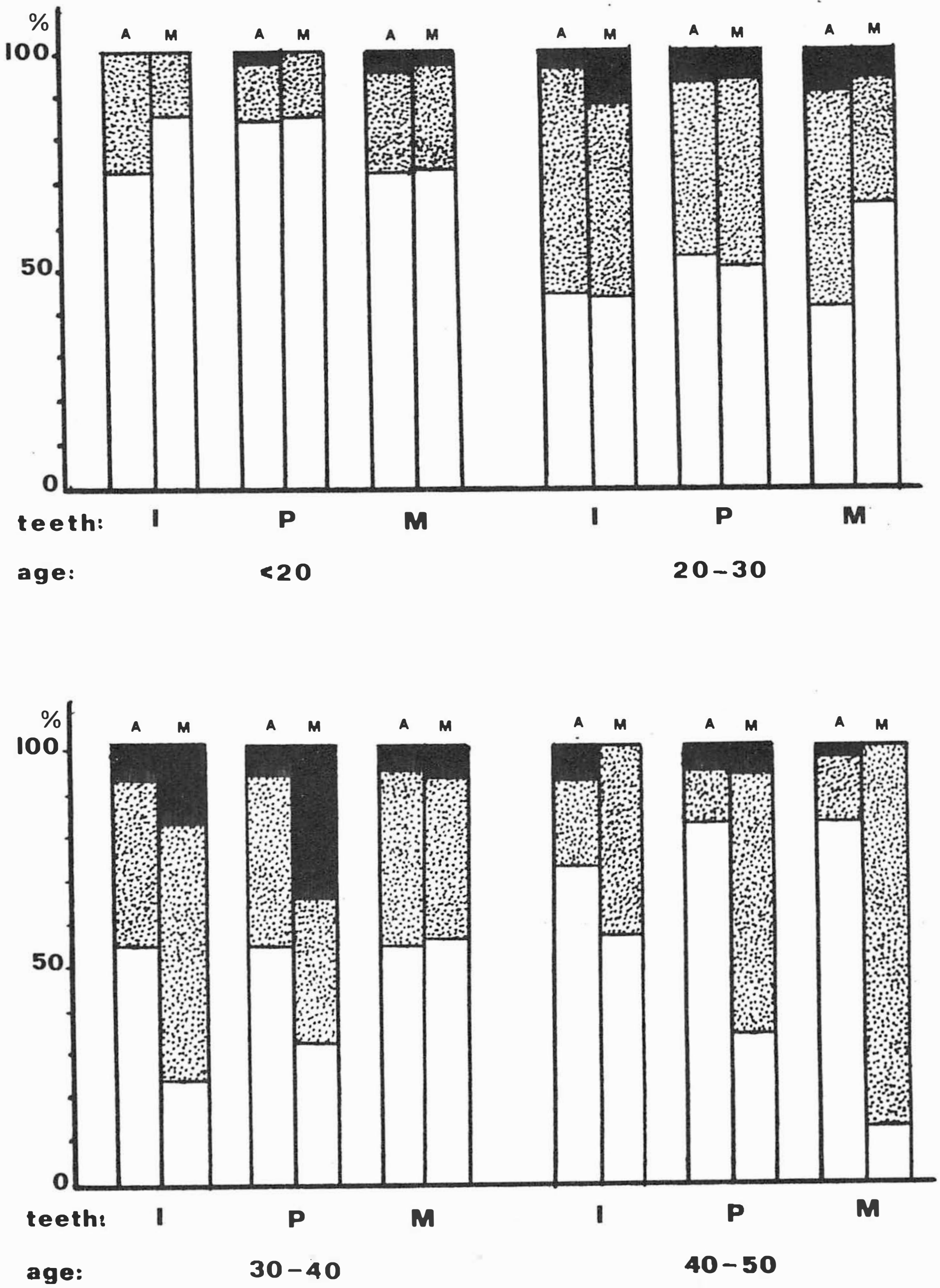


Figure 13. Comparison of Calculus Experience by Age and Tooth Class between the Archaic and Mississippian Samples: The Mandibular Dentition.

Percentages displayed are: white, no (score 1); stipled, some (score 2 and 3); and much (score 4 and 5) calculus. The tooth classes are: incisal (including canines) (I), premolars (P), and molars (M). In each paired comparison, the Archaic data is displayed to the left and the Mississippian, to the right.

