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The End of Prehistory in the Land of Coosa

Oral Health in a Late Mississippian Village

Mark C. Griffin

Griffin previews the topic of New World colonization with his exploration of oral health among constituents of the Coosa paramount chiefdom during the protohistoric period and immediately preceding European contact. Like Betsinger and Smith (chapter 3), Griffin addresses health and the transition to agriculture, which again is a frequent topic among bioarchaeological contributions to understanding culture history and the adoption of intensive agriculture. But also like Betsinger and Smith, Griffin does not uncover evidence of widespread and monolithic adoption of maize agriculture. This chapter overlaps spatially and temporally with Betsinger and Smith also, in that Griffin's David Davis site sample represents the Dallas phase of the Mississippian period, and in this research, he assesses caries frequencies. Griffin's work also echoes Listi's (chapter 2) in his examination of linear enamel hypoplasia to assess diet and health. Like Listi, he discovers that the relationship is not always linear and is more suggestive of local variability in the adoption of maize agriculture. A novel contribution of this work is the consideration of both environmental and cultural nonalimentary factors in differences in frequency of dental caries, suggesting that these conditions resulted in a change in oral pH or in the introduction of antimicrobial compounds that inhibited cariogenic bacterial growth. Overall,

Griffin's results shed light on the diversity of subsistence practices and cultural adaptations among prehistoric Native Americans on the eve of contact.

In the late prehistory of southeastern North America, the extensive period of European colonization and acculturation had a dramatic impact on native populations. Research has suggested that the intensive period of Spanish colonization accelerated the biological, social, political, and economic changes initiated by the shift from a foraging economy to an agricultural one (Baker and Kealhofer 1996; Larsen 2001; Larsen and Milner 1994; Verano and Ubelaker 1992). Understanding the lifeways and health status of native southeastern US populations immediately prior to this period of extensive contact is important for understanding the nature and extent of population changes after intensive acculturation. Unfortunately, firsthand ethnographic documentation for the protohistoric Southeast is scant. Hudson and Tesser (1994) refer to this time period as "the forgotten centuries" due to the general absence of historic records. Documentation of changes spurred by this period of colonization is, therefore, largely limited to the archaeological and osteological record because of the paucity of historical documents for the protohistoric Southeast.

Although the transition to agriculture was neither uniform nor complete in the precontact southeastern United States, many populations had shifted from a foraging subsistence to an agricultural one prior to European colonization (Hutchinson et al. 1998, 2000; Larsen 1993, 1995; Powell 1988). Bioarchaeological research has indicated that a transition to a predominantly agricultural subsistence pattern often had negative health effects (Cucina et al. 2011; Halcrow et al. 2013; Larsen et al. 1991; Lukacs 1992; Temple and Larsen 2007; Watson 2008), many of which can be linked to nutrient deficiency. For instance, although maize can provide adequate caloric intake, it contains only small amounts of protein (< 4 grams per pound) and lacks two essential amino acids, lysine and tryptophan, and a vitamin, niacin. The lack of even one amino acid in the diet will preclude the utilization of the rest (Stini 1971). Consequently, an increased reliance on maize to the exclusion of other complementary food resources necessarily leads to poorer nutrition. One reliable indicator of malnutrition is elevated prevalence of linear enamel hypoplasia (LEH) (Caufield et al. 2012). Maize, a highly fermentable carbohydrate, has the capacity to alter the bacterial balance in the oral cavity and predispose individuals to caries. Oral bacteria associated with dental car-

ies have also been shown to have a major role in the development of serious extraoral diseases including cardiovascular disease, rheumatoid arthritis, inflammatory bowel disease, colorectal cancer, and respiratory tract infections (Han and Wang 2013; Meurman et al. 2004). Therefore, a shift to an agricultural subsistence economy has disease impacts that go far beyond the oral cavity.

This research examines the human skeletal sample from the David Davis site (40HA301). This site was occupied from around AD 1550 to 1600, a span of only fifty years. This brief snapshot in time allows for fine-grained observation of individuals living immediately before extensive European contact and colonization. Most other sites in this region (e.g., Ledford [Sullivan 1986], King [Blakely 1988], and Little Egypt [Hally 1979]) derive from much longer time periods and therefore frequently have very complicated and insecure chronologies; often it is impossible to confidently assign individual burials to discrete time periods, complicating assessment of health status for particular time periods. The findings for this site are more representative of the period immediately prior to contact than those obtained for other sites from the region.

The David Davis site is located along South Chickamauga Creek in Chattanooga, Tennessee (fig. 4.1), and is culturally and temporally affiliated with the Mississippian Dallas phase. Middle and Late Mississippian Dallas culture in southeastern Tennessee has been documented at approximately sixty-five settlements along the Tennessee River and its tributaries. The David Davis site is unique among these sites because of its relatively short duration of occupation and because it is one of the likely stopping points for the 1539–43 de Soto *entrada* (Alexander and Trudeau 2008). Several clusters of Late Mississippian sites on the Coosawattee River in north Georgia have been proposed by Hally and coworkers (1990) as the Rome polity—also likely visited by de Soto—that forms the center of the Coosa paramount chiefdom from 1540 to 1560. This polity may also have included the David Davis site and related sites in southeastern Tennessee (Hally 2008).

Investigations at 40HA301 indicate that it was a multiuse site with both domestic and mortuary features. A total of 105 mortuary features containing 173 individuals was excavated from the site. Spatial analysis suggests six areas of mortuary concentration, all of which appear to be associated with residential structures. The positions of the burials were almost exclusively semiflexed, with one example of an adult extended interment and one infant extended interment.

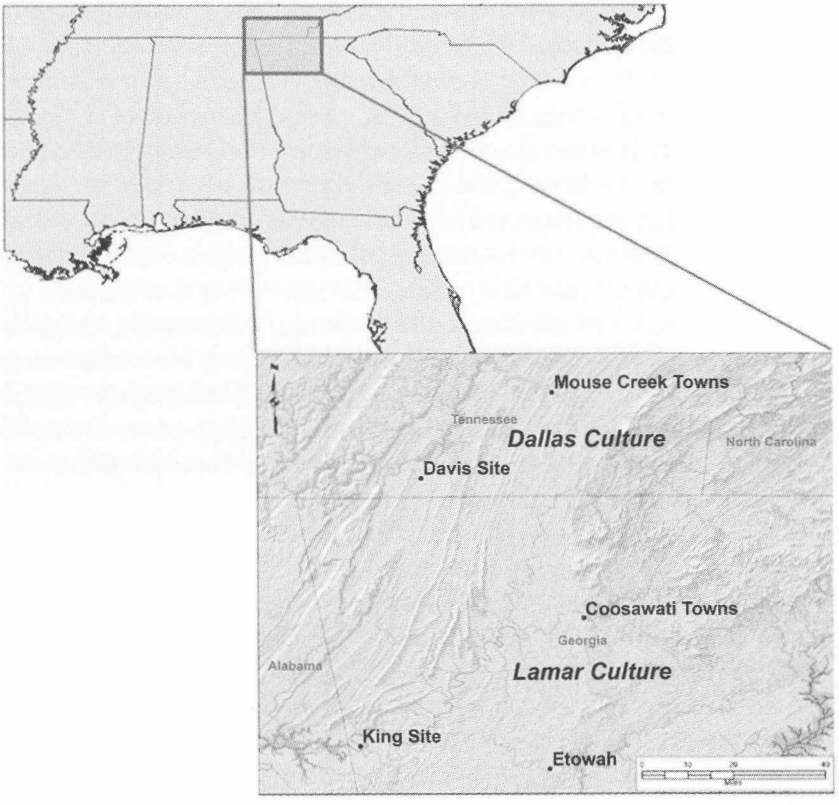

Figure 4.1. Location of David Davis site (40HA301) (Mark C. Griffin, after Alexander and Trudeau 2008).

