International Journal of Paleopathology 44 (2024) 51–64

Contents lists available at ScienceDirect

International Journal of Paleopathology

journal homepage: www.elsevier.com/locate/ijpp

Chronic maxillary sinusitis in palaeopathology: A review of methods

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ARTICLE INFO

Keywords:
Respiratory Disease
Literature Review
Diagnostic Criteria

ABSTRACT

Objective: This study reviews the palaeopathological literature discussing maxillary sinusitis to examine current trends and issues within the study of this condition, and to make recommendations for future research in this area.
Materials: Seventy-five studies were identified through a literature search of digital and physical sources.
Methods: Information regarding study metadata, the populations investigated, sinusitis diagnostic criteria, and sinusitis prevalence was examined.
Results: Populations from the UK and Europe were the most studied, reflecting both palaeopathology's systemic colonialism and academic legacies. Most studies used diagnostic criteria published in the mid-1990s, with some subsequent studies modifying these criteria.
Conclusions: The diagnostic criteria from 1995 are widely used but do not include all possible bone changes seen within sinusitis. There is also a need for researchers to engage in issues of data reductionism when using descriptive categories for archaeological sites and populations.
Significance: This paper provides considerations as to how the 1995 diagnostic criteria may be revised by future researchers and synthesises much of the published sinusitis prevalence data to assist researchers interested in the palaeopathology of respiratory disease.
Limitations: More general osteological research, which includes palaeopathological information, was likely missed from this review due to the choice of key terms and languages used in the literature search.
Suggestions for Further Research: Additional research into sinusitis in archaeological populations outside of Western Europe is required. Further work examining the ability to compare pathological data from macroscopic observation and medical imaging would be advantageous to palaeopathology as a whole.

1. Introduction

Chronic sinusitis, the persistent inflammation of the mucosal lining of the paranasal sinuses, is a ubiquitous health problem, with approximately 6–12% of patients in the Western world affected according to clinical estimates (Dietz de Loos et al., 2019; Fokkens et al., 2020; Orlandi et al., 2016). The aetiology of chronic sinusitis is often difficult to determine, but its causative factors can be placed into three broad categories: congenital predisposition, systemic susceptibility, and the environment (Lewis et al., 1995). In the twenty-first century, environmental factors are now more prominent health concerns for humanity. Over 50% of the global population live in urban environments (Zhang, 2016) and over 99% of the global population are breathing air that exceeds World Health Organisation guidelines on air pollution (World Health, 2022). Respiratory diseases have accounted for multiple epidemics and the recent COVID-19 pandemic.

As palaeopathology progresses into the 21st century, the transdisciplinary value of the field is being explored and commended for what it can offer to contemporary questions and issues (Buikstra et al., 2023). Palaeopathologists have used chronic sinusitis to examine the impact of climate change, industrialisation, and urbanisation on health in the past, as well as a general indicator of an individual's respiratory health (Boyd, 2020; Davies-Barrett et al., 2021; Krenz-Niedbała and Łukasik, 2016; Lewis, 2002; Lewis et al., 1995). However, the standard diagnostic criteria (Boocock et al., 1995a) used by palaeopathologists to identify the presence of chronic sinusitis is almost 30 years old. Whilst it can be debated when a piece of academic work can be considered out of date or limited relevance, many would likely agree that after three decades it is time for a method and its related pieces of work to be reviewed. In this vein, this paper will review palaeopathological

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https://doi.org/10.1016/j.ijpp.2023.11.005
Received 30 April 2023; Received in revised form 17 November 2023; Accepted 28 November 2023
Available online 25 December 2023

literature, both published and unpublished, on chronic maxillary sinusitis, identify trends in publication and methods whilst also compiling the examined data into a single available source for other researchers interested in chronic sinusitis and respiratory disease.

1.1. Chronic sinusitis, osteitis and bioarchaeology

The paranasal sinuses are four sets of bilateral air-filled chambers within the ethmoid, sphenoid, frontal and maxillary bones of the facial skeleton (Whyte and Boeddinghaus, 2019). Whilst the exact anatomical function of these sinuses is debated by comparative anatomists (Márquez, 2008), these chambers are lined with a mucous membrane (mucosa) which helps to maintain a stable and healthy internal environment (Gudis et al., 2012). The mucosa is comprised of mucus producing ciliated epithelial cells which enable inhaled particulates and pathogens to be trapped and cleared from the sinus (Stannard and O'Callaghan, 2006). Ostium, small holes within the sinus wall, allow for the drainage of the contaminated mucus into either the ostiomeatal complex or sphenoethmoidal recess, thus removing the trapped particulates and pathogens (Jones, 2001). If the ostium, ostiomeatal complex or sphenoethmoidal recess becomes blocked, then mucus can accumulate within the affected sinus which creates a deoxygenated environment with a lowered pH which will promote the growth of anaerobic bacteria and can damage the cilia, leading to inflammation of the sinus. (Naclerio and Gungor, 2001). In clinical settings sinusitis is classed as an acute inflammation when any symptoms have resolved within 12 weeks, while any inflammation of sinusitis exceeding 12 weeks is deemed to be chronic (Sinusitis, 2023). Whilst viral infection is the typical cause of acute forms of sinusitis (Rosenfeld, 2016), other possible contributing factors can include physicality (e.g., craniofacial variation, nasal obstructions and/or trauma), the environment (e.g., air pollution, population crowding) and other health conditions (e.g., allergic rhinitis, dental disease, and infectious diseases such as leprosy) (Brook, 2009; Min et al., 1996; Psillas et al., 2021; Romeo and Dykewicz, 2014; Simkovich et al., 2019). Inflammation within the sinuses can become cyclical, as often the primary form of ostial blockage is the inflammation of the surrounding mucosa, which can become more inflamed as the quantities of pathogens and particulates held in the accumulating mucus increase (Brook, 2009; Naclerio and Gungor, 2001). The clinical diagnosis of chronic sinusitis often relies on the use of medical imaging techniques such as CT scans. Evidence of sinusitis visible on CT scans may appear as ostial narrowing or obstruction, thickening or opacification of the mucosa and opaque sinuses, indicative of high levels of fluid therein (Dykewicz and Hamilos, 2010; Lund and Kennedy, 1997; Okushi et al., 2013).

Osteitis can develop within sinusitis, but it is not considered a criterion for a clinical diagnosis. Osteitis can simply be defined as inflammation of marrow-less bone, but there is no universally agreed definition within the clinical literature and other terms may be used such as osteomyelitis, neo-osteogenesis, or bone remodelling (Bhandarkar et al., 2012; Leung et al., 2016; Videler et al., 2011). Osteitis and its role within chronic sinusitis has been less studied by clinicians compared to the role of the mucosa (Bhandarkar et al., 2012). The aetiology and pathogenesis of osteitis within sinusitis are unclear, with clinicians suggesting a transference of the inflammation in the mucosa to the underlying bone or a more direct bacterial infection of the bone itself as possible causes (Antunes and Kennedy, 2014; Naclerio and Gungor, 2001; Orlandi et al., 2016; Videler et al., 2011). Despite this, the incidence of osteitis in cases of chronic sinusitis, examined through radiological and histological methods, is as high as 50–60% (Georgalas et al., 2010; J. T. Lee et al., 2006; Snidvongs et al., 2012). Clinical studies have also shown a statistically significant relationship between the severity of osteitis seen and the severity of chronic sinusitis (Cho et al., 2006; Georgalas et al., 2010; J. T. Lee et al., 2006; Snidvongs et al., 2012). Specific types of bone changes noted in clinical contexts include periosteal thickening, new bone formation, and bony erosion (deShazo and Swain, 1995).

It is these changes to the sinus walls, alongside others, which have been taken by bioarchaeologists as evidence that chronic sinusitis was present in life (Wells, 1977). Whilst sinusitis can occur in any of the paranasal sinuses, the maxillary sinus is the largest of the sinuses and often the best-preserved and most accessible, leading bioarchaeological research to focus on these (Davies-Barrett et al., 2021; Sundman and Kjellström, 2013b) As such, this review will also focus on palaeopathological literature focusing upon chronic maxillary sinusitis.

2. Materials and methods

An online literature search using Google Scholar was performed with the key terms "Archaeology", "Chronic", "Maxillary" and "Sinusitis". This search used the terminal date of December 2022 and was performed in English, French, Spanish and German to broaden the search outside of papers using English key terms or titles regardless of the written language of the main text. Data collection occurred between 2020 and the start of 2023, with the search being repeated several times to capture publications that were newly published, recently digitised or made available by authors.

