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Maxillary Sinusitis as an Indicator of Respiratory Health in Past Populations

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ABSTRACT Chronic infectious respiratory disease in a past human population is investigated through the quantification of maxillary sinusitis among Iroquoian horticulturists. Three hundred forty-eight right and left maxillae of a Southern Ontario Iroquoian skeletal sample, Uxbridge Ossuary, ca. AD 1440, were examined for evidence of chronic infection (minimum number of individuals = 207: 114 adults, 22 adolescents, 38 juveniles and 33 infants). Modern clinical criteria were applied to differentiate lesions of respiratory and dental origin. Osseous lesions of the maxillary sinuses were observed in 50% of the individuals examined. These lesions are morphologically consistent with nonspecific lesions observed in other past populations that have been attributed to the presence of pathogens. The prevalence of maxillary sinusitis increases with age. Osseous changes suggestive of maxillary sinusitis of respiratory origin are at a maximum prevalence in juveniles and adolescents. In adults, infection of dental origin becomes a confounding factor in the identification of sinusitis of respiratory origin. Fifteenth century Iroquoians were experiencing high airborne pathogen levels and poor indoor air quality. The prevalence of maxillary sinusitis and the exploration of the origin of tissue injury may contribute to our reconstruction of the quality of life and the respiratory health status of past human populations. Am J Phys Anthropol 111:301–318, 2000.

The presence of infectious disease is a universal phenomenon across all living organisms including *Homo sapiens*. One mode of pathogen transmission is often the airborne route. Inhalation of pathogens may result in infectious diseases of the upper respiratory tract such as maxillary sinusitis. Sinusitis, an inflammatory disease of the sinuses, is one of the most commonly reported infectious diseases in modern human populations, affecting an estimated 14% of North Americans (Kaliner et al., 1997). Between 1985 and 1992, sinusitis was the fifth leading cause for dispensing antibiotic prescriptions in the United States (McCaig and Hughes, 1995). Quality of life is often compromised by sinusitis, and productivity may be reduced (Gliklich and Metson, 1995). If left untreated, sinusitis may result in changes to bone morphology (Antonelli et al., 1992; Tovi et al., 1992).

The ubiquity of respiratory disease in contemporary human populations (Tovi et al, 1992), the potential for chronic soft tissue infection to result in changes to bone morphology (Ortner and Putschar, 1981), and skeletal evidence of sinusitis in some past

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populations (Boocock et al., 1995; Gregg and Gregg, 1987; Lew and Sirianni, 1997; Lewis et al., 1995; Panhuysen et al., 1997; Wells, 1977) suggest that quantification of osseous lesions of the maxillary sinuses in skeletal samples may be used to infer the respiratory health status of past human populations. Through quantification of osseous evidence of inflammatory response in the maxillary sinuses, we seek to increase our understanding of the respiratory health status of a human prehistoric population in which there is reason to expect respiratory stressors (Pfeiffer, 1984). The skeletal sample is from a single Iroquoian interment event. We predict that this sample will show a high frequency of maxillary sinusitis because the people lived in longhouses, which have been shown to facilitate the spread of airborne infectious disease (Chen, 1988), and because they used wood fires indoors for cooking and heating, which have been associated with increased pathogen entry into the respiratory mucosa (Brachman, 1990; Wright et al., 1994) and with increased respiratory disease (Chen et al., 1990; Pimentel et al., 1998).

PREVIOUS RESEARCH

The study of infectious disease in human skeletal remains has traditionally concentrated on two areas: infectious disease processes that normally invade bony tissue, such as tuberculosis and leprosy, and nonspecific infections that result from the spread of soft tissue lesions to bone, such as periostitis and osteomyelitis (Steinbock, 1976; Ortner and Putschar, 1981). There has been little work until recently on the mucosal-lined cavities within bone, such as the paranasal sinuses and specifically the maxillary sinuses. The maxillary sinuses are relatively inaccessible to direct examination, making them difficult to study. Osseous lesions of the maxillary sinuses were mentioned in early work on pre-Columbian Peruvians in the context of dental health and were identified as oro-antral fistulae (Leigh, 1937; Moodie, 1928). Wells (1977) was the first to analyze maxillary sinus bone morphology in a manner that was more than an adjunct to general palaeopathological description. In 15 temporally diverse British samples (Wells, 1977), and in the Crow Creek massacre sample (Gregg and Gregg, 1987), the prevalence of maxillary sinusitis was reported to be less than 7%. In contrast, in more recent studies (Boocock et al., 1995; Lew and Sirianni, 1997; Lewis et al., 1995; Panhuysen et al., 1997), the prevalence of maxillary sinusitis has been estimated to range between 30 and 55% in their respective skeletal samples. The discrepancies may reflect the historical development of the discipline of paleopathology, the increased interstudy consistency of the morphological descriptions employed (Ortner, 1991), and the intersample variability in post-mortem breakage patterns that facilitate sinus examination.

Early attempts to quantify the prevalence of osseous lesions of the maxillary sinuses (Wells, 1977) were thwarted by a dearth of sinuses accessible to direct methods of visualization. In an effort to overcome this obstacle, Wells borrowed endoscopic technology from the clinical practice of medicine for use in the study of ancient respiratory disease. This technique, however, requires drilling small access holes in the maxilla to allow access of the endoscopic tube. Permission may or may not be given for such invasive techniques in ancient human skeletal material, depending on the nature and cultural affiliation of the sample. As a result, the largest sample for the sites represented in Wells' preliminary study has only 37 individuals. Pooling of the data for each time period to increase sample size assumes homogeneity among the samples, which may not reflect the reality of the cultural context of those samples. Wells (1977) proposed a wide range of possible reasons for the varying proportions of sinusitis observed in the different skeletal populations, including differences in climate, predominant face shapes, occupational hazards, methods of dwelling construction, and amounts of indoor ventilation in the time periods represented.

More recently, since chronic exposure to wood smoke has been shown to cause paralysis of the cilia of the respiratory epithelium (de Koning et al., 1985; Wright et al., 1994), air quality has been proposed to account for the observed prevalence differences of maxillary sinusitis in rural (39%) and urban (55%) Medieval England (Lewis et al., 1995). Hypotheses concerning indoor air quality are consistent with correlations between chronic exposure to wood smoke and the increased prevalence of respiratory infection in living populations (Albalak, 1997; D'Souza, 1997; Ellegård, 1996; Headland, 1989; Pérez-Padilla et al., 1996).

Most particulates, including pathogens, enter the maxillary sinuses through the natural ostium from the nasal fossa: the rhinogenous route (Melén, 1994). Pathogens inhaled into the maxillary sinus may cause primary infection within the sinus. However, an alternate route of infection through the floor of the sinuses may result from periapical abscessing and periodontal disease (Melén, 1994; Melén et al., 1986; Shafer et al., 1974). The thin layer of bone between the apex of the molar roots and the maxillary sinus may be resorbed as a result of periapical abscessing. Destruction of the bone may also occur if excessive force is applied during tooth extraction (Scott and Dixon, 1959). Disruption of the mucosa on floor of the sinus in either case may allow pathogens of dental origin access to the sinus.

Clinically, sinusitis is assumed to be of rhinogenous origin if dental examination is normal and if the infection fails to be resolved after conservative medical treatment. Only when there is radiological evidence of an oro-antral fistula, periapical abscessing or nonvital teeth in close association with the maxillary sinus mucosa is the origin of infection considered to be the dentition (Melén, 1994). Following these clinical criteria, the absence of evidence of infection in the alveolar bone surrounding the maxillary molar and premolar roots in dry bone specimens may indicate a rhinogenous origin of sinus infection.

Panhuysen et al. (1997) were the first to attempt to quantify lesions of the maxillary sinuses by source of infection. However, the pooling of data from three skeletal samples, and the broad time span over which the interment events occurred (eleven centuries) make inferences concerning the etiology of maxillary sinusitis and the relationship between the observed presence of infectious disease and population health elusive. In the pooled sample, the prevalence of maxillary sinusitis increases with age (Panhuysen et al., 1997). The present study attempts to overcome these difficulties through the application of the clinical criteria (Melén, 1994) to a large skeletal sample (N = 207) from a single Iroquoian interment event in southern Ontario that is dated to the fifteenth century A.D.

MAXILLARY SINUS PATHOBIOLOGY

The bone that surrounds the lumen of the maxillary sinus is shared in common with the floor of the orbit, the medial wall of the nasal fossa, and the alveolar bone surrounding the roots of the maxillary dentition. The maxillary sinus has only one natural opening, the ostium, high on the medial wall of the sinus, allowing communication with the nasal fossa. The flow of air across the ostium during normal inspiration facilitates the entry of airborne particulates into the maxillary sinuses (Wagenmann and Naclerio, 1992).

The maxillary sinuses function as the body's first line of defense against airborne particulates and pathogens (Brandtzaeg et al., 1996; Lindberg et al., 1997) by the creation of both a physical and a chemical barrier. Mucous glycoproteins synthesized by goblet cells in the mucosal epithelium form an extracellular physical barrier on the epithelial surface that traps airborne particulates (Cormack, 1984). The remainder of the mucosa is comprised of pseudostratified ciliated columnar epithelial cells. The physical barrier created by the ciliated cells has two components: tight junctions and cilia. The tight junctions effectively join the plasma membranes of adjacent epithelial cells at the lumenal surface preventing extracellular migration of pathogens into the underlying highly vascularized connective tissue (Cormack, 1984). The mucus is propelled by the cilia against gravity toward the ostium of the sinus, and in the absence of disease, the mucus in the maxillary sinuses may be replaced every 10 to 20 minutes (Norlander et al., 1994). The maintenance of a patent ostium allows clearance of the pathogen-containing mucus from the sinus (Kaliner, 1992). Antimicrobial molecules, such as nitric oxide (Lindberg et al., 1997), secretory immunoglobulin A, lactoferrin, and lysozyme (Kaliner, 1992) in the fluid surrounding the cilia and the antioxidant properties of the mucous glycoproteins (Wright et al., 1994) function as a chemical barrier to infection. Disruption of any components of the physical and/or chemical barrier can result in a build-up of fluid within the sinus, provide an ideal culture medium for bacterial growth and result in tissue injury. A cascade of inflammatory events is initiated, leading to the development of sinusitis, disruption of mucosal homeostasis, and altered epithelial function (Kaliner et al., 1997).

Inflammation is a self-regulating response to a tissue injury of chemical, physical, or biological origin. This response normally leads to tissue regeneration and repair (Mitchell and Cotran, 1997). Chemical signals of tissue injury initiate increased migration of plasma proteins and leukocytes into the loose connective tissue surrounding the vasculature. T-lymphocytes, neutrophils, eosinophils, and mast cells synthesize inflammatory mediators such as interleukin-1 (IL-1), interleukin-6 (IL-6), tissue necrosis factor-β (TNF-β) and transforming growth factor-β (TGF-β) (Brandzaeg et al., 1996). Repeated or chronic tissue injury or infection may lead to an altered immune environment in which aberrant regulation of the inflammatory process prevails. The self-perpetuating inflammatory cycle may result in tissue damage, fibrosis, and scarring (Kaliner et al., 1997).

The highly vascularized connective tissue layer directly beneath the epithelium of the sinus mucosa provides a conduit for the rapid response to mucosal injury. Only the *lamina propria* of the sinus mucosa, which is tightly bonded to the periosteum, separates the site of the inflammatory response from the surrounding bone. Inflammatory mediators such as IL-1, IL-6 and TNF-β may stimulate osteoclast proliferation and activation, while TGF-β may increase osteoblast production (Gowen, 1994). Thus, in addition to the functions of tissue regeneration and repair, chronic or repeated inflammation of the sinus mucosa may result in damage to the surrounding bony tissue. With the inspired air and the mucosal vasculature in close proximity to the surrounding bone, the maxillary sinuses provide a unique opportunity to examine the effects of the airborne environment, for example the particulates in wood smoke, on bone tissue.

SINUSITIS

Sinusitis is broadly defined as inflammation of the mucosa of the paranasal sinuses (Melén, 1994). Efforts have been made to standardize the clinical criteria for diagnosis of sinusitis and there is general agreement among clinicians regarding major and minor symptom categories (Shapiro and Rachelefsky, 1992). Positive diagnosis is confirmed when the patient exhibits two of the major criteria, or one major and at least two of the minor criteria. The major criteria include purulent nasal discharge, purulent pharyngeal drainage, and cough. Minor criteria are periorbital edema, head ache, facial pain, tooth ache, ear ache, sore throat, foul breath, increased wheezing, and fever. Acute sinusitis lasts more than 7 days but less than 1 month, whereas sinusitis is considered to be chronic when the symptoms are more than 3 months in duration (Shapiro and Rachelefsky, 1992).

Maxillary sinusitis can be caused by many factors (Guo et al., 1997; Kaliner et al., 1997). An increased prevalence of infectious disease in a population is associated with decreased host defense mechanisms and /or the creation of conditions favorable to host-to-host transmission of pathogens, pathogen entry into the host, and pathogen survival and reproduction within the host (Finlay and Falkow, 1997). Studies in modern populations suggest that a wide variety of risk factors are associated with increased prevalence of respiratory disease. These factors include chronic exposure to wood smoke (Albalak, 1997; D'Souza, 1997; Ellegård, 1996; Headland, 1989; Pérez-Padilla et al., 1996), crowded dwellings (Chen, 1988; D'Souza, 1997), high population density, poor sanitary conditions, the presence of concomitant respiratory infections (D'Souza, 1997), and periapical abscessing (Melén et al., 1986; Shafer et al., 1974).

Although wood is the primary biomass fuel used in modern populations, other fuels high in organic content such as grass and crop residues such as corn cobs are also burned (Pérez-Padilla et al., 1996). Within the category of wood smoke exposure, three risk factors for respiratory tissue injury have been identified: gaseous emissions, particulates, and the reduced humidity which results when wood is burnt within confined spaces of dwellings.

Chronic exposure to the gases in wood smoke: carbon dioxide, carbon monoxide, and sulfur dioxide (Chen et al., 1990; D'Souza, 1997), is associated with respiratory distress symptoms (Chen et al., 1990). Increased concentrations of carbon dioxide decrease mucociliary function and reduce pathogen clearance from the sinuses (Reimer, 1987).

The incomplete combustion of biomass fuels produces high concentrations of particulates (de Koning et al., 1985). They contain reactive oxygen species (ROS) such as the free radicals of oxygen and nitrogen dioxide (Halliwell and Cross, 1994). The chronic exposure to ROS in wood smoke results in oxidant stress of the respiratory epithelium, depletion of tissue anti-oxidant reserves, and damage to the mucociliary transport system (de Koning et al., 1985; Wright et al., 1994). Reactive oxygen species may increase the permeability of the epithelial cell plasma membranes to pathogens and initiate inflammation (Brachman, 1990; Wright et al., 1994). Tissue edema associated with inflammation may reduce the diameter of the ostium or cause its obstruction, trapping pathogens within the sinus (Kaliner, 1992). Mucous glycoproteins are degraded, reducing the effectiveness of the mucous physical barrier (Wright et al., 1994).

Since the controlled use of fire began, humans have been exposed to smoke from the combustion of biomass fuels. In the evolutionary history of *Homo sapiens*, biomass fuels have been the only fuels in use until very recently. The use of biomass fuels by more than half of late twentieth century households exposes most humans to this risk factor for the development of respiratory disease (Chen et al., 1990; Pimentel et al., 1998). In modern Andean Bolivia, high particulate concentrations produced by the indoor burning of biomass fuels for cooking are associated with a higher prevalence of respiratory infection than in culturally similar communities where indoor particulate concentrations are lower because cooking occurs outdoors (Albalak, 1997). In Mozambique, high levels of airborne particulates resulting from the indoor use of biomass fuels for cooking are associated with increased cough symptoms (Ellegård, 1996). Similarly, in Mexico, the risk of chronic airway disease is directly proportional to the number of hour-years of wood fuel used in cooking (Pérez-Padilla et al., 1996). In groups of forest dwellers in the Philippines, the use of smoldering fires to repel mosquitoes is associated with chronic coughing and a high prevalence of lung-related morbidity and mortality (Headland, 1989).

Decreased humidity is associated with increased permeability of the respiratory epithelium to pathogens (Brachman, 1990). It may increase an individual's susceptibility to infectious respiratory disease. In Karachi, Pakistan, lower levels of humidity are recorded within dwellings where frequent cooking occurs. Household risks for respiratory infections in this study included crowding, poor dwelling ventilation and the indoor use of biomass fuels (D'Souza, 1997). Other infections can reduce immune competence and can increase the susceptibility to respiratory infections. Poor sanitary conditions can increase the overall pathogen load of the population (D'Souza, 1997).

Culturally influenced dwelling construction practices may affect human behavior and create microenvironments conducive to respiratory pathogen transmission. In some living populations in Sarawak, Malaysia, dwellings are multi-family longhouses rather than single-family houses. Among individuals living in multi-family dwellings, the frequency and duration of social contacts have been shown to be of sufficient intensity and duration to substantially increase the prevalence and transmission of airborne infectious diseases such as tuberculosis and leprosy (Chen, 1988).

IROQUOIAN CULTURAL PARAMETERS

Archaeological evidence from fifteenth century longhouse settlements in southern Ontario suggests that the Iroquoian population was growing in size and density (Dodd et al., 1990; Warrick, 1990) and was experiencing a concomitant decline in sanitary conditions

(Saunders et al., 1992). Large oblong dwellings, ranging in length from 14 to 70 meters, housed 20 to 100 matrilineally-related individuals. Along the length of the longhouse, centrally placed hearths were spaced about five meters apart (Dodd et al., 1990; Finlayson, 1985) with two families sharing each hearth. The year's supply of firewood was stored beneath the sleeping benches that ran along each wall of the longhouse, restricting the amount of living space per family. Ethnohistoric documentation in the seventeenth century suggests that the average Iroquoian family had five members (Thwaites 1896–1901, cited in Saunders et al., 1992). If family size were similar in the fifteenth century, the resulting living floor area per person would be less than 1 square meter, much less than the 1.5 square meters per person below which D'Souza (1997) considers crowding to be a risk factor for respiratory infection.

Ethnohistorical data of Iroquoian life and experimental archaeological evidence suggest that the longhouse dwelling environment can be identified as a risk factor for the development of respiratory disease. Historical accounts written by the Jesuits in the sixteenth and seventeenth centuries (Thwaites 1896–1901, cited in Heidenreich, 1971; Trigger, 1969, 1976) portray Iroquoian longhouses as examples of crowded, smoky environments with poor air quality. The cooking of maize soup over slow indoor fires, central hearths without chimneys, fires for heat in winter, and the possible use of smoldering fires in summer to repel insects suggest that chronic exposure to wood smoke would be inevitable for Iroquoians. Experiments in a reconstructed longhouse confirm the difficulty of smoke dissipation from the longhouse interior (Fecteau, 1979).

Crowding also occurred within the villages. Villages covered an area ranging from 1.2 to 3.2 hectares (Poulton n.d., cited in Finlayson, 1985). The smallest villages are estimated to have housed approximately 400 individuals, and the largest about 2,000 inhabitants. The distance between longhouses within a village is often less than 3 meters, and middens (refuse dumps) are located near longhouse entrances. As the population of a village increased, longhouses were extended, occasionally incorporating areas previously used as middens into the dwelling.

By the fifteenth century, the ceremonial reburial of human remains in a large communal ossuary was the predominant form of Iroquoian mortuary practice. The secondary burial occurred during the Feast of the Dead, which was celebrated in association with village relocation that historically occurred every 8–12 years. The remains of individuals deceased since the previous feast were disinterred, then placed into the ossuary pit (Thwaites 1896–1901, cited in Trigger, 1976). Analysis of the distribution of bones within the Kleinburg historic ossuary (Pfeiffer, 1980) corroborates ethnohistoric accounts that deliberate commingling of the skeletal elements occurred as the remains were placed in the ossuary during the Feast of the Dead.

If fifteenth century longhouses and villages created conditions that promoted the transmission of infectious respiratory disease and facilitated the development of inflammation of upper respiratory tissues, the changes to bone morphology and the prevalence of maxillary sinusitis that are observed in the Uxbridge Ossuary skeletal sample should be consistent with those observed in other past populations. If factors influencing sinusitis affected all members of the population equally, the prevalence of maxillary sinusitis should be consistent across ages and sexes.

MATERIALS AND METHODS

The skeletal sample with a minimum of 457 individuals, comes from a fifteenth century southern Ontario Iroquoian ossuary (Pfeiffer, 1983). The site, the Uxbridge Ossuary, was located just south of Lake Simcoe, 35 km north of Lake Ontario, in close proximity to the historically-documented region of Huronia. The radiocarbon date[1] of AD 1440 (I-9865) with a calibrated one-sigma range of 1410–1483 (Stuiver and Reimer, 1993) and the lack of grave goods in the ossuary which is consistent with archaeologi-

[1]The radiocarbon date (Isotopes Code No: I-9865) was obtained from a sample of charcoal that was 72 inches below the ground surface in a good archaeological context within the ossuary. The age is 480 ± 80 years. The uncalibrated date is A.D. 1490.

cally documented pre-contact burial practices (Jamieson, 1981) places the site prior to European contact. Three hundred forty-eight complete or partial maxillae were examined for changes to bone morphology of the maxillary sinuses [minimum number of individuals (MNI) = 207: 114 adults, 22 adolescents, 38 juveniles and 33 infants].

The purposeful commingling of the remains during the Feast of the Dead presents a major challenge for analysis, in that the reconstruction of individuals is not possible. The maxillae examined could not be matched with their respective infracranial skeletal elements. This limits the range of hypotheses that can be tested.

The maxillae were sorted by age and, where possible, by sex of the individual. The age-at-death of nonadults was assessed using the modified Schour and Massler dental formation and eruption chronology (Ubelaker, 1989). Where tooth buds and incompletely erupted teeth were present, the dental formation scheme of Moorees et al. (1963a,b) was used. Individuals with third permanent molars erupted but not worn were placed in a young adult category of 20 to 29 years. Older adults were divided into middle adults, 30 to 50 years, and older adults, greater than 50 years, on the basis of the pattern of total obliteration of the sutures of the hard palate (Mann et al., 1987). The extent of post-mortem palatal breakage in the sample precluded the use of the total score of the four palatal sutures (Mann et al., 1987) that has been critiqued by Gruspier and Mullen (1991). Because no prevalence differences were observed between young and middle adults, a combined age category of younger adults, aged 20 to 50 years, was used in the statistical analysis. For adult individuals with both the maxillary sinus(es) and cranium present (N = 30), sex was estimated using cranial morphology (Buikstra and Ubelaker, 1994). The sinuses and alveolar processes in the different subgroups of the sample were then examined for the presence of pathologically altered bone.

To ensure that the maxilla of each individual was only counted once, criteria for inclusion in the study were established. In individuals less than 20 years of age, sinuses estimated to be at least 80% complete were included. In adults, the presence of a sinus floor complete above at least two permanent molars was required. The left and right sides of the maxilla were present in equal proportions in the sample. For the statistical analysis, only data from the right sides of the maxillae were used.

The Pearson chi square statistic was used to test null hypotheses of the independence of pairs of categorical variables. The probability value used for statistical significance was 0.05. Once a lack of independence among pairs of variables was established, hierarchical log-linear analysis, with partitioning of the error term using the likelihood ratio chi square statistic (SPSS statistical software package, 1995), was used to identify interaction relationships among the variables: age-at-death, remodeling and abscessing in the three-variable statistical model and among age-at-death and remodeling independent of abscessing (RemIndep) for the two-variable statistical model.

Maxillary sinus lesion classification

The osseous lesions of the maxillary sinuses in the Uxbridge skeletal sample were examined macroscopically. The lesions were classified by morphological type following a modification of the system recently established by Boocock et al. (1995). The system follows that advocated by Ortner (1991, 1997) for the description of changes to bone morphology that are seen in more accessible skeletal elements, and that are attributed to the response of bone to the presence of pathogens.

The classification of the changes to bone morphology on the floor of the maxillary sinuses is modified from the categories of "spicules," "pitting," and "remodeled spicules" (Boocock et al., 1995). The category of "white pitted bone" was initially included, but was not found in the Uxbridge Ossuary sample. Three additional categories — "plaque," "lobules," and "cysts" — were created to classify lesions encountered in the Uxbridge sample that differ from the lesions described by Boocock et al. (1995), but are similar to categories used by Ortner and Putschar (1981), Buikstra and Ubelaker (1994) and Ortner (1997) to describe bone

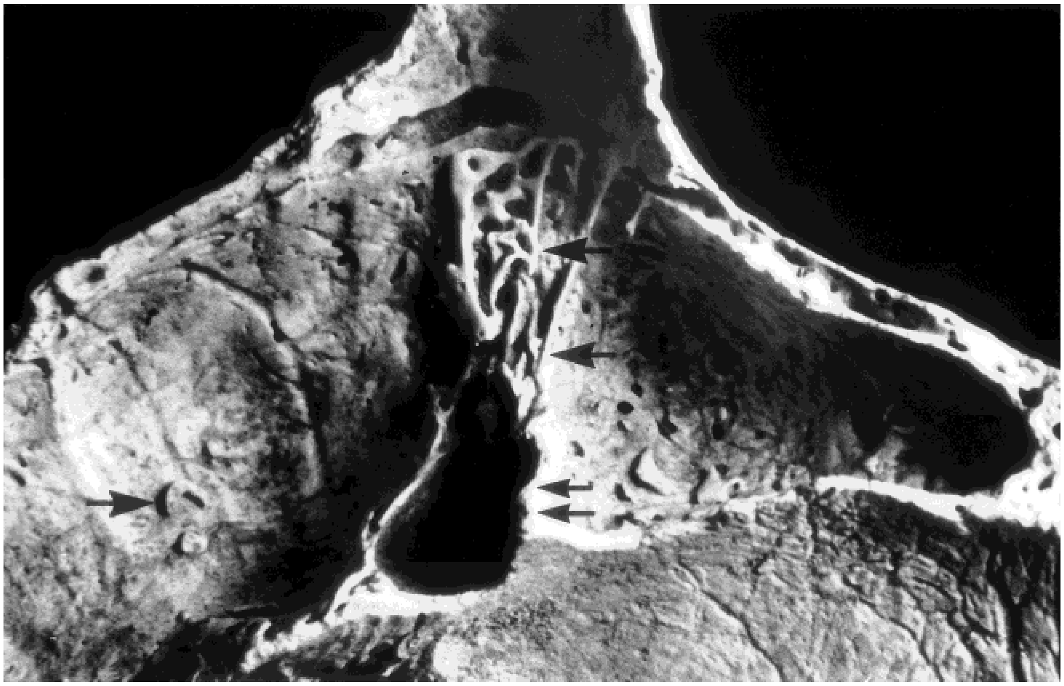

Fig. 1. Spicules (arrows) and a cyst (double arrow) are present in the left maxillary sinus of an adult. Anterior is to the right of the photograph.

morphology that diverges from the usually smooth appearance of the periosteal surface. In each of the categories of osseous lesions, the absence of any bony reaction was scored "0." The categories of spicules and pits describe bony changes occurring on a scale of increasing severity of the reaction. Four gradations are discernible for each category. Once initial assessment was complete, lesion absence was assigned for gradations 0 and 1. The codification for plaque, lobules, and cysts is more descriptive in nature.

The category of "spicules" (Fig. 1) is used to describe a continuum of bone deposition on the periosteal surface of the bone. Single, isolated fine diameter spikes of bone projecting 2–4 mm from the periosteal surface of the bone are the minimum observations in the spicules category. Spicules that were observed in small groups have moderate bridging between the spikes of bone, forming small stellate plates of bone 1–2 mm in diameter. These plates of bone are parallel to, and 1–2 mm above, the periosteal surface. The most severe reactions in the spicules category formed multiple partially overlapping layers of small stellate discs of bone with extensive bridging.

"Cysts" are hemispherical depressions in the bone, with a smooth interior surface and no bony projections into the volume of the cyst. The codification of cysts describes the morphology of the bone deposition surrounding and creating the rim of the cyst. The rims are described as smooth (Fig. 1), surrounded by spicules, or created by crosswalls on the floor of the sinus.

"Pits" (Fig. 2) are described as holes in the periosteal surface of the bone that are less than 1 mm in diameter for low density and medium density pits. At higher density, adjacent pits fuse to create holes 3–5 mm in diameter in the periosteal surface. Pits represent bone resorption, and they may be associated with the hypervascularization that occurs during the initial stages of infection.

Changes to bone morphology that are classified as "plaque" (Fig. 3) vary in two parameters: the texture of the surface, and

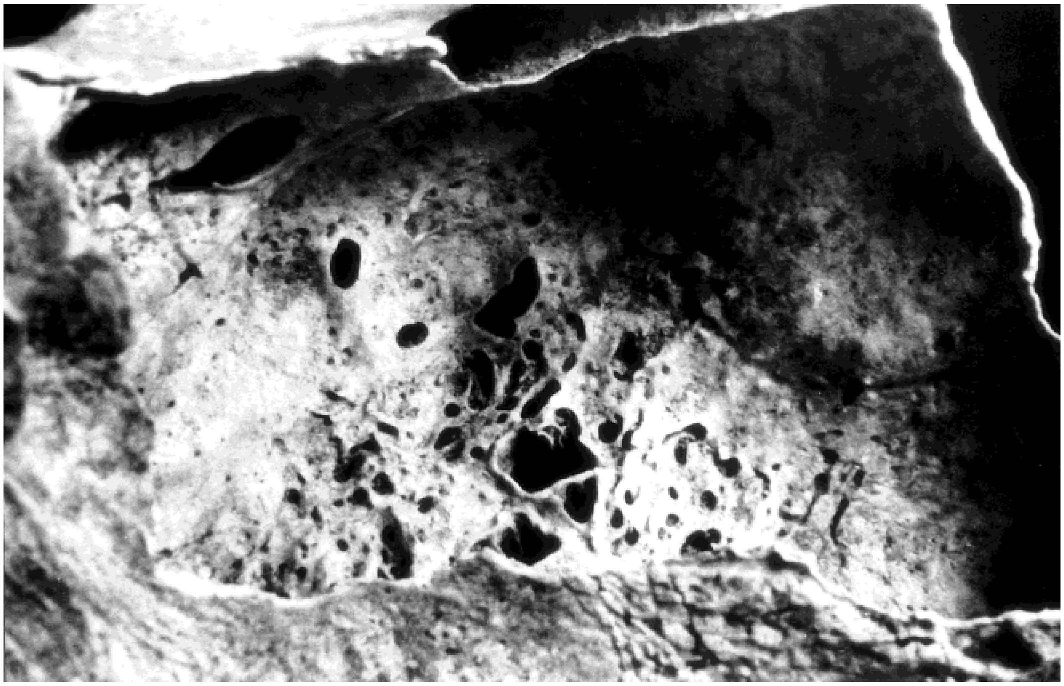

Fig. 2. Coalescing pits are present in the floor of this right maxillary sinus. Anterior is to the left of the photograph.

the thickness of the bony reaction. The surface of the plaque can appear smooth and dense or porous. Two thicknesses of each texture of plaque are distinguished: less than 1 mm and greater than 1 mm. "Lobules" are rounded masses of bone on the periosteal surface of the sinus. The codification of lobules distinguishes between bone deposition at the margin of an oro-antral fistula and bone deposition that is not in association with a cloaca connecting the oral cavity and the maxillary sinus.

Twenty-seven intact skulls were trephined through the posterior wall of the maxillary sinus to allow examination of the interior of the sinus. A 2.7 mm diameter, 30° angle, rigid endoscope was used for the visualization of the maxillary sinus lumen. The signal was recorded on videotape for analysis of lesion morphology.

Intra-observer error for maxillary sinus lesion classification was tested on 10 juvenile and 10 adult maxillae or maxillary fragments assigned from a random number table. The scores for the categories of spicules, pits, and lobules were identical in 80% of cases for spicules and pits, 90% for both plaque and lobules for the juveniles tested, and 100% for plaque and lobules for the adults. Each score obtained was then assessed for presence or absence of the lesion type. In only one case out of 20 did the second assessment not concur with the first. One adult differed in the pits category. During the original scoring, the pits category was the most problematic. In order to maintain consistency, "type" specimens classified in each level of severity were used as reference standards during specimen assessment.

To distinguish between dental and rhinogenous origin of sinus infection, the alveolar bone surrounding the molar and premolar tooth roots was examined for morphological changes that suggest the presence of infectious processes. In cases where the tooth or tooth root(s) were not lost ante-mortem, abscessing was characterized in terms of cloacae either to the buccal and lingual surfaces of the alveolar bone or to the maxil-

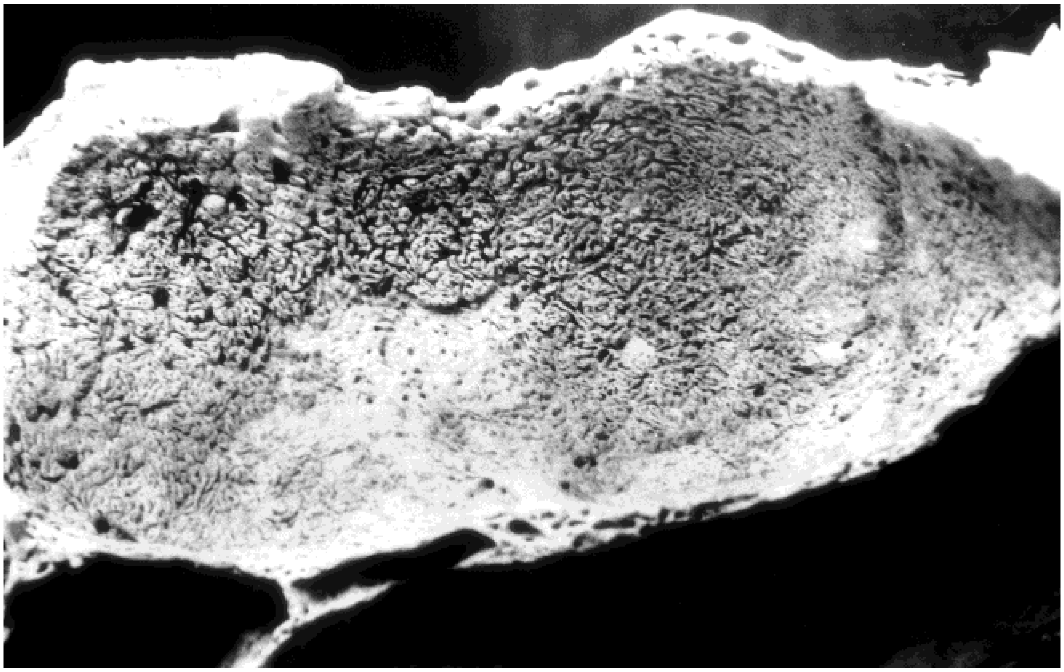

Fig. 3. Thick, porous plaque covers the floor of the sinus of this older adult. Anterior is to the left of the photograph.

TABLE 1. Morphological changes to the sinus and the alveolar process

Age (years)	Age category	N	Remodeling n (%)	Abscessing n (%)	RemIndep[1] n (%)
0–3	Infants and young children	33	3 (9.1)	0 (0.0)	3 (9.1)
4–11	Juveniles	38	17 (44.1)	1 (2.6)	16 (42.1)
12–19	Adolescents	22	11 (50.0)	1 (4.6)	10 (45.5)
20–50	Younger adults	98	60 (61.2)	43 (43.9)	26 (26.5)
>50	Older adults	16	12 (75.0)	13 (81.3)	1 (6.3)
Total		207	103 (49.8)	58 (28.0)	56 (27.1)

[1] RemIndep = remodeling independent of abscessing.

lary sinus lumen. The extent of healing after ante-mortem tooth loss was assessed by the amount of tooth socket left unfilled and the extent to which the alveolar bone has been resorbed. Taking a conservative approach, a dental source of infection was assigned if any cloacae were present or if following ante-mortem tooth loss the tooth socket was not completely filled in, that is, not completely healed at the time of death.

RESULTS

Half (49.8%) of the maxillae examined show changes to bone morphology consistent with maxillary sinusitis (Table 2). The proportion of total remodeling in the maxillary sinuses increases significantly ($\chi^2_{(4df)} = 31.45$, $P < 0.001$) with age (Table 1 and Fig. 4). Abscessing in the total sample also increases ($\chi^2_{(4df)} = 65.7$, $P < 0.001$) with age (Table 1 and Fig. 4). Hierarchical log-linear analysis using the likelihood ratio χ^2 (LR χ^2) statistic suggests that a third-order effect (the interaction among all three variables simultaneously) is not necessary for accurate description of the data (LR $\chi^2_{(4df)} = 1.30$, $P = 0.86$). From tests of partial associations, each of the two-way interaction terms age*remodeling (LR $\chi^2_{(4df)} = 60.46$, $P < 0.05$), age*abscessing (LR $\chi^2_{(4df)} = 17.34$, $P < 0.05$), and abscessing*remodeling (LR $\chi^2_{(1df)} = 15.46$, $P < 0.05$) are required in the statisti-

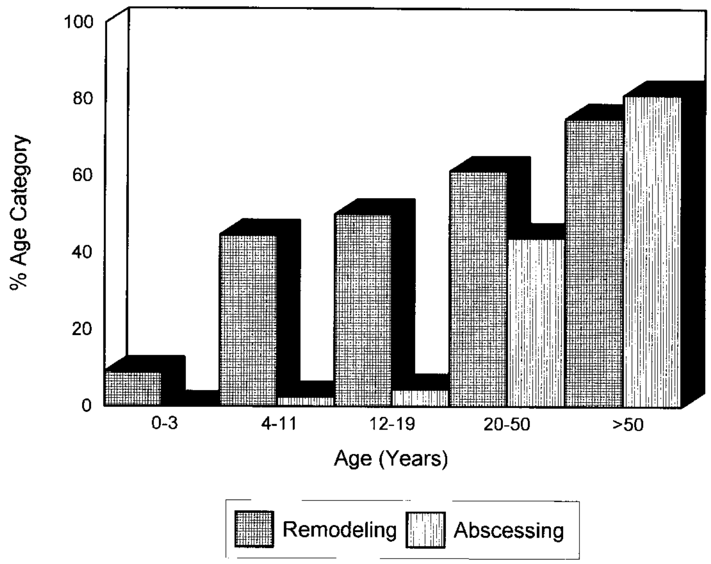

Fig. 4. Morphological changes to the floor of the maxillary sinus and the alveolar process. N = 207. (See Table 1 for numbers of maxillae examined in each age category).

cal model. The main effects of age-at-death (LR ($\chi^2_{(4df)}$ = 87.17, $P < 0.05$) and abscessing (LR ($\chi^2_{(4df)}$ = 41.40, $P < 0.05$) are required. Remodeling (LR ($\chi^2_{(4df)}$ = 0.005, P = 0.94) is not required for accurate statistical description of the data.

Remodeling and abscessing were collapsed into one variable in order to examine the relationship between age and remodeling for the two sources of infection: the respiratory tract and the dentition. Remodeling that is independent of alveolar abscessing (RemIndep) is present in all age categories. RemIndep increases to a maximum in adolescents then declines during adulthood (Table 1) The distribution across age categories is significantly different from the distribution expected due to chance ($\chi^2_{(4df)}$ = 17.06, $P < 0.002$). The prevalence of sinusitis that is independent of alveolar abscessing represents a minimum level of sinusitis of respiratory origin in the sample. In individuals with alveolar abscessing, remodeling may be caused in response to infection of respiratory origin, dental origin, or both. However, in dry bone specimens with both remodeling and abscessing, the source of the infection cannot be determined. Hierarchical log-linear analysis suggests that a second-order effect (the interaction between the two variables) is necessary for accurate description of the data (LR $\chi^2_{(12df)}$ = 96.99, $P <$ 0.05). From tests of partial associations, the two-way interaction term age* RemIndep (LR $\chi^2_{(df)}$ = 17.58, $P < 0.05$) is required in the statistical model. The main effects of age-at-death (LR $\chi^2_{(4df)}$ = 87.17, $P < 0.05$) and RemIndep (LR $\chi^2_{(3df)}$ = 43.33, $P < 0.05$) are also required.

TABLE 2. Individuals with remodeling

Age (years)	N	Abscessing absent n (%)
0–3	3	3 (100.0)
4–11	17	16 (94.1)
12–19	11	10 (90.9)
20–50	60	26 (43.3)
>50	12	1 (8.3)
Total	103	56 (54.4)

In over 90% of the infants, juveniles, and adolescents with osseous lesions, the remodeling observed is independent of alveolar abscessing (Table 2). In adults, alveolar abscessing becomes a confounding factor, probably obscuring sinusitis of respiratory origin.

The osseous lesion types observed in the sample are not present in equal proportions (Table 3). Spicules, plaque, and lobules represent bone deposition, while pits represent bone resorption. Evidence of bone resorption and deposition occur with equal prevalence in the maxillary sinus lesions (spicules 63.1%, pits 59.2%). In the category combinations, 88% of the lesions contain pits, and 66% contain spicules.

TABLE 3. Proportion of osseous lesion types observed

Lesion type	Proportion n	(%)
Spicules	29	28.2
Pits	23	22.3
Plaque	3	2.9
Lobules	2	1.9
Combinations	46	44.7
Total	103	100.0

TABLE 4. Proportion of males and females with remodeling (Rem), abscessing (Absc) and remodeling independent of abscessing (RemIndep)

	N	Rem n (%)	Absc n (%)	RemIndep n (%)
Female	13	11 (84.6)	9 (69.2)	4 (30.8)
Male	17	13 (76.4)	10 (58.5)	3 (17.7)
Total	30	24 (80.0)	19 (63.3)	7 (23.3)

There are no significant differences in the prevalence of remodeling, abscessing, or remodeling independent of abscessing between females and males in the sample (Table 4). The small sample size of thirty individuals, however, makes these conclusions tentative.

DISCUSSION AND CONCLUSIONS

Our results suggest that at least half of the individuals interred in the Uxbridge Ossuary suffered from chronic or recurring maxillary sinus infections. Slightly more than one-quarter of the individuals (28%) exhibit changes to the morphology of the alveolar bone indicating periapical abscessing of the premolars or molars, or abscessing associated with ante-mortem tooth loss. Changes to the bone morphology of the floor of the maxillary sinuses that are independent of alveolar abscessing are present in 28% of the individuals in the sample. The prevalence of bony lesions in the maxillary sinuses (among adults) varies among ages but not between sexes. The prevalence of total osseous evidence of maxillary sinusitis increases with age. Osseous changes suggestive of maxillary sinusitis of respiratory origin are at a maximum prevalence in juveniles and adolescents. In individuals with remodeling, the proportion that does not also have alveolar abscessing decreases with age.

The role of dental factors

Dental health is poor in the Uxbridge population (Patterson, 1984). It is likely that poor dental hygiene compounded the cariogenic effects of maize soup, a staple of fifteenth century Iroquoian diet. Individuals with sinusitis of both respiratory and dental origin cannot be distinguished from those with sinusitis of dental origin alone. The variable of total remodeling does not distinguish among the changes to bone morphology that result from sinusitis of respiratory origin, dental origin, and respiratory origin in individuals who also have alveolar abscessing. As a result, hierarchical log-linear analysis suggests that the main effect of total remodeling is not required in the statistical model to adequately describe the data. There is, however, an interaction effect of remodeling and abscessing due to the dental origin component scored in the variable total remodeling. If there is an interaction between two variables, the cell count observed will be different than that predicted from knowledge of the variable main effects alone (Norušis, 1995). By combining the two variables, remodeling and abscessing, it is possible to effectively partition the observations of remodeling into two groups: remodeling in the presence of alveolar abscessing, and remodeling in the absence of macroscopic evidence of alveolar abscessing. The category of remodeling in the presence of alveolar abscessing also does not distinguish between remodeling of dental origin and remodeling of respiratory origin in individuals who also have alveolar abscessing.

Remodeling that is independent of abscessing underestimates in two ways the prevalence of individuals who, in life, suffered from maxillary sinusitis of respiratory origin. Not everyone with maxillary sinusitis will have periosteal involvement or bone remodeling as a result of the infectious process (Tovi et al., 1992). In addition, the nature of the sample, dry bone specimens, precludes observation of the disease process. Once alveolar abscessing has occurred, and without direct observation of the disease process, it is not possible to distinguish in skeletal remains between primary maxillary sinus bone remodeling and remodeling

TABLE 5. Prevalence of maxillary sinusitis in past populations

Century	Site location	Prevalence (%)	N
6th–11th	Britain	6.8[1]	204
Medieval	Britain	3.6[1]	83
14th	South Dakota	3.9[2]	129
15th	Southern Ontario	49.8[3]	207
12th–17th	Chichester	54.9[4]	133
12th–16th	Urban Yorkshire	55.0[5]	245
12th–14th	Rural Yorkshire	39.0[5]	268
7th–17th	Maastricht	38.9[6]	126
19th	New York State	47.0[7]	69

[1] Wells (1977).
[2] Gregg and Gregg (1987).
[3] Current study.
[4] Boocock, Roberts, and Manchester (1995).
[5] Lewis, Roberts, and Manchester (1995).
[6] Panhuysen, Coenen, and Bruintjes (1997).
[7] Lew and Sirianni (1997).

that is secondary to dental infection or the extent to which alveolar abscessing may be a confounding factor. However, since individuals without maxillary sinus lesions and individuals with remodeling in the absence of alveolar abscessing (RemIndep) occur in all age categories in the Uxbridge Ossuary sample, it is not considered necessary to exclude adults from consideration. The prevalence of RemIndep reflects a minimum level of respiratory health of the Uxbridge Ossuary sample, that is, the general susceptibility of individuals to chronic respiratory infections and the airborne pathogen level of their environment.

The prevalence of maxillary sinusitis observed in this study is consistent with the results of other recent studies (Table 5), where prevalence ranges from 30 to 50%. Because our classification system was revised somewhat, comparison of the absolute prevalence of lesion types cannot be directly compared among the studies. However, the photographs accompanying previous studies (Boocock et al.,1995; Lew and Sirianni, 1997; Panhuysen et al., 1997) suggest that the lesion morphology being described is the same and that inter-sample total lesion prevalence comparisons are thus valid.

The role of specific infectious disease

Boocock et al. (1995) have found a higher prevalence of "white pitted" bone in leprous than in non-leprous individuals. This suggests that certain microorganisms may increase the likelihood of "characteristic" osseous changes and a diagnosis of leprous or non-leprous could be assigned. However, the constraints placed on changes to bony tissues necessitate determination of the spatial distribution of lesions within each individual for confirmation of a diagnosis (Ortner, 1991). Because the Medieval English skeletal sample studied by Boocock et al. (1995) was a series of individual burials, the distribution of lesions throughout an individual body could be determined. The association of "white pitted bone" with leprous individuals was thus possible. The purposeful commingling of the skeletal elements during the ritual secondary interment of the fifteenth century Iroquoians precludes diagnosis on the basis of the spatial distribution of lesions in each individual.

Tuberculosis was present in the people of the Uxbridge Ossuary (Braun et al., 1998; Pfeiffer, 1984, 1991). In *Mycobacterium tuberculosis* infections, lesions are characterized by the predominance of bone destruction of epiphyseal surfaces and vertebral bodies. Bone deposition occurs only after substantial bone destruction in cases where mechanical stabilization of the remaining bone is necessary (Ortner and Putschar, 1981; Steinbock, 1976). Although not diagnostic of tuberculosis, infection of the upper respiratory tract by *M. tuberculosis* is well documented (Grewal et al., 1995; Lee and Drysdale, 1993; Ramages and Gertler, 1985). Based on numerous examples of skeletal changes consistent with tuberculosis at Uxbridge (Pfeiffer, 1984), a predominance of maxillary lesions showing only bone resorption might be expected. Twenty-two percent of the lesions with a single morphological type are classified as pits. In combinations, although most (88%) have changes characterized as pits, all the other morphological types observed are forms of bone deposition. Pits do not predominate over the morphological types that represent bone deposition. The balance of lesions is morphologically consistent with those reported among other past populations. However, this could still be consistent with mycobacterial infection, if bone resorption weakened the walls of the sinus sufficiently. Transfer of masticatory forces from the oral cavity to the upper maxillofacial skeleton (Enlow, 1990) could result in bone deposition in response to mechanical forces of mastication.

An alternative explanation for the role of *Mycobacterium tuberculosis* in the sinuses of the Uxbridge population may be derived from contemporary clinical evidence of maxillary sinusitis. Microorganisms that are isolated from the maxillary sinuses are usually mixed populations of *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Moraxella catarrhalis*, and *Actinomyces* spp. (Daele, 1997; Kaliner et al., 1997; Tovi et al., 1992). In tuberculous infection, decreased immune competence could result in co-infections of the above organisms with *Mycobacterium tuberculosis*. The direct access of the maxillary sinuses to external airborne sources of pathogens may result in bone deposition superimposed on the bone resorption caused by tuberculosis to give the appearance of a nonspecific infection.

Evidence from in vitro bone remodeling studies (Nair et al., 1996) suggests that another scenario is also possible. Calvarial bones and long bones are formed by intramembranous and endochondral ossification, respectively. Cell cultures derived from these two developmentally different bone tissues may respond differently to the same osteolytic mediators, such as tumor necrosis factor (TNF) and epidermal growth factor (Nair et al., 1996). This suggests that osseous evidence of, for example, *Mycobacterium tuberculosis* infection in the maxillofacial skeleton may not exhibit the predominantly lytic effects characteristic of mycobacterial infections that are observed in the infracranial skeleton. Regions of the infracranial skeleton, such as the vertebral bodies which are characteristically resorbed in tuberculous infection, may be less likely to exhibit co-infections with "surface" organisms that may cause bone proliferation, because of their placement deep within the soft tissues of the body. The low likelihood of mixed infections within the vertebral column and the high visibility of osseous lesions of the vertebral bodies contrast greatly with the high probability of mixed infections in the maxillary sinuses. Skeletal material of different developmental origins may have differing responses to mycobacterial infection. The bony response that is recognized as characteristic is also the one that is easily accessible for examination and that is well described in the clinical (Des Prez and Heim, 1990; Hopewell, 1995; Rich and Ellner, 1994) as well as the paleopathological literature (Morse, 1961; Ortner and Putschar, 1981; Steinbock, 1976).

The role of air quality

In a comparison of two Medieval English skeletal samples, the prevalence of maxillary sinusitis was significantly higher in the sample exposed to the high levels of air pollutants of the medieval industrializing urban environment than in the rural sample (Lewis et al., 1995). Within a given community, males and females were affected equally. Our study suggests that Iroquoian men and women were also exposed to similar types and intensities of predisposing factors for the development of chronic sinusitis.

Culture may influence the construction of microenvironments that may be preferentially more detrimental to only certain segments of a population (Schell, 1992). Seventeenth century ethno-historic accounts (Thwaites 1896–1901, cited in Heidenreich, 1971 and Trigger, 1976) suggest that Iroquoian women were responsible for the tending of the fires that heated the longhouse, and for the preparation and slow cooking of the maize soup. The interior of the longhouse is portrayed as a continually smoky environment. Experimental archaeology confirms that in winter, although fires in each of five central hearths in a reconstructed longhouse raised the temperature to 12°C, the smoke generated from the five fires burning continuously for 36 hours created symptoms of burning eyes and lung congestion of sufficient intensity to prematurely terminate the experiment (Fecteau, 1979). Allowing the fires to burn down each evening (Fecteau et al., 1994), may have helped the smoke to dissipate, thus reducing the intensity of the deleterious health effects. However, Trigger (1969) suggests that at least some fires were kept burning at all times to reduce the necessity of restarting the fire. Given the presence of airborne pathogenic microorganisms, crowded dwellings, and reliance on wood fires for heat, any differences between women and men in exposure to wood smoke may not have been sufficient to cause differences in the prevalence of respiratory disease. In Mozambique, cough symptoms are significantly more prevalent in individuals chronically exposed to wood smoke than to emissions from the burning of charcoal and modern fuels. Wood fires produced airborne inhalable particulates in concentrations in excess of twice those produced by the other fuels tested (Ellegård, 1996). If the exposure to wood smoke experienced by fifteenth century Iroquoians was comparable to the levels experienced by the wood users in modern Mozambique, the entire Iroquoian population could be predisposed to the development of maxillary sinusitis.

Life history factors

The prevalence of osseous lesions of the maxillary sinuses varies among the subgroups with respect to age-at-death. "Total remodeling," sinusitis of respiratory plus dental origin, increases with age (Table 1). Fewer infants with remodeling were observed than expected based on the overall sample prevalence of total remodeling. Maxillofacial infection in infants may lead rapidly to meningitis and death (Scott and Dixon, 1959). Since bone remodeling occurs late in the disease process (Ortner, 1991), the lack of pathological alteration to bone morphology does not preclude the presence of acute infectious disease processes in the soft tissues (Wood et al., 1992). Death of the infants without pathologically altered bone involvement may reflect the underdevelopment of the immune system and the resulting inability of the very young to effectively fight infection (Ulijaszek, 1987). In infants, an undeveloped mucosal immune response (Husband and Gleeson, 1996) may result in fewer leukocytes attracted to the site of infection and lower concentrations of cytokines in the respiratory mucosa. Activation by cytokines of the cycles of osteoclast and osteoblast recruitment that are characteristic of infection in adults may be reduced. In addition, reduced immune function in infants may facilitate the rapid progression of respiratory infection to meningitis and death before macroscopic changes to the bone can occur. Infants also undergo rapid maxillofacial growth, with continual changes to the maxillary sinuses (Enlow, 1990). Evidence of pathogen-stimulated bone remodeling may have been removed ante-mortem, since the growth fields within the maxillary sinuses are negative (resorptive).

In juveniles and adolescents, more remodeling that is independent of abscessing was observed than would be predicted from the proportion of juveniles and adolescents in the sample. This may reflect the ability of juvenile and adolescent immune systems to respond to the presence of a pathogen as well as the presence of immunity resulting from prior exposure to the pathogens. Hence, juveniles and adolescents may develop chronic rather than acute infection of the upper respiratory tract, allowing time for bony changes to occur. The eruption of the maxillary dentition may not be a confounding factor in the identification of periosteal inflammatory responses. The floor of the maxillary sinus is a field of negative growth and bone resorption occurs at the periosteal surface even during tooth eruption (Enlow, 1990). Of the nonadults with remodeling, 90% had evidence of bone deposition on the periosteal surface of the sinus floor.

In juveniles and adolescents, over 90% of the remodeling is independent of alveolar abscessing (Table 2). In younger adults, the same frequency was observed as in the overall sample. In older adults, a lower proportion of remodeling independent of abscessing was observed than in the total sample. With increasing age, the cumulative effects of poor dental health, increased length of time for caries development, and increasing amounts of tooth wear with age resulted in extensive abscessing and ante-mortem tooth loss. These may have masked sinus infection of respiratory origin.

The airborne pathogen level in the environment influences the rate of inhalation of pathogens into the maxillary sinuses and the types of diseases that result. The air quality in the environment, measured by decreased levels of humidity within dwellings (D'Souza, 1997) and by increased levels of particulates such as wood smoke (Albalak, 1997), plays a crucial role in predisposing individuals to upper respiratory infections and facilitating damage to respiratory tissues.

The presence of chronic infectious disease may contribute to or be a result of reduced immune function (Shell-Duncan, 1997). In the Uxbridge Ossuary population, the presence of tuberculosis may have reduced the immune competence of most of the village inhabitants and increased the population susceptibility to other infections such as sinusitis. Conversely, the presence of sinusitis may also have contributed to the transmission of tuberculosis. Crowded dwellings and dwelling microenvironments, in which chronic exposure to wood smoke cannot be avoided, may cause respiratory tissue damage that facilitates primary tuberculous infection as well as the reactivation of latent tuberculosis in individuals previously healthy enough to have survived the primary tuberculous infection (Des Prez and Heim, 1990). This may account for more juveniles and adolescents than expected with chronic sinusitis. The prevalence of maxillary sinusitis may thus be a useful indicator of endemic chronic respiratory distress.

The osseous lesions of the maxillary sinuses in the Uxbridge Ossuary sample have the same range of morphology as maxillary sinus lesions observed in populations where tuberculosis has not been identified as a cause of morbidity. That is, the lesions are the result of nonspecific inflammatory responses of bone to injury of unknown origin. Because of the constraints of bone growth and the absence of observable disease process in dry bone samples, it may not be possible to make a differential diagnosis without knowledge of the spatial distribution of lesions within individuals. In Iroquoian ossuary samples, the commingling of skeletal elements during the ceremonial secondary interment precludes the reconstruction of individuals so that the proportion of individuals with both sinusitis and tuberculosis cannot be determined.

Through an assessment of risk allocation (Huss-Ashmore, 1992; Schell, 1992), culture cannot be seen to be neutral with respect to health status. Chronic exposure to wood smoke, with impairment of ciliary function (de Koning et al., 1985; Wright et al., 1994) and increased permeability of respiratory epithelial plasma membranes to pathogens (Brachman, 1990; Wright et al., 1994), may facilitate the development of upper respiratory inflammation. Thus, culturally determined risk factors such as those resulting in the chronic exposure to wood smoke, in specific temporal and spatial contexts, may produce microenvironments that could contribute to adverse health outcomes and promote the occurrence of upper respiratory disease. It has long been known that the consequences of cultural choices may affect the immune status of the individual and the population. Although it is not possible to distinguish among the various factors potentially responsible for the osseous lesions observed, the negative consequences of culturally influenced choices may be seen in the form of a high prevalence of inflammatory diseases such as maxillary sinusitis.

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