Field assessments of sex and age at death suggest differing spatial grouping according to sex; however, the burials do not appear to be spatially segregated by age or by the presence or absence of mortuary goods (Alexander and Trudeau 2008).

The overall condition of the skeletal sample from 40HA301 is very poor, with most of the burial features consisting of highly fragmentary and incomplete remains. Even though the general condition of the skeletal remains is less than optimal, the condition of the dental remains is quite good. Therefore, the most complete information regarding the health of individuals for this site comes from the dental anatomy. Three aspects of the dental anatomy are examined: dental caries, LEH, and dental wear. It is expected, based on the date for the site, that patterns of caries and LEH will show a population experiencing the disease and dietary stress associated with a relatively recent shift to an agricultural subsistence system and that the

prevalence of oral disease and dietary stress will be similar to other precontact agricultural populations in the region.

Oral Pathology and Dental Wear

Caries Etiology

Nearly 1,200 indigenous species of microflora inhabit the human oral cavity (Jenkinson 2011). Most of these organisms are commensal. That is, they are not harmful to their host, and some are actually beneficial. These microorganisms, collectively referred to as biofilm, live in normally stable microbial communities of viruses, mycoplasma, bacteria, Archaea, fungi, and protozoa (Marsh and Martin 2009; Meurman et al. 2004; Palmer 2014). In the healthy individual, there is a delicate balance between commensal and facultative pathogenic microflora of the oral cavity (Kidd and Fejerskov 2004; Liljemark and Bloomquist 1996; Palmer 2014). Oral microorganisms dynamically adapt to changes in their immediate environment, allowing these protean communities to maintain a synergistic homeostasis (Forng et al. 2000). Disruptions of the oral environment that exceed this adaptive capability allow facultative pathogenic species to proliferate resulting in disease processes like dental caries. Dental caries result from three interrelated contributors: (1) disturbance of the balance between commensal and facultative pathogenic oral microflora, (2) frequent consumption of fermentable carbohydrates, and (3) host susceptibility mediated by genetic and nongenetic influences (Lingström et al. 1994; Marsh 1995).

Some of the major pathogenic oral bacteria are of the genus *Streptococcus*. Only seven of the more than forty identified species of *Streptococcus*, collectively known as the mutans streptococci, are pathogenic and have been implicated in human caries and endocarditis (Coykendall 1989; Innings et al. 2005; Law et al. 2007). The two most common mutans streptococci in humans are *Streptococcus mutans* and *Streptococcus sobrinus* (Coykendall 1989). However, research demonstrating the frequent presence of caries in the absence of mutans streptococci indicates that the disturbance of oral microbiotic balance is more important in caries etiology than the presence of a particular organism (Giacaman et al. 2010; Kleinberg 2002; Simón-Soro et al. 2013). When pathogenic bacteria proliferate in the oral cavity, they produce metabolic wastes that contribute organic acids and proteases to the oral fluids (Featherstone 2004; Liljemark and Bloomquist 1996). The lowered pH makes the oral environment more favorable for the pathogenic organisms (Caufield et al. 2015).

The metabolic wastes can dissolve the mineral component of dental enamel, producing a carious lesion and offering the pathogenic organisms access to the bloodstream.

Hypoplasia Etiology

Developmental defects of enamel (DDE) are common in the human dentition (Elfrink et al. 2012; William et al. 2006). DDE result from heritable conditions or insults to the ameloblasts at vulnerable stages of amelogenesis (Ford et al. 2009; Taji et al. 2011). Acquired types of DDE are more common than inherited types (Ford et al. 2009). Defects are classified as either hypomineralization or hypoplasia (Elfrink et al. 2012; Slayton et al. 2001). Hypoplasia is a defect characterized by a reduction in the thickness of the enamel rather than abnormal mineralization (Sabel et al. 2010; Taji et al. 2011).

Enamel hypoplasia (EHP), a form of DDE, has been linked to specific infections (e.g., gastrointestinal, urinary, respiratory), asthma, otitis media, chicken pox, and malnutrition (Caufield et al. 2012; Ford et al. 2009; Taji et al. 2011). Ameloblastic activity is disrupted in these conditions through direct cellular damage from the infecting microorganism, derangement due to increased body temperature, or from secondary systemic insults (Taji et al. 2011). Histological research suggests that the period of damage to the enamel is relatively brief and that the ameloblasts subsequently recover (Taji et al. 2011).

LEH, a severe form of EHP, has frequently been linked to malnutrition (Caufield et al. 2012). However, Nelson and coworkers (2013) suggest that malnutrition may simply be a symptom of a larger constellation of contributory medical problems that create an environment for calcium and mineral insufficiency. LEH is specifically defined as a macroscopic defect manifested as a linear reduction in the enamel thickness with rounded, smooth borders and a base that is often rough (Sabel et al. 2010). The linear defects are roughly parallel to the cementoenamel junction and perpendicular to the tooth's long axis (Goodman and Song 1999; Hillson 1996). LEH is important clinically because the reduction in enamel thickness increases risk for caries, tooth sensitivity, and excessive wear (Nelson et al. 2013; Slayton et al. 2001).

Dental Wear Etiology

Dental enamel reduction (dental wear) is an age-related phenomenon that occurs in all human populations and is a contributing factor in oral disease risk (Lee et al. 2012). Dental wear results from three con-

tributors: (1) attrition from tooth-on-tooth contact, (2) abrasion from the friction of foreign substances on the enamel, and (3) erosion from the chemical dissolution of enamel not due to biofilm (Kaidonis et al. 1998). Dental wear primarily depends on diet and age of the individual. Abrasive diets (e.g., hunter-gatherer) produce more rapid and severe wear than diets that are softer and more highly processed (e.g., agricultural) (Deter 2009). Nonalimentary wear from activities like basket making can cause major departures from these general wear patterns (Grant 2010).