TABLE 31

SUMMARY DATA OF CALCULUS FREQUENCY FOR THE ARCHAIC AND MISSISSIPPIAN SAMPLES

			Archaic								Mississippian							
		N	Maxilla Age^a				Mandible Age^a				Maxilla Age^a				Mandible Age^a			
Tooth Class	Severity	cum %	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Incisors and Canines	none	N	56	45	116	66	50	35	97	73	49	91	56	18	39	61	28	20
		%	73.0	57.7	71.6	91.6	71.4	43.8	56.4	72.3	89.1	64.1	58.3	94.7	86.6	43.3	26.6	57.1
	some	N	20	28	44	6	20	44	66	20	6	48	40	1	6	50	63	15
		%	97.0	100.0	75.9	100.0	100.0	98.8	94.8	92.1	100.0	97.9	100.0	100.0	100.0	78.7	86.6	100
	much	N	1	--	2	--	--	1	9	8	--	3	--	--	--	30	14	--
		%	100.0	--	100.0	--	--	100.0	100.0	100.0	--	100.0	--	--	--	100.0	100.0	--
Premolars	none	N	45	17	71	51	45	31	65	71	33	61	33	7	30	53	26	6
		%	81.8	29.8	58.2	94.4	83.3	53.5	53.7	82.6	97.1	61.0	55.9	50.0	83.3	50.5	32.5	33.3
	some	N	10	26	46	3	8	23	51	11	1	39	24	7	6	46	41	11
		%	100.0	87.7	98.4	100.0	98.2	93.1	95.9	95.4	100.0	100.0	96.6	100.0	100.0	94.3	67.0	94.4
	much	N	--	1	2	--	1	4	5	4	--	--	2	--	--	6	13	1
		%	--	100.0	100.0	--	100.0	100.0	100.0	100.0	--	--	100.0	--	--	100.0	100.0	100.0
Molars	none	N	52	22	100	36	46	33	105	83	16	76	39	5	31	77	37	1
		%	83.9	27.1	58.8	56.3	71.9	40.7	55.0	72.2	57.1	55.1	50.0	25.0	72.1	65.8	54.4	12.5
	some	N	10	44	47	16	14	41	84	30	11	57	32	13	11	34	27	7
		%	100.0	81.5	99.4	85.9	93.8	91.4	98.9	98.3	96.4	96.4	91.0	90.0	97.7	94.9	94.1	100.0
	much	N	--	15	1	4	4	1	2	2	1	5	7	2	1	6	1	--
		%	--	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--

[a] Age = 1, <20; 2, 20-30; 3, 30-40; 4, 40-50, 5, 50+.

favor calculus accumulation (Carranza, 1979). Therefore, the oral cavity in older individuals contains less oral debris than younger individuals. Calculus tends to accumulate in the Mississippian sample. This is expected considering the reduced attrition rate characteristic of the sample.

The level of calculus frequency and severity for the Archaic sample in the younger age spectrum is difficult to interpret. In spite of excessive attrition, the Archaic sample possesses calculus equivalent to the Mississippian sample. Whether this indicates elevated Archaic frequencies or reduced Mississippian frequencies is difficult to ascertain. Consideration of the problem is found in the ensuing chapter.

Horizontal Bone Loss

The loss of bone height is acknowledged to be a multifactorial process. Denuding of the roots, however, is the most prominent consequence of periodontal disease involvement. In order to identify bone loss attributable to periodontal disease, the other contributing factors, namely age and attrition, needed to be controlled for. This has not been done in other studies which have considered horizontal bone loss.

The sample consisted of teeth possessing enough crown and alveolar crest to yield the tooth cervical height measurement. Only teeth with antagonists were considered for evaluation in order to eliminate tooth extrusion bias introduced through the process of continuous eruption.

Because of the small size of the tooth cervical height measure, tooth types were not liberally collapsed to increase sample sizes. Between type tooth size differences (particularly between the incisors and canines) could have introduced a bias in the TCH measurement. Instead, the sexes were pooled and the attrition levels 1-6 (i.e., levels with crown height) were collapsed to form three attrition levels (slight, moderate, severe). The means for tooth cervical height were calculated and are reproduced in Table 32.

Since the objective of the bone loss evaluation was to detect patterns rather than significant differences between the means, the mean scores were graphed and evaluations were made from the graphs. The plots of the maxillary and mandibular incisors are found in Figure 14. Canines are plotted in Figure 15. The plot of the means for premolars is in Figure 16 and the plots for the molars (M1 and M2 only) are found in Figure 17. The data was appropriately controlled for attrition and age.

