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Dental Caries Evidence for Dietary Change: An Archaeological Context

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INTRODUCTION

The study of pattern of health and lifestyle from human dentition has been an important area of investigation throughout much of the history of dental anthropology. In this regard, the analysis of pathological processes in enamel, its underlying tissue, and the associated bone supporting the teeth has proved of immense value in understanding the relationship between diet and dental health (Huss-Ashmore et al., 1982; Goodman et al., 1984; Larsen, 1987a). It is the purpose of this chapter to present findings on diachronic change in the prevalence of dental caries in archaeological populations by way of study of a well documented series from the Southeastern United States, especially with relation to dietary reconstruction and behavioral inference.

CAUSES AND CONSEQUENCES

Contrary to what is presented in much of the anthropological literature, dental caries are not lesions arising from invasion of the crown or root surface by microorganisms. Rather, dental caries is a disease *process* characterized by the focal demineralization of dental hard tissues by organic acids produced by bacterial fermentation of dietary carbohydrates, especially sugars (Newbrun, 1982; Larsen, 1982, 1987a). Although the distinction between the lesions and the process leading to their appearance and development may seem minor, it is, nevertheless, an important one.

The factors involved in this disease are multiple and can be divided into two general groups: essential factors and modifying factors. Essential factors include (1) teeth that have surfaces exposed to the oral environment; (2) presence of aggregates of complex indigenous oral bacterial flora (e.g., *Streptococcus mutans, Lactobacillus acidophilus*), salivary glycoproteins, and inorganic salts that adhere to the tooth surfaces (dental plaque); and (3) diet. Modifying factors include those that affect primarily site distribution and speed of carious lesion development (Rowe, 1975). Observations on modifying factors in particular have resulted in a better understanding of the disease process. These factors include, but are not limited to, tooth crown morphology and size, developmental enamel defects, occlusal surface attrition, food texture, certain systemic diseases, age, heredity, salivary composition and flow, nutrition, periodontal disease, enamel elemental composition, and presence of fluoride and other local geochemical factors (see Rowe, 1975; Leverett, 1982; Milner, 1984; Schneider, 1986; Powell, 1985; Larsen, 1987a; Calcagno and Gibson, 1988; Hildebolt et al., 1988, 1989). The genesis of dental caries is very closely tied to a complex interaction of both essential and modifying factors, making it important that they be understood in documenting the etiology of the disease process.

The ultimate consequence of the disease is cavitation, and if left unchecked, pulpal disease. In extreme cases, the purulent infection from a carious tooth may extend into the cavernous sinus with death resulting (Haymaker, 1945). Although the frequency in human populations of the fatal consequences of this and other dental infections is unknown, it underscores the potential selective nature in human populations (see Chapter 5, *this volume*).

BRIEF HISTORY OF STUDY

The study of dental caries has a long history reflected as a copious literature documenting its prevalence in human populations. The first systematic study of human dentitions involving geographical and chronological control was by J.R. Mummery (1870). In an examination of more than 1,600 dentitions housed in various museum and private collections, Mummery was among the first to document a temporal trend for increase in frequency of carious lesions, particularly in recent, complex societies compared with earlier populations. Mummery related the increase in cariogenesis to an increase in demand on the human brain during the first seven years of life, a period of time that corresponds to the development of the dentition. Mummery "feared that a large amount of dental disease is originated by overtaxing the active brain of the child" (1870: 73). He concluded:

> May we not therefore reasonably suppose that through the diminished vitality consequent upon this diversion of the formative energy from the teeth, by premature mental exertion, these organs necessarily become degenerated; and that this circumstance constitutes one great difference between the teeth of the intellectual and those of the uncultivated families of man (1870: 73).

Since the time of Mummery, it has become clear that psychological factors probably play little if any role in cariogenesis. At least since the late nineteenth century, the research agenda has been largely dominated by dietary and other oral environmental factors in the interpretation of caries prevalence. In this regard, considerable research has been done on the effects of dietary change on teeth. Most importantly, various workers have documented a trend for an increase in dental decay with the introduction of carbohydrates in general and sugar in particular (e.g., sucrose) in both recent populations (e.g., Oranje et al., 1935–37; Price, 1936; Russell et al., 1961; Mayhall, 1970; Mellanby and Mellanby, 1951) and in extinct (archaeological) populations (e.g., Colyer, 1922; Leigh, 1925; Stewart, 1931; Goldstein, 1948; Brothwell, 1959; Hardwick, 1960; Brinch and Møller-Christiansen, 1949; Lunt, 1974; Moore and Corbett, 1971, 1973, 1975; Corbett and Moore, 1976; Buikstra, 1977; Turner, 1979; Manchester, 1983; Milner, 1984; Powell, 1985; and many others).

The anthropological community has been most concerned with the implications of diet in understanding the disease and identifying specific cariogenic foods. The remainder of this chapter addresses this research topic through the study of a time successive series of dentitions from archaeological mortuary sites on the Southeastern Atlantic coast of the United States. This region provides an excellent context for examining the role of diet and dental caries, because it is well documented by archaeological and ethnohistoric data and by other, independent, approaches to dietary reconstruction and population history.

ARCHAEOLOGICAL AND DIETARY CONTEXT

Human populations occupied the Southeastern U.S. Atlantic coastal zone for some 4,000 years prior to the arrival of Europeans in the sixteenth century (Thomas et al., 1978; Larsen, 1982; Milanich and Fairbanks, 1980). This area is part of the Georgia Bight, a large embayment that is dominated by a series of marsh and barrier islands extending from North Carolina to northern Florida (Fig. 1). Today, the estuarine and marine resources are reputed to be among some of the richest in the world; all available archaeological evidence indicates that native populations in the region relied heavily on these resources (Reitz, 1988). Additional evidence indicates that hunting of deer, smaller mammals, birds, and other animals, as well as collection of plants were important aspects of subsistence activities. Hunting, however, appears to have been secondary to use of marine resources for the acquisition of animal protein (e.g., fishes and invertebrates) (Reitz, 1982, 1988).

During the twelfth century AD, concomitant with the appearance of temple mounds and other evidence of greater social complexity (e.g., the Irene Mound site), there is an increase in number, size, and duration of habitation sites suggesting a population increase (Larsen, 1982, 1984). Despite the rather meager botanical evidence for the use of cultigens (see Larsen, 1982; Thomas, 1987; Reitz, 1988), horticulture appears not to have played as an important role in the Georgia Bight as in inland areas, and it is doubtful that cultigens replaced wild animal foods.

Although cultigens were used to a lesser extent on the coast than in inland areas, a number of changes seen in human skeletal remains in the region suggest that they were important in late prehistoric societies in the region. For example, there is an increase in nonspecific as well as specific infections (Larsen, 1981, 1982, 1984; Powell, 1987), reduction in frequency of osteoarthritis, and decline in skeletal robusticity and bone strength (Larsen, 1982, 1984; Ruff et al., 1984; Larsen and Ruff, n.d.).

The Spanish colonial efforts and the establishment of mission outposts in particular during the sixteenth

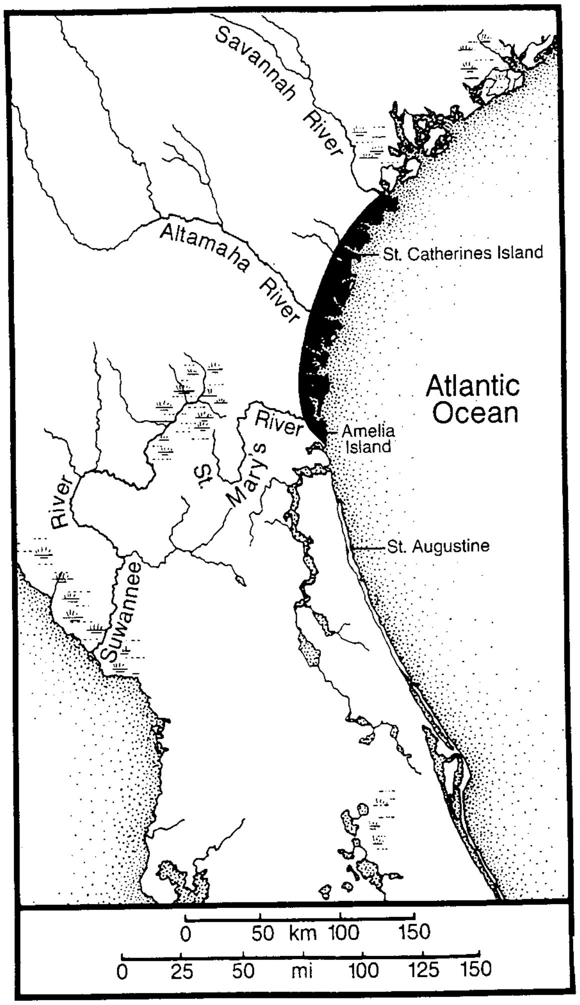

Fig. 1. Map of Georgia Bight showing study area (shaded).

and seventeenth centuries saw profound social, cultural, and biological changes for native populations, but the specific details are not well understood. Native populations were aggregated into centralized villages associated with mission centers (Hann, 1988). Given the function of some of the missions as crop-producing centers used to help feed the distant population of St. Augustine, the capitol of *La Florida,* one would suspect that there was an increase in emphasis on plant cultigens, especially maize. However, because of a number of problems—sampling, preservation, and other issues—the traditional archaeological sources of evidence for dietary reconstruction are not clear on this point.

Analysis of nitrogen and carbon isotopic composition by Schoeninger and co-workers (1990) has provided an independent source of data for interpreting dietary change in the precontact and contact period populations from the Georgia coast. They have found that marine resources are consumed throughout the prehistoric record and into the contact period. However, marine foods and nonmarine plants (and presumably the animals such as deer that ate these plants) are partly replaced with terrestrial foods, especially maize. This replacement occurs late in prehistory and is further magnified in the contact period. Below, we detail the impact of these dietary changes on the dentition, especially as it relates to changing caries patterns reflecting the cariogenic component of past diets.

MATERIALS AND METHODS

Human dentitions from different subsistence regimes and time periods were examined from a single culture group known as Guale (pronounced "wallie"). Before European contact, the Guale occupied the area that extends from the North Edisto River to the lower Satilla River in southern Georgia (Jones, 1978). In 1566, a series of Spanish missions were established in the region and, except for several native revolts, they remained occupied by both native populations and Spaniards until late in the seventeenth century (Thomas et al., 1978; Thomas, 1987). The principal northern Spanish outpost on the Atlantic coast—*Santa Catalina de Guale*—was abandoned in 1680 and subsequently reestablished on Sapelo Island to the south (Bushnell, 1986). Continued harassment by nonmissionized Indians, pirates, and British military forced yet another relocation to Amelia Island just south of the present Georgia-Florida border (Bushnell, 1986).

For purposes of this analysis, the dental sample representative of this succession of populations was divided into four subsamples, including precontact preagricultural (1000 BC–AD 1150; n = 201 individuals), precontact agricultural (AD 1150–1550; n = 275 individuals), early contact (AD 1607–1680; n = 324 individuals), and late contact (AD 1686–1702; n = 95 individuals) (Table 1). The precontact dentitions were recovered from a number of mortuary localities on the Georgia coast (Larsen, 1982); the early contact period is represented by dentitions from *Santa Catalina de Guale* on St. Catherines Island, Georgia (Larsen, 1987b); and the late contact period is represented by dentitions from the descendent population, *Santa Catalina de Guale de Santa Maria* on Amelia Island, Florida (Larsen and Saunders, 1987).

The study used 11,574 teeth from 895 individuals. For each tooth, all surfaces were observed macroscopically for carious lesions. These lesions ranged

TABLE 1. Dental Samples from Georgia and Florida Coasts

Subsample	Dates	Individuals[a] (n)	Teeth (n)
Precontact Preagricultural	1000 BC–AD 1150	201[b]	2438
Precontact Agricultural	AD 1150–1550	275[c]	4260
Early Contact	AD 1607–1680	324[d]	3274
Late Contact	AD 1686–1702	95[e]	1602

[a]Sites (number of individuals in parentheses):
[b]Evelyn Plantation (4), Airport (34), Deptford site (23), Walthour (1), Cannons Point (14), Cedar Grove Mounds (8), Sea Island Mound (21), Marys Mound (5), Johns Mound (46), Charlie King Mound (11), Cunningham Mound C (3), McLeod Mound (13), Seaside Mounds (18).
[c]Creighton Island Mound (1), Low Mound (1), Townsend Mound (2), Deptford Mound (2), Norman Mound (22), Kent Mound (21), Lewis Creek (14), Red Knoll (4), Oatland Mound (1), Seaside Mound II (2), Irene Mound (205).
[d]*Santa Catalina de Guale* (324).
[e]*Santa Catalina de Guale de Santa Maria* (95).

in size from small pits to total crown destruction. In extreme instances, crown destruction was accompanied by loss of part or most of the tooth root. In this discussion, we report only on the frequency in percentage of teeth affected for tooth types.

Dental caries is an age-progressive process. Thus, factors of diet aside, skeletal populations with relatively greater numbers of older individuals should contain more carious teeth. Therefore, it is important that control of age be undertaken in comparative studies. For the precontact and early contact periods, age at death was estimated on the basis of dental development for preadults (Ubelaker, 1984) and functional occlusal wear for adults (Miles, 1963). For the late contact series, greater preservation of dental and skeletal remains permitted the use of other standard age indicators. For the preadults, we used dental development for age estimation; for adults, in addition to functional occlusal wear, we employed cranial suture closure, and metamorphosis of the symphyseal face of the pubis and auricular surface of the ilium (Larsen et al., n.d.). Summary ages for adults were then calculated based on principal components weighting (cf. Lovejoy et al., 1985; Larsen et al., n.d.).

A number of workers have shown difference in caries prevalence between females and males (e.g., Burns, 1979; Kelley, 1985; Walker, 1986). Therefore, we report frequency in adults with sexes combined and females and males separately. Gender determination was made on the basis of observation of standard morphological characteristics—especially in the pelvis and the cranium—if key areas of anatomy were available for study (cf. Buikstra and Mielke,1985).

RESULTS

Examination of the results of this analysis indicate that there is a change in frequency of individuals affected by dental caries (Fig. 2, Table 2). This comparison includes those individuals with at least one carious tooth. In comparison of the precontact preagricultural and precontact agricultural dentitions, there is about a 50% increase for the total sample (made up of adult females, males, unsexed, and preadults), a 60% increase for females, a 52% increase for males, and a 48% increase for preadults.

In comparison of the precontact agricultural and early contact dentitions, with the exception of the male sample, there is an actual decline in percent of individuals affected. The total sample shows a 24% decline, the females an 18% decline, and the preadults a 26% decline. Males show a 12% increase. Comparison of early contact and late contact dentitions shows that there is a dramatic increase in frequency of individuals affected by dental caries: total sample, 47% increase; females, 36% increase; males, 24% increase; and preadults, 42% increase.

Because comparisons of individuals affected by dental caries does not take into consideration missing teeth, a more meaningful comparison is percent of teeth affected by dental caries for each tooth type (I1, I2, C···M3). Although each tooth type was analyzed separately, for purposes of this discussion, we have lumped all mandibular and maxillary incisors (I1 + I2), canines (C), premolars (P3 + P4), and molars (M1 + M2 + M3) into these four respective categories (Fig. 3). Data for individual tooth type comparisons are provided in Table 3. Figure 3 shows the comparisons of the two precontact and two contact

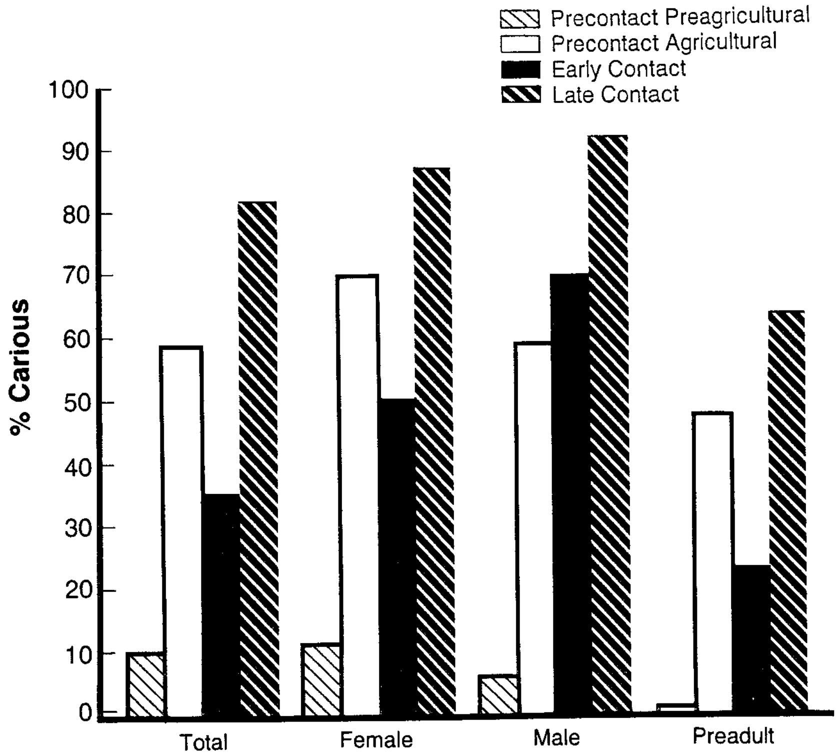

Fig. 2. Percentage of teeth affected by dental caries: total sample, female, male, preadult.

TABLE 2. Frequency of Individuals (%) Affected by Dental Caries[a,b]

	PP		PA		EC		LC		χ^{2d}
	n[c]	%	n	%	n	%	n	%	(p<0.05)
Total sample	201	9.0	275	58.9	324	34.8	95	82.1	PP/PA,PA/EC,EC/LC
Female	75	10.7	108	69.4	39	51.2	31	87.0	PP/PA,PA/EC,EC/LC
Male	49	6.1	80	58.7	27	70.3	35	94.2	PP/PA,EC/LC
Preadult	36	0.0	56	48.2	101	22.7	28	64.2	PP/PA,PA/EC,EC/LC

[a]Includes individuals with at least one carious lesion.
[b]PP, Precontact Preagricultural; PA, Precontact Agricultural; EC, Early Contact; LC, Late Contact.
[c]Number of individuals observed with at least one tooth present in the maxillary and mandibular dentitions combined.
[d]Comparisons showing statistically significant change.

period samples for all teeth. For the incisors, there is a small, but consistent, increase from the precontact preagricultural to the precontact agricultural to the early contact period. For the canines, premolars, and molars, the pattern revealed is an increase in the precontact agricultural group, a slight decline in the early contact period, followed by a dramatic increase in the late contact sample. Comparison of female teeth affected by dental caries shows a similar pattern: increase for the incisors from precontact preagricultural through the late contact period; and for the canines, premolars, and molars, an increase from precontact preagricultural to precontact agricultural, followed by a decrease in the early contact period, and an increase in the late contact period (Fig. 4, Table 4). A pattern of increase for the males is shown (Fig. 5, Table 5). Unlike the females, males show an increase in frequency of teeth affected by dental caries in the incisors, canines, and molars. Premolars are the only tooth category to show a decline in frequency. Moreover, although both sexes show an increase in frequency of carious lesions, with an espe-

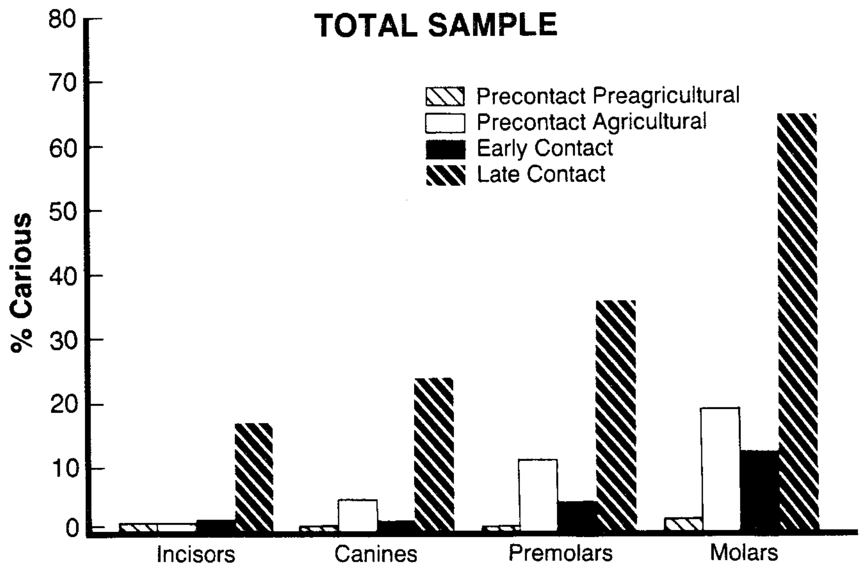

Fig. 3. Percentage of teeth affected by dental caries: total sample.

cially marked increase during the late contact period, the increase in males is not as dramatic as that shown in females.

Figure 6 illustrates the sex differences in frequency of teeth affected by dental caries for each of the four subsamples. With the exception of a few of the female/male tooth type comparisons, males are generally less affected by the disease process than are females. The most notable exception is early contact molars. By and large, however, there is a greater frequency of carious lesions for females in most of the comparisons.

Comparison of preadult teeth for each of the four periods is shown in Figure 7 and Table 6. With the exception of deciduous incisors, there is a gradual increase or no change in frequency of teeth affected by dental caries during the first three periods—precontact preagricultural to precontact agricultural to early contact. This is followed by a jump in frequency in the late contact period. The increases are not as marked as for those discussed previously, but the differences between frequency of preadult and adult teeth affected by dental caries reflects, of course, the fact that the preadult teeth were not exposed to caries promoting factors for as long as adult teeth.

DISCUSSION

Results of this study can be summarized as follows. First, there is an increase in frequency of individuals and teeth affected by the disease process in the precontact agricultural period relative to the precontact preagricultural period. Second, there is a slight decrease in cariogenic activity in the early contact sample in comparison with the late contact sample. Third, there is a dramatic increase in frequency of carious lesions in the late contact period. Fourth, males have fewer carious lesions than females.

Precontact Preagricultural–Agricultural Comparisons

The older the individual, the longer the time that tooth surfaces have been exposed to cariogenic factors. Therefore, older individuals should be more affected by the disease than younger individuals. In reference to archaeological series, some workers have shown a higher frequency of carious teeth in older age cohorts relative to younger age cohorts (e.g., Manchester, 1983). The increase in the precontact agricultural sample may, therefore, simply reflect an older skeletal series in the agricultural group compared with the preagricultural group. However, examination of age at death profiles (Fig. 9) shows that the agricultural group is younger than the preagricultural group; the former contains a greater proportion of younger adults than the latter. The difference is statistically significant (Kolmogorov-Smirnov: $p<0.05$). Therefore, it is unlikely that difference in age composition of the two samples can account for the increase in cariogenesis during later prehistory on the Georgia coast.

We believe that a more likely explanation for the

TABLE 3. Frequency (%) of Carious Teeth per Tooth Type: Total Sample[a]

	PP		PA		EC		LC		χ^{2c}
Tooth	n[b]	%	n	%	n	%	n	%	(p<0.05)
Maxilla									
I1	113	0.8	177	2.3	104	3.8	85	18.8	PA/EC,EC/LC
I2	95	0.0	178	2.8	126	1.5	85	20.0	EC/LC
C	126	0.0	244	8.3	170	1.1	92	23.9	PP/PA,PA/EC,EC/LC
P3	149	0.0	248	17.3	201	5.4	84	29.7	PP/PA,PA/EC,EC/LC
P4	149	0.0	255	11.6	201	4.9	88	38.6	PP/PA,PA/EC,EC/LC
M1	188	0.5	325	14.8	245	10.2	86	45.3	PP/PA,EC/LC
M2	193	1.0	306	12.5	234	11.1	65	66.1	PP/PA,EC/LC
M3	163	4.9	228	13.6	175	17.7	61	63.9	PP/PA,EC/LC
dI1	12	0.0	19	10.5	9	0.0	23	4.3	—
dI2	10	0.0	18	11.5	10	0.0	23	4.3	—
dC	18	0.0	28	0.0	21	0.0	30	13.3	EC/LC
dM1	26	0.0	47	19.1	25	20.0	37	24.3	PP/PA
dM2	20	0.0	49	8.2	53	7.5	25	32.0	EC/LC
Mandible									
I1	64	0.0	164	0.0	118	1.6	86	6.9	—
I2	84	0.0	197	1.5	128	0.7	97	20.6	EC/LC
C	126	0.0	233	2.6	199	1.5	99	24.2	EC/LC
P3	136	0.0	277	5.1	250	2.8	94	30.8	PP/PA,EC/LC
P4	151	0.0	257	10.9	232	3.4	82	46.3	PP/PA,PA/EC,EC/LC
M1	174	1.7	320	22.9	238	13.8	72	68.0	PP/PA,PA/EC,EC/LC
M2	174	3.5	280	24.5	228	15.7	57	80.7	PP/PA,PA/EC,EC/LC
M3	173	2.9	248	25.0	188	23.4	55	72.7	PP/PA,EC/LC
dI1	7	0.0	9	0.0	5	20.0	29	6.8	—
dI2	11	0.0	15	0.0	10	0.0	35	5.7	—
dC	19	0.0	26	0.0	21	0.0	36	2.7	—
dM1	28	0.0	56	5.4	37	0.0	43	27.9	EC/LC
dM2	29	0.0	56	5.4	46	15.2	33	33.3	—
Total	2,438	1.3	4,260	11.4	3,274	8.0	1,602	34.2	PP/PA,PA/EC,EC/LC

[a]PP, Precontact Preagricultural; PA, Precontact Agricultural; EC, Early Contact; LC, Late Contact.
[b]Number of teeth observed for presence or absence of carious lesions. Only teeth with known age at death are included. Teeth with unknown age at death are not included in the log-linear analysis.
[c]Comparisons that show statistically significant change.

increase in carious lesions is related primarily to the adoption and progressively increased focus on maize during the late prehistoric occupation of the Georgia Bight. It has been established by many others besides us that maize consumption resulted in an increase in dental caries prevalence in New World populations (see Milner, 1984; Larsen, 1987a). Maize contains a significant amount of sucrose (2–6%) and, should therefore, be considered a cariogenic food (cf. Hardinge et al., 1965; Coykendall, 1976). Moreover, because sucrose is a simple sugar, it is more readily metabolized by oral bacteria than other, more complex carbohydrates.

Milner (1984) has summarized published and unpublished data on dental caries prevalence among eastern North American native populations. In this summary, it was reported that predominantly prehistoric and historic populations (Late Woodland, Mississippian, Contact) had 4.5–43.4% carious teeth. By contrast, generally earlier populations practicing hunting/gathering subsistence strategies (Archaic, Early Woodland, Middle Woodland) had 0.4–7.8% carious teeth.

In order to increase the number of samples discussed by Milner (1984), we have examined additional reports discussing frequencies of carious teeth

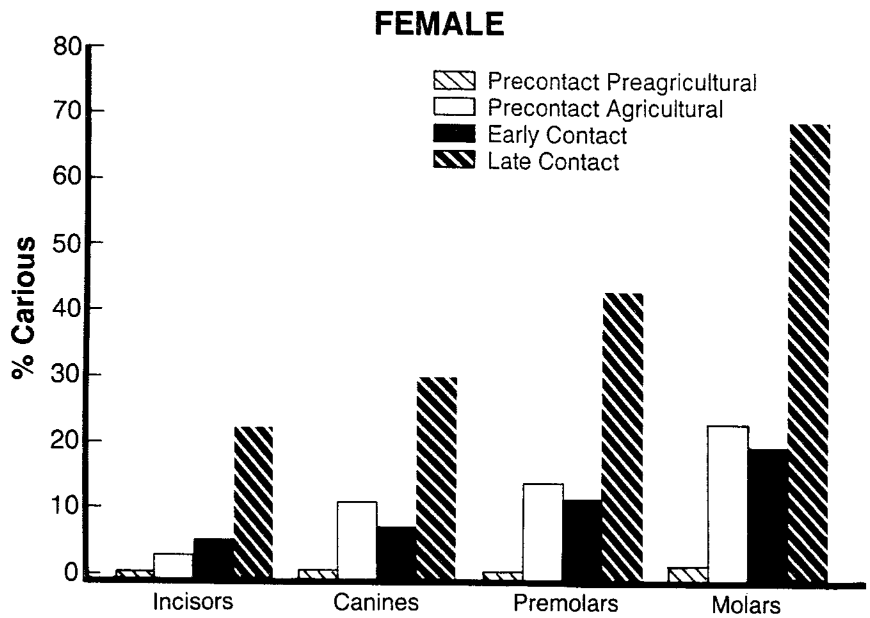

Fig. 4. Percentage of teeth affected by dental caries: female.

from eastern North American sites. Table 7 includes a list of 75 archaeological dental samples and percent carious teeth for each. A graphic representation of these data is shown in Figure 8. On the basis of these comparisons, the dichotomy in frequency of carious teeth between preagricultural (pre-Late Woodland) and agricultural (post-Middle Woodland) dentitions is straightforward. That is, only three post-Middle Woodland sites have less than seven percent carious teeth, and three pre-Late Woodland samples have >7% carious teeth. Our findings from the Georgia and Florida coasts, then, conform to the trend summarized here. That is, populations known to have included maize as a component of diet (late prehistoric and contact periods) have generally higher percentages of teeth (>7%) affected by dental caries than populations that did not (less than seven percent). This trend is apparent despite problems arising from interobserver recording variation and sample heterogeneity (see also Milner, 1984).

Precontact Agricultural–Early Contact Comparisons

Why the small decrease in frequency of carious lesions in the early contact period relative to the precontact agricultural period? Like the above, one explanation may be related to the age composition of the two subsamples used in the analysis. However, comparison of age at death in the two periods shows that the early contact sample is *older* than the precontact agricultural period. Thus, age of observed individuals does not explain the slight decrease in frequency of carious lesions in the early contact period.

A more important consideration relates to composition of the precontact agricultural sample. That is, most (75%) of the individuals in the agricultural precontact sample are from the Irene Mound site. The Irene Mound site is a Mississippian ceremonial/habitation center that may contain individuals ingesting relatively more maize than non-Irene Mound site individuals. The latter include individuals not associated with a Mississippian center but are roughly contemporaneous with the Irene Mound site.

By way of comparison, 60.1% of the Irene Mound site individuals were affected by dental caries, and 47.1% of non-Irene Mound site individuals were affected by dental caries. This difference is not statistically significant (chi-square: $p<0.5$). Comparison of these two samples by frequency of *teeth* affected by dental caries, however, indicates a statistically significant difference between Irene Mound site and non-Irene Mound site (chi-square: $p<0.005$). That is, 11.3% (366/3217) and 8.0% (84/1043) of the respective Irene Mound site and non-Irene Mound site teeth were carious. The difference in frequency of carious lesions between Irene Mound site and non-Irene Mound site samples might also be explained by different age compositions of the two subsamples if the Irene Mound site contains a greater number of

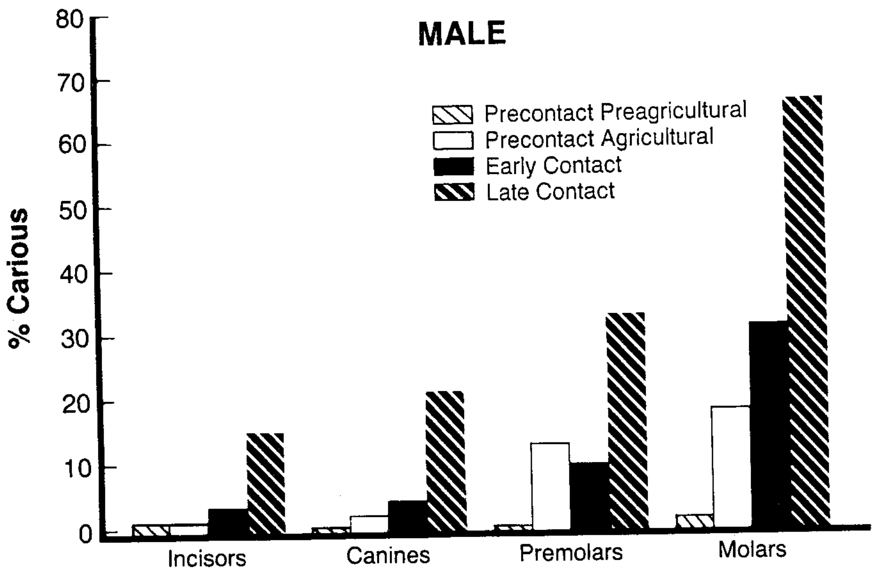

Fig. 5. Percentage of teeth affected by dental caries: male.

TABLE 4. Frequency (%) of Carious Teeth per Tooth Type: Female[a]

	PP		PA		EC		LC		χ^2[c]
Tooth	n[b]	%	n	%	n	%	n	%	(p<0.05)
Maxilla									
I1	48	0.0	82	3.7	23	8.6	35	31.4	EC/LC
I2	39	0.0	66	6.0	25	8.0	38	31.5	EC/LC
C	52	0.0	103	17.0	37	5.4	37	29.7	PP/PA,EC/LC
P3	61	0.0	100	21.0	40	17.5	29	34.4	PP/PA
P4	61	0.0	114	14.4	38	5.2	40	47.5	PP/PA,EC/LC
M1	73	0.0	144	16.7	43	20.9	33	51.5	PP/PA,EC/LC
M2	77	0.0	129	18.3	42	7.1	29	65.5	PP/PA,EC/LC
M3	73	0.0	109	17.4	32	12.5	24	79.1	PP/PA,EC/LC
Mandible									
I1	33	0.0	58	0.0	25	4.0	39	7.6	—
I2	42	0.0	84	2.4	27	0.0	44	20.4	EC/LC
C	60	0.0	98	5.1	41	7.3	44	29.5	EC/LC
P3	65	0.0	124	8.1	44	11.3	39	35.8	PP/PA,EC/LC
P4	76	0.0	135	13.9	37	10.8	33	51.5	PP/PA,EC/LC
M1	79	1.3	131	26.8	31	29.0	21	61.9	PP/PA,EC/LC
M2	86	1.2	131	31.5	35	20.0	19	84.2	PP/PA,PA/EC,EC/LC
M3	92	1.1	117	26.1	33	24.2	21	80.9	PP/PA,EC/LC
Total	1,017	1.2	1,725	15.2	553	12.3	525	41.9	PP/PA,EC/LC

[a]PP, Precontact Preagricultural; PA, Precontact Agricultural; EC, Early Contact; LC, Late Contact.
[b]Number of teeth observed for presence of absence of carious lesions.
[c]Comparisons that show statistically significant change.

older individuals than the non-Irene Mound sites. However, statistical comparison of the age profiles shows that the Irene Mound site sample is considerably *younger* than the non-Irene Mound site sample (Kolmogorov-Smirnov: $p<0.05$). Therefore, it is highly unlikely that the Irene Mound site sample is more carious than the non-Irene Mound site sample because of differences of age composition.

TABLE 5. Frequency (%) of Carious Teeth per Tooth Type: Male[a]

	PP		PA		EC		LC		χ^{2} [c]
Tooth	n[b]	%	n	%	n	%	n	%	(p<0.05)
Maxilla									
I1	37	2.1	63	0.0	21	4.7	39	12.8	PA/EC
I2	31	0.0	58	1.7	25	0.0	41	12.1	—
C	35	0.0	82	4.9	31	6.4	49	20.4	—
P3	39	0.0	88	27.6	32	12.5	50	26.0	PP/PA
P4	38	0.0	89	13.4	30	13.3	46	30.4	PP/PA
M1	46	0.0	94	18.5	33	21.1	33	42.4	PP/PA
M2	47	0.0	89	13.5	34	29.4	33	63.6	EC/LC
M3	40	0.0	81	16.1	36	30.5	35	57.1	PP/PA,EC/LC
Mandible									
I1	15	0.0	58	0.0	19	5.2	39	7.6	—
I2	24	0.0	70	1.4	21	4.7	44	25.0	EC/LC
C	42	0.0	85	0.0	26	0.0	49	22.4	EC/LC
P3	43	0.0	93	3.2	33	6.0	51	29.4	EC/LC
P4	41	0.0	92	8.0	33	3.0	44	45.4	EC/LC
M1	47	2.1	100	22.0	23	30.0	28	78.5	PP/PA,EC/LC
M2	47	2.1	85	12.9	27	37.0	31	90.3	PP/PA,EC/LC
M3	45	2.1	98	22.9	28	39.2	35	65.7	PP/PA,EC/LC
Total	617	0.6	1,325	10.9	452	15.9	647	36.3	PP/PA,PA/EC,EC/LC

[a]PP, Precontact Preagricultural; PA, Precontact Agricultural; EC, Early Contact; LC, Late Contact.
[b]Number of teeth observed for presence or absence of carious teeth.
[c]Comparisons that show statistically significant change.

Interestingly, in both the non-Irene Mound site dentitions and the early contact dentitions, 8.0% of teeth were affected by dental caries. These data suggest, then, that Irene Mound site individuals may have had a relatively greater component of maize in their diets than both the contemporary non-Irene Mound individuals as well as the later early contact period population. However, study of stable isotopic carbon and nitrogen compositions suggests that the early contact population from St. Catherines Island ingested more maize and less marine foods than the earlier Irene Mound population. Alternatively, it is possible that the early contact population had a higher rate of premortem tooth loss, therefore eliminating teeth from observation. Unfortunately, the generally poor preservation of maxillary and mandibular skeletal elements in the St. Catherines mission series prevents us from examining this issue in detail. It is quite possible that other, unknown factors might be responsible for the similarity in dental caries prevalence in the non-Irene Mound and Santa Catalina series.

Although there is a statistically significant reduction in frequency of dental carious lesions for all tooth types combined (I1 + I2 + ··· M3) in the early contact sample relative to the precontact agricultural sample (chi-square: $p<0.05$), comparisons for the individual tooth types shows that most of the differences in the individual tooth type comparisons are not statistically significant (see Table 3). Most of the differences shown in the precontact preagricultural/precontact agricultural and early contact/late contact comparisons are statistically significant, however (see Table 3). We conclude that the reduction in frequency of carious lesions from the precontact agricultural period to the early contact period is not of great importance. Rather, the more important change in frequency of carious lesions occurs prior to European contact with the adoption of maize as well as late in the contact period.

Early Contact–Late Contact Comparisons

Why the profound increase in carious lesions during the late contact period? Perhaps the increase merely reflects an older population in the late contact period than in the preceding periods. Indeed, com-

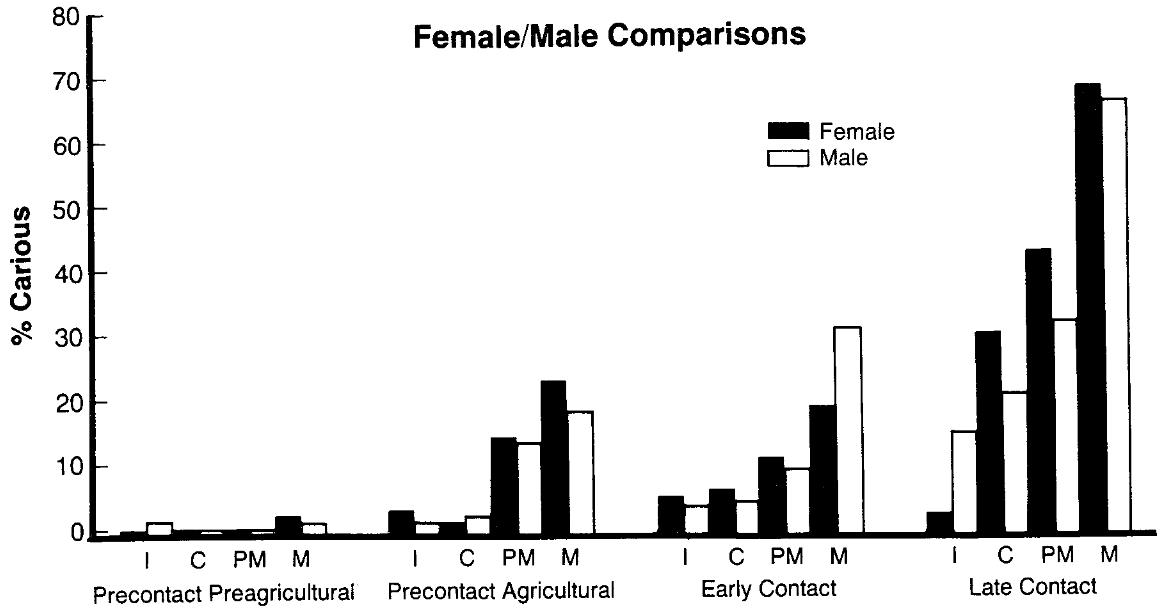

Fig. 6. Percentage of teeth affected by dental caries: female/male comparisons.

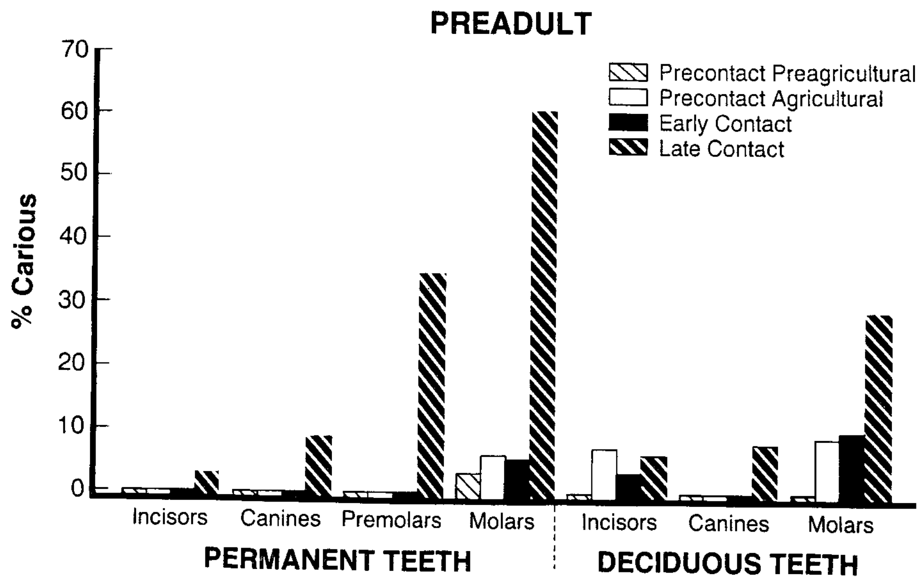

Fig. 7. Percentage of teeth affected by dental caries: preadult.

parison of mortality (age at death) profiles for the four periods shows a clear pattern of change from the precontact preagricultural to the late contact period (Fig. 9). Comparison of the late contact mortality curves shows a generally older population, with a greater number of individuals in the 35 years and older cohorts compared with the early contact curve. This difference is statistically significant (Kolmogorov-Smirnov: $p<0.01$). Given the presence of a greater number of older adults in the late contact period sample, one would expect a greater frequency of carious lesions relative to earlier time periods.

In order to test the hypothesis that the increase in caries experience is not a product of age composition of the subsamples, we have applied a hierarchical log-linear analysis to caries experience (presence/absence of carious lesions) and age at death (ages distributed in four 10-year age classes: 10–19.9, 20–29.9, 30–39.9, 40–49.9) for the four periods (precontact preagricultural, precontact agricultural,

TABLE 6. Frequency (%) of Carious Teeth per Tooth Type: Preadult[a]

Tooth	PP		PA		EC		LC		χ^{2c}
Maxilla	n[b]	%	n	%	n	%	n	%	($p<0.05$)
I1	13	0.0	38	0.0	31	0.0	9	0.0	—
I2	13	0.0	35	0.0	41	0.0	8	12.5	EC/LC
C	16	0.0	40	0.0	40	0.0	6	16.6	EC/LC
P3	18	0.0	45	0.0	39	0.0	5	20.0	EC/LC
P4	16	0.0	32	0.0	36	0.0	4	75.0	EC/LC
M1	30	0.0	70	2.9	75	8.0	19	52.6	EC/LC
M2	21	0.0	49	2.0	42	0.0	5	60.0	EC/LC
M3	14	0.0	29	0.0	8	0.0	0	0.0	—
dI1	13	0.0	19	10.5	9	0.0	22	4.5	—
dI2	10	0.0	18	11.1	10	0.0	23	4.3	—
dC	12	0.0	28	0.0	21	0.0	30	13.3	—
dM1	26	0.0	47	19.1	24	20.8	37	24.3	PA/EC
dM2	20	0.0	49	8.2	51	7.8	25	32.0	PA/EC,EC/LC
Mandible									
I1	11	0.0	28	0.0	39	0.0	12	0.0	—
I2	15	0.0	49	0.0	44	0.0	11	0.0	—
C	12	0.0	47	0.0	37	0.0	5	0.0	—
P3	19	0.0	51	0.0	47	0.0	7	0.0	—
P4	17	0.0	31	0.0	41	0.0	4	75.0	EC/LC
M1	33	0.0	71	12.7	81	1.2	23	65.2	PA/EC,EC/LC
M2	25	16.0	50	6.0	46	8.6	4	75.0	EC/LC
M3	10	0.0	18	5.6	21	4.7	0	0.0	—
dI1	7	0.0	9	0.0	7	14.2	29	6.8	—
dI2	11	0.0	15	0.0	10	0.0	35	5.7	—
dC	19	0.0	26	0.0	21	0.0	36	2.7	—
dM1	28	0.0	56	5.4	37	0.0	43	27.9	EC/LC
dM2	29	0.0	56	5.4	46	15.2	34	40.5	—
Total	458	0.9	1,006	3.9	904	4.3	436	20.8	PP/PA,EC/LC

[a]PP, Precontact Preagricultural; PA, Precontact Agricultural; EC, Early Contact; LC, Late Contact.
[b]Number of teeth observed for presence or absence of carious lesions.
[c]Comparisons that show statistically significant change.

early contact, late contact) following statistical procedures outlined by Everitt (1977). This analysis was applied to six teeth: maxillary and mandibular right first, second, and third molars. The distribution (period, age group, frequency) of carious teeth for each of these teeth is shown in Table 8.

For the simultaneous assessment of the interaction of the three variables (caries, age at death, and period) and their relative importance, hierarchical log-linear models were fit to cell frequencies (see Knoke and Burke, 1980). That is, the logarithm of the expected cell frequency is written as an *additive* function of main effects and interactions in a manner similar to analysis of variance models. The three-dimensional model is expressed in the following equation:

$$\log F_{ijk} = T + L_c + L_a + L_p + L_{ca} + L_{cp} + L_{ap} + L_{cap}$$

were F_{ijk} is the expected value of the observed cell frequency, T is the "grand mean," and L represents the main effects of caries (c), age (a), and period (p), the two dimensional interactions between the three variables, and the three-dimensional interaction, respectively. In such a hierarchical model, the presence of higher order effects (e.g., caries-age-period) implies the presence of all lower order effects involving the three variables (see Bishop et al., 1975; Fienberg, 1977). A test of a particular model involves the computation of the expected cell frequencies under that model and uses the likelihood ratio statistic G^2 as a

TABLE 7. Frequency of Carious Lesions (%) in Selected Eastern North American Archaeological Skeletal Series

Site(s)	Period/cultural affiliation	%[a]	Source[b]
Overhill Cherokee	Contact	14.5	1
Sauk	Contact	2.5	1
RI-1000	Contact	32.9	2
Silverheels	Contact	18.9	2
Ripley	Contact	14.6	2
Kleiss	Contact	27.9	12
Kleinburg	Contact	40.6	13
Carton	Contact	27.3	13
Christian Island	Contact	23.3	13
Maurice Ossuary	Contact	27.6	13
Milton	Contact	17.5	13
Orchid	Contact	30.3	13
Roebuck	Contact	25.0	13
Shaver Hill	Contact	28.1	13
Pine Harbor	Contact	8.9	14
Oakwood Mound	Mississippian	8.2	1
Hardin Village	Mississippian	32.1	1
Madisonville	Mississippian	34.7	1
Angel	Mississippian	10.3	1
Central Illinois River	Mississippian	7.8	1
Stone Quarry	Mississippian	21.0	1
Kane Mounds	Mississippian	28.3	1
Mississippi Valley	Mississippian	4.5	1
Lubbub	Mississippian	12.5	1
Moundville	Mississippian	8.6	1
Nodena	Mississippian	18.3	1
Powers Phase	Mississippian	11.5	1
Caddo	Mississippian	25.3	4
Turpin	Mississippian	24.8	6
Anderson Village	Mississippian	13.2	7
Various	Mississippian	7.8	10
Serpent Pits	Mississippian	10.8	13
Belcher Mound	Mississippian	10.7	1
Bentsen-Clark	Mississippian	14.1	1
Caddo sites	Mississippian	43.4	1
Sam Kaufman	Mississippian	16.2	1
Bunola	Late Woodland	31.2	1
Campbell	Late Woodland	17.7	1
Varner	Late Woodland	34.2	1
Menands Bridge	Late Woodland	22.0	2
McFayden Mound	Late Woodland	13.0	3
Scioto Trails	Late Woodland	2.2	7
Hatten Mound	Late Woodland	15.5	9
Libben	Late Woodland	22.4	11
Bennett	Late Woodland	30.2	13
Glenn Williams	Late Woodland	22.4	13
Miller	Late Woodland	26.4	13
McCutchen	Middle Woodland	7.5	1
Sam and Wann sites	Middle Woodland	7.8	1
Fourche Maline	Middle Woodland	0.1	5
Mound City	Middle Woodland	3.3	7

(continued)

TABLE 7. Frequency of Carious Lesions (%) in Selected Eastern North American Archaeological Skeletal Series (Continued)

Site(s)	Period/cultural affiliation	%[a]	Source[b]
Schultz Focus	Middle Woodland	7.2	8
LeVesconte Mound	Middle Woodland	6.5	13
Donaldson II	Middle Woodland	7.7	13
Serpent Mounds	Middle Woodland	2.6	13
Surma	Middle Woodland	7.4	13
Cowan Creek Mound	Early Woodland	6.2	1
Galbreath Mound	Early Woodland	3.0	1
McMurray Mounds	Early Woodland	3.4	1
Sidner Mounds	Early Woodland	2.0	1
Donaldson I	Early Woodland	0.0	13
Muzzey Lake	Archaic	6.9	1
Stratton-Wallace	Archaic	7.0	1
Williams Cemetery	Archaic	1.1	1
Williams Kame	Archaic	0.7	1
Hatten Mound	Archaic	3.4	1
Indian Knoll	Archaic	0.4	1
Indian Knoll	Archaic	3.7	1
Old Copper sites	Archaic	0.4	1
DuPont	Archaic	2.5	6
Davis	Archaic	2.4	7
Boose	Archaic	4.3	7
Kirian Treglia	Archaic	3.9	7
McKee	Archaic	4.8	7
Stech Shulte	Archaic	5.7	7

[a]% (number of carious teeth/total number of teeth) × 100.
[b]Sources: 1, Milner, 1984; 2, Kelley et al., 1987; 3, Wilson, 1986; 4, Powell, 1986; 5, Powell, 1985; 6, Perzigian et al., 1984; 7, Sciulli and Schneider, 1986; 8, Phenice, 1969; 9, Klepinger and Henning, 1976; 10, Andrews, 1934–35; 11, Fanno, 1968; 12, Gillings and Beck, 1967; 13, Patterson, 1984; 14, Larsen, unpublished data.

measure of fit. The data were analyzed using the BMDP program 4F (Dixon, 1985).

Table 9 presents the results of log-linear three-way interaction analysis for partial association of variables (caries, age at death, period). The chi-square values are for the three-way interaction only. None of the three-way interactions reaches statistical significance ($p<0.05$) indicating, therefore, that there is no significant three-way interaction between the three variables. It should be stressed that this analysis is not synonymous with the test for mutual independence by use of three-dimensional contingency tables (cf. Zar, 1984:72–74). The test for mutual independence tests the null hypothesis that there are no interactions (either three-way or two-way) among any of the variables. This stage of the application of log-linear analysis merely examines association in three-way interaction.

Having established that no significant three-way interaction is present, a saturated log-linear analysis was applied to the three variables (caries, period, age at death). All models with at least one two-way interaction were considered in addition to the model of complete independence. Table 10 gives the likelihood ratio chi-square values, degrees of freedom, and significance for each of the possible models starting with the model of complete independence. Variable C is the presence/absence of carious lesions, variable P is the period (precontact preagricultural, precontact agricultural, early contact, late contact), and variable A is the age at death (distributed into four 10-year age classes).

In log-linear analysis, the null hypothesis is analogous to a model as represented by a particular equation. In the analysis, the acceptance of a particular model is not simply determined by the significance of the test statistic computed for that model. Rather, one must also consider the difference between the models in a given hierarchy. Because a likelihood ratio statistic is also computed for each difference, it can be

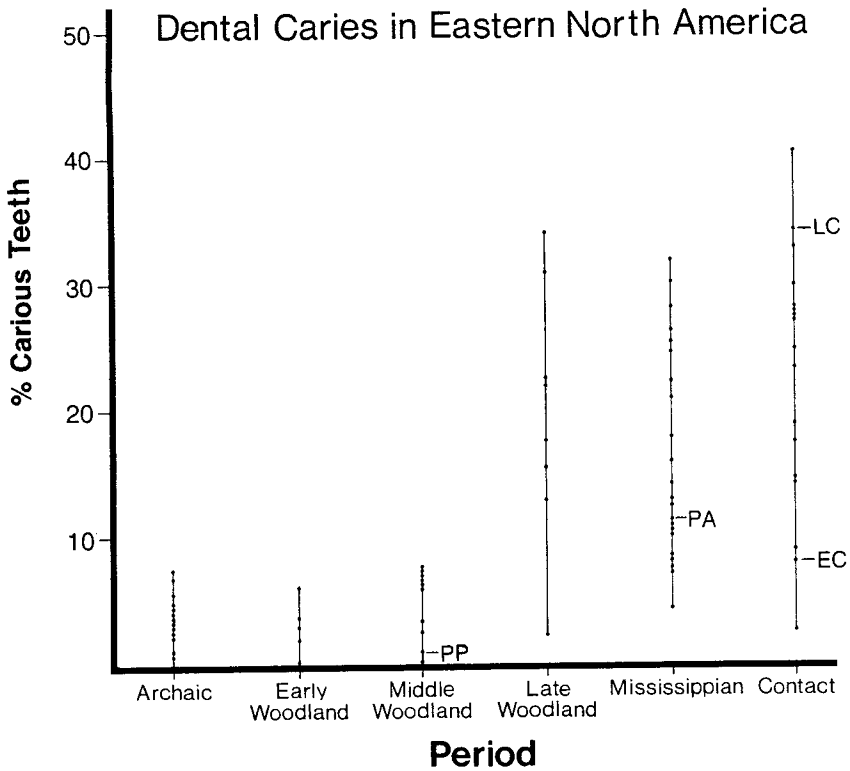

Fig. 8. Percentage of teeth affected by dental caries in selected eastern North American archaeological samples. (Each dot on the vertical bars represents an archaeological dental sample.)

determined if the addition of an interaction term significantly reduces the differences between the observed and the expected values.

It has been suggested that dental caries is an age dependent phenomenon. The samples from the four periods exhibit very different age compositions and frequencies of carious lesions. It has already been demonstrated that the increase in caries over the four periods is not likely related to an increase in age at death over time. To examine further the relationships between the variables, all two-way interactions were included in the hierarchical log-linear analysis and the differences between models compared.

Table 11 presents the results of the comparisons among models. For each of the six teeth observed, there is a significant interaction between period and age at death (difference between models a and b). There is also a significant interaction between period and caries (difference between models b and d). However, only two teeth (maxillary first and second molars), show a significant interaction between caries and age at death (difference between models b and c). Furthermore, only one tooth (maxillary first molar) shows a significantly better "fit" with the addition of an interaction between caries and age at death (difference between models d and e).

Because it is appropriate to choose the simplest model that adequately fits the observed data, model d offers a better choice for the maxillary second and third molars and the mandibular molars. Therefore, three two-way interactions (caries-age, age-period, caries-period) are required to fit a model to the data for the maxillary first molar, whereas only two two-way interactions (age-period, caries-period) are required for the maxillary second and third molars.

This pattern (adding the interaction of caries-age) may be explained by the difference in age of eruption for the permanent molars. Because the first molar erupts approximately six years earlier than the second molar and approximately 12 years earlier than the third molar, there should be a greater caries-age interaction in the first molar than in either the second or third molars. That is, the first molar is exposed to caries promoting factors for a longer period of time than the other two molars. In this study, the mandibular first molar does not seem to adhere to this hypothesis. In sum, although there is some age inter-

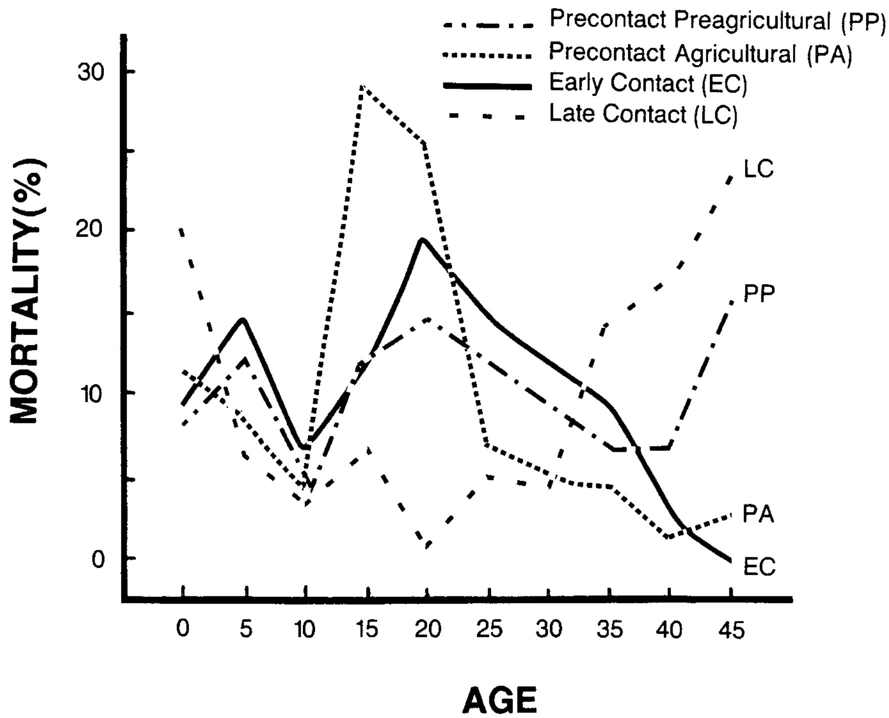

Fig. 9. Mortality comparisons in precontact preagricultural, precontact agricultural, early contact, and late contact groups.

action, increasing age at death for the four periods does not explain increase in cariogenic activity.

Female–Male Comparisons

Why the greater number of female teeth affected by dental caries than male teeth? Like the above comparisons, it is possible that age at death for females is generally greater than age at death for males. However, application of hierarchical log-linear analysis to each of the two subperiods showing higher prevalence of carious lesions in females than in males (precontact agricultural and late contact) indicates that the interaction between the three variables of caries, age, and sex is not significant (Table 12).

Although a review of the anthropological literature and clinical literature shows little consensus on causes of gender differences in dental health, including dental caries prevalence, two areas of interpretation for these differences is most often cited—physiological and behavioral. Walker (1986) summarized these interpretations and we draw from his discussion below.

With regard to physiological factors, it is known that female teeth erupt earlier than male teeth, therefore resulting in a relatively longer exposure to caries-promoting factors in them (Dunbar, 1969; DePaola et al., 1982). It has long been thought that pregnancy compromises dental health, and leads to an increase in periodontal disease and dental caries. Review of the dental literature, however, does not support this interpretation (e.g., Ziskin, 1926; Dunning, 1962; Toverud et al., 1952).

Various researchers have examined mineral composition of teeth of pregnant women. No evidence could be found for gender differences that might be responsible for differences in the caries experience (e.g., Deakins and Looby, 1943; Dragiff and Karshan, 1943). A number of workers have shown an increase in gingival inflammation during the latter part of pregnancy (cf. Loe and Silness, 1963; Loe, 1965; Arafat, 1974), but found no association between this condition and tooth loss. Maier and Orban (1949) showed no significant differences between pregnant and nonpregnant women in severity of gingival inflammation.

Thus, it seems unlikely that physiological differences could explain variation in frequency of dental carious lesions between females and males. If physiological differences between females and males did explain variation, it would be expected that a consistent pattern of cariogenic variation in all human populations would exist. Although many populations show a higher prevalence of dental caries in females than males (e.g., Hrdlička, 1916; Hooton, 1930;

TABLE 8. Frequency of Carious Teeth (%) by Age and Period for Each Tooth

		Age group							
		10–19.9		20–29.9		30–39.9		40–49.9	
Tooth	Period[a]	n[b]	%	n	%	n	%	n	%
Maxilla									
M1	PP	15	0.0	18	0.0	12	0.0	11	0.0
	PA	41	2.4	47	8.5	23	30.4	10	30.0
	EC	25	0.0	49	2.0	26	15.4	5	40.0
	LC	7	57.1	5	40.0	12	58.3	15	33.3
M2	PP	15	0.0	19	0.0	13	0.0	10	0.0
	PA	40	5.0	41	9.7	22	18.2	10	10.0
	EC	27	0.0	44	18.2	26	23.1	6	20.0
	LC	6	66.7	5	80.0	11	72.7	10	50.0
M3	PP	10	0.0	17	11.7	10	0.0	10	0.0
	PA	24	20.8	37	16.2	18	33.4	8	0.0
	EC	16	0.0	42	23.8	26	15.4	4	50.0
	LC	3	100.0	4	75.0	12	50.0	12	50.0
Mandible									
M1	PP	17	0.0	21	0.0	16	0.0	16	0.0
	PA	46	28.2	48	16.6	20	25.0	10	10.0
	EC	29	13.8	37	13.5	16	18.7	4	50.0
	LC	6	100.0	4	50.0	8	50.0	7	71.4
M2	PP	19	5.2	23	0.0	16	0.0	16	0.0
	PA	44	27.3	43	18.6	19	10.5	11	9.1
	EC	31	6.4	44	29.5	26	7.7	3	0.0
	LC	5	100.0	5	80.0	10	80.0	10	80.0
M3	PP	13	7.7	21	14.3	19	0.0	17	0.0
	PA	31	19.3	47	21.3	19	10.5	9	0.0
	EC	17	5.9	44	31.8	28	35.7	2	50.0
	LC	3	100.0	5	80.0	12	75.0	10	50.0

[a]PP, Precontact Preagricultural; PA, Precontact Agricultural; EC, Early Contact; LC, Late Contact.
[b]Number of teeth observed for presence or absence of carious lesions.

Newman and Snow, 1942; Swärdstedt, 1966; Behrend, 1978; Hillson, 1979; Burns, 1979; Turner, 1979; Kelley, 1985; Schmucker, 1985; Bennike, 1985; Walker, 1986; Formicola, 1986–1987; Rathbun, 1987; Kestle, 1988; see discussions in Larsen, 1983, 1987a; see also Chapter 11, *this volume*), there are a number of notable exceptions indicating that this is not a universal pattern (e.g., Barmes, 1962; Walker and Hewlett, 1990; Burns, 1979, 1982; Wells, 1980).

As we have established, the increase in frequency of carious lesions from the preagricultural precontact period to the late contact period reflects a dietary change. Because the increase is less marked in

TABLE 9. Three-Dimensional Log-Linear Analysis: Interaction for Caries, Age, and Period (Partial Association)

Tooth	D.F.	χ^2	p
Maxilla			
M1	12	14.07	0.2964
M2	12	6.99	0.8582
M3	12	15.25	0.2283
Mandible			
M1	12	7.98	0.7865
M2	12	9.39	0.6692
M3	12	11.03	0.5259

TABLE 10. Log-Linear Analysis for Caries, Period, and Age

Model	Interaction variables	Likelihood ratio χ^2 (G^2)	D.F.	p
Right maxillary M1				
(a)	{C} {P} {A}	112.81	31	0.0000
(b)	{C} {PA}	69.44	19	0.0000
	{P} {CA}	92.32	27	0.0000
	{A} {CP}	69.69	28	0.0000
	{CP} {CA}	49.21	24	0.0018
(c)	{CA} {PA}	48.95	15	0.0000
(d)	{CP} {PA}	26.33	16	0.0496
(e)	{CP} {CA} {PA}	14.07	12	0.2964
Right maxillary M2				
(a)	{C} {P} {A}	103.21	31	0.0000
(b)	{C} {PA}	71.30	19	0.0000
	{P} {CA}	89.98	27	0.0000
	{A} {CP}	48.00	28	0.0107
	{CP} {CA}	34.78	24	0.0717
(c)	{CA} {PA}	58.08	15	0.0000
(d)	{CP} {PA}	16.10	16	0.4462
(e)	{CP} {CA} {PA}	6.99	12	0.8582
Right maxillary M3				
(a)	{C} {P} {A}	79.19	31	0.0000
(b)	{C} {PA}	44.22	19	0.0009
	{P} {CA}	76.90	27	0.0000
	{A} {CP}	51.83	28	0.0040
	{CP} {CA}	49.54	24	0.0016
(c)	{CA} {PA}	41.93	15	0.0002
(d)	{CP} {PA}	16.86	16	0.3948
(e)	{CP} {CA} {PA}	15.25	12	0.2283
Right mandibular M1				
(a)	{C} {P} {A}	106.89	31	0.0000
(b)	{C} {PA}	70.92	19	0.0000
	{P} {CA}	103.14	27	0.0000
	{A} {CP}	46.76	28	0.0145
	{CP} {CA}	43.00	24	0.0099
(c)	{CA} {PA}	67.17	15	0.0000
(d)	{CP} {CA}	10.79	16	0.8224
(e)	{CP} {CA} {PA}	7.98	12	0.7865
Right mandibular M2				
(a)	{C} {P} {A}	139.93	31	0.0000
(b)	{C} {PA}	93.63	19	0.0000
	{P} {CA}	136.40	27	0.0000
	{A} {CP}	62.15	28	0.0002
	{CP} {CA}	58.61	24	0.0001
(c)	{CA} {PA}	90.10	15	0.0000
(d)	{CP} {PA}	15.85	16	0.4636
(e)	{CP} {CA} {PA}	9.39	12	0.6692

(continued)

TABLE 10. Log-Linear Analysis for Caries, Period, and Age (Continued)

Model	Interaction variables	Likelihood ratio χ^2 (G^2)	D.F.	p
Right mandibular M3				
(a)	{C} {P} {A}	104.34	31	0.0000
(b)	{C} {PA}	60.54	19	0.0000
	{P} {CA}	101.42	27	0.0000
	{A} {CP}	59.47	28	0.0005
	{CP} {CA}	56.54	24	0.0002
(c)	{CA} {PA}	57.61	15	0.0000
(d)	{CA} {PA}	15.66	16	0.4768
(e)	{CP} {CA} {PA}	11.03	12	0.5259

TABLE 11. Differences Among Log-Linear Models

Difference between models	Likelihood ratio χ^2 (G^2)	D.F.	p
Right maxillary M1			
(a) and (b)	43.37	12	<0.001
(b) and (c)	20.49	4	<0.001
(b) and (d)	43.11	3	<0.001
(d) and (e)	12.26	4	<0.025
Right maxillary M2			
(a) and (b)	31.91	12	<0.010
(b) and (c)	13.22	4	<0.025
(b) and (d)	55.20	3	<0.010
(d) and (e)	9.11	4	n.s.
Right maxillary M3			
(a) and (b)	34.97	12	<0.001
(b) and (c)	2.29	4	n.s.
(b) and (d)	27.36	3	<0.001
(d) and (e)	1.61	4	n.s.
Right mandibular M1			
(a) and (b)	35.97	12	<0.001
(b) and (c)	3.75	4	n.s.
(b) and (d)	60.13	3	<0.001
(d) and (e)	2.81	4	n.s.
Right mandibular M2			
(a) and (b)	46.30	12	<0.001
(b) and (c)	3.53	4	n.s.
(b) and (d)	77.78	3	<0.001
(d) and (e)	6.46	4	n.s.
Right mandibular M3			
(a) and (b)	43.80	12	<0.001
(b) and (c)	2.93	4	n.s.
(b) and (d)	44.88	3	<0.001
(d) and (e)	4.63	4	n.s.

males, we suggest that males were ingesting a relatively smaller proportion of maize than were their female counterparts. These findings are consistent, we believe, with the sexual division of labor reported for most Southeastern U.S. native populations. Hudson (1976) and others (see Swanton, 1942, 1946;

TABLE 12. Three-Dimensional Log-Linear Analysis: Interaction for Caries, Age, and Sex (Partial Association)

Period	Tooth	D.F.	χ^2	p
Precontact Agricultural	Maxilla			
	M1	4	3.13	0.5360
	M2	4	1.36	0.8517
	M3	4	2.95	0.5668
	Mandible			
	M1	4	0.15	0.9972
	M2	4	0.78	0.9410
	M3	4	1.73	0.7852
Late Contact	Maxilla			
	M1	4	1.91	0.7520
	M2	4	2.77	0.5975
	M3	4	4.46	0.3476
	Mandible			
	M1	4	1.39	0.8467
	M2	4	6.71	0.1521
	M3	4	4.87	0.3014

Van Doren, 1928) described a strict sexual division of labor for most activities. Among other activities, females were responsible for most plant gathering, planting and care of crops, and food preparation. By contrast, males were responsible for hunting. A case could be argued for a greater consumption of maize in that component of the population that is responsible for its care and preparation for food. That is, because females care for crops and prepare food, they would have relatively greater exposure to cariogenesis than males. This interpretation is consistent with ethnographic accounts whereby individuals involved in hunting (males) receive a relatively greater proportion of meat than do those individuals not involved in hunting (females) (cf. McArthur, 1960; Lee, 1968; Woodburn, 1968; Meehan, 1977; Hayden, 1979, 1981).

Another behavioral factor is difference in pattern and frequency of eating between females and males. In experimental laboratory animals and in humans, individuals ingesting cariogenic foods frequently have a higher frequency of carious lesions than individuals who restrict eating to a few times daily (Gustafsson et al., 1954; Weiss and Trithart, 1960; Konig et al., 1969; Konig, 1970; Nizel, 1973; Rowe, 1975). Because females are primarily responsible for food preparation in virtually all societies, they have greater access to caries-promoting foods than do males, who are not generally responsible for this activity. This factor may explain in part the differences in caries rates between females and males reported by us and by other workers.

CONCLUSIONS

Analysis of prevalence of dental caries shows a general increase through time in the Georgia Bight. The increase in frequency of carious lesions first occurs in the last few centuries prior to European contact, probably as a result of the introduction and intensification of maize agriculture in the region. Although analysis of isotopic data reveals a further increase in consumption of maize during the early contact period, there is a slight decline in frequency of carious lesions. However, the late contact period is marked by a dramatic increase in the disease. Most likely, this phenomenon reflects yet a further increase in focus on plant carbohydrates, namely maize. These data strongly suggest, then, a reorientation of native subsistence prior to and after the establishment of mission centers by Europeans. The dietary reorientation was especially dramatic during the Spanish mission period. This change in dietary focus appears to have had a relatively greater impact on dental health in females than in males in these populations.

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Advances in Dental Anthropology

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