Materials and Methods

The Population Sample

Laboratory assessment of sex and age at death could be accomplished for roughly half of the 173 individuals in the David Davis sample. Sex and age at death were assessed using the standards of Buikstra and Ubelaker (1994). Seventy-eight individuals were sufficiently complete to allow accurate sex assessment from the pelvis (44 female and 34 male). The highly fragmentary nature of the remains did not allow for sex estimation on the remaining individuals. Age at death could be assessed for 101 individuals; 62 individuals were less than 18 years of age and 39 individuals were 18 or older. The remaining individuals lacked sufficient diagnostic criteria to estimate age at death.

Carious Lesions

To examine frequencies of carious lesions in the 40HA301 sample, each tooth was examined with 3.5x dental loupes, a 3-mm Microlux Transilluminator fiberoptic diagnostic light, and stainless steel dental probes. Fiberoptic transillumination offers a superior method of lesion detection compared with other macroscopic methods (Davies et al. 2001; Pretty 2006). Carious lesions were only counted with the presence of a definable pit (Buikstra and Ubelaker 1994; Cucina et al. 2011; Halcrow et al. 2013; Lukacs 1989). Tooth discolorations alone were not counted as carious lesions. Wasterlain and coworkers (2011) suggest that this method underestimates the actual number of carious teeth; however, all of the comparative studies used here use the minimum criteria of a definable pit for lesion identification. Lesions were recorded with regard to their location on the tooth (occlusal, cervical, buccal, lingual, mesial, and distal). Maximum lesion size was measured in millimeters using a Paleo-Tech Helios type needle point caliper. The data reported here have been reduced to lesion pres-

ence and absence because the comparative studies for the region do not include details regarding numbers of lesions on particular teeth, lesion sizes, or lesion locations. To facilitate comparison with other sites, left and right antimeres were pooled while maintaining separate counts for each tooth classification in the maxillary and mandibular dentitions. Maintaining counts for separate tooth classifications allows for the detection of intraoral patterns of disease (Caglar et al. 2007; Cucina et al. 2011; Hillson 2001; Temple and Larsen 2007; Wasterlain et al. 2009).

Linear Enamel Hypoplasias

Dental enamel differs from bone in that it cannot be remodeled after tooth formation. LEHs therefore form a permanent chronological record of a stressful event during the first seven years of life (Goodman and Rose 1990). Enamel is laid down in a series of layers beginning at the cusp of the tooth and proceeding toward the cementoenamel junction (Ritzman et al. 2008). Thus, a measurement taken from the LEH to the cementoenamel junction can be used to calculate the age at which the stress event occurred (Goodman et al. 1980; Ritzman et al. 2008). Lewis and Roberts (1997) advise that because tooth crown heights differ from population to population, corrective equations must be used to calculate times of LEH formation for each unique population. Although this method would certainly make age at occurrence estimates more accurate, it is of little practical value in populations that exhibit considerable wear from an early age. This is because the corrective equations require a sample of teeth with no wear from the population, which are frequently unavailable.

All anterior teeth for the dentitions from 40HA301 were examined with 3.5x dental loupes and 3-mm Microlux Transilluminator fiberoptic diagnostic light for the presence of linear enamel defects. Teeth included in the data reported below had at least 2 mm of continuous enamel measured from the cementoenamel junction to the occlusal surface. The distance to the middle of each defect was measured from the cementoenamel junction (measured in millimeters using a Paleo-Tech Helios type needle point caliper). Defects were not recorded unless they were both visible under magnification and detectable by dental probe (Goodman and Rose 1990). An LEH was counted as present only when the defect spanned the majority of the labial tooth surface (Griffin and Donlon 2009). To facilitate comparison with other sites, left and right antimeres were pooled while maintaining separate counts for each tooth classification in the maxil-

lary and mandibular dentitions. The method of Goodman and Rose (1990) was used to estimate age of occurrence for the enamel defects in this population. Corrective equations suggested by Ritzman and coworkers (2008) were not used because of the absence of teeth with no wear needed to calibrate the equations.

Dental Wear

The systematic observation of dental wear has long been a standard part of bioarchaeological studies; however, the method of measurement has been far from standardized. Numerous scoring systems have been proposed attempting to account for variations in dentin exposure (Dreier 1994; Molnar 1971; Molnar et al. 1983; Richards 1984; Scott 1979), reduction of crown height (Tomenchuk and Mayhall 1979), and angle of wear plane (Hall 1976; Molnar 1971; B. H. Smith 1984). Unfortunately, standardizing a method of recording dental wear is nearly impossible because the way in which human dentitions wear is far from standard and depends on a number of complex biological and behavioral factors.

Each tooth in the 40HA301 sample was scored for dental wear using the Smith wear system (B. H. Smith 1984) because of its simplicity, which reduces inter- and intraobserver error. Unique wear patterns are best detected by recording wear at each individual tooth location. Wear was recorded for each tooth position for the assessment of intrasite wear patterns. However, left and right antimeres were pooled for intersite comparisons because published comparison data for populations of appropriate geographic location and time period mostly consist of pooled data.

Results

Examination of carious lesion frequencies in the teeth from 40HA301 (table 4.1, figs. 4.2 and 4.3) reveals that the overall frequencies are similar to contemporaneous populations of the geographic region (11 percent for the maxillary dentition and 10.9 percent for the mandibular dentition). Compared with other populations (fig. 4.4), these frequencies are not significantly different from the early contact samples from the Georgia coast. Similar to other populations, the molars are the most affected teeth. Molars usually have the highest frequencies of carious lesions due to their complex fissure patterns (Ferreira Zandoná et al. 2012). Comparison of carious lesion frequencies between males and females reveals that as in most populations, females ex-

Table 4.1. Carious Lesion Frequencies from 40HA301

	Site		Female		Male	
Tooth	**No.**	**%**	**No.**	**%**	**No.**	**%**
Maxilla						
I1	143	7.79	51	17.65	38	5.26
I2	140	7.86	49	20.41	42	—
C	156	4.49	63	9.52	44	—
P3	153	8.5	57	14.03	46	2.17
P4	150	7.33	57	12.28	44	4.54
M1	173	12.14	60	16.67	45	8.89
M2	148	19.59	55	27.27	45	20
M3	112	20.53	47	23.4	38	18.42
Total	1175	11.03	439	17.65	342	7.4
Mandible						
I1	114	5.26	50	8	33	6.06
I2	133	5.26	56	8.93	36	5.55
C	158	6.33	65	12.31	50	4
P3	161	9.94	61	16.39	53	5.66
P4	148	8.78	59	13.56	46	6.52
M1	159	14.46	47	21.28	47	14.89
M2	145	20.69	54	24.07	47	25.53
M3	115	16.52	45	11.11	44	22.73
Total	1133	10.91	437	14.46	356	11.37
Site Total	2308	10.97	876	16.04	698	9.39

hibit higher frequencies for most teeth. Only one tooth (lower M2) exhibits differences tested by chi-square that are not statistically significant ($p < 0.05$). Comparison of frequencies of carious lesions found in individuals younger than eighteen years to individuals older than eighteen years reveals that there are no statistically significant ($p < 0.05$) differences tested by chi-square between the two age groups. Frequencies of carious lesions at 40HA301 indicate a population with moderate to low levels of caries.

The LEH frequencies in the 40HA301 sample show moderate to low levels of hypoplastic defects (table 4.2, fig. 4.5). Comparison of these frequencies with other population samples from the region (fig. 4.6) reveals that the frequencies of hypoplastic defects at 40HA301 are lower than those for any other comparative site. Chi-square analysis for each tooth location comparing 40HA301 to each of the other regional sites yields statistically significant ($p < 0.05$) differences for

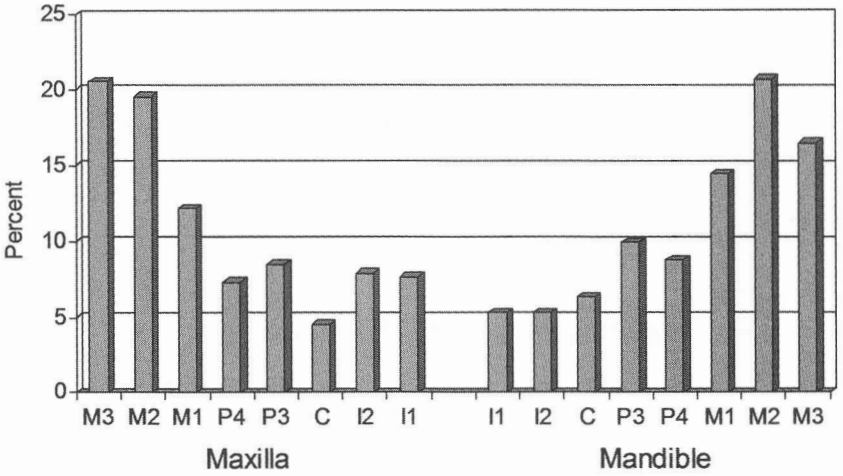

Figure 4.2. Frequencies of carious lesions in maxillary and mandibular dentitions for 40HA301 (M3 = third molar, M2 = second molar, M1 = first molar, P4 = second premolar, P3 = first premolar, C = canine, I2 = lateral incisor, I1 = central incisor) (Mark C. Griffin).

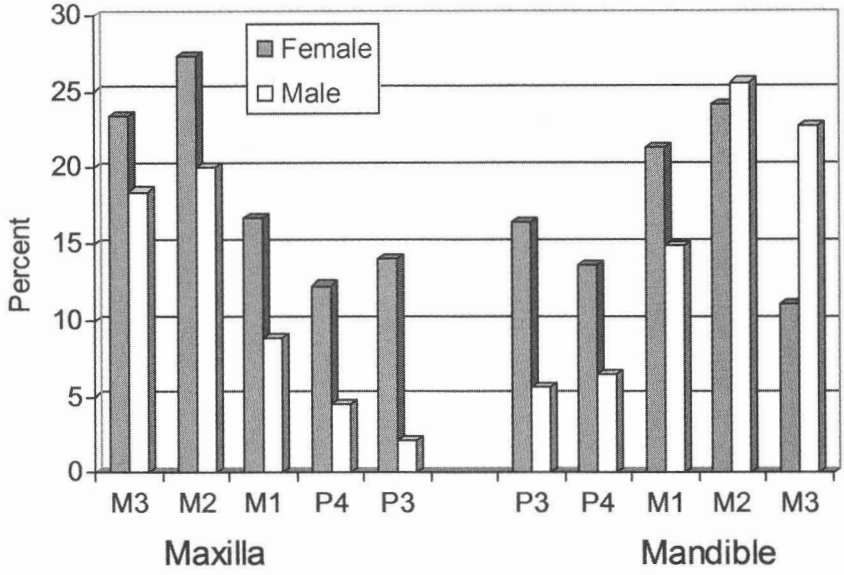

Figure 4.3. Frequencies of carious lesions in maxillary and mandibular dentitions of females and males for 40HA301 (M3 = third molar, M2 = second molar, M1 = first molar, P4 = second premolar, P3 = first premolar) (Mark C. Griffin).

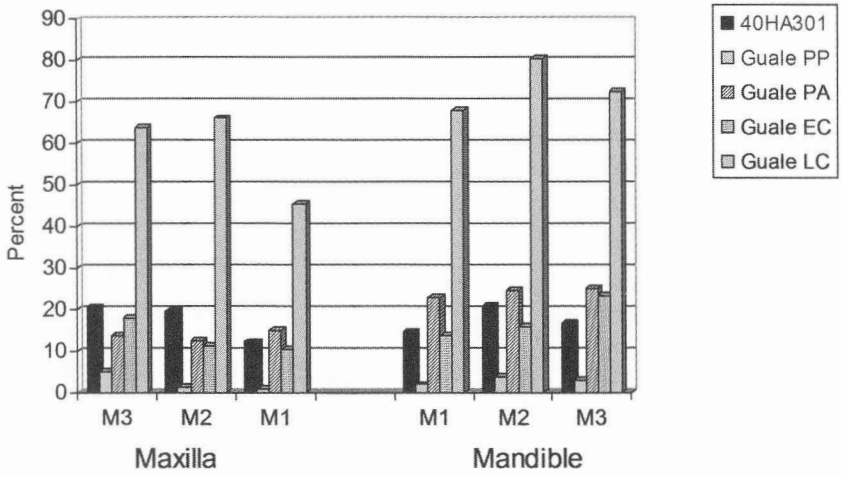

Figure 4.4. Frequencies of carious lesions in 40HA301 and four other southeastern US population samples (PP = precontact preagricultural, PA = precontact agricultural, EC = early contact, LC = late contact, M3 = third molar, M2 = second molar, M1 = first molar) (comparative data from Larsen et al. 1991) (Mark C. Griffin).

Table 4.2. Frequencies of Teeth with Enamel Hypoplasias from 40HA301

	Site		Female		Male	
Tooth	**No.**	**%**	**No.**	**%**	**No.**	**%**
Maxilla						
I1	127	53.54	38	68.42	35	48.57
I2	122	31.15	37	40.54	40	37.5
C	141	50.35	51	49.02	42	64.28
P3	137	3.65	47	—	42	9.52
P4	139	.72	50	2	42	—
M1	152	4.6	49	4.08	40	5
M2	125	6.4	41	—	42	9.52
M3	85	2.35	36	—	31	6.45
Total	1028	19.1	349	20.51	314	22.61
Mandible						
I1	98	—	41	—	25	—
I2	113	6.19	42	7.14	31	3.22
C	141	69.50	50	80.00	47	74.47
P3	138	2.17	51	—	46	4.35
P4	135	—	50	—	45	—
M1	132	—	37	—	42	—
M2	120	—	42	—	40	—
M3	84	—	34	—	33	—
Total	961	9.73	347	10.89	309	12.30
Site total	1989	14.42	696	15.7	623	16.43

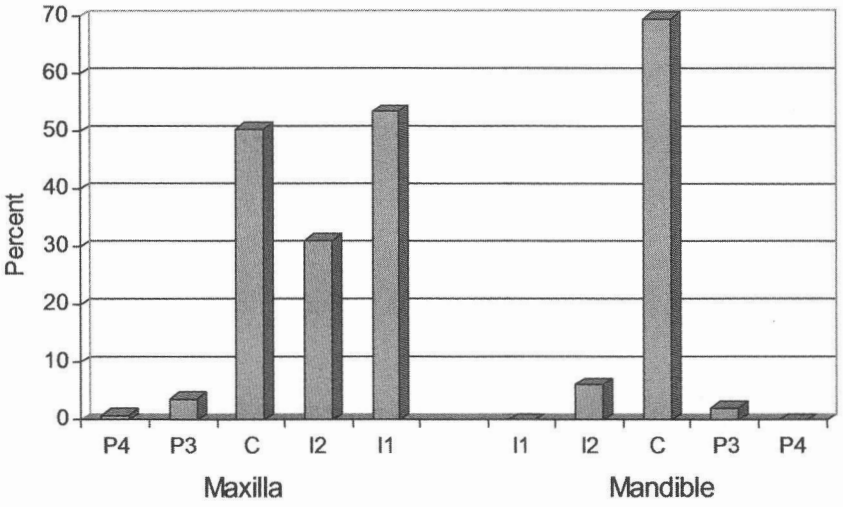

Figure 4.5. Frequencies of enamel hypoplasias in maxillary and mandibular dentitions of 40HA301 (P4 = second premolar, P3 = first premolar, C = canine, I2 = lateral incisor, I1 = central incisor) (Mark C. Griffin).

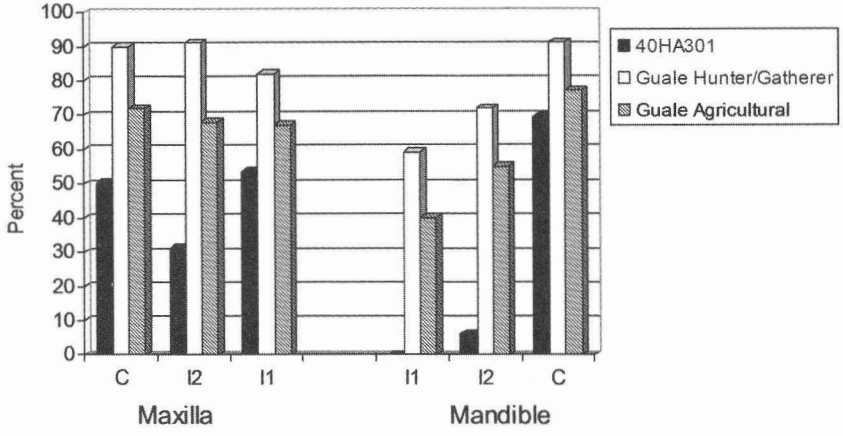

Figure 4.6. Frequencies of enamel hypoplasias in 40HA301 and two other prehistoric population samples (C = canine, I2 = lateral incisor, I1 = central incisor) (Mark C. Griffin).

every comparison. The low to moderate levels of LEH frequencies observed here indicate a relatively healthy population. Most of the defects (84 percent) cluster in the three- to five-year age range (fig. 4.7). This pattern is typical of most populations and likely corresponds to ages at which individuals are at highest risk for childhood illnesses. Males and females have similar frequencies of enamel defects in the

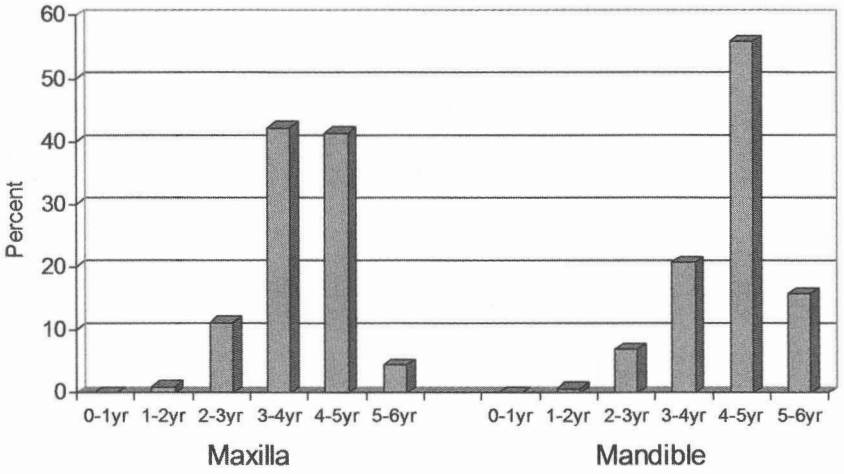

Figure 4.7. Age distribution of enamel hypoplasias in maxillary and mandibular canines (calculated using the regression equations from Goodman and Rose 1990) (Mark C. Griffin).

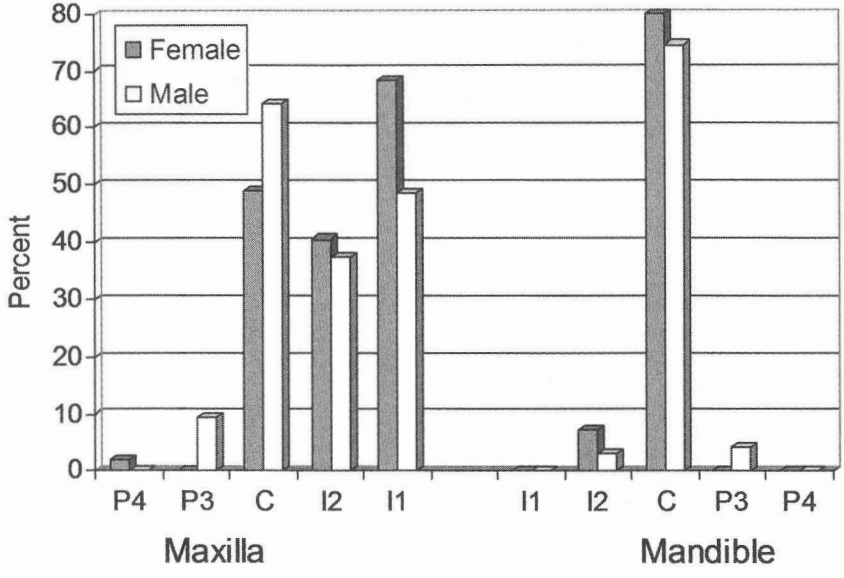

Figure 4.8. Frequencies of enamel hypoplasias in maxillary and mandibular dentitions of females and males for 40HA301 (P4 = second premolar, P3 = first premolar, C = canine, I2 = lateral incisor, I1 = central incisor) (Mark C. Griffin).

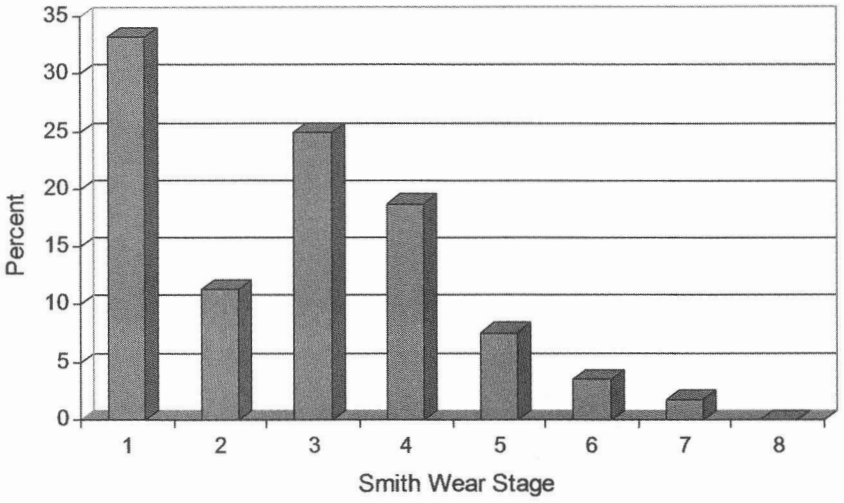

Figure 4.9. Frequencies of B. H. Smith (1984) composite dental wear scores for 40HA301 (Mark C. Griffin).

40HA301 sample (fig. 4.8). The only tooth with a statistically significant difference is the maxillary central incisor (chi-square $p < 0.05$).

Examination of the average wear across the entire skeletal sample (fig. 4.9) indicates a population exhibiting low to moderate dental wear. Wear scores are reported by individual tooth and as composite scores (average wear across all teeth of an individual). The average composite dental wear for the sample is 2.7 (on a scale from 1 to 8) with nearly 70 percent of the sample exhibiting average wear scores of 3 or below. Comparing composite wear scores for samples can be somewhat deceiving when there is unusual wear on individuals' teeth. Examination of average wear for each tooth position for 40HA301 (fig. 4.10) illustrates the importance of detecting wear patterns across the whole dentition. Although the composite wear scores are relatively low, the anterior dentition for this sample shows an unusually high level of wear. Comparison of male and female average wear scores (see fig. 4.10) reveals consistently higher wear in males. More than half of the differences are statistically significant ($p < 0.05$).

Discussion

These statistical results highlight three important findings for the 40HA301 population. The skeletal sample exhibits caries prevalence

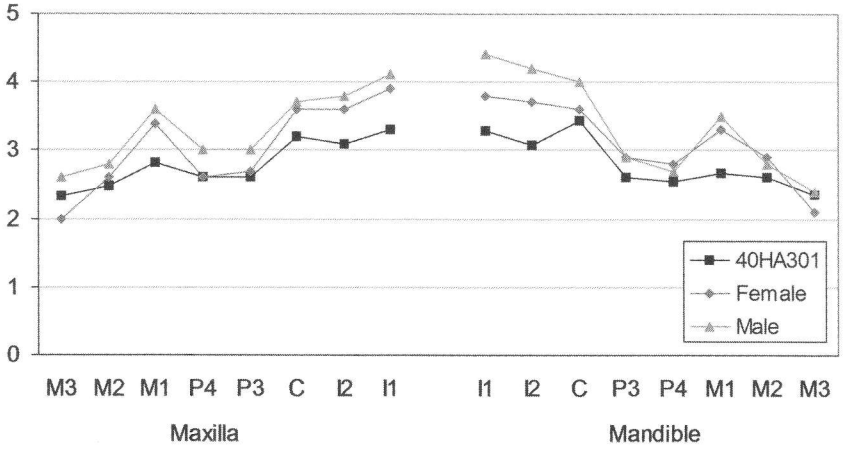

Figure 4.10. Mean dental wear by tooth class and sex for 40HA301 (M3 = third molar, M2 = second molar, M1 = first molar, P4 = second premolar, P3 = first premolar, C = canine, I2 = lateral incisor, I1 = central incisor) (Mark C. Griffin).

that is similar to other precontact populations from this geographic region. The LEH frequencies for 40HA301 are the lowest of all the comparative regional samples. Dental wear shows an unusual pattern of heavy wear of the anterior dentition. The patterns of caries prevalence, LEH frequencies, and dental wear can be interpreted in the context provided by bioarchaeological studies in the southeastern United States, recent clinical findings, and the ethnohistoric record. These three sources of interpretive evidence provide at least three possible explanations for the observed patterns.

One possible explanation for the pattern of pathological conditions observed (caries and LEH) in the 40HA301 population is provided by research showing that the shift from a foraging economy to an agricultural one was not complete in all parts of the southeastern United States before European contact (Hutchinson et al. 1998, 2000; Larsen 1993, 1995; Powell 1988). At the time of European contact, a highly varied array of subsistence economies were strongly influenced by the local environment and available natural resources. Schoeninger (2009) found that across North America and even in localized geographic areas of the same region maize adoption was not a uniform event. That is, not all communities adopted agriculture at the same time or to the same extent. For instance, along a 25-km section of the Mississippi and Illinois Rivers, many population cen-

ters had a very limited dependence on maize long after adjacent populations had made a considerable commitment to maize production (Schoeninger 2009). The same phenomenon can also be seen in prehistoric Georgia and Florida (Hutchinson et al. 2000; Hutchinson and Norr 2006; Schoeninger 2009). In these areas, intensive maize utilization was not seen until after the beginning of European conquest. Only after European colonization did the native inhabitants in these areas abandon their reliance on local vegetative and faunal resources and adopt the European pattern of full reliance on agriculture.

Analyses of nearby populations contemporaneous with 40HA301 have shown a similar pattern of partial adoption of agriculture. In an examination of sites from the lower Mississippi valley, Rose and coworkers (1991) found no contemporaneity between maize dependency and transitions to the Mississippian period. They suggest that although maize was grown in some unknown quantity it did not constitute a staple in the local diet. Analyses of dental wear, dental caries, and botanical data indicate a reliance at these sites on indigenous starchy seeds such as knotweed (*Polygonum erectum*), maygrass (*Phalaris caroliniana*), and goosefoot (*Chenopodium berlandieri*). This dietary pattern persisted in many areas well into the Mississippian period. Hogue and Melsheimer (2008) found a similar pattern for east-central Mississippi, using carbon isotope ratios and dental microwear to examine dietary patterns in protohistoric populations of the region. They found that the isotope values and microwear indicated a return to naturally available plant resources (predominantly nuts) in the protohistoric period. They suggest that reliance on hard nuts in the protohistoric was more intensive than among pre-Mississippian populations. A similar pattern is seen in the protohistoric period of the Little Tennessee River valley, where hickory and walnut were the most abundant plant food remains found at Mississippian sites (Chapman and Shea 1981). Heavy reliance on indigenous resources into the protohistoric era is also seen in coastal regions of the southeastern United States. Schoeninger and coworkers (1990), using carbon and nitrogen stable isotopes, demonstrated the inhabitants of the Georgia coast placed a heavy focus on wild plant and animal resources for the period prior to the twelfth century AD. After AD 1150, the native subsistence strategy began a shift to agriculture, although isotope analysis indicates that fish still represented a large percentage of the native diet (Larsen et al. 1992; Reitz and Scarry 1985; Schoeninger et al. 1990).

In addition to the paleobotanical evidence for the southeastern

United States, examination of faunal remains indicates a heavy reliance on nonplant resources that are directly tied to local resources (Bogan 1982; Pavao-Zuckerman 2000). In other words, the local patterns of faunal resource exploitation are most closely related to availability of local resources. In a survey of prehistoric and protohistoric sites in the southeastern United States, Pavao-Zuckerman (2000) found a significant reliance on faunal resources before European contact. She found a great variety of faunal assemblages at the various sites and found that the fauna that predominated at individual sites depended on the local environment. Coastal areas showed a predominance of marine resources, while inland sites showed a predominance of terrestrial fauna.

Frequencies and distribution of carious lesions in the 40HA301 sample are similar to those reported for the precontact inhabitants of the Georgia coast (Larsen et al. 1991). Frequencies of carious lesions in upper and lower molars for the two groups are remarkably similar (see fig. 4.4). This finding is of particular significance considering the dietary reconstructions for the precontact inhabitants of the Georgia coast. Dietary reconstructions for the precontact agricultural Guale of coastal Georgia indicate a substantial portion of the diet was derived from marine resources. In other words, they were not exclusively or even predominantly reliant on maize agriculture. The similar frequencies and distribution of carious lesions in the 40HA301 sample point to the possibility that this population was also more reliant on local indigenous resources (plant and animal) rather than focusing predominantly on maize agriculture. The notably low LEH frequency observed at 40HA301 lends support for this hypothesis. Increases in LEH frequency have been linked to intensive utilization of maize. The low frequencies in this sample are more congruent with a subsistence system that was not predominantly maize based.

A second possibility for the pattern of pathological processes observed in the 40HA301 population is suggested by recent clinical research regarding the capacity of different carbohydrates to alter the microbial balance of the oral cavity. Dental caries prevalence has been used in bioarchaeological studies as an indicator of overall dental health and dietary changes in past populations (Larsen et al. 1991; Sciulli 1997; Šlaus et al. 2011; Temple and Larsen 2007; Williams and Murphy 2013). Most of these studies have concluded that there is a direct relationship between increased consumption of carbohydrates associated with agriculture and increased prevalence of caries.

However, recent clinical research indicates that the relationship between complex carbohydrates and caries is more complicated than the relationship between simple sugars and caries (Beighton et al. 1996; Hujoel 2009; Lingström et al. 1994, 2000; Moynihan 2012).

Clinical research has demonstrated that the relationship between consumption of low molecular weight (LMW) carbohydrates (white flour and white sugar) and caries is rather direct (Lingström et al. 2000; Moynihan and Kelly 2014). The LMW carbohydrates, such as sucrose, are highly fermentable and also act as a substrate for the synthesis of polysaccharides in dental plaque (Bowen 2002). Therefore, the long-term consumption of LMW carbohydrates lowers oral pH, which favors cariogenic microflora at the expense of the commensal species (Paes Leme et al. 2006; Parisotto et al. 2010). The relationship between complex carbohydrate consumption and caries prevalence is far less conclusive (Lingström et al. 2000).

Research with in vitro biofilm and nonhuman species has shown that complex carbohydrates are substantially less cariogenic than sucrose or glucose (Duarte et al. 2008; Thurnheer et al. 2008). In vivo human research has also shown that unless complex carbohydrates undergo extensive processing they generally do not offer sufficient bioavailability of the sugars necessary for cariogenic bacterial proliferation (Lingström et al. 2000) or do so at a significantly reduced rate (Moynihan 2012). The manner in which the carbohydrate is processed is far more important than the amount or type of the carbohydrate consumed (Grenby 1990; Harper et al. 1985). Modern industrial processing methods used for complex carbohydrates, such as high-temperature extrusion, explosion puffing, or "instantization," produce starches with far higher glycemic and hydrolytic indices than their less intensively processed counterparts (Brand et al. 1985; Ross et al. 1987). In other words, starches that have been gelatinized and partially degraded during processing are far more cariogenic than starches processed in other manners (Lingström et al. 2000). Equally important is the finding that the combination of sucrose and starch vastly amplifies the cariogenic potential of sucrose alone (Campain et al. 2003; Duarte et al. 2008; Moynihan 2012). These modern clinical findings are important for bioarchaeological research. Specifically, the cariogenic capacity of complex carbohydrates found in the modern diet is a direct result of the means and methods of manufacture and not an inherent characteristic of the food items found in preindustrial diets. Analysis of microbiota in dental calculus for populations spanning the last ten thousand years confirms this association

(Adler et al. 2013). That is, shifts in the microbiota from predominantly commensal to predominantly pathogenic did not occur until the industrial revolution. The low prevalence of caries at 40HA301 might be explained by preparation methods for dietary items rather than the dietary items themselves. Some of the traditional maize preparation methods (e.g., hot-water immersion) were not sufficient to gelatinize the starch.

A final possibility that explains both the patterns of pathological processes and the unusual wear patterns observed in the 40HA301 population sample is the introduction of cariostatic compounds to the oral cavity. Dietary items and nonalimentary material consistently in contact with the oral cavity have the capacity to alter the microbial environment, potentially disrupting the ability of pathogenic bacteria to displace the commensal bacteria. Specifically, phenolic compounds found in dietary and nondietary plant materials have antimicrobial properties (Dai and Mumper 2010; Lattanzio et al. 2008). M. Griffin (2014) showed a link between depressed caries prevalence and the introduction of phenolic compounds into the oral cavity in a precontact Native American population sample. Specifically, dietary items (acorns and high-tannin nuts) and oral manipulation of basket-making materials (willow) were the likely explanations for the depressed prevalence of caries and periodontal disease. Acorns and high-tannin nuts have been shown to be ubiquitous staples in the diets of many Native American groups in the southeastern United States (Gremillion 1995; Hann 1986). Maize preparation methods used in the southeastern United States also introduced cariostatic compounds to the oral cavity. Two of these preparation techniques were "hickory milk" (tannic acid) soaking and alkali treatment with lime (calcium hydroxide) or lye (sodium hydroxide) (Hally 1983; Hudson 1976; Katz et al. 1974). Sodium hydroxide nixtamalization has been shown to enhance and rapidly accelerate gelatinization of maize starch during boiling increasing its cariogenicity (Ragheb et al. 1995). Calcium hydroxide nixtamalization does not produce the same elevated gelatinization (Robles et al. 1988). Both calcium hydroxide and sodium hydroxide have been clinically shown to have powerful antimicrobial effects due to their high pH (Mohammadi and Dummer 2011; Sangwan et al. 2013). In fact, calcium hydroxide is the most common clinically used treatment for serious carious lesions (Fuks et al. 2012). The introduction of these compounds to the oral cavity would have suppressed the facultative pathogenic bacteria for the

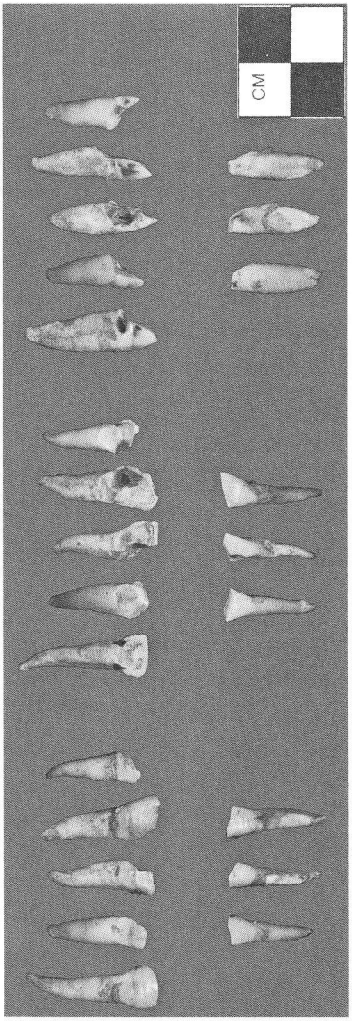

Figure 4.11. Abnormal anterior dental wear at 40HA30 (courtesy of Alexander Archaeological Consultants, Inc., and Tennessee Department of Environment and Conservation, Division of Archaeology).

population at 40HA301, in spite of the increased cariogenecity caused by nixtamalization of maize.

The pattern of dental wear observed in the dentitions from 40HA301 (see fig. 4.10) provides further evidence of the introduction of cariostatic compounds to the oral cavity. That is, the anterior dentition exhibits an unusually high level of wear and a series of wear facets that are likely not alimentary in nature (see figs. 4.10, 4.11, and 4.12). Comparison of the overall wear gradient for the individuals at 40HA301 to that of other precontact sites (see fig. 4.12) further il-

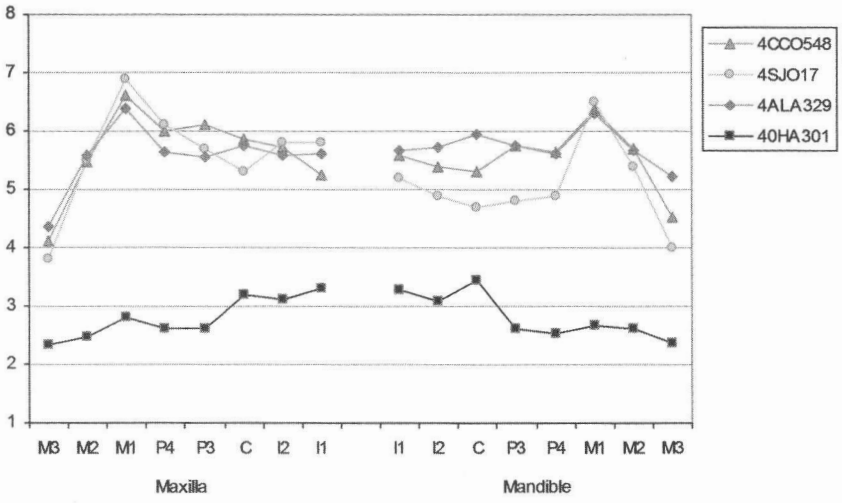

Figure 4.12. Mean dental wear by tooth class and sex for 40HA301 and three California populations: CA-CCO-548, CA-SJO-17, and CA-ALA-329 (M3 = third molar, M2 = second molar, M1 = first molar, P4 = second premolar, P3 = first premolar, C = canine, I2 = lateral incisor, I1 = central incisor) (comparative data from Griffin and Donlon 2009; Molnar 1971; Jurmain 1990) (Mark C. Griffin).

lustrates the unusual nature of the wear pattern observed here. The wear gradients show that rather than exhibiting the usual pattern of highest wear on M1, the individuals at 40HA301 exhibit the highest wear on incisors and canines (see fig. 4.12). Grant (2010) observed a similar pattern of wear in central California populations that is likely linked to basket-making activity. The unique grooves worn on teeth in these populations are most likely the result of traditional methods of willow splitting. These activities have been linked to elevated oral levels of polyphenols and depressed prevalence of caries and periodontal disease in ancient California (M. Griffin 2014). The most common basket-making material in the precontact US Southeast was river cane (*Arundinaria* spp.) (Platt et al. 2009). Bamboos like river cane have been found to contain an enormous variety of flavones and glycosides, some of which have powerful antimicrobial properties (Choudhury et al. 2012; Van Hoyweghen et al. 2012). Flavones have been shown to have antibacterial activity specific to the mutans streptococci (Badria and Zidan 2004; Varoni et al. 2012). Traditional methods of cane splitting for basket weaving in the southeastern United States also involve the use of the teeth (Gregory 2006).

Regular oral manipulation of river cane would have introduced considerable levels of bacteriostatic compounds to the oral cavity.

Conclusions

The examination of dental caries and LEH frequencies at 40HA301 indicates a population with relatively low prevalence of both. Various possible explanations for low prevalence of caries and LEH emerge for this population. Low prevalence of these oral pathologic conditions may indicate the nature of habitual dietary items. That is, the frequencies of carious lesions observed here are comparable to populations that had not fully adopted maize agriculture. Likewise, frequencies of LEH observed at 40HA301 are similar to populations who participated in mixed economies including significant amounts of indigenous resources. Two novel interpretations for the low prevalence of caries and enamel defects observed here emerge from considering the wear data for the site and the findings of recent clinical studies. One of these possibilities is the manner of preparation of potentially cariogenic dietary staples. Unless complex carbohydrates are highly processed, they do not have the same cariogenic potential of LMW carbohydrates. Maize that is simply boiled in water does not gelatinize in the way that nixtamalized maize does. A final possibility explaining the low prevalence of caries and LEH here is the introduction of cariostatic materials into the oral cavity via the diet and nonalimentary tooth use. Recent clinical studies have demonstrated that the suppression of facultative pathogenic bacteria in the oral cavity has a profound effect on prevalence of oral diseases. The low prevalence of dental caries, combined with the unique nonalimentary wear pattern and low prevalence of LEHs at 40HA301 are most consistent with a mechanism of oral bacterial suppression.

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