The plots of the tooth cervical height means reveal a pattern which, in many ways, parallels the results obtained from the calculus evaluation. Three primary patterns are apparent. First, the greatest disparity between means tends to occur in the advanced age classes. Mississippian Tooth Cervical Height means become larger than the Archaic. This agrees with the calculus pattern described in the previous section. The second pattern which can be identified is the apparent reductions in mean values with age in the Archaic sample. The rate at which bone loss occurs seems to dramatically decrease. This

TABLE 32

SUMMARY DATA OF THE CERVICAL HEIGHT MEASUREMENT FOR THE ARCHAIC AND MISSISSIPPIAN SAMPLES

		Archaic						Mississippian					
	Age	Maxilla Attrition			Mandible Attrition			Maxilla Attrition			Mandible Attrition		
Tooth Class	N	slight[a]	moderate[b]	severe[c]	slight	moderate	severe	slight	moderate	severe	slight	moderate	severe
Incisors	1[d]	1.21	1.71	2.58	1.55	1.53	5.55	1.49	1.25	--	1.27	--	--
	N	17	12	4	25	7	4	22	3	--	24	--	--
	2[e]	1.84	1.57	2.72	2.54	4.43	2.85	2.03	2.78	--	2.12	2.77	--
	N	7	17	11	7	19	5	21	33	--	27	22	--
	3[f]	3.60	1.08	2.45	--	3.47	2.48	1.79	2.06	2.23	1.79	2.06	2.23
	N	2	33	28	--	31	27	7	21	19	7	21	19
	4[g]	--	1.60	2.51	--	5.05	3.21	--	3.00	3.30	4.00	5.25	5.10
	N	--	2	8	--	2	11	--	2	4	1	2	3
Canines	1	1.39	1.90	--	1.41	--	4.00	1.35	--	--	1.25	--	--
	N	7	4	--	12	--	2	9	--	--	4	--	--
	2	1.75	2.03	2.33	1.50	2.89	2.80	1.46	2.39	4.00	1.40	2.57	--
	N	4	9	4	3	12	3	26	13	1	9	12	--
	3	1.20	1.72	2.58	--	1.62	3.07	2.27	1.89	2.27	1.80	2.59	3.65
	N	3	11	25	--	9	26	3	13	10	4	26	2
	4	--	--	2.44	--	2.60	2.73	--	--	3.56	--	3.14	3.90
	N	--	--	8	--	4	7	--	--	4	--	4	4
Premolars	1	1.05	1.46	2.50	1.35	1.18	4.00	1.27	--	--	1.11	--	--
	N	9	6	4	10	14	2	18	--	--	18	--	--
	2	1.25	1.87	2.01	1.00	1.94	2.41	1.59	1.94	1.88	1.59	1.94	1.76
	N	3	14	21	2	32	17	68	10	3	68	12	3
	3	--	2.08	2.49	--	1.55	2.34	1.74	2.31	2.47	2.46	2.03	3.10
	N	--	4	54	--	7	33	29	16	4	36	26	8
	4	--	--	2.93	--	--	2.29	3.03	2.86	2.10	3.10	3.08	2.30
	N	--	--	15	--	--	33	3	5	2	2	3	4
Molars	1	1.13	1.22	1.81	1.68	0.97	2.01	1.03	--	--	1.14	--	1.00
	N	6	12	11	3	17	7	31	--	--	16	--	1
	2	--	1.63	2.86	--	1.41	2.07	2.24	2.04	2.59	1.52	1.81	2.65
	N	--	8	19	--	13	24	7	19	15	32	38	6
	3	1.15	2.29	2.64	--	1.64	2.02	2.26	1.80	2.21	2.69	2.62	2.38
	N	2	6	23	--	6	27	10	10	10	9	18	13
	4	--	2.35	--	--	--	3.35	5.50	2.78	4.15	--	--	3.45
	N	--	2	--	--	--	2	1	2	3	--	--	4

[a] Slight wear = attrition levels 1 and 2.

[b] Moderate wear = attrition levels 3 and 4.

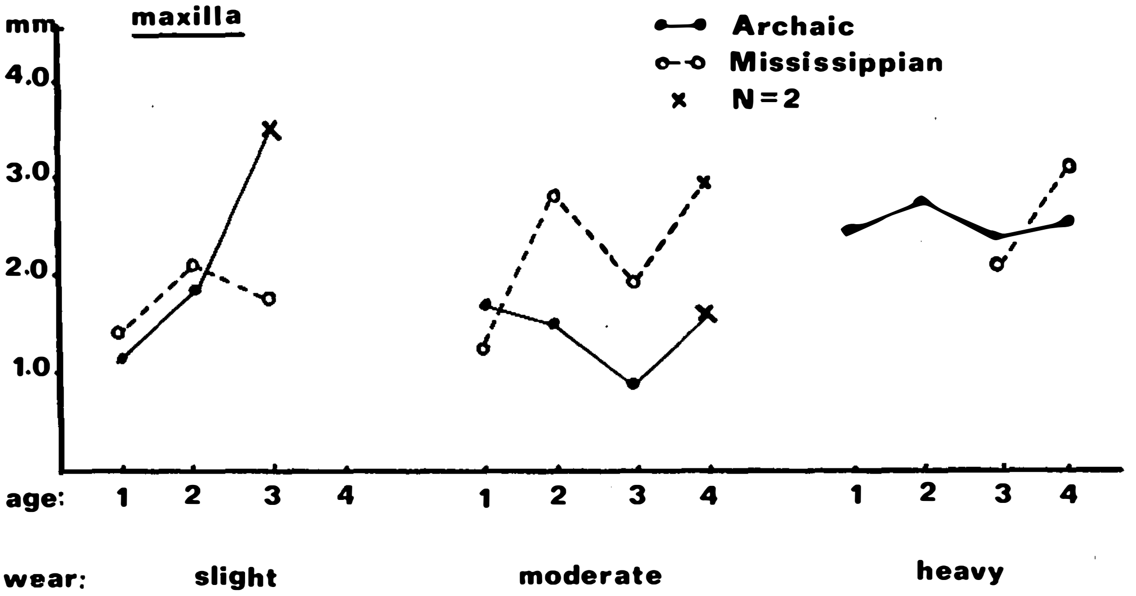
[c] Heavy wear = attrition levels 5 and 6.

[d] Individuals <20 years of age.

[e] Individuals ages 20-30.

[f] Individuals ages 30-40.

[g] Individuals ages 40-50.



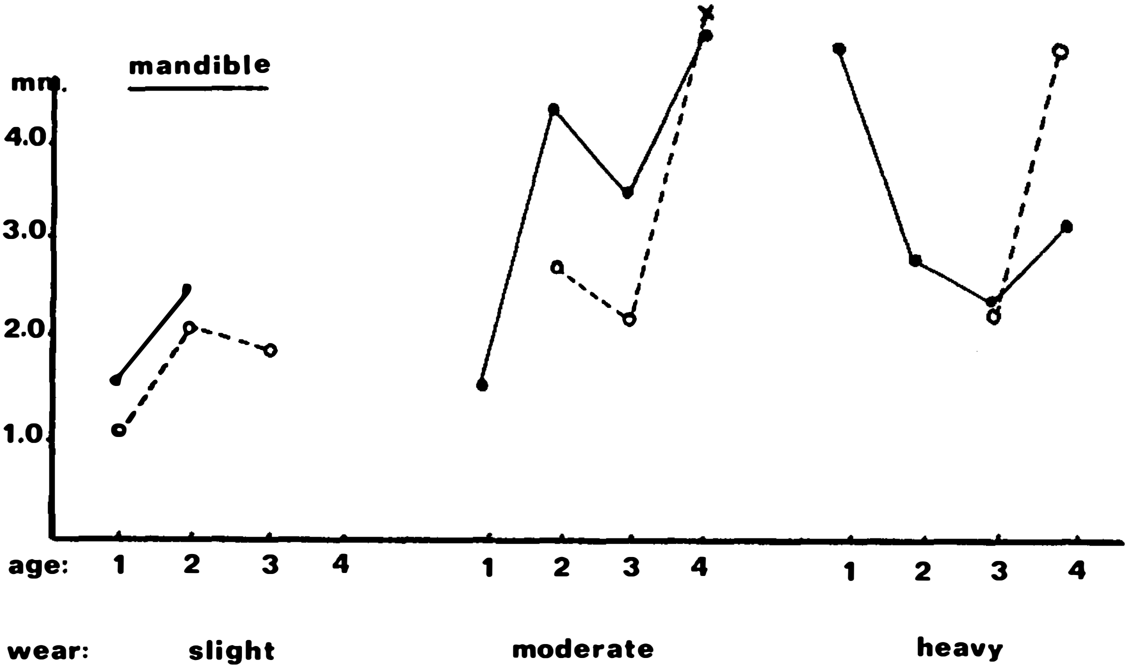


Figure 14. Plot of the Mean for the Cervical Height Measurement for Incisors by Age and Level of Attrition.

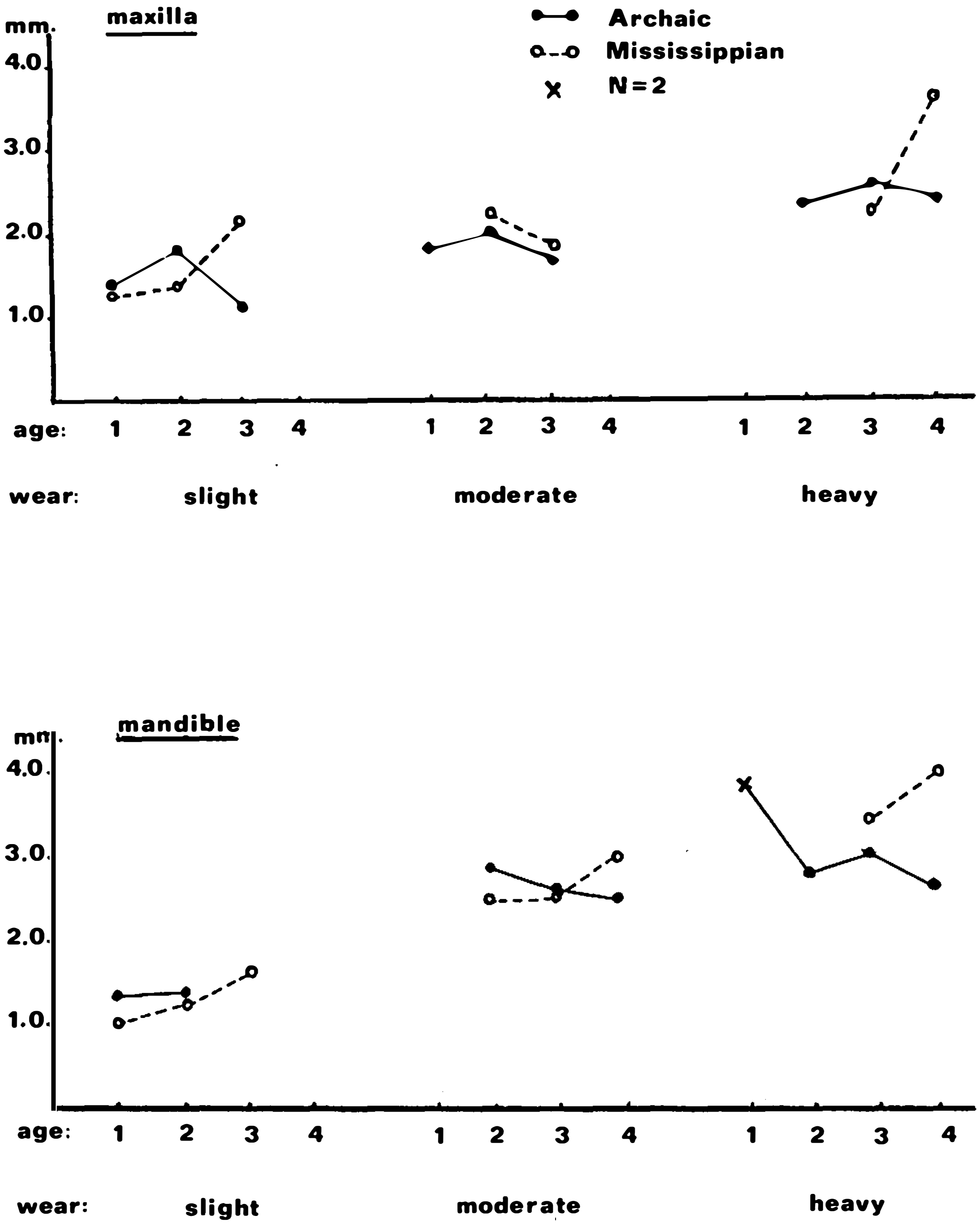


Figure 15. Plot of the Means for the Cervical Height Measurement for Canines by Age and Level of Attrition.