The following information was recorded, as published and where available:

- The type of source: Journal Article; Book Chapter/Monograph; Masters or PhD Dissertation/Thesis; Conference Presentation.
- The number and location of sites included in the source, and whether they were composites of multiple sites.
- Site information: The broad period and date range; environment (e.g., urban, rural); socioeconomic status (e.g., low, high); Subsistence Strategy (e.g., hunter-gatherer, agriculture).
- The inclusion criteria, methodology for examination of the sinuses, and diagnostic criteria for sinusitis.
- The number of individuals examined and the prevalence of sinusitis, occurrence of odontogenic sinusitis, and whether the crude prevalence, true prevalence, or both were provided.
  - Crude prevalence is calculated as the individuals affected/the individuals with the required skeletal element, or the individuals affected/total individuals present. Identifying which of these calculations has been applied is not always simple and often results from osteological reports, particularly older ones, only provided information detailing how many individuals were affected by a particular condition with no further information about how many individuals had the relevant skeletal element present (Roberts and Cox, 2003). In cases where a crude prevalence had not been provided, this was calculated preferentially in relation to the number of individuals with the required skeletal element, if information was available, otherwise it was calculated in relation to the total number of individuals for the site.
  - True prevalence is calculated as the number of relevant skeletal elements affected/total number of relevant skeletal elements present.

Physical copies of literature available in libraries accessible to the authors were also examined where possible. Where prevalence was published in secondary sources, the primary source was identified and searched for using Google Scholar, academic library catalogues, or, for sites in the United Kingdom (UK), the Archaeological Data Service (https://archaeologydataservice.ac.uk/). Where primary sources for prevalence data could not be accessed, only the prevalence data and site data available within the secondary source were recorded.

Published prevalence was assumed to be crude where no stratum-specific information was present. The date range for missing primary sources was assigned as the date range for the period rather than a specific range for the site. The exceptions to this were two sites in London (Christchurch Spitalfields and St Bride's Lower Churchyard), as these sites are well documented outside of the missing primary sources. The subsistence strategy for all missing primary sources was assumed to be "agriculture", as they were all from the UK and dated to the Roman period (CE 43 – 410) or later.

Where sites were noted to be composites, additional information regarding how many sites formed the composite was sought within the original text or corresponding supplementary data and this information was included in the calculations of the total number of sites that have been studied in the identified literature. If a composite site contained a site that had not already been published elsewhere, then that site was not included in the total number of sites studied. For example, in the composite site "St Helen-on-the-walls and Fishergate House, York" (Shapland et al., 2015), only Fishergate House is counted towards the count of unique sites, as St Helen-on-the-walls had been published three times elsewhere (Lewis, 2002; Lewis et al., 1995; Roberts et al., 1998). Additionally, the composite sites published in Wells (1977) are not included in this calculation, as there was not enough information present in the paper to indicate how many unique sites comprised the composite sites. Correlations were calculated as Pearson's Correlation Coefficient.

3. Results

3.1. Study metadata

Seventy-five studies (see Supplementary Data 1) were identified with a mean of 1.25 studies being produced per year since the earliest in 1967 (Fig. 1). Five (6.66%) of these had no date of production (Conheeney and Waldron, n.d.; Harman, n.d.; Lee, n.d.-a, n.d.-b; Wells and Collis, n.d.).

The largest source of maxillary sinusitis studies was the secondary source of Roberts and Cox (2003) which included 32 (42.66%) of the 75 studies found. Of these 32, the primary source could be accessed in 15 cases, 14 of the inaccessible primary sources were cited as unpublished case reports, and the final three studies have not been digitised and no physical copy could be accessed. Of the 61 studies and published reports, the majority were located within peer-reviewed journals (n = 27, 44.26%), The three journals containing the greatest number of studies were the *American Journal of Physical Anthropology* [now the *American Journal of Biological Anthropology*] (n = 7), the *International Journal of Osteoarchaeology* (n = 6), and the *International Journal of Paleopathology* (n = 4). Following peer-reviewed journals were: site monographs (n = 21, 34.43%), Masters or PhD dissertations/theses (n = 8, 13.11%), book chapters (n = 4, 6.56%), and conference abstracts (n = 1, 1.64%). Most studies were written in English (n = 71, 94.66%), with two studies in German, one study available in both Russian and English, and one study in Chinese, which included an English title and abstract.

3.2. Site information

Across the 75 studies, sinusitis prevalence was calculated 146 times for populations from 130 named sites, and 17 of these named sites were composites (see Supplementary Data 1). Where composite sites were identified, the number of sites comprising the composites was noted. Removing unidentifiable sites or sites already published elsewhere, increased the total number of populations represented to 157. The global distribution of these populations, according to modern geopolitical boundaries, was spread across 20 countries but was concentrated in Europe with 105 populations (67.31%) on the continent, with the UK being the country with the most studied populations (n = 63, 40.13%), followed by the United States of America (USA) (n = 24, 15.29%) and Sweden (n = 18, 11.46%) (Fig. 2).

This geographic dominance by the UK can be attributed to the studies included within Roberts and Cox (2003) and Masters or PhD dissertations/theses, as these represent 33 studies and 53 sites. Within peer-reviewed articles, populations from the UK are still the most commonly studied, with eight articles representing a minimum of 15 sites. Populations from all other countries featured in this study were represented in peer reviewed journals except Austria, Germany, and Iceland. Date ranges were available for 144 sites, and 123 of these were dated to within the last two millennia; 14 sites had ranges over the transition between BCE and CE dates, and only seven sites had exclusively BCE date ranges (Fig. 3). The most commonly represented country of origin for the populations which were dated outside of the last two millennia was Sudan (see Supplementary Data 1).

Descriptions of a site's environment were present in 112 cases. Most sites were reported as being either urban (n = 50, 44.64%) or rural (n = 50, 44.64%), and there were two sites which transitioned from

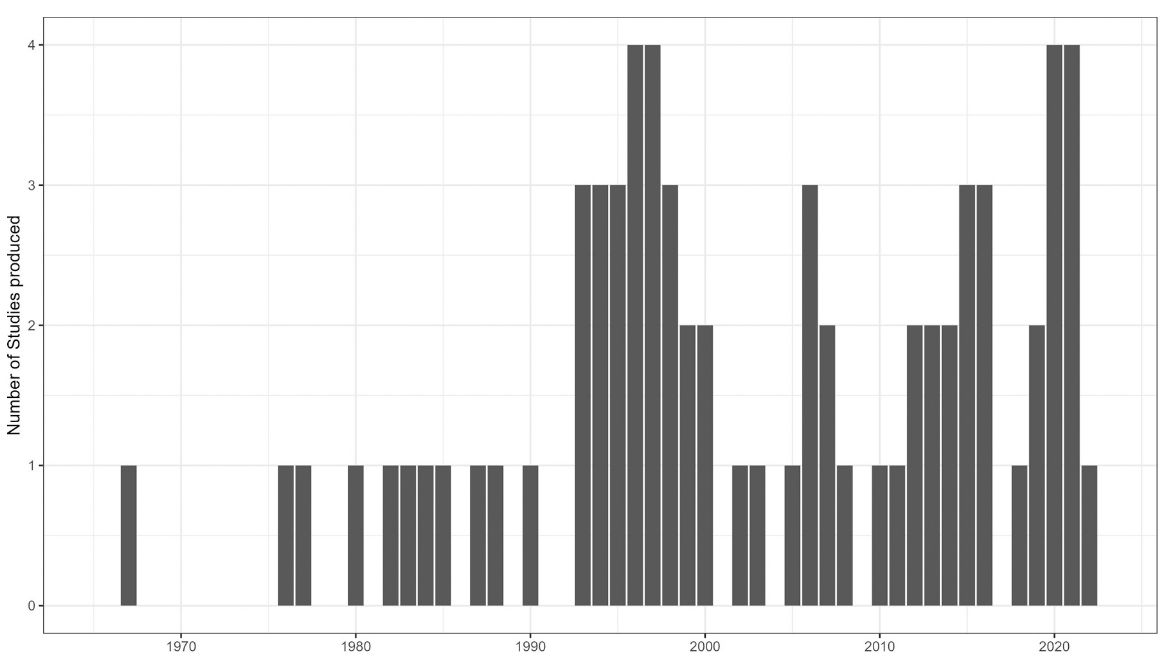
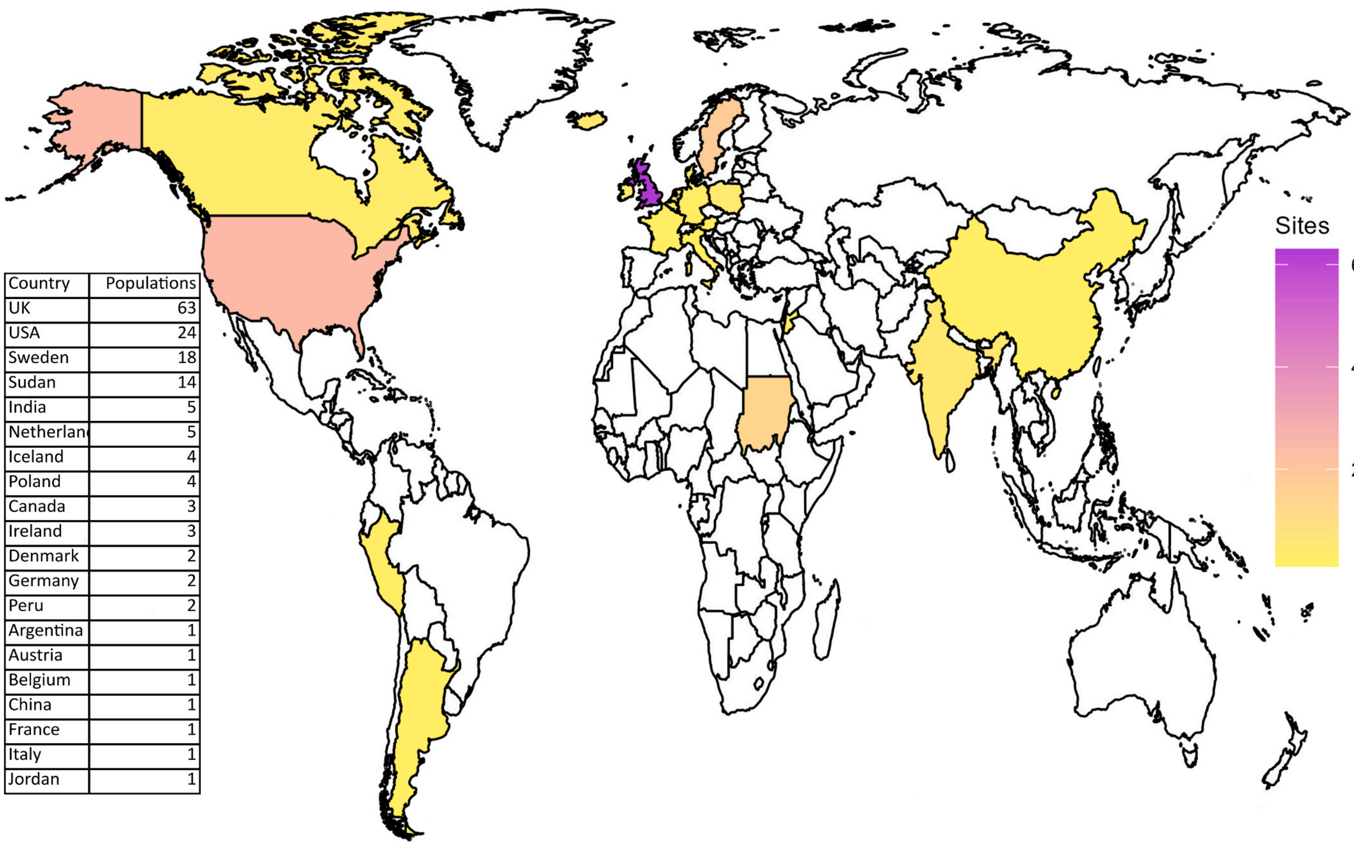


Fig. 1. Number of studies on maxillary sinusitis produced per year in palaeopathological literature.



Country	Populations
UK	63
USA	24
Sweden	18
Sudan	14
India	5
Netherlan	5
Iceland	4
Poland	4
Canada	3
Ireland	3
Denmark	2
Germany	2
Peru	2
Argentina	1
Austria	1
Belgium	1
China	1
France	1
Italy	1
Jordan	1

Fig. 2. The number of populations per country featured within palaeopathological literature on sinusitis.

rural to urban across their date range. The other environmental descriptors used were farm/community church (n = 3); semi-urban (n = 2); proto-urban (n = 1); early urban (n = 1); monastery church and cemetery (n = 1); industrial (n = 1); and monastic (n = 1) (see Supplementary Data 1).

Subsistence information could be assessed for 138 sites, with most being associated with agriculture (n = 128, 92.75%). The other sites were described as hunter-gatherer (n = 4), agro-pastoral (n = 3), and transitional between agropastoral and agriculture (n = 1) or hunter-gatherer and early agriculture (n = 2) (see Supplementary Data 1).

Descriptors of a site's socioeconomic status were reported in 25 cases, with low socioeconomic sites forming the largest group (n = 11, 44.00%). High socioeconomic sites were present six times. The remaining sites represented either mixtures of lower and middle socioeconomic populations (n = 3) or middle and higher socioeconomic populations (n = 5) (see Supplementary Data 1).

3.3. Existing methodologies

Sinusitis methodologies were examined in 55 of 75 studies (72.33%) (see Supplementary Data 2). This was not possible for 17 studies reported in Roberts and Cox (2003), as discussed above, as well as three other pieces of work (Bernofsky, 2006; Gregg and Gregg, 1987; Merrett, 2003), as no digitised or physical versions of the texts could be found.

3.3.1. Inclusion criteria

Twenty-one studies did not provide any explicit inclusion criteria for their work relating to the physical preservation of the maxillary sinus. Nineteen of these were general osteological reports rather than works focused on sinusitis. The other two were Wells (1977), who outlined some of the pathological changes that can be identified in the maxillary sinuses with a primary focus on maxillary sinusitis, and Zubova et al. (2022), who presented a meta-analysis of published sinusitis prevalence.

Twenty-two studies specified that individuals with at least one maxillary sinus should be present without further clarification, and 11 studies provided further clarification. Four studies specified that the floor of whichever sinus was present should be complete (Boocock et al., 1995a; Krenz-Niedbała and Łukasik, 2016; Sundman and Kjellström, 2013a; Eriksson, 2019). Mushrif-Tripathy (2014) and Riccomi et al., (2021) take this further, requiring a sinus with both the sinus floor and the wall to be preserved. DiGangi and Sirianni (2017) targeted individuals that had at least one intact maxilla whilst Zubova et al. (2020) targeted individuals with fully developed maxillary sinuses. Three studies specified a minimal percentage of sinus preservation for individuals to be included. Davies-Barrett et al. (2021) required at least 5% of a sinus to be present for an individual to be included in their analysis, whereas Bernofsky (2010) and Casna et al. (2021) required a minimum of 25% of the sinus to be present, though Bernofsky (2010) only required the presence of one maxillary sinus whereas Casna et al. (2021) required both sinuses to be present. Both these studies also had additional criteria, with Bernofsky (2010) accepting complete sinuses where a natural opening of 5 mm was present to allow the use of an endoscope. Casna et al. (2021), in contrast, provided further restrictions with individuals showing signs of dental disease, lytic lesions in the vertebrae and/or new bone formation on the ribs being excluded from further analysis. The only study requiring a broader inclusion criterion than the presence of a maxillary sinus was Mays et al. (2014). This study required the presence of an intact nasal cavity with at least one or both middle nasal conchae surviving, as the work was focused on the presence of concha bullosa rather than sinusitis.

Only three studies (Boyd, 2020; Roberts, 2007; Shapland et al., 2015) explicitly stated that individuals who could not be sexed were excluded from their analysis, with Roberts (2007) and Boyd (2020) wanting to examine sex differences in the prevalence of chronic

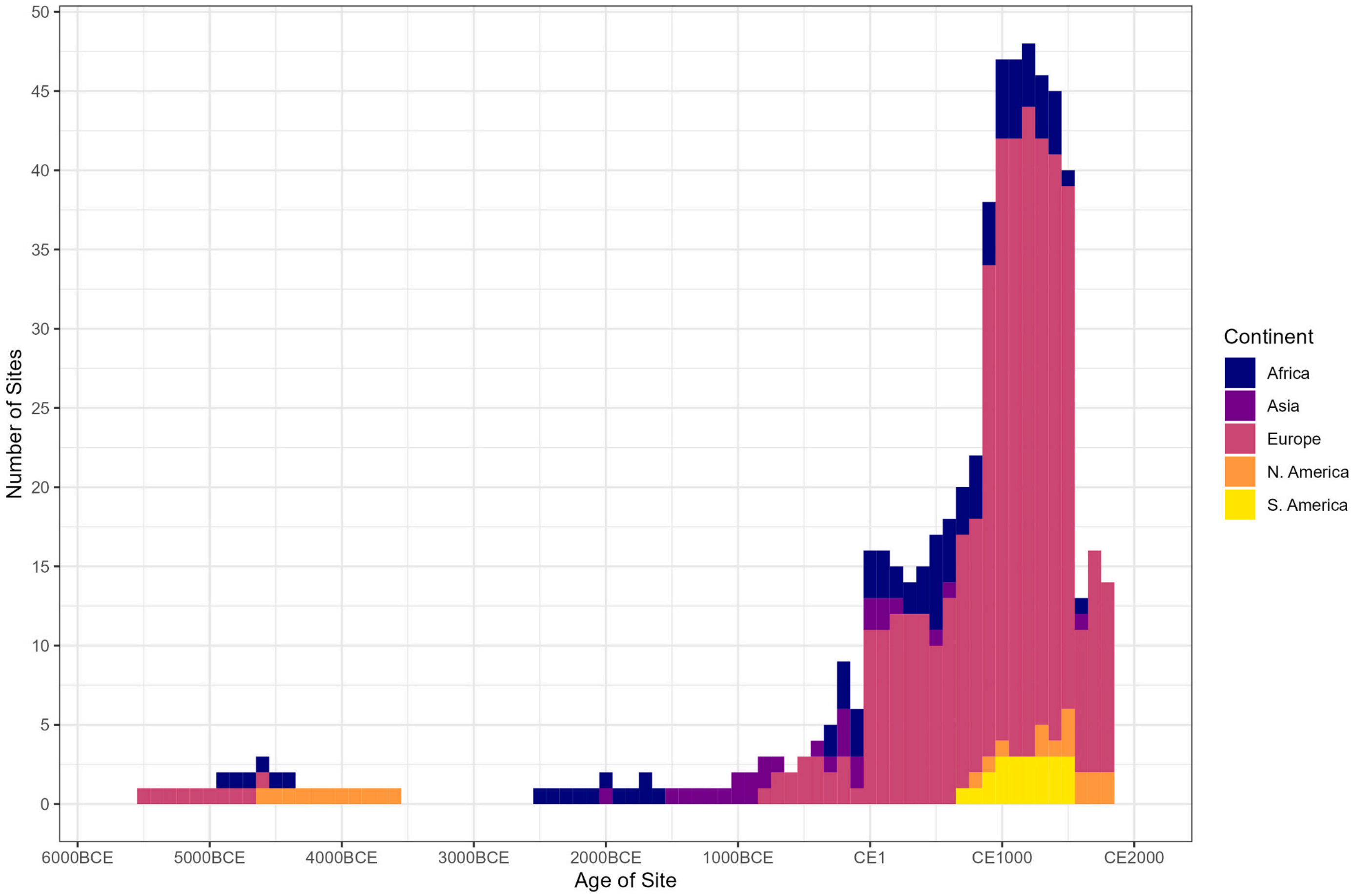


Fig. 3. The concentration of site occupation or use, by continent, across time.

maxillary sinusitis and Shapland et al. (2015) examining only female individuals.

Fifty-three studies contained information on whether included individuals were adult, non-adult or both, though Lew and Sirianni's (1997) conference abstract did not include any information regarding the age of the individuals examined. Most studies featured both adults and non-adults in their work (n = 37, 69.81%), followed by adult-only studies (n = 13, 24.53%) and three studies focused solely on non-adults (5.66%) (see Supplementary Data 1). The age at which individuals were deemed an adult ranged between 17 and 25 years of age.

3.3.2. *Sinusitis diagnostic criteria and methods*

The first systematic guide to bone changes seen in archaeological examples of chronic maxillary sinusitis was published by Boocock et al. (1995a). The five changes Boocock et al. (1995a) noted within maxillary sinuses were categorised as follows (see Fig. 4):

1. Pitting: Fine pits are often seen in association with other types of bone changes.
2. Spicules: Thin spikes of bone which have a cancellous nature and which appear to have been applied to the original bone surface.

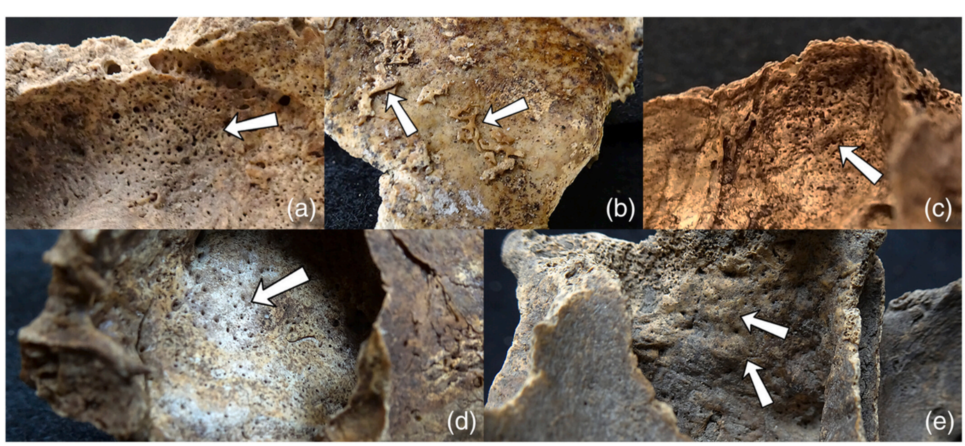


Fig. 4. Examples of bone changes related to chronic maxillary sinusitis seen by Casna et al. (2021, Fig. 4), with lesions indicated by the white arrows: a) pitting; b) spicules; c) remodelled spicules; d) pitted white bone; e) "other" (pictures taken by M. Casna). Licensed for use by CC BY 4.0.

3. Remodelled Spicules: The spicule formations appear to be remodelling into the sinus walls. The spicules may merge and become plaque-like or form bone with the appearance of molten wax.
4. White Pitted Bone: Discrete areas of change which are highly pitted and white when compared to the surrounding bone. This may sometimes transmit to the outer surface of the sinus.
5. Thickened Sinus Walls/Lobules: The walls of the sinus are thickened and porous and the interior of the sinus contains lobules of white bone. It should be noted that whilst Boocock et al. (1995a) note this bone change as being sometimes present, they do not list it specifically as part of their diagnostic criteria. As such, most subsequent studies using Boocock et al. (1995a) do not include it as part of the original diagnostic criteria.

Eleven studies predated Boocock et al. (1995a) (see Supplementary Data 1), and these either stated that individuals were present with sinusitis or described some of the bone changes observed. Twenty-one of the 43 studies (48.84%) produced after Boocock et al. (1995a) reference this study directly (Fig. 5). In the 14 studies that had no direct or secondary link to Boocock et al. (1995a), there were no diagnostic criteria provided, with nine noting only that pathological changes in the sinuses were observed.

Thirty-five studies examined sinuses only when the internal surfaces were observable to the naked eye and 19 used endoscopes. Of these, seven drilled holes through the sinus walls to create access points, whereas the other 12 used taphonomic alterations or anatomically occurring breaks in the bone as access points (e.g., the lower orbital wall as used by Casna et al. (2021)). Ten of the studies, which used endoscopes, provided no information as to what view angles were used to visualise the sinuses examined. Six different view angles were used by the nine papers that recorded this detail, these were 0° (n = 4), 30° (n = 5), 45° (n = 2), 60° (n = 1), 70° (n = 4), and 90° (n = 2). Where multiple view angles were used, the most common combination was 0°, 30°, and 70°. In addition to macroscopic and endoscopic visualisation, histological analysis was used once (Klinger, 2016) and two studies used CT scanning to examine sinuses within complete crania (Zubova et al.,

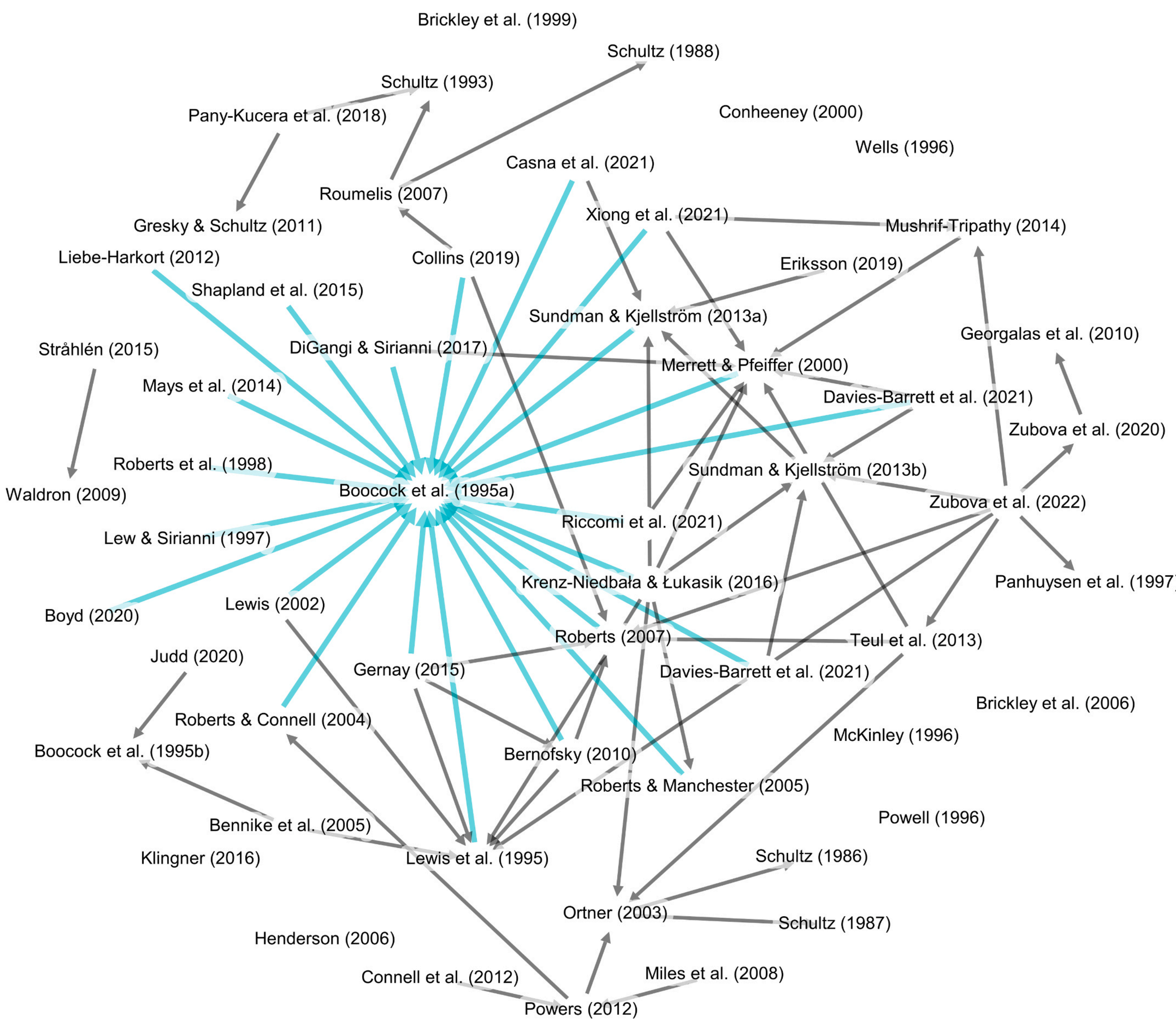


Fig. 5. Network analysis of studies produced from 1995 onwards and their references for maxillary sinusitis diagnostic information. Light connections signify references to (Boocock et al. (1995a); Brickley et al., 1999; Conheeney, 2000; Gernay, 2015; Gresky and Schultz, 2011; Henderson, 2006; Judd, 2020; Klingner, 2016; Liebe-Harkort, 2012, Miles et al., 2008; Ortner, 2003; Powell, 1996; Powers, 2012; Roberts and Connell, 2004; Roberts and Manchester, 2005; Schultz, 1986; Schultz, 1987; Schultz, 1988; Schultz, 1993; Waldron, 2009; Wells, 1996).

2020, 2022).

Twenty-six studies included a discussion of maxillary dental disease within their methodologies. As stated above, Casna et al. (2021) excluded individuals with signs of dental disease from their analysis. Boyd (2020) chose not to include dental data, though available, in their analysis. In addition, Eriksson (2019) stated in their discussion that they did not include any maxillary sinusitis in their results that was considered to have a dental origin, though they do not state whether this means that individuals with observable dental disease were excluded from their study initially. The remaining 23 studies recorded eight different forms of dental disease, though no study recorded all eight. The eight forms recorded were oroantral fistulae (n = 15), antemortem tooth loss (n = 12), dental abscesses (n = 11), periodontal disease (n = 9), caries (n = 7), periapical lesions (n = 7), calculus (n = 1) and osteomyelitis (n-1). No studies that included both abscesses and fistulae defined the difference between these categories, and only one study (Krenz-Niedbała and Łukasik, 2016) employed a diagnostic differential framework for abscesses (Ogden, 2007). It should be noted that without studies providing diagnostic criteria for the range of dental conditions that could be broadly defined as alveolar cavities of pulpal origin (e.g., periapical lesion, dental abscess, fistulae), it is potentially impossible to precisely identify what type of dental lesions were being recorded. Two studies (DiGangi and Sirianni, 2017; Mushrif-Tripathy, 2014) also noted whether the molars' roots protruded into the sinus. Zubova et al. (2020) recorded whether there were channels which connected the sinus to the alveoli.

In this vein, of the 40 studies which included the issue of dental disease in their methods, results, or discussions, 27 provided an explanation of which criteria could be considered potentially diagnostic of odontogenic sinusitis. Three studies (Panhuysen et al., 1997; Pany-Kucera et al., 2018; Teul et al., 2013) suggest an odontogenic cause if any dental disease was present and Stråhlén (2015) linked sinusitis to a severe case of caries. The remaining 24 studies focused on either the presence of dental abscesses and/or some form of a "connection" between the sinus and dentition. These connections most commonly took the form of oroantral fistulae but also included microscopic defects and channels visible on CT scans which connected the alveoli to the sinuses which did not form fistulae. Most commonly used were the presence of a connection between the sinuses and the dentition and/or alveolar bone regardless of the presence of dental disease (n = 10) and the presence of a connection between the sinus and a dental abscess (n = 10). The presence of an abscess without explicit information as to whether this is connected to the maxillary sinus was used by three studies (Brickley et al., 2006; Merrett and Pfeiffer, 2000; Mushrif-Tripathy, 2014). In addition, Merrett and Pfeiffer (2000) and Mushrif-Tripathy, (2014) also considered sockets which were not completely healed after antemortem tooth loss to be a criterion for odontogenic sinusitis.

3.3.3. *Diagnostic modifications*

Eleven studies which referenced Boocock et al. (1995a) modified the original criteria, with a further five studies following these modifications or providing further modifications (Table 1). These modifications

Table 1
The modifications present within the 16 studies which modify the Boocock et al. (1995a) diagnostic criteria.

Study	Bone Changes included									Other modifications/comments
	Pitting	Bone Spicules	Remodelled Spicules	White Pitted Bone	Lobules	Plaque	Cysts	Hole	Other	
Boocock et al. (1995b)	X	X	X	X	X					
Bennike et al. (2005)		X	X	X						Excludes "Pitting" as studying non-adults.
Casna et al. (2021)	X	X	X	X					X	
Collins (2019)	X	X	X	X						Roumelis (2007) scoring system for the promontory of the middle ear adapted for maxillary sinusitis. Sinusitis in non-adults was only recorded where spicules were formed, or pitting was large enough to suggest pathological coalescing.
Davies-Barrett et al. (2021)	X	X	X	X					X	"White Pitted Bone" was renamed as "Porous New Bone" to avoid confusion with "Pitting".
Davies-Barrett et al. (2021)	X	X	X	X					X	"White Pitted Bone" was renamed as "Porous New Bone" to avoid confusion with "Pitting".
DiGangi and Sirianni (2017)	X	X	X							
Eriksson (2019)	X	X	X		X					Modifies the scoring system presented by Sundman and Kjellström (2013a) to account for the difference in size between non-adult and adult sinuses.
Krenz-Niedbała and Łukasik (2016)	X	X	X	X	X	X	X			Each lesion is recorded according to severity, defined by % of the affected area of the sinus. Excludes "Pitting" when studying non-adults.
Lewis (2002)		X	X	X						Excludes "Pitting" as studying non-adults.
Merrett and Pfeiffer (2000)	X	X	X		X	X	X			Bone changes are scored according to the severity of the reaction (score breakpoints are specific to each bone change).
Mushrif-Tripathy (2014)	X	X			X		X	X		
Riccomi et al (2021)	X	X	X	X	X	X	X			
Sundman and Kjellström (2013a)	X	X	X	X					X	Bone changes are scored based on the severity of changes and the size of the area affected. Each surface of the sinus is recorded individually rather than the sinus as a whole.
Sundman and Kjellström (2013b)	X	X	X	X					X	Follows the scoring system presented bySundman and Kjellström (2013a)
Teul et al (2013)	X	X	X		X		X			
Xiong et al. (2021)	X	X			X	X	X	X		

typically focused on the addition of bone changes not already described by Boocock et al. (1995a) or authors excluding specific bone changes described by Boocock et al. (1995a) because they were not present within their sample. Pitting was also excluded in four studies (Bennike et al., 2005; Collins, 2019; Krenz-Niedbała and Łukasik, 2016; Lewis, 2002) when non-adults were analysed because there is a risk that developmental pitting within the alveolar bone superior to the developing teeth may be confused with inflammatory pitting (Lewis et al., 1995). The additional categories seen in the modified methods are as follows (definitions for "Plaque" and "Cysts" adapted from Merrett and Pfeiffer (2000) and "Hole" from Mushrif-Tripathy (2014)):

- Plaque: A deposition of smooth and dense or porous bone on the sinus walls.
- Cysts: Hemispherical depression with a smooth interior surface into the bone.
- Hole: An opening with a rounded margin that has formed due to tooth roots penetrating the sinus floor.
- Other: Changes not otherwise described by Boocock et al. (1995a).

Scoring systems to describe the severity of chronic maxillary sinusitis have been devised on several occasions by researchers (Collins, 2019; Merrett and Pfeiffer, 2000; Sundman and Kjellström, 2013a). Merrett and Pfeiffer (2000) scored each bone change depending on the severity of the change seen (e.g., pits: from low density and less than 1 mm in diameter to high density and 3–5 mm in diameter where smaller pits have fused) or variations in the change seen (e.g., plaques: can vary in texture: smooth and dense or porous; and thickness: less than or greater than 1 mm). Sundman and Kjellström's (2013a) scoring system focused on how much of the sinus floor or wall was covered by bone changes (0: no change, 1: changes in an area 1.5 cm^2 >, 2: changes in an area 1.5–2.5 cm^2, 3: changes covering 50%< of the sinus wall). Collins (2019) adapted the scoring system presented by Roumelis (2007) for scoring changes in the tympanic cavity to cover bone changes within the maxillary sinus. This system combines the consideration of both the type of change seen and the amount of the sinus the change is present in, with lower grades focusing on smaller areas of bone deposition and higher grades focusing on large areas exhibiting destructive bone changes.

3.4. Recorded prevalence of sinusitis

All of the 75 studies provided a crude prevalence ($n = 147$) in their work or information from which a crude prevalence could be calculated. The crude prevalence for maxillary sinusitis ranged from 0.00% to 100.00% (see Supplementary Data 1) with a mean value of 38.30%. Two sets (McKinley, 1996; Wells and Cayton, 1980) of prevalence values were found to differ from the values published in Roberts and Cox (2003) as additional individuals with sinusitis were recorded in the original texts. A typographical error was also identified in the prevalence value for Skriðuklaustur as reported in Collins (2019). A weak negative correlation was calculated between the sample population size and the reported prevalence ($r(144) = -.19$, $p = .020$). This becomes a moderate negative correlation ($r(143) = -.41$, $p < .001$) when the outlier sample population ($N = 5387$) from Connell et al. (2012) was removed from the analysis. Of the 55 studies that were accessible, 31 studies provided sex-specific prevalence for 74 populations, with three studies (Bernofsky, 2010; Boyd, 2020; Panhuysen et al., 1997) providing a single sex-specific prevalence for some or all sites included within the study due to small sample sizes. Male-specific prevalence was provided for 68 populations and ranged between 1.56% and 100.00%, with a mean prevalence of 51.52%. Female-specific prevalence was provided for 72 populations and ranged between 2.50% and 100.00%, with a mean prevalence of 52.43%.

True prevalence was present in seven studies representing 34 sites (see Supplementary Data 1). These ranged between 5.41% and 100.00%, with a mean prevalence of 52.73%. Male-specific true prevalence was available for 19 populations and ranged between 16.67% and 100.00%, with a mean prevalence of 49.63%. Female-specific true prevalence was available for 18 populations and ranged between 20.30% and 100.00%. Bernofsky (2010) again provides several sex-specific prevalence that are for combinations of individual sites, rather than site-specific.

Thirty-two studies provided crude prevalence rates where sinusitis occurred in the presence of dental disease, with the specific dental diseases as deemed relevant by each study, for 67 populations, with Bernofsky (2010) being the only study to provide prevalence for a combination of sites rather than individual sites (see Supplementary Data 1). Crude prevalence of sinusitis with dental disease present ranged between 0.00% and 56.67%, with an mean prevalence of 13.95%. Sex-specific prevalence for sinusitis in the presence of dental disease was present in 15 studies. Fourteen studies provided male-specific prevalence and 13 studies provided female-specific sites for 35 and 34 populations, respectively. Male-specific prevalence ranged between 0.00% and 100.00%, with an mean prevalence of 19.77%, and female-specific prevalence ranged between 0.00% and 55.00%, with an mean prevalence of 15.17%. Only three studies (Bernofsky, 2010; Mays et al., 2014; Riccomi et al., 2021) provided true prevalence for sinusitis in the presence of dental disease for 14 populations. This ranged between 5.54% and 34.16%, with a mean value of 18.59%. Sex-specific true prevalence in the presence of dental disease was provided by Bernofsky (2010) and Riccomi et al. (2021) for 13 populations. The male true prevalence ranged between 5.80% and 46.55%, with a mean value of 22.77%, whilst the female true prevalence ranged between 0.00% and 43.75%, with a mean value of 19.83%.

4. Discussion

Before discussing the results of this study, it is important to acknowledge several limitations in this paper. More studies and reports containing information about archaeological sinusitis certainly exist than have been identified in the present study, but the choice of key terms and languages meant they could not be identified. On the former of these factors, this is inevitable due to the lack of digitisation of reports, particularly those produced before the rise of global internet networks in the mid to late 1990 s. On the latter, whilst it may have been advantageous to include non-Romance or Germanic languages, the authors' working knowledge of these languages is severely limited and would have impaired their ability to rate translations and interpret results. However, this limitation can only be considered of concern where there is clear evidence of missing studies in other languages. Reviewing the introductions of the studies produced by academics based outside of Western Europe and only non-Romance/Germanic studies (Mushrif-Tripathy, 2014; Xiong et al., 2021; Zubova et al., 2020), there is a distinct lack of additional references to other studies of maxillary sinusitis in the countries where the authors are based (India, Russia, China), regardless of language of production. Of these, Mushrif-Tripathy (2014) is the only study to reference published research into Indian archaeological populations (Mushrif-Tripathy and Walimbe, 2006; Reddy, 2002) but they incorporate this data into their paper. This does suggest that there is a highly limited amount of published literature on archaeological maxillary sinusitis outside of the works produced within English.

4.1. Issues in archaeological sinusitis research

In reviewing the palaeopathological literature on sinusitis, the production of Boocock et al.'s (1995a) diagnostic criteria has been of clear benefit to the investigation of respiratory disease in the past. However, in the wake of increased theoretical consideration of palaeopathological diagnostic methods and criteria (such as Mays (2018, 2020) and Vlok (2023)) and the various modifications presented by researchers to Boocock et al. (1995a), it must be asked if this diagnostic guide is currently fit for purpose at almost thirty years after its production.

Reviewing the original criteria presented by Boocock et al. (1995a) shows that the definitions for the criteria can be somewhat vague for the "pitting" and "spicules" categories, with little information provided regarding the size these features can take, or what the cut-off between the "spicules" and "remodelled spicules" categories may be. Additionally, the criteria are potentially not inclusive enough of the different pathological bone changes that have been identified within the sinuses, with researchers making the addition of three specific categories and one general "other" category to better record the changes they see. The terminology used in the original category titles may also need refining to ensure each is distinct from the others to avoid confusion. This was highlighted in the studies by Davies-Barrett, Owens, et al. (2021) and Davies-Barrett, Roberts, et al. (2021) where "white pitted bone" was changed to "porous new bone" to avoid confusion with the "pitting" category. As shown by Biehler-Gomez et al. (2020) and highlighted by both Appleby et al. (2015) and Buikstra et al. (2017), clarity in the descriptors and terminology used to describe pathological lesions in bone is critical to ensuring rigour, understanding, and reproducibility in palaeopathology. This is as applicable to newly introduced diagnostic categories as it is to existing ones. In Mushrif-Tripathy (2014) and Xiong et al., (2021), the category of "hole" is used with the definition of "a hole with rounded margin is formed due to penetration by roots of teeth" (Mushrif-Tripathy, 2014, p. 16). Whilst the inclusion of a definition does allow readers to clearly understand what is meant by this specific usage of the category, non-technical language is vague and risks confusion if researchers are attempting to compare results between studies.

Another source of potential confusion within the sinusitis categories is "pitting" itself. As outlined above, several studies have chosen to exclude the use of the "pitting" category when dealing with non-adult remains. Lewis et al. (1995) were the first study to explicitly discuss the presence of sinusitis in the remains of non-adult individuals. They note two issues in the study of sinuses in non-adults, which they define as individuals aged 0–16 years. First, before the age of three years, the sinuses are not developed enough and are too porous to provide much useful information. Second, although the sinus is large enough for examination by the age of seven years, its location superior to the maxillary alveolar bone, which contains the forming teeth, results in developmental pitting which may obscure or be confused with inflammatory pitting. Of the studies in this review that note this potential confusion, we see three types of reaction. First, some remove "pitting" as a diagnostic category when dealing with non-adults (Bennike et al., 2005; Krenz-Niedbała and Łukasik, 2016; Lewis, 2002). Second, Collins (2019) retains the category but it is only applied to pits that are large enough to suggest the coalescing of smaller pits through pathological bone erosion or the past presence of an abscess or oroantral fistula. Third, studies adjust their inclusion criteria by age to exclude individuals who may exhibit this developmental pitting (Davies-Barrett, Roberts, et al., 2021; Sundman and Kjellström, 2013a).

It is in this third group that we face a potential issue. Both Davies-Barrett, Roberts, et al. (2021) and Sundman and Kjellström (2013a) perform this exclusion based on the degree of dental development present, with Sundman and Kjellström (2013a) excluding individuals where the second molar was not fully erupted. In addition, Davies-Barrett, Roberts, et al. (2021) exclude individuals where the third molar is not fully erupted. It can be argued that the more conservative option of the two is the one performed by Davies-Barrett, Roberts, et al. (2021) as the third molar, on average, does not fully erupt until around 20 years of age (AlQahtani et al., 2010, Table 11). Whilst many of the studies provided minimal ages for what they deemed to be an adult, the ageing methods used are not always present with statements such as "Only adult individuals, aged 20 years or older, were analysed" (Roberts, 2007, p. 797) in text. With the natural variation in dental eruption times, particularly with the third molar, being aware that developmental pitting may still be present in younger adult individuals where a third molar has not yet fully erupted is important. However, it should be noted that the degree to which developmental pitting may occur when it is only the third molar which is still developing (around 12 years of age onwards) is unclear, especially compared to when multiple teeth are still developing and erupting (before around 12 years of age).

Further research into the pathophysiology of the bone changes encountered in maxillary sinusitis would likely be beneficial in this regard. Clinically, minimal work has been undertaken on the bone changes seen in maxillary sinusitis. From a diagnostic perspective, this has focused typically on the use of CT scans to determine the thickness of the sinus walls (Georgalas et al., 2010; Hyo et al., 2006; J. T. Lee et al., 2006) with no categorisation of the bone changes present. Other clinical work has focused more on the role that bone may play within chronic maxillary sinusitis. These studies have observed that the rate of bone turnover in sinusitis is similar to that seen within osteomyelitis (Kennedy et al., 1998) and that the inflammation present can spread through the Haversian canals of the bone and also cause fibrosis within the canals (Khalid et al., 2002; Perloff et al., 2000). However, this work typically uses histological methods, so neither the diagnostically focused nor more general investigative clinical studies are working at the macroscopic scale that most palaeopathologists will work in. As such, palaeopathologists must take the lead here, with Collins (2019) presenting some initial work on this discussion. They note that many studies which used the Boocock et al. (1995a) criteria considered "pitting" to be indicative of the first stage of sinusitis, followed by the formation of spicules and then white pitted bone and lobules. This would make sense as pitting in the rest of the skeleton is considered to be a hallmark of early periosteal reaction. However, Collins (2019, p. 145) posits that due to the functional properties of the mucosa and the physiological processes of bone formation, it is in fact "spicules" that are representative of the early stages of chronic inflammation, representing ossified mucosa. They base this on evidence seen where similar anatomical relationships are present, such as between the pleura and periosteum of the ribs leading to subperiosteal reactions (Roberts et al., 1994; Santos and Roberts, 2006), and evidence of fibro-osseous production affecting the tympanic sub-mucosa before any osteitis of the ossicles (Mansour et al., 2015). This present pathophysiology is incorporated into the scoring system for sinusitis that Collins developed (2019, Table 4.2), which was designed to account for the type and severity of changes seen to better consider how the function of the sinus was impaired. With its basis in the pathophysiology of sinusitis, this system is arguably more holistic than other sinusitis scoring systems (Merrett and Pfeiffer, 2000; Sundman and Kjellström, 2013a) which focus either on the types of bone change individually or just the coverage of these changes within the sinus. However, further investigation of this pathophysiology would likely be of benefit to explore how the different categories of bone changes that may be observed in sinusitis may occur.

The final area of concern is the lack of clearly defined criteria for distinguishing odontogenic and rhinogenic sinusitis. Researchers have recorded a variety of different dental pathologies when also looking for maxillary sinusitis (see above), though the likelihood of any of these being the causative agent for odontogenic sinusitis will vary. From a clinical perspective, the most common cause of odontogenic sinusitis is iatrogenic (illness as the result of medical intervention) injury to the mucosal membrane of the periosteum. A review of almost 700 patients found that 65.7% of odontogenic cases were accounted for by an iatrogenic origin, whilst apical periodontal pathologies (apical granulomas, odontogenic cysts, and apical periodontitis) accounted for 25.1% and periodontitis only 8.3% of cases (Lechien et al., 2014). This same study found that the teeth most frequently involved were the first molar (35.6%), second molar (22%), third molar (17.4%) and second premolar (14.4%) (Lechien et al., 2014). Whilst dentistry is certainly known to have occurred in ancient civilisations and before, archaeological evidence for this is rare (Becker, 2014; Coppa et al., 2006; Forshaw, 2009). As such, archaeologists are more likely to come across pathological rather than iatrogenic causes. As already seen, most archaeological studies do not consider a potential diagnosis of odontogenic sinusitis without a direct connection between the sinus and the dentition being present (Davies-Barrett, Roberts, et al., 2021; Davies-Barrett, Owens, et al., 2021; Roberts, 2007).

As already stated, rhinogenic sinusitis has a complex and varied aetiology, which archaeologically is often impossible to identify. As such, some researchers choose to exclude individuals with dental disease to remove this confounding variable from their data and to produce more clear results as to what relationship, if any, there may be between sinusitis and the other factors being investigated. If this exclusion is not undertaken, then clear reporting as to the prevalence of possible odontogenic sinusitis must be present, otherwise, future researchers may accidentally include this confounding variable within their research. For example, in the largest meta-analysis of archaeological sinusitis, which included 21 sites and almost 2000 individuals (Zubova et al. 2022), 174 (8.81%) individuals showed sinusitis alongside dental disease (see Supplementary Data 1), but this data could not be accounted for in all cases as it was not always clearly stated. Whilst the inclusion of this data is unlikely to have strongly changed the conclusions of the meta-analysis that climatic variables show the strongest association with sinusitis prevalence, the removal of these individuals would no doubt change the exact strength of this relationship. As such, if further studies want to build on the Zubova et al. (2022) method, the removal of possible odontogenic cases of sinusitis during data acquisition should be considered. Equally, researchers need to render data regarding the occurrence of sinusitis alongside dental disease clear within their papers, for this factor to be considered.

In summary, there are several factors to be considered by researchers proposing the development of new diagnostic criteria:

1. Any bone changes witnessed should be described using clear and distinct terminology, preferably conforming to the Nomenclature in Palaeopathology (Manchester et al., 2016).
2. Provide clear guidelines about whether it is appropriate to consider pitting as a pathological change in non-adults.
3. Consider the pathophysiology of sinusitis and incorporate this into the development of the diagnostic criteria. This will enable researchers to better understand the severity of the disease they are examining and could be incorporated into a scoring system for sinusitis (e.g., Collins, 2019).
4. Provide clear guidelines about how best to record and report the prevalence of sinusitis in relation to dental disease. Incorporation of the modified Istanbul Protocol (Appleby, 2023, p. 53) would allow the production of a hierarchy of dental pathologies that can be considered consistent with odontogenic sinusitis.

4.2. Broader issues in palaeopathology

From this investigation, several comments can be raised more broadly about palaeopathology. First, as shown above, there is a clear geographical dominance of European populations, particularly from the UK, with a temporal concentration on the last two millennia, with a principal focus on the 10th to 16th centuries. This is reflective of the broader state of palaeopathology, with Grauer (2023, p. 2) stating that "the extraordinary number of analyses completed on North and South American, British and European, and North African human remains […] reflects axes of power during centuries of colonization". This legacy can be seen in the reviewed research with most, if not all, of the South American and Nubian populations examined for sinusitis being held within Western institutions and their associated articles only involving Western academics as authors. It should be noted here that this does not preclude the involvement of curators and/or officials from these populations' countries of origin in making decisions about what access or research can occur; however, researchers should remain considerate of how the individuals and populations they study have ended up being curated in particular institutions, especially if these populations are from the Global South. Grauer (2023) also notes a focus in Western academia on preindustrial/industrial and prehistoric/historic binaries and the authors would argue a focus on urban/rural binaries reflects this academic focus. These foci can be seen in the rationale behind the study of archaeological sinusitis, as these often focus on the changing air quality experienced by European populations with the expansion of urbanisation, as well as the change in pollutant exposure that occurred in concert with changes in patterns of industry and sociocultural behaviours.

However, this does not adequately explain the dominance of UK populations studied, even among the European populations, within sinusitis, and more broadly palaeopathological, research. Part of this dominance is likely due to the UK having a large commercial archaeology sector, which is heavily linked to development, particularly infrastructure (Aitchison and Rocks-Macqueen, 2022). Without this, it is likely that much of the data found within Roberts and Cox (2003) or the production of detailed site monographs, inclusive of full osteological reports such as Brickley et al. (2006) and Connell et al. (2012), would have been unlikely. Academic interest must also be acknowledged as being partially responsible for this dominance. The work of Calvin Wells (1908–1978) at the University of Bradford, UK, is consistently cited as the earliest published article discussing sinusitis in archaeological human remains (Wells, 1977). The University of Bradford continued to train palaeopathologists interested in maxillary sinusitis, such as Emeritus Professor Charlotte Roberts (Durham University, UK) and Professor Mary Lewis (University of Reading, UK). These three individuals are responsible for almost a quarter of the studies ($n = 18$, 24.00%) reviewed in this article. So, whilst academia is expanding global networks with more scholars from diverse backgrounds accessing scholarship with the help of the internet and open-access articles, it can be suggested that the palaeopathology of maxillary sinusitis has an academic home within the UK. Because of these factors, it is not surprising that UK populations are overrepresented within archaeological research into sinusitis. However, diversifying and strengthening palaeopathology requires broadening research participants and developing a truly global focus.

Another key issue to address is data reductionism. A keystone of the field of palaeopathology are comparative studies (Zuckerman et al., 2016). Researchers must consider the degree to which data reductionism may be present within their own or another's data. This may occur when a researcher provides data on the prevalence by sex or age at death, or when broad and often binary categories are created to describe anthropogenic factors. Using simple binary categories on global data without the creation of appropriate subcategories obscures the complexities of both human lived experience and past environments around the world.

For example, it is common for urban and rural sites to be compared, but researchers must evaluate whether populations and sites are truly comparable. At Pucará de Tilcara, Argentina, a sinusitis prevalence of 25% (Zubova et al., 2020) was reported, whereas, at Sigtuna, Sweden, the prevalence is between 80% and 95% (Sundman and Kjellström, 2013b, 2013a). These sites are urban sites that were occupied at similar times (c. 10th/11th to 16th centuries CE) and may be considered comparable apart from their geographic location. However, Pucará de Tilcara is described as having open-plan residential buildings that prevented the accumulation of smoke and allergenic particles, whilst its hilltop location facilitated natural ventilation of the settlement (Zubova et al., 2020). In contrast, Sigtuna was situated on a peninsula with no ventilation advantage and the buildings themselves had few windows, roof openings, or other methods of regular ventilation (Tesch, 2016). Structurally, the buildings at Sigtuna are similar to those of the Danish Iron Age (500 BCE–CE 700), which have been experimentally shown to contain levels of indoor pollution which would affect the general health of individuals inside them (Skov et al., 2000). So, whilst these sites may seem comparable due to a shared label and chronology, they do not reflect differences in the lived experience of the residents, nor differences in exposure to risk factors for disease.

Importantly, this is not a call for dropping descriptive labels for archaeological sites. Instead, this is a call for researchers to consider the range of variables that may influence data and either control for them or incorporate them to generate more nuanced results reflective of complex human existence. In the case of sinusitis, this may include noting the risk of exposure to airborne pollutants and allergenic substances or irritants. For example, Davies-Barrett, Roberts, et al. (2021) found that whilst urban environments may have influenced the susceptibility of individuals to sinusitis, the increasing prevalence seen over time could also be attributed to increasing environmental aridity and intensifying agricultural practices. Incorporation of non-osteological research may also be beneficial and worth considering. For example, Shillito et al. (2022) found similar levels of indoor pollution to Skov et al. (2000) in a recreated house at Çatalhöyük, Turkey, despite noting that there was no recorded palaeopathological evidence indicative of respiratory disease.

Second, the methods by which palaeopathological changes are examined must be considered. Medical imaging techniques have a long history of being used as a complementary tool to the macroscopic investigation of pathological changes seen on dry bone (Coqueugniot et al., 2020). In the study of sinusitis, two medical imaging techniques have been used: endoscopy and CT imaging. As already noted, endoscopy is widely used in the study of sinusitis and has been since the publication of Wells (1977). Whilst invaluable in allowing the internal surfaces of more complete sinuses to be examined, it does have potential drawbacks. Davies-Barrett (2018) notes that some bone changes (e.g., spicules) are easier to observe with endoscopes than other pathological lesions because they cast a shadow and that the access angles for an endoscope can be restricted, compromising visualisation of the internal surfaces. Additionally, the comparability of data derived from different makes of endoscopes and view angles to explore bone changes within the sinus has not been tested. The outstanding question is whether the prevalence of pathologies recorded through CT scans can be compared with those identified macroscopically. For sinusitis research, CT scans are advantageous as they allow the complete examination of crania without risking damage to the sinus walls, as well as identifying subtle connections between signs of dental pathology and the sinuses which are not visible macroscopically (Zubova et al., 2020). The two studies that used CT scans to date (Zubova et al., 2022, 2020) rely on a clinical methodology (Georgalas et al., 2010) to diagnose the presence of sinusitis. This methodology focuses on the metric evaluation of sinus wall thickness, with osteitis deemed present if the sinus wall is $\geq$ 3 mm. As outlined above, Merrett and Pfeiffer's (2000) scoring system includes the observation of bone changes smaller than 1 mm.

This suggests that comparing data derived from macroscopic assