Diet and Dental Caries in Post-Medieval London

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Abstract This paper explores the dentition of individuals excavated from two post-medieval London cemeteries. Individuals from Chelsea Old Church, a middle-class group, and St. Bride's lower churchyard, a working-class group, were selected and studied. The relative dental status of each group was explored by determining the prevalence of individuals and teeth affected by dental caries. The overall dental status of both class groups was found to be poor; diet was the most likely causative factor. Access to cariogenic foods such as sugar and refined flour likely affected individuals' dental status regardless of their social class.

Keywords Bioarchaeology · Diet · Status · Dental caries · Antemortem tooth loss

Introduction

The study of skeletons from archaeological sites, or bioarchaeology, provides an opportunity to explore human health and disease in the past using direct evidence (e.g., Buikstra 1977, 1991; Larsen 1997; Zuckerman and Armelagos 2011). The field focuses on excavated human remains from funerary contexts such as cemeteries and crypts ranging in date from prehistory to the early modern period. In recent years in England there has been an increase in excavations of post-medieval contexts in advance of modern infrastructure development, particularly in London (National Planning Policy Framework 2012). Studies of post-medieval cemeteries are advantaged with contemporary cultural and historical data that provide a context in which to interpret the biological data.

The socioeconomic division between rich and poor and how this divide may affect individuals' wellbeing is a concern for bioarchaeologists and contemporary researchers alike. Rapid urbanization in the United Kingdom is putting extreme pressure on

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infrastructure and health services, causing further stratification of society (Hills et al. 2010). The World Health Organization's European Healthy Cities Network (WHO 2010) discusses equity in health and inclusiveness in cities, citing the connection between urban poverty and ill health. Current research suggests that poverty and inequality have independent and considerable effects on the relationship between health and national income (Biggs et al. 2010). Wilkinson and Pickett (2009) have explored how increasing inequality worldwide is negatively affecting peoples' mental and physical health. Sir Michael Marmot, past president of the British Medical Association, states "[that] despite living in one of the richest and most developed countries in the world, many individuals in the UK have a poor start in life simply because they are born on the wrong side of the tracks" (British Medical Association 2010). Modern clinical studies indicate that individuals of a lower social status tend to have poorer oral health, and note the differences in oral health between city and rural dwellers (e.g., Källestål and Wall 2002; Locker 2000).

This paper explores the link between social classes and dental status in eighteenth- to early nineteenth-century London, England, and specifically a comparison of dental status between two post-medieval London groups: Chelsea Old Church, a middle-class group, and St. Bride's lower churchyard, representing a working-, or lower-class, group (Fig. 1). To place this research in context, it is necessary first to consider eighteenth-century London as a location that could have imposed health risks on its population. London in the eighteenth century experienced an extreme period of industrial revolution and urbanization. The city had a population of about 585,000 individuals by the end of the seventeenth century (Razzell 2007; Wrigley and Schofield 1981). Over the period dubbed the "long eighteenth century" (ca. 1675–1825) London contained approximately 10 % of England's total population and its population grew at a rate consistent with the rest of the country (Landers 1990, 1991). Relative levels of health could be affected by an individual's social standing. The social makeup of London circa 1780 saw the top 1 % of metropolitan households holding 21 % of the wealth, and the top 20 % of households holding just over 75 % of the total wealth (Sheppard 1998). The "middling sort," or middle class, made up 20–30 % of London's population and were paid, on average, between £60 and £200 per annum (Sheppard 1998). The working class, or "inferior sort," felt the discrepancy in wealth most acutely; they made up nearly 75 % of London's population and yet were paid, on average, less than £60 per annum (Sheppard 1998). The working class were, on the whole, not banished to exclusively working-class districts, but were instead crammed into slum tenements. The poor became an increasing problem throughout the eighteenth century; in 1722 parishes were first permitted to build workhouses. Though they were meant to put the able-bodied to work, many workhouses devolved into cheap lodging for the enfeebled (Porter 2000).

Overcrowding of slum tenements due to rapid urbanization without adequate public sanitation and a lack of consistent water supply and sewage disposal were constant pressures upon health (Haines 2004; Porter 2000; Sheppard 1998). As late as the 1840s there were still more than 30,000 people with no access to fresh water either from pipes or communal street taps (Wohl 1983). Levels of sanitation were poor in households and workplaces due to overcrowding; most sewage was dumped unceremoniously in the River Thames (Harvey 1968). In general, living conditions in cities and towns were worse than in rural areas (Williams and Galley 1995). Life in the countryside was

Fig. 1 John Rocque's map, "Plan of the Cities of London and Westminster and Borough of Southwark, with the Contiguous Buildings: 1749." St. Bride's lower churchyard is marked with a *black arrow*. Chelsea Old Church is located just off the bottom left hand corner of the plan. Note the highly concentrated streets of central London versus the open fields and gardens of the outer areas (courtesy Museum of London)

perceived to be healthier. Rural conditions were not inherently good, but, as Friedrich Engels stated in his study of the English working classes: "dirty habits…do no great harm in the countryside where the population is scattered. On the other hand, the dangerous situation which develops when such habits are practised among the crowded population of big cities, must arouse feelings of apprehension and disgust" (quoted in Wohl 1983, p. 4).

Diet was a great divider of the classes in eighteenth- and early nineteenth-century London. Staples of any Londoner's diet were bread, potatoes, and tea, while foodstuffs such as eggs, milk, meat, fruit, and vegetables were imported to the city (Drummond and Wilbraham 1957). The industrial revolution was accompanied by agricultural improvements such as on-farm grain processing (Pelizzon 2000), a change that saw the advent of purer refined flour. This change spurred the rise in popularity of fine white breads for people of all classes, while rye and barley breads fell from favor (Pelizzon 2000). Braudel (1981, p. 137) refers to the "revolution in white bread" occurring after 1750 with members of the lower class replacing rye breads with white bread despite the higher cost. The rapid commercialization of the food trade meant that quantity was being emphasized over quality, and there was a marked deterioration in the quality of many foodstuffs, particularly those available to the poor. Not only were many of the foods of lesser quality, but what was available was often expensive. Meats in London cost significantly more than in the countryside, meaning most working-class families ate little to no meat. Further, those who managed to access meat often ran out of fuel to cook it properly (Drummond and Wilbraham 1957). Working-class diets were usually heavy in carbohydrates and fats, but low in protein and deficient in vitamins (Wohl 1983). The diet of the working class generally consisted of bread, butter, cheese, beer, and tea, with the intermittent addition of potatoes, cabbage, and carrots. Workhouse diets were similar, comprising bread, cheese, beer, and a little meat. Middle- and high-class families were more likely to supplement their diets with luxuries such as

chocolate, sweets, eggs, and cream, which meant they ingested a diet higher in calories and nutrients (Drummond and Wilbraham 1957).

Nutrition as a single factor may not have utmost significance, but in combination with the realities of working-class life—damp houses and overcrowded workplaces, cold, heavy labor, and poor sanitation—it had a great effect on health. Infants were the first to be affected negatively by diet; breast-fed babies were often victims of harmful weaning practices, such as feeding weanlings a mixture known as pobs—bread, water, sugar, treacle, and milk—or flour and donkey's milk (Fildes 1986; Lanphear 1990; Lewis 2007). In the nineteenth century, the British Association undertook a study of 53,000 children attending industrial and public schools, and determined that 11- and 12-year-old boys from industrial schools stood nearly five inches shorter than their better-fed counterparts (Wohl 1983). Contemporary descriptions provide a shocking picture of the working-class and poor citizens of London (e.g., Eden 1797; Maitland 1756; Scott 1773), leaving modern observers to conclude that there were two different Englands, one for the rich and another for the poor.

From a contextual point of view, there is ample evidence to indicate that people of different statuses lived different lives in London. This study focuses on dental caries prevalence in lower- and middle-class individuals to investigate whether class differences had a quantifiable effect upon individuals' dentition.

Sites of Study

The research was conducted on 168 individuals excavated by the Museum of London Archaeological Services in the late twentieth century. Seventy-eight individuals were from Chelsea Old Church, a middle-class site. Chelsea Old Church is located within the parish of Chelsea, an area which, in the eighteenth century, was known as one of the "five villages beyond the Bills," or beyond the 109 London parishes covered by the Bills of Mortality, the other four being Hammersmith, Paddington, Marylebone, and St. Pancras (Porter 2000, p. 98). These parishes were ruled by their local governments rather than the localized London government and were generally inhabited by individuals and families seeking the benefits of living close to London while maintaining a more rural lifestyle. In 1724 Daniel Defoe described the Chelsea parish as "a village of palaces" (quoted in Russet and Pocock 2004, p. 80). The Chelsea Old Church churchyard is one of eight recorded burial grounds in the parish. Chelsea Old Church itself dates from 1157; the original building was constructed in the thirteenth century, with seventeenth-century additions (Russet and Pocock 2004). Most individuals excavated from this cemetery were buried in wooden coffins laid in earth-cut stacked graves; however, nine lead coffins were also found in addition to two burial vaults and two brick-lined graves (Cowie et al. 2008). Coffin plates for 20 individuals were discovered, comfortably dating the Chelsea churchyard for use between 1712 and 1842 (Cowie et al. 2008).

The other individuals under analysis were from St. Bride's lower churchyard, located within the parish of St. Bride's, London on Farringdon Street. The lower churchyard is one of three burial locations in the parish; the other two, the main churchyard and church crypt, are associated with St. Bride's Church, Fleet Street. Parish records show that in 1800 the population of the parish was 7078 individuals

while the total number of occupied houses was 830 (Miles 2010). The registrar of St. Bride's noted that between 15 and 20, and sometimes 30 people were living in one house (Miles 2010). Parish burial grounds generally charged different rates depending upon the burial location in the cemetery; St. Bride's had no such differentiation and therefore it was the poorer members of the parish, lodgers, inhabitants of the Bridewell workhouse, and individuals from the Fleet prison that were laid to rest in St. Bride's (Kausmally 2008). Fleet prison was mainly inhabited by debtors, and a total of 41 former prisoners were buried in the lower churchyard (Miles 2010). Most individuals in this excavation were buried in wooden coffins, mainly elm, stacked up to eight deep in the open yard, while 47 were found in a brick vault. The cemetery was likely created due to overcrowding in the St. Bride's Church crypt and churchyard, and it was dated for use approximately between 1770 and 1849 (Miles and Conheeney 2005).

Human Skeletal Analysis

Chelsea Old Church and St. Bride's lower churchyard were selected for analysis. Originally two hundred individuals were selected, one hundred from each collection, subdivided further into 50 male and 50 female individuals in an effort to compare both sex and class. The individuals were chosen from the Wellcome Osteological Research Database (WORD) according to the numerical codes they had been assigned; the first 50 adult females and first 50 adult males were selected to be part of the study sample. Of the 200 individuals studied, 168 had dentition (78 from Chelsea and 90 from St. Bride's) present and formed the final study sample, for a total of 2466 teeth present (1172 Chelsea, 1294 St. Bride's). The other 32 individuals were excluded because no maxillae or mandible were present for observation. All dental data presented in this study are drawn from the authors' observations of the teeth.

The two skeletal collections examined are curated by the Museum of London Centre for Human Bioarchaeology and recorded in the WORD according to the standards outlined by Connell and Rauxloh (2003). When the individuals were originally analyzed (Cowie et al. 2008; Kausmally 2008), biological sex was determined using general cranial and pelvic morphology (see Connell and Rauxloh 2003). Researchers utilized standard anthropological techniques for estimating age, including assessing changes in tooth wear (Brothwell 1981), the pubic symphyses (Brooks and Suchey 1990), the auricular surface (Buckberry and Chamberlain 2002; Lovejoy et al. 1985), and the sternal rib ends (İşcan et al. 1984, 1985). Only individuals assigned a sex of definite male or definite female in the database were considered for this research and only if they had reached adulthood, or the age of at least 18 according to their database entry, according to the osteological methods referenced above, in order to study the possible differences between sexes in rates of dental caries.

Dental Caries: Causes and Bioarchaeological Studies

Dental caries is an infectious condition causing local demineralization and destruction of dental enamel, dentine, and cement. Oral bacteria adhere to tooth surfaces and feed upon nutrients in saliva and gingival crevice fluid. A variety of bacteria inhabit the oral

cavity, though the *Streptococcus mutans* group and *Lactobacillus acidophilus* are known to be most cariogenic, particularly when coupled with a high-sugar diet (Hillson 1996, 2001, 2005). The oral cavity supplies many locales for bacterial colonization; where bacteria can build up, it is known as dental plaque. Plaque bacteria ferment dietary carbohydrates, producing organic acids that demineralize the dental enamel. Progressive demineralization may manifest itself as slight enamel opacity to massive cavitations, ultimately causing loss of dental crowns or roots, known as antemortem tooth loss (Larsen 1997; Nikiforouk 1985). Dental caries is crucial to bioarchaeological interpretations because it is one of the most common pathological lesions found in archaeological human remains (Lanfranco and Eggers 2010).

A number of diachronic studies have been completed on British dental material to investigate patterns of dental caries. Overall, these studies have found an increase in rates of dental caries through time and a change in carious lesion locations from the cementoenamel junction (area where the crown enamel and cementum-covered root of the tooth meet), to an increase in lesions at interproximal contact areas (where two adjoining teeth meet) and occlusal fissures (the biting surfaces of the teeth) (Brothwell 1959; Hardwick 1960; Hillson 2005). Studies of Romano-British material (e.g., Moore and Corbett 1971; Whittaker et al. 1981) show low rates of dental caries, with molars more commonly affected than the anterior teeth. Medieval British material has been studied in some detail. Authors generally discovered that the cementoenamel junction was the most common site for carious lesions and that there was some movement toward lesions at the interproximal surfaces (e.g., Kerr et al. 1988; Lunt 1986; Moore and Corbett 1973; Olsson and Sagne 1976; Tattersall 1968). These findings are similar to those from medieval Croatia (Marin et al. 2005).

Fewer studies have been completed on more recent material, but Moore and Corbett's (1975) investigation of seventeenth-century remains found an overall higher prevalence of dental caries than previous periods and a significant change of carious lesion locations to the interproximal areas and occlusal fissures. These patterns continue into the nineteenth century (Corbett and Moore 1976); more lesions were found in anterior teeth and the overall prevalence of dental caries is higher. Results from the lower-class Cross Bones cemetery in London show widespread dental caries in the sample group, with a high frequency of carious lesions appearing in the occlusal fissures of molars (Brickley et al. 1999). Dental data from the middle-class Christ Church Spitalfields research show more interproximal than buccal or lingual surfaces affected by dental caries (Whittaker 1993). Overall, studies of British material have found molars to be the most commonly affected tooth group, while canines and incisors are the least affected.

Research Recording Methods

Teeth were recorded as Present (P), Root only (R), lost Antemortem (AM), or lost Postmortem (PM). Teeth were recorded as present if they could be successfully identified and assigned a side. A tooth was designated 'root only' if the entire crown was lost, either due to a carious lesion or to extreme dental wear. Tooth loss was classified as antemortem (before death) or postmortem (after death). A tooth was recorded as lost antemortem if the alveolus (tooth socket) was partially or completely closed or remodeled. To distinguish antemortem tooth loss from congenital absences, a

number of factors were taken into consideration, including space available for the missing tooth, presence or absence of wear facets on adjacent teeth, and wear on the opposing teeth (Freeth 2000). Teeth were determined to have been lost postmortem if there was an empty alveolar socket with no evidence of healing. The prevalence of antemortem tooth loss and postmortem tooth loss was calculated based upon the total number of preserved tooth sockets.

Caries were assessed macroscopically under bright light using a 10× magnifying glass. A tooth was identified as carious if there was a clear destruction of the external surface of the enamel or cementum (Fig. 2). Discolouration of the enamel, such as brown spots, was not considered as evidence of a carious lesion unless there was cavitation below the discolouration. The total number of carious lesions was recorded, as well as their location on the tooth (occlusal, mesial, distal, lingual, and buccal) following the descriptions of locations outlined by Moore and Corbett (1971). Lesions were recorded as 'gross' if most or all of the crown surface was destroyed and the site of origin could not be determined. The lesions were photographed using a Canon PowerShot SD1100 Digital ELPH. The prevalence of carious teeth was calculated as the total number of teeth from each tooth group with at least one carious lesion divided by the total number of teeth in each tooth group (true prevalence rate or TPR) and by individuals affected who had teeth preserved to observe (crude prevalence rate or CPR). It is crucial to note that tooth wear may obscure or interact with carious lesions (e.g., Maat and Van der Velde 1987; Meiklejohn et al. 1992); therefore, this research necessarily reports a minimal estimation of overall caries prevalence.

Results

The research sample consisted of the skeletal remains of 168 individuals, 78 from Chelsea Old Church with a total of 1294 teeth, and 90 from St. Bride's lower

Fig. 2 Maxillae of individual from Chelsea Old Church (OCU00 20) with antemortem tooth loss and dental caries (photo by Madeleine Mant)

churchyard with a total of 1172 teeth. Table 1 displays the number of teeth analyzed and the prevalence of antemortem and postmortem tooth loss in the samples. Two sample t-tests revealed that there was no statistically significant difference between any of the analyzed groups in terms of antemortem or postmortem tooth loss. The true prevalence of antemortem tooth loss (Fig. 3) in the study was 41.0 %; the true prevalence of postmortem tooth loss was low, at 8.3 %. Incisors were most frequently lost postmortem while molars had the highest rate of preservation.

Table 2 shows the crude and true prevalence rates for caries, corrected caries prevalence, and the mean caries per individual. When the caries correction factor is applied to control for antemortem tooth loss caused by caries, following the methods outlined by Lukacs (1992, 1995), females of both groups have a higher true prevalence of caries than the males. Despite these differences, however, two sample t-tests for significant difference were carried out and revealed that none of the groups showed significant differences when it came to dental caries.

Table 3 displays the prevalence of carious lesions in the analyzed samples as broken down by tooth group. The combined St. Bride's results had a range of caries frequency rates by tooth group from canines at 17.1 % affected to molars at 37.8 %. The Chelsea individuals ranged from 8.6 % of incisors affected to 39.0 % of molars affected by caries. In all four sample groups, the molars have the highest prevalence of teeth affected by caries, ranging from 35.7 % of molars affected (St. Bride's males) to 40.4 % (St. Bride's females). The molar results were significantly different in all four groups (the St. Bride's males and Chelsea females at $P<0.001$ and the St. Bride's females and Chelsea males at $P<0.05$). There was a statistically significant difference ($P<0.05$) between the two sites when comparing the incisors – the St. Bride's sample had a higher level of carious incisors than the Chelsea individuals. No other comparison by tooth type between the sample groups was statistically significant.

Table 4 displays the frequency of carious lesions with respect to the tooth surface on which the carious lesion was observed. The gross caries and root caries data were not included in the determination of carious lesion prevalence according to location on the crown, the results of which appear in Table 5. There was a significant difference between interproximal (mesial and distal) and buccal/lingual surfaces; in all four

Table 1 Summary of individuals, teeth, and tooth sockets observed

Group	Individuals	Teeth present	Total sockets	AM loss n(%)[a]	PM loss n(%)
St. Bride's M[b]	45	697	1287	484 (37.6)	106 (8.2)
St. Bride's F[c]	45	597	1346	608 (45.2)	142 (10.5)
Group total	90	1294	2633	1092 (41.5)	248 (9.4)
Chelsea M	40	585	1144	498 (43.5)	61 (5.3)
Chelsea F	38	587	1071	392 (36.6)	92 (8.6)
Group total	78	1172	2215	890 (40.2)	153 (6.9)
Grand total	168	2466	4848	1982 (41.0)	401 (8.3)

[a] Number affected (percentage affected)

[b] Males

[c] Females

Fig. 3 Mandible of individual from St. Bride's lower churchyard (FAO90 1422) with antemortem tooth loss (photo by Madeleine Mant)

sample groups there was a statistically significant higher prevalence of interproximal caries than buccal/lingual caries ($P<0.001$). There was a significantly higher prevalence of interproximal caries than occlusal caries in the St. Bride's males ($P<0.001$).

Table 6 displays the prevalence of carious lesions compared between the maxillary and mandibular teeth. There was a statistically significant higher prevalence of maxillary incisor caries in both St. Bride's ($P<0.001$) and Chelsea ($P<0.05$). In the Chelsea sample there was also a statistically significant higher prevalence of caries ($P<0.05$) in the maxillary canines, maxillary premolars, and mandibular molars.

Discussion

In this dental analysis there were no significant differences in the rates of caries in individuals separated by sex or social status. The Chelsea Old Church skeletal sample had a 79.5 % prevalence rate of individuals affected by caries with 21.5 % prevalence

Table 2 True and crude prevalence rates for dental caries

Group	Observed tooth count	Corrected[a]	Individual count	Mean caries
	(carious/total)=%	(carious/total)=%	(carious/total)=%	per individual[a]
St. Bride's M[b]	175/697=25.1	545/1181=46.1	37/45=82.2	3.89
St. Bride's F[c]	168/597=28.1	776/1204=64.5	34/45=75.6	3.73
Group total	343/1294=26.5	1300/2385=54.5	71/90=78.9	3.81
Chelsea M	128/585=21.9	460/1083=42.5	30/40=75.0	3.20
Chelsea F	124/587=21.1	462/979=47.2	32/38=84.2	3.26
Group total	252/1172=21.5	928/2062=45.0	62/78=79.5	3.23

[a] Following Lukacs (1992, 1995)

[b] Males

[c] Females

Table 3 Dental caries by tooth group affected (TPR)

	St. Bride's M[a]	St. Bride's F[b]	Total	Chelsea M	Chelsea F	Total
Incisors						
Present	191	153	344	159	166	325
Caries n(%)	41 (21.5)	30 (19.6)	71 (20.6)[c]	14 (8.8)	14 (8.4)	28 (8.6)
Canines						
Present	111	106	217	101	96	197
Caries n(%)	17 (15.3)	20 (18.9)	37 (17.1)	10 (9.9)	13 (13.5)	23 (11.7)
Premolars						
Present	185	166	351	151	163	314
Caries n(%)	42 (22.7)	49 (29.5)	91 (25.9)	38 (25.2)	32 (19.6)	70 (22.3)
Molars						
Present	210	171	381	174	162	336
Caries n(%)	75 (35.7)[c]	69 (40.4)[d]	144 (37.8)	66 (37.9)[d]	65 (40.1)[c]	131 (39.0)

[a] Males

[b] Females

[c] Statistically significant ($P<0.001$)

[d] Statistically significant ($P<0.05$)

amongst the teeth studied. The St. Bride's sample displayed a prevalence of 78.9 % of individuals affected with 26.5 % of all teeth affected by caries. The results demonstrate that the prevalence of caries was high for the analyzed individuals, regardless of their social status. These data are similar to results reported for contemporary sites in London and other sites in England (Roberts and Cox 2003). For example, Chelsea Old Church and Cross Bones burial ground (Brickley et al. 2006), a lower-class London site, both have a crude prevalence of 79.5 % affected by caries. In contrast, the true prevalence rates of teeth affected show that St. Bride's lower, a working-class sample, has a rate of

Table 4 Tooth surfaces affected by dental caries

	St. Bride's M[a]	St. Bride's F[b]	Chelsea M	Chelsea F
Occlusal n(%)[c]	19 (9.6)	20 (10.6)	20 (13.9)	25 (18.5)
Mesial n(%)	36 (18.2)	31 (16.4)	21 (14.6)	28 (20.7)
Distal n(%)	39 (19.7)	40 (21.2)	32 (22.2)	28 (20.7)
Buccal n(%)	16 (8.1)	8 (4.2)	19 (13.2)	19 (14.1)
Lingual n(%)	7 (3.5)	5 (2.6)	1 (0.7)	5 (3.7)
Gross n(%)	32 (16.2)	36 (19.0)	24 (16.7)	25 (18.5)
Root n(%)	49 (24.7)	49 (25.9)	27 (18.8)	5 (3.7)
Total	198	189	144	135

[a] Males

[b] Females

[c] Number of surfaces affected (percentage of total surfaces affected)

Table 5 Caries prevalence by location on tooth crown

	St. Bride's M[a]	St. Bride's F[b]	Chelsea M	Chelsea F
Occlusal				
Surfaces	674	574	566	569
Caries n(%)[c]	19 (2.8)	20 (3.5)	20 (3.5)	25 (4.4)
Interproximal[d]				
Surfaces	1348	1148	1132	1138
Caries n(%)	75 (5.6)[fg]	61 (5.3)[f]	53 (4.7)[f]	56 (4.9)[f]
B+L[e]				
Surfaces	1348	1148	1132	1138
Caries n(%)	23 (1.7)	13 (1.1)	20 (1.8)	24 (2.1)

[a] Males

[b] Females

[c] Number affected (percentage of total affected)

[d] combined mesial and distal surfaces

[e] combined buccal and lingual surfaces

[f] statistically significant ($P<0.001$), interproximal and B+L

[g] statistically significant ($P<0.001$), interproximal and occlusal

26.5 %, while St. Nicholas' Church (Boyle et al. 1998), a middle-class site from Sevenoaks, UK, has a rate of 14.1 %. These data suggest that both working- and

Table 6 Caries prevalence by maxillae and mandible

	St. Bride's max[a]	St. Bride's man[b]	Chelsea max	chelsea man
Molars				
Present	181	200	164	172
Caries n(%)[c]	61 (33.7)	83 (41.5)	53 (32.3)	78 (45.3)[e]
Premolars				
Present	135	216	131	183
Caries n(%)	34 (25.2)	57 (26.4)	40 (30.5)[e]	30 (16.4)
Canines				
Present	93	124	84	113
Caries n(%)	17 (18.3)	20 (16.1)	15 (17.9)[e]	8 (7.1)
Incisors				
Present	140	204	142	183
Caries n(%)	46 (32.9)[d]	25 (12.3)	25 (17.6)[e]	3 (1.6)

[a] Maxilla

[b] Mandible

[c] Number affected (percentage of total affected)

[d] Statistically significant ($P<0.001$)

[e] Statistically significant ($P<0.05$)

middle-class post-medieval people were eating a cariogenic diet and not maintaining effective oral hygiene. The relationship of social status with dental caries is not clearly defined. When the elite individuals in a group are consuming more animal protein and fewer carbohydrates, the non-elites, who consume more carbohydrates, tend to have higher prevalences of dental caries (Frayer 1984). Similar results were found in Belize (White 1994), where higher-class individuals had significantly lower caries rates than the lower classes, likely indicating greater access to animal proteins rather than a diet based upon maize. In contrast, Cucina and Tiesler (2003) noted that among the Classic Maya, people of higher social status likely had easier access to cariogenic foods. Further, in Swärdstedt (1966) work on medieval Swedish remains, the low-, middle-, and upper-class individuals showed no significant difference in dental caries rates, implying that individuals were eating a similar diet regardless of social rank. These varied results demonstrate the importance of considering cultural and historical context when studying human remains.

Much of the bioarchaeological literature reports that females tend to have higher rates of caries than males. Research internationally and through time have yielded similar results (e.g. Danforth et al. 1997; Larsen 1983; Lukacs 1992, 1996), including eighteenth-century individuals from Christ Church Spitalfields, London (Whittaker and Molleson 1996). Lukacs and Largaespada (2006) investigated the sex differences in caries rates and posited that the dissimilar rates are caused by interactions of earlier dental eruption in females, changes in female sex hormones, biochemical composition and flow of saliva, pregnancy compromising the immune system, and food cravings and aversions during pregnancy. This approach challenges the previous anthropological method of interpreting sex differences in dental caries purely through behavioral variation and the sexual division of labor (e.g., Cohen and Bennett 1993; Walker and Hewlitt 1990). In contrast, Corbett and Moore (1976) work on post-medieval British remains revealed that males and females tended to have similar rates of caries and Saunders et al. (1997) did not find a relationship between sex and overall caries rates. These findings suggest that whether or not there is an inherent physiological difference that predisposes females to developing caries (as has been argued by Lukacs 2008), factors such as diet must be at work to increase a male's chances of developing caries. Wohl (1983) explains that, during the post-medieval period, the male heads of households were usually fed the largest share of food; therefore, increased consumption of cariogenic foods may explain the similar caries prevalence rates amongst the sexes found in the current research.

The caries data are typical of the post-medieval period. More caries were found in interproximal areas than in buccal or lingual locations. Past research has found an increase in dental caries in interproximal areas through time (e.g., Brothwell 1959; Corbett and Moore 1976; Hardwick 1960). In addition, molars had significantly more dental caries than any other tooth group, and both datasets demonstrated more root caries in the posterior (premolars and molars) region of the dentition. Hillson (1996) states that molars, followed by premolars, are most commonly affected by caries – likely due to molars' large coronal surface area, deep occlusal fissures, and posterior location that may reduce oral hygiene. The maxillary incisors of both groups had a statistically significant higher prevalence of caries than the mandibular incisors. Hillson (2005) notes that the maxillary incisors are more commonly affected by caries than the lower incisors, but warns that the low preservation rate of incisors in many archaeological sites may explain the difference.

The interpretation of caries prevalence rates and patterns observed is enhanced and supported by a similarly high prevalence of antemortem tooth loss in both datasets. The Chelsea data show a CPR of 87.2 % of individuals affected, and a TPR of 40.2 % of teeth affected. Similarly, the St. Bride's CPR was 92.2 % and TPR was 41.5 %. Statistical tests revealed no significant differences between any of the groups, separated by sex or social status. Although some studies have found females tend to have higher rates of antemortem tooth loss (Frayer 1988; Lukacs 1992), these studies also found females to have significantly higher rates of dental caries, a finding not replicated in this investigation. These data, when compared to contemporary London and English sites (Roberts and Cox 2003), are shown to be typical findings. Tooth loss may occur for many reasons, including periodontal disease and continuing eruption (Freeth 2000; Glass 1991). In addition, gross dental caries may cause tooth loss.

The high prevalence of antemortem tooth loss found in both datasets may partially be explained by poor oral hygiene amongst both classes, and the tendency to remove carious teeth rather than choosing the more expensive option of fillings. In addition, all individuals studied were adults and past studies have found an increase in alveolar bone loss and resulting antemortem tooth loss in older age categories (Costa 1982; Kerr 1990; Swärdstedt 1966). Individuals with plaque deposits on their teeth may experience gingivitis, or the inflammation of the oral soft tissues, which may lead to periodontitis, or the irritation of underlying bone. Indeed, Hillson (2005) notes that periodontitis leading to alveolar bone loss is an age-progressive condition and is found in the majority of adults in late middle age today.

Oral Hygiene and Dentistry

Oral hygiene and dentistry developed throughout the eighteenth and nineteenth centuries, but were still, by modern standards, inadequate for encouraging and maintaining oral health. There was no dental school to train dentists in England until 1858 (Whittaker 1993) and therefore, during the seventeenth and eighteenth centuries, dentistry was commonly practiced by barbers and blacksmiths (Harvey 1968). Certain advances were made during the eighteenth century, including the dismissing of the tooth-worm theory of caries causation by Pierre Fauchard, and the increasing creation of dental prostheses (Roberts and Cox 2003). Unfortunately, existing oral hygiene practices generally did little to improve an individual's oral health. Toothbrushes, tooth picks, tooth pastes, powders, and mouth washes were all available during the eighteenth century (Weinberger 1948), although toothbrushes were not commonly used and the pastes often included caustic ingredients that whitened teeth, but ultimately destroyed the enamel (Roberts and Cox 2003). A common dental procedure, then, was tooth extraction for carious teeth. Tools such as forceps, pelicans, elevators, and tooth keys were used for such practices, while fillings—made from gold, lead, pitch, wax, silver, or mercury—were usually reserved for the rich (Roberts and Cox 2003; Weinberger 1948).

Carbohydrates and Dental Caries

The use of sugar throughout the eighteenth century is a key factor in the development of caries, and its increase in use is directly linked to the increase in tea drinking

throughout Britain. Though sugar had been imported into England in small quantities since the twelfth century (Whittaker and Molleson 1996), the industrial revolution in England was characterized by an increase in the consumption of sugar and refined carbohydrates. Tea imports from the East Indies and China had become cheaper toward the end of the seventeenth century and this trade opened up considerably during the eighteenth century. In 1760, at least 5 million lbs (2,268mT) of tea was imported, and by 1800 at least 20 million lbs (9,071mT) was being imported annually (Drummond and Wilbraham 1957). As tea drinking increased, so did sugar consumption. The English colonies of Barbados and the Leeward Isles (Caribbean Sea) were the first to develop a sugar industry, and by 1753 there were 120 sugar bakeries in England and Scotland, 80 of those in London itself (Harvey 1968). Deerr (1950) estimates the sugar consumption in kilograms per person per year had increased from 1.8 kg in 1700 to 3.6 kg in 1750, reaching 8.2 kg per person by 1800. In Britain, sugar consumption per person had reached 6.7 kg/annum by 1792 (Palubeckaite et al. 2006), indicative of growing rates of sugar consumption throughout the eighteenth century (Mitchell and Deane 1962). Later, the British doubled their consumption of sugar during the nineteenth century (Deerr 1950), consuming mostly cane sugar imported from the Caribbean Sea. This dramatic increase can be explained by the lifting of tariffs on sugar in the early nineteenth century; incremental reductions began in 1845 until tariffs were entirely removed in 1875 (Moore 1993). This sugar was not only being purchased by the middle and upper classes for use in tea, sweets, and pies, but the lower classes were spending a large proportion of their annual income on sugar. Sir Frederick Eden, in his study of the English poor in 1797, reported that it was not uncommon for a working class family making only £40 a year to be spending £2 of that purely on tea and sugar (quoted in Drummond and Wilbraham 1957).

The more refined milling techniques for flour that were being introduced also increased the popularity of fine white breads over the darker rye and barley varieties. The refined carbohydrates found in these white breads are more cariogenic than the more basic carbohydrates found in rougher grain breads (Corbett and Moore 1976; Moore 1993). Refined flour served to soften English diets, causing less tooth wear, and allowing plaque to accumulate (Hillson 1996). Moore (1993) supports this argument, stating that the combined effects of increased imports of cane sugar into Britain, beginning in the seventeenth century, and the purer refined flour produced by improved milling technology contributed to the rising prevalence of dental caries. Small-molecule carbohydrates contribute to a softer, increasingly cariogenic diet. Many researchers posit that an increased dependence upon carbohydrates and the introduction of refined sugars have increased the rates of caries diachronically for many human groups (e.g., Burt 1993; Hardwick 1960; Mayhall 1970; Miura et al. 1997; Moore 1993; Oranje et al. 1935–37; Palubeckaite et al. 2006; Price 1936; Russell et al. 1961; Saunders et al. 1997; Whittaker and Molleson 1996).

Limitations of the Study and Future Directions

A cemetery population is clearly not the same as a living population and must not be assumed to be a homogenous cohort (Grauer and McNamara 1995). Cemeteries are cumulative samples that comprise deaths over a period of time. The individuals buried

in Chelsea Old Church and St. Bride's lower churchyard were not necessarily born and raised in London. Robust population growth in London was caused by the migration of individuals from across the British Isles and Europe from the seventeenth to nineteenth centuries (Finlay and Shearer 1986; Landers 1993). Therefore, some observed ante-mortem tooth loss and dental caries may have been affected by individuals' diets while living in other locations.

Cariogenicity is multifactorial in aetiology. Other factors that may affect cariogenicity include fluoridation; fluoride can protect the dental enamel from devel-oping cavities. In most locations in England natural fluoride levels in drinking water are too low to positively prevent caries (BFS 2012). Further research, following the example of Woodward and Walker (1994), must be completed to determine to what extent fluoride may have been affecting the levels of dental caries in the past. Myriad factors may influence the incidence and speed of development of dental caries, including occlusal surface wear (e.g., Maat and Van der Velde 1987; Meiklejohn et al. 1992), age (Hunt et al. 1992), salivary composition and flow (Lukacs 2008), and geochemical factors (e.g., Hildebolt et al. 1988).

Further studies of the dentition of individuals living during the long eighteenth century focusing on factors such as dental wear, the accumulation of calculus, and periodontal disease will provide a fuller picture of oral health. Incorporating the study of juvenile individuals into future research will allow for comparison with other contemporary London sites where juveniles were studied, such as Christ Church Spitalfields (Whittaker 1993) and Kingston-upon-Thames (Start and Kirk 1998), middle-class sites found in central and southwest London respectively. Further research concerning the Chelsea Old Church and St. Bride's lower churchyard collections should endeavour to include young, middle, and older adults to investigate the effect of age distribution in skeletal samples on reported dental caries prevalence.

Conclusions

The similarities in caries rates between the Chelsea and St. Bride's datasets indicate that individuals from both classes were likely consuming similar cariogenic diets, but whether sugar was found in expensive imported fruits, sweetmeats, tarts, or simply accompanying tea cannot be established purely by examining dentition. The similarity in bread ingestion likely contributed to the lack of significant differences in caries rates between the two groups. Placing the dental caries results into their historical context is nevertheless crucial for understanding the lack of class differentiation in dental status. It is clear that dental caries are not a sufficiently sensitive indicator of social class and must be considered within a suite of biological, palaeopathological, and historical factors in bioarchaeological research.

Individuals living in cities are presented with a unique set of challenges. There is evidence to suggest that poverty breeds ill health, but this investigation has demon-strated that wealthier individuals are not always healthier. This research sought to understand if class differences in post-medieval London were reflected in individuals' dental status and the generated results show a mixed picture. A percentage of both the lower- and middle-class groups buried in the sites examined, and both sexes in each group, were affected by dental caries and antemortem tooth loss. The two status groups

were not separated by significant differences in the prevalence of antemortem tooth loss or the prevalence of carious lesions. The working- and middle-class groups studied are both a product of their time, subject to the stresses and conditions of growing up and living in the eighteenth century. The working class of St. Bride's lower churchyard and the middle class interred at Chelsea Old Church were at risk from cariogenic diets and poor oral hygiene. This bioarchaeological study demonstrates that urban life provides risks and challenges for individuals regardless of their social class.

References

Biggs, B., King, L., Basu, S., and Stuckler, D. (2010). Is wealthier always healthier? the impact of national income level, inequality, and poverty on public health in Latin America. *Social Science & Medicine* 71: 266–273.

Boyle, A. and Keevil, G. (with a contribution by Cox, M., Kneller, P. and Haslam, R.) (1998). "To the praise of the dead, and anatomie": the analysis of post-medieval burials at St. Nicholas, Sevenoaks, Kent. In Cox, M. (ed.), *Grave Concerns: Death and Burial in England 1700–1850*, Council for British Archaeology, York, pp. 85–99.

Braudel, F. (1981). *Civilization and Capitalism, 15th to 18th Century, Volume I: The Structures of Everyday Life*, Harper and Row, New York.

Brickley, M., Buteux, S., Adams, J., and Cherrington, R. (1999). *The Cross Bones Burial Ground, Redcross Way, Southwark, London. Archaeological excavations (1991–1998) for the London Underground Limited Jubilee Line Extension Project*, Museum of London, London.

Brickley, M., Buteux, S., Adams, J., and Cherrington, R. (2006). *St. Martin's Uncovered: Investigations in the churchyard of St. Martin's-in-the-Bull Ring, Birmingham, 2001*, Oxbow, Oxford.

BFS (British Fluoridation Society). (2012). One in a million: the facts about water fluoridation. 3rd ed. http://www.bfsweb.org/onemillion/04%20One%20in%20a%20Million%20-%20The%20Dental%20Benefits%20of%20Water%20Fluoridation.pdf.

British Medical Association. (2010). New President For The BMA: Sir Michael Marmot. Medical News Today. http://www.medicalnewstoday.com/releases/193848.php.

Brooks, S. T., and Suchey, J. M. (1990). Skeletal age determination based on the *os pubis*: a comparison of the Ascadi-Nemeskeri and Suchey-Brooks methods. *Journal of Human Evolution* 5: 227–238.

Brothwell, D. R. (1959). Teeth in earlier human populations. *Proceedings of the Nutrition Society* 18: 59–65.

Brothwell, D. R. (1981). *Digging Up Bones*, Natural History Museum, London.

Buckberry, J. L., and Chamberlain, A. T. (2002). Age estimation from the auricular surface of the ilium: a revised method. *American Journal of Physical Anthropology* 119: 231–239.

Buikstra, J. E. (1977). Biocultural dimensions of archeological study: a regional perspective. In Blakely, R. L. (ed.), *Biocultural Adaptation in Prehistoric America*, University of Georgia Press, Athens, pp. 67–84.

Buikstra, J. E. (1991). Out of the appendix and into the dirt: comments on thirteen years of bioarchaeological research. In Powell, M. L., Bridges, P. S., and Mires, A. M. W. (eds.), *What Mean These Bones? Studies in Southeastern Bioarchaeology*, University of Alabama Press, Tuscaloosa, pp. 172–188.

Burt, B. A. (1993). Relative consumption of sucrose and other sugars: has it been a factor in reduced caries experience? *Caries Research* 27: 56–63.

Cohen, M. N., and Bennett, S. (1993). Skeletal evidence for sex roles and gender hierarchies in prehistory. In Miller, B. D. (ed.), *Skeletal Differences and Gender Hierarchies*, Cambridge University Press, Cambridge, pp. 273–296.

Connell, B., and Rauxloh, P. (2003). *A Rapid Method for Recording Human Skeletal Data*, Unpublished Museum of London report, London.

Corbett, E., and Moore, W. J. (1976). Distribution of dental caries in ancient British populations IV: the 19th century. *Caries Research* 10: 401–414.

Costa, R. L. (1982). Periodontal disease in the prehistoric Ipiutak and Tigara skeletal remains from Point Hope, Alaska. *American Journal of Physical Anthropology* 59: 97–110.

Cowie, R., Bekvalac, J., and Kausmally, T. (2008). *Late 17th- to 19th-Century Burial and Earlier Occupation at All Saints, Chelsea Old Church, Royal Borough of Kensington and Chelsea*, Museum of London, London.

Cucina, A., and Tiesler, V. (2003). Dental caries and ante-mortem tooth loss in the Northern Peten area, Mexico: a biocultural perspective on social status differences among the Classic Maya. *American Journal of Physical Anthropology* 122: 1–10.

Danforth, M. E., Jacobi, K. P., and Cohen, M. N. (1997). Gender and health in the colonial Maya of Tipu, Belize. *Ancient Mesoamerica* 8: 13–22.

Deerr, N. (1950). *The History of Sugar*, vol. 2, Chapman and Hall, London.

Drummond, J. C., and Wilbraham, A. (1957). *The Englishman's Food: A History of Five Centuries of English Diet*, Jonathan Cape, London.

Eden, F. M. (1797). *The State of the Poor: A History of the Labouring Classes in England*, J. Davis, London.