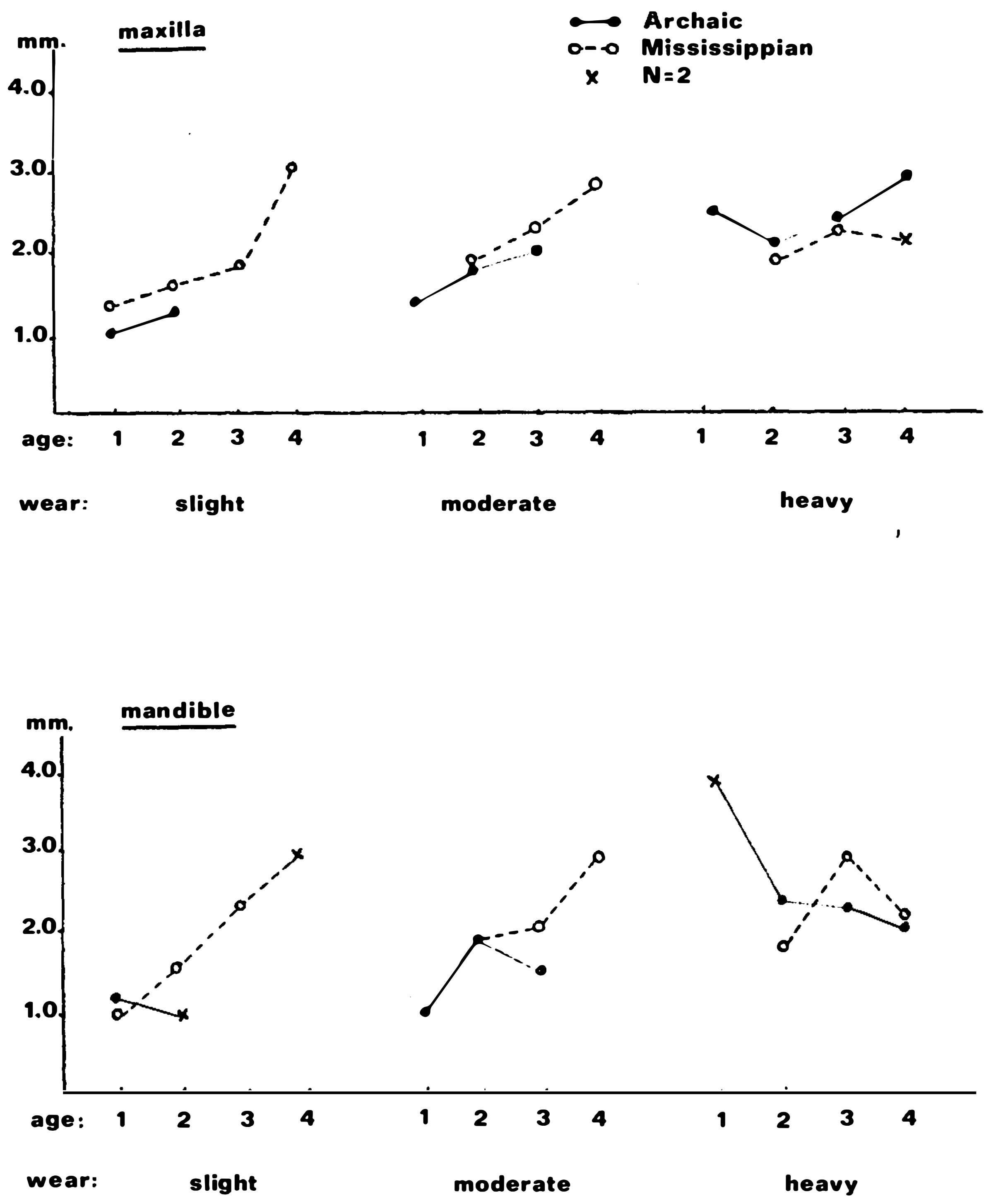


Figure 16. Plot of the Means for the Cervical Height Measurement for Premolars by Age and Level of Attrition.

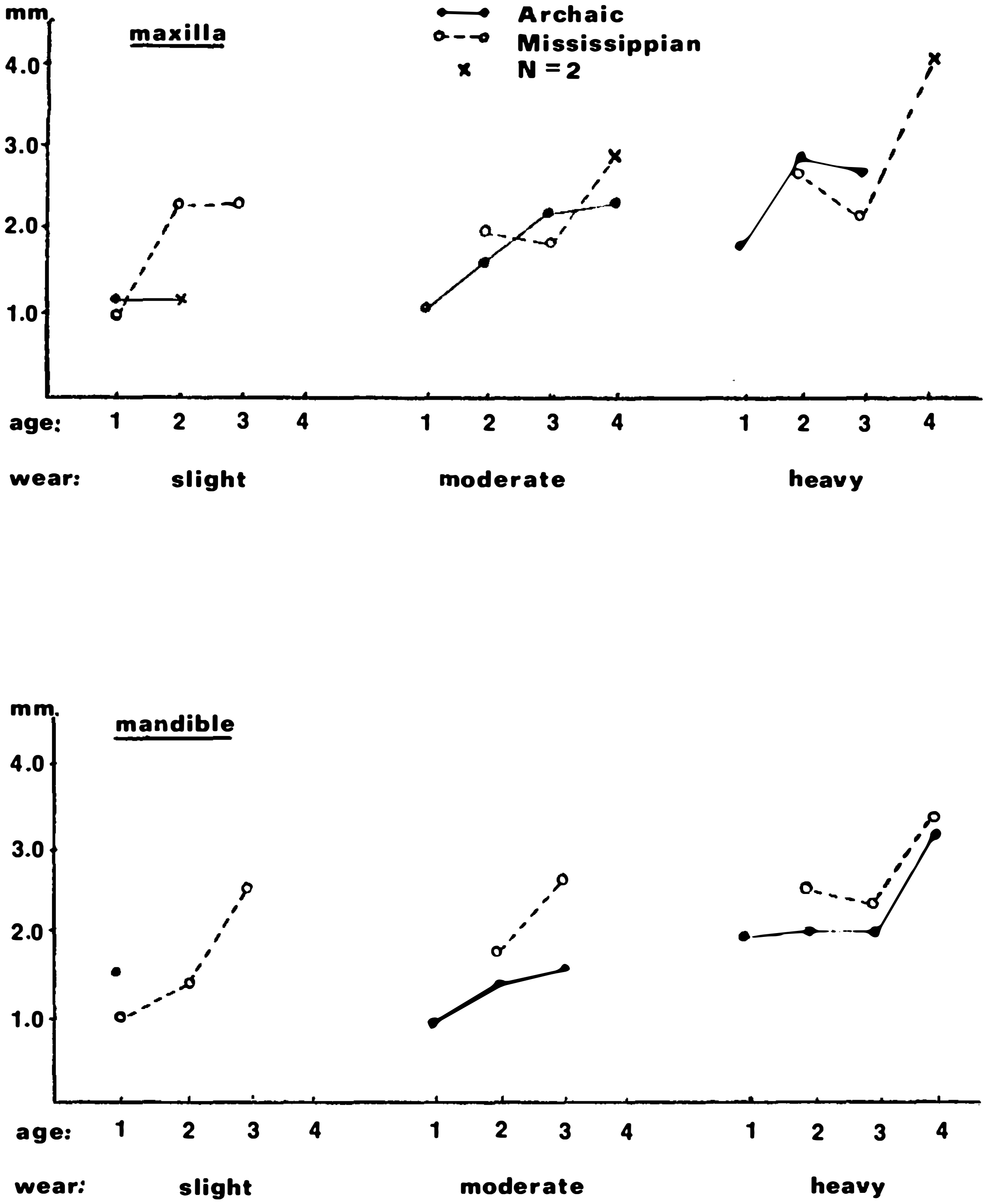


Figure 17. Plot of the Means for the Cervical Height Measurement for Molars (M_1 and M_2) by Age and Level of Attrition.

pattern may be seen in the maxillary incisors, the maxillary and mandibular canines, and maxillary molars. The pattern is suggested in the mandibular premolars. This corresponds well with the reduced calculus experience for the Archaic sample. Since oral debris is the primary etiologic agent responsible for bone loss, it is logical to suggest that the reduction in the amount of calculus concomitant with age in the Archaic sample results in a reduction in the rate of bone loss. The mediating role of attrition in reducing the amount of oral debris serves to highlight the interplay of processes in ultimately determining oral health status.

The third pattern which may be discerned focuses on the close correspondence of mean values in the early age classes. Where Archaic and Mississippian means are available, the Archaic value is just as likely to be above the Mississippian value as not. This pattern is rendered significant in conjunction with the calculus data. Archaic younger age classes are characterized by more oral debris. The sensitivity of calculus accumulation to the texture of the diet and the indications that the Archaic diet was abrasive, should have resulted in a greater Mean Cervical Height value for the Mississippian sample. The fact that they do not invites speculation. The final chapter considers the problem.

CHAPTER VI

SUMMARY AND DISCUSSION

The results obtained and presented in the previous chapter need to be summarized and evaluated. By and large, subsistence contrasts between the Archaic and Mississippian samples have been identified. However, not all of these results conform to what was anticipated from the literature and need to be discussed. This discussion follows a brief summary of the results.

The difference in caries incidence between the two subsistence systems conforms to the wide body of data available for hunter/gatherers and agriculturalists. Apart from possessing a low caries incidence, the Archaic sample is also characterized by caries located as the cervix of the tooth. Carious teeth are also found more frequently in the posterior tooth row. Caries in the Archaic sample are logically the results of food impaction, which provides the nutrient substrate for the glycolytic production of demineralizing acids. The process of attrition exposes the vulnerable tooth cervix to these acids. The patterns which have emerged from the Archaic data are in agreement with other hunter/gatherer data.

The caries picture is quite different for the Mississippian sample. Caries are not only much more frequent, owing to the consumption of the cariogenic cultigen maize, but the lesions are found in a wider range of sites along the tooth row. These results also conform to what is known about the pattern of caries in agriculturalists. Demineralizing activity is identified at least equally as often on the crown as at the cervix.

Factors which may affect caries incidence within a stratified society were not considered. Sample size was the prohibitive factor. In the present analysis, no statistically significant sex differences in caries experience were detected. Sex differences had been identified elsewhere (Larson, 1981), but are apparently not present in the Tennessee Valley area. If any differences do exist, status associated caries incidence may operate to obscure them.

The difference in rate of tooth attrition between the Archaic and Mississippian samples is statistically significant for all teeth and over all age classes. The Archaic sample is characterized by a rapid attrition rate which is maintained throughout the lifetime of the sample members. Since the rate at which the teeth are abraded has been attributed to food texture, it can be inferred that the consistency of the food volus is appreciably different between the subsistence systems. This has already been implied from the evaluation of the temporomandibular joint in these same populations (Hinton, 1981a), and from the nature of the food remains (fecal) obtained from equivalent samples from Kentucky (e.g., Robbins, 1971; Yarnell, 1974; Marquardt, 1974). The ethnographic material for Indians of the Southeast also suggested that textural contrasts are likely (Hudson, 1976; Swanson, 1946).

The form of anterior tooth wear also exhibits subsistence contrasts. The Archaic is characterized by labio-lingual rounding of the incisal teeth, a feature typical of hunter/gatherer samples (e.g., Molnar, 1968; Hinton, 1981b). The Mississippian sample exhibits cupped wear. The presence of cupped wear has been attributed to reliance on the anterior teeth subsequent to the loss of the posterior teeth to caries (Molnar, 1968). Cupped wear is present preferentially on maxillary incisors and canines. Only one case of cupped wear was found in the mandible. The size of the occlusal surface may be a critical factor in the development of cupping, however, the absence of cupping in the mandibular canines cannot simply be explained by critical occlusal surface diameter. Other factors involved may include the youth of the sample (and its concomitant low levels of attrition), and tooth use activities.

In the Mississippian sample, another anterior tooth wear form was identified and found in greater frequency than cupped wear. This form is referred to as lingual wear and consists of the preferential attritioning of the lingual tooth surface. The etiology of this particular form is not apparent at this time. Lingual wear also possesses a segregated distribution along the tooth row. Factors involved in the distribution are also not determinable at the present time.

The use of the anterior teeth as a tool has been observed in Eskimos and Australian aborigines. The presumed consequence of extensive use of the anterior teeth as a tool is, presumably, excessive abrading of the anterior teeth. The single interpopulational study of the patterns of anterior to posterior wear has identified contrasts between samples of hunter/gatherer and agriculturalists (Hinton, 1981b).

These same results were not obtained in the present analysis. The Archaic sample is more similar to the Mississippian than to the other hunter/gatherer groups. It is hypothesized that since the hunter/gatherer model is based on populations inhabiting marginal environments, it is possible that the more varied environment of the Archaic sample did not provide the pressure to utilize the anterior teeth extensively in a nonmasticatory capacity.

The pattern of periodontal disease pathogenesis reveals subsistence differences. The severity of periodontal disease in the Archaic sample decreases with increasing age. The opposite is true for the Mississippian. Attrition is seen as the modulating factor. Attrition eliminates the interdental crevices which encourage food impaction and undisturbed plaque proliferation. With a reduction in the amount of oral debris, reparative bone growth overtakes the rate of destruction and the mean of bone height loss reduces.

The apparent high levels of oral debris and bone loss in Archaic young adults is difficult to interpret. The samples should theoretically be distinct over all the age grades. This is based on epidemiology and the soft food texture proposed for the Mississippian sample and the high degree of occlusal stress proposed for the Archaic sample. It is not certain whether the Archaic sample is experiencing high levels of oral debris or whether the Mississippian sample is experiencing a low level of debris accumulation.

If the Archaic debris and bone loss data may be interpreted to mean a high level of periodontal disease involvement for the sample, then based on the background literature introduced in an earlier chapter the regular consumption of carbohydrates in a form or quantity which permits calculus accumulation may be proposed. This debris accumulates in spite of masticatory stress. Only with the elimination of the ares which favor plaque accumulation does calculus, and concomitantly, bone loss reduce in rate.

If the amount of debris and bone loss experienced by the Mississippian sample represents a low level of periodontal disease involvement, then carbohydrate consumption (noncariogenic) may be intermittant and/or in small quantities. Since high levels of occlusal stress are not proposed for this sample, amount and frequency of carbohydrate consumption are the primary factors involved in periodontal disease status.

The difficulty in interpreting the results gleaned from the present analysis apparently does not stem from problems with the quantification or analytical techniques. Calculus and cervical height are independently quantified and the results mirror each other quite closely. The major problem appears to be the absence of a baseline upon which to assess the results. Therefore, at the present time, specific subsistence differences cannot be identified in the Archaic and Mississippian samples on the basis of periodontal disease independent of attrition. However, in considering oral health status, the role of attrition as a modulating influence in the pathogenesis of periodontal disease is a significant one. The result of the intervention of attrition is a reduction in the ultimate destructive effects of loss of bone height for the Archaic sample.

In sum, subsistence differences are apparent in most of the parameters investigated in the present study. More extensive examination of anterior and posterior wear contrasts for hunter-gatherer samples from a wider range of environments may be needed. More detailed periodontal disease data is certainly needed. The attempt to establish a baseline in the present analysis has not yielded diagnostic results. However, the value of controlling for extraneous contributors of bone loss (attrition and age) has been demonstrated.

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VITA

Maria Ostendorf Smith was born in Chicago, Illinois on May 27, 1952. She attended Alvernia High School in that city where she graduated in 1970. In August of 1973 she received a Bachelor of Arts degree in Anthropology with Honors and High Distinction from the University of Illinois Chicago Circle. Mrs. Smith attended the University of Michigan in Ann Arbor from the Fall of 1973 to the Spring of 1975, earning a Master's degree in Anthropology. She was admitted into the Ph.D. program in Anthropology at The University of Tennessee, Knoxville, in the Fall of 1975. Maria Smith is married to Fred H. Smith (m. December 28, 1974), a biological anthropologist. The couple have one son, Burton Thomas, born November 13, 1980.