Fildes, V. (1986). *Breasts, Bottles and Babies: A History of Infant Feeding*, Edinburgh University Press, Edinburgh.

Finlay, R., and Shearer, B. (1986). Population growth and suburban expansion. In Beier, A. L., and Finlay, R. (eds.), *London 1500–1700: The Making of the Metropolis*, Longman, London, pp. 37–59.

Frayer, D. W. (1984). Tooth size, oral pathology and class distinctions: evidence from the Hungarian Middle Ages. *Anthropologiai Kozlemenyek* 28: 47–54.

Frayer, D. W. (1988). Caries and oral pathologies at the Mesolithic sites of Muge: Cabeço da Arruda and Moita do Sebastião. *Trabajo Antropologia e Etnologia* 27: 9–25.

Freeth, C. (2000). Dental health in British antiquity. In Cox, M., and Mays, S. (eds.), *Human Osteology in Archaeology and Forensic Science*, Cambridge University Press, Cambridge, pp. 227–237.

Glass, G. B. (1991). Continuous eruption and periodontal status in pre-industrial dentitions. *International Journal of Osteoarchaeology* 1: 265–271.

Grauer, A. L., and McNamara, E. M. (1995). A piece of Chicago's past: exploring childhood mortality in the Dunning Poorhouse cemetery. In Grauer, A. L. (ed.), *Bodies of Evidence: Reconstructing History Through Skeletal Analysis*, Wiley-Liss, New York, pp. 91–103.

Haines, M. R. (2004). Growing incomes, shrinking people: can economic development be hazardous to your health? historical evidence for the United States, England, and the Netherlands in the nineteenth century. *Social Science History* 28: 249–270.

Hardwick, J. L. (1960). The incidence and distribution of caries throughout the ages in relation to the Englishman's diet. *British Dental Journal* 108: 9–17.

Harvey, W. (1968). Some dental and social conditions of 1696–1852 connected with St. Bride's Church, Fleet Street, London. *Medical History* 12: 62–76.

Hildebolt, C. F., Molnar, S., Elvin-Lewis, M., and McKee, J. K. (1988). The effect of geochemical factors on prevalences of dental diseases for prehistoric inhabitants of the State of Missouri. *American Journal of Physical Anthropology* 75: 1–14.

Hills, J., Brewer, M., Jenkins, S. P., Lister, R., Lupton, R., Machin, S., Mills, C., Modood, T., Rees, T., and Riddell, S. (2010). *An Anatomy of Economic Inequality in the UK: Report of the National Equality Panel*, Centre for Analysis of Social Exclusion, London School of Economics and Political Science, London.

Hillson, S. (1996). *Dental Anthropology*, Cambridge University Press, Cambridge.

Hillson, S. (2001). Recording dental caries in archaeological human remains. *International Journal of Osteoarchaeology* 11: 249–289.

Hillson, S. (2005). *Teeth*, 2nd ed, Cambridge University Press, Cambridge.

Hunt, R. J., Drake, C. W., and Beck, J. D. (1992). *Streptococcus mutans*, lactobacilli, and caries experience in older adults. *Special Care in Dentistry* 12: 149–152.

İşcan, M. Y., Loth, S. R., and Wright, R. K. (1984). Age estimation from the rib by phase analysis: white males. *Journal of Forensic Sciences* 29: 1094–1104.

İşcan, M. Y., Loth, S. R., and Wright, R. K. (1985). Age estimation from the rib by phase analysis: white females. *Journal of Forensic Sciences* 30: 853–863.

Källestål, C., and Wall, S. (2002). Socio-economic effect on caries. Incidence data among Swedish 12–14 year-olds. *Community Dentistry & Oral Epidemiology* 30: 108–114.

Kausmally, T. (2008). Farringdon: St Brides lower churchyard, http://archive.museumoflondon.org.uk/Centre-for-Human-Bioarchaeology/Database/Post-medieval+cemeteries/St+Brides+lower.htm.

Kerr, N. W. (1990). The prevalence and pattern of distribution of root caries in a Scottish medieval population. *Journal of Dental Research* 69: 857–860.

Kerr, N. W., Bruce, M. F., and Cross, J. F. (1988). Caries experience in the permanent dentition of late mediaeval Scots (1300–1600 A.D.). *Archives of Oral Biology* 33: 143–148.

Landers, J. (1990). Age patterns of mortality in London during the "long eighteenth century": a test of the "high potential" model of metropolitan mortality. *Social History of Medicine* 3: 27–60.

Landers, J. (1991). London's mortality in the "long eighteenth century": a family reconstitution study. *Medical History. Supplement* 11: 1–28.

Landers, J. (1993). *Death and the Metropolis: Studies in the Demographic History of London 1670–1830*, Cambridge University Press, Cambridge.

Lanfranco, L. P., and Eggers, S. (2010). The usefulness of caries frequency, depth, and location in determining cariogenicity and past subsistence: a test on early and later agriculturalists from the Peruvian coast. *American Journal of Physical Anthropology* 143: 75–91.

Lanphear, K. M. (1990). Frequency and distribution of enamel hypoplasias in a historic skeletal sample. *American Journal of Physical Anthropology* 81: 35–43.

Larsen, C. S. (1983). Behavioral implications of temporal change in cariogenesis. *Journal of Archaeological Science* 10: 1–8.

Larsen, C. S. (1997). *Bioarchaeology: Interpreting Behavior from the Human Skeleton*, Cambridge University Press, Cambridge.

Lewis, M. (2007). *The Bioarchaeology of Children: Perspectives from Biological and Forensic Anthropology*, Cambridge University Press, Cambridge.

Locker, D. (2000). Deprivation and oral health: a review. *Community Dentistry & Oral Epidemiology* 28: 161–169.

Lovejoy, C. O., Meindl, R. S., Pryzbeck, T. R., and Mensforth, R. P. (1985). Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age at death. *American Journal of Physical Anthropology* 68: 15–28.

Lukacs, J. R. (1992). Dental paleopathology and agricultural intensification in South Asia: new evidence from Bronze Age Harappa. *American Journal of Physical Anthropology* 87: 133–150.

Lukacs, J. R. (1995). The "caries correction factor": a new method of calibrating dental caries rates to compensate for antemortem tooth loss of teeth. *International Journal of Osteoarchaeology* 5: 151–156.

Lukacs, J. R. (1996). Sex differences in dental caries rates with the origin of agriculture in South Asia. *Current Anthropology* 37: 147–153.

Lukacs, J. R. (2008). Fertility and agriculture accentuate sex differences in dental caries rates. *Current Anthropology* 49: 901–914.

Lukacs, J. R., and Largaespada, L. L. (2006). Explaining sex differences in dental caries prevalence: saliva, hormones, and "life-history" etiologies. *American Journal of Physical Anthropology* 18: 540–555.

Lunt, D. A. (1986). Mediaeval dentitions from St Andrews. *British Archaeological Reports International Series* 291: 215–224.

Maat, G. J. R., and Van der Velde, E. A. (1987). The caries-attrition competition. *International Journal of Anthropology* 2: 281–292.

Maitland, W. (1756). *The History and Survey of London*, T. Osborne and J. Shipton, London.

Marin, V., Hrvoje, B., Mario, S., and Zeljko, D. (2005). The frequency and distribution of caries in the mediaeval population of Bijelo Brdo in Croatia (10th to 11th century). *Archives of Oral Biology* 50: 669–680.

Mayhall, J. T. (1970). The oral health of a Canadian Inuit community: an anthropological approach. *Journal of Dental Research* 56(Special Issue C): C55–C60.

Meiklejohn, C., Wyman, J. M., and Schentag, C. T. (1992). Caries and attrition: dependent or independent variables? *International Journal of Anthropology* 7: 17–22.

Miles, A. (2010). *A post-medieval population from London: excavations in the St Bride's Lower Churchyard 75–82 Farringdon Street, City of London*. EC4. Unpublished Museum of London report, London.

Miles, A. and Conheeney, J. (2005). *A post-medieval population from London: Excavations in the St Bride's Lower Churchyard 75–82 Farringdon Street, City of London*, EC4. Unpublished Museum of London report, London.

Mitchell, B. R., and Deane, P. (1962). *Abstract of British Historical Statistics*, Cambridge University Press, Cambridge.

Miura, H., Araki, Y., Haraguchi, K., Arai, Y., and Umenai, T. (1997). Socioeconomic factors and dental caries in developing countries: a cross-national study. *Social Science and Medicine* 44: 269–272.

Moore, W. J. (1993). Dental caries in Britain. In Geissler, C., and Oddy, D. J. (eds.), *Food, Diet and Economic Change Past and Present*, Leicester University Press, Leicester, pp. 50–61.

Moore, W. J., and Corbett, E. (1973). The distribution of dental caries in ancient British populations II, Iron Age, Romano-British and Mediaeval Periods. *Caries Research* 7: 139–153.

Moore, W. J., and Corbett, E. (1975). The distribution of dental caries in ancient British populations III, the 17th century. *Caries Research* 9: 163–175.

Moore, W. J., and Corbett, E. (1971). The distribution of dental caries in ancient British populations I, Anglo Saxon Period. *Caries Research* 5: 151–168.

National Planning Policy Framework (2012). *National Planning Policy Framework*. http://webarchive. nationalarchives.gov.uk/20120919132719/http://www.communities.gov.uk/documents/ planningandbuilding/pdf/2116950.pdf.

Nikiforouk, G. (1985). *Understanding Dental Caries*, Basel Karger, New York.

Olsson, G., and Sagne, S. (1976). Studies of caries prevalence in a mediaeval population. *Dentomaxillofacial Radiology* 5: 12–18.

Oranje, P., Noriskan, J. N., and Osborn, T. W. B. (1935–37). The effect of diet upon dental caries in the South African Bantu. *South African Journal of Medical Science* 1–2: 57–62.

Palubeckaite, Z., Jankauskas, R., Ardagna, Y., Macia, Y., Rigeade, C., Signoli, M., and Dutour, O. (2006). Dental status of Napoleon's Great Army (1812) mass burial of soldiers in Vilnius: childhood peculiarities and adult dietary habits. *International Journal of Osteoarchaeology* 16: 355–365.

Pelizzon, S. (2000). Grain flour, 1590–1790. *Review (Fernand Braudel Center)* 23: 87–195.

Porter, R. (2000). *London: A Social History*, Penguin, London.

Price, W. A. (1936). Eskimo and Indian field studies in Alaska and Canada. *Journal of the American Dental Association* 23: 417–437.

Razzell, P. (2007). *Population and Disease: Transforming English Society 1550–1850*, Caliban, London.

Roberts, C., and Cox, M. (2003). *Health and Disease in Britain: From Prehistory to the Present Day*, Alan Sutton, Stroud.

Russell, A. L., Consolazio, C. F., and White, C. L. (1961). Dental caries and nutrition in Eskimo scouts of the Alaska National Guard. *Journal of Dental Research* 40: 594–603.

Russet, A., and Pocock, T. (2004). *A History of Chelsea Old Church: the Church that Refused to Die*, Chelsea Old Church, London.

Saunders, S. R., De Vito, C., and Katzenberg, M. A. (1997). Dental caries in nineteenth century Upper Canada. *American Journal of Physical Anthropology* 104: 71–87.

Scott, J. (1773). *Observations on the Present State of the Parochial and Vagrant Poor*, Edward and Charles Dilly, London.

Sheppard, F. (1998). *London: A History*, Oxford University Press, Oxford.

Start, H., and Kirk, L. (1998). "The bodies of Friends": the osteological analysis of a Quaker burial ground. In Cox, M. (ed.), *Grave Concerns: Death and Burial in England 1700–1850*, Council for British Archaeology, York, pp. 167–177.

Swärdstedt, T. (1966). *Odontological Aspects of a Medieval Population in the Province of Jämtland/Mid-Sweden*, Tiden-Barnängen Tryckerier, Stockholm.

Tattersall, I. (1968). Dental palaeopathology of mediaeval Britain. *Journal of the History of Medicine and Allied Sciences* 23: 380–385.

Walker, P. L., and Hewlitt, B. S. (1990). Dental health, diet, and social status among Central African foragers and farmers. *American Anthropologist* 92: 383–398.

Weinberger, B. W. (1948). *An Introduction to the History of Dentistry, Volume 1*, C.V. Mosby, St. Louis.

White, C. D. (1994). Dietary dental pathology and cultural change in the Maya. In Herring, A., and Chan, L. (eds.), *Strength in Diversity: A Reader in Physical Anthropology*, Canadian Scholars' Press, Toronto, pp. 279–302.

Whittaker, D. K. (1993). Oral health, in Molleson, T. and Cox, M. (eds.), *The Spitalfields Project: Volume 2, The Anthropology, The Middling Sort*, Council for British Archaeology Report 6, York, pp. 49–65.

Whittaker, D. K., and Molleson, T. (1996). Caries prevalence in the dentition of a late eighteenth century population. *Archives of Oral Biology* 41: 55–61.

Whittaker, D. K., Molleson, T., Bennett, R. B., Edward, I., Jenkins, P. R., and Llewelyn, J. (1981). The prevalence and distribution of dental caries in a Romano-British population. *Archives of Oral Biology* 26: 237–245.

Wilkinson, R., and Pickett, K. (2009). *The Spirit Level: Why Equality is Better for Everyone*, Penguin, London.

Williams, N., and Galley, C. (1995). Urban–rural differentials in infant mortality in Victorian England. *Population Studies* 49: 401–420.

Wohl, A. S. (1983). *Endangered Lives: Public Health in Victorian Britain*, Methuen, Cambridge.

Woodward, M., and Walker, A. R. P. (1994). Sugar consumption and dental caries: evidence from 90 countries. *British Dental Journal* 176: 297–302.

WHO (World Health Organization). (2010). Thematic strands of the conference. http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/urban-health/activities/healthy-cities/who-european-healthy-cities-network/meetings-of-the-who-european-healthy-cities-network/the-hidden-cities-addressing-equity-in-health-and-inclusiveness-in-cities/thematic-strands-of-the-conference.

Wrigley, E. A., and Schofield, R. S. (1981). *The Population History of England, 1541–1871*, Edward Arnold, London.

Zuckerman, M. K., and Armelagos, G. J. (2011). The origins of biocultural dimensions in bioarchaeology. In Agarwal, S. C., and Glencross, B. A. (eds.), *Social Bioarchaeology*, Wiley-Blackwell, Chichester, pp. 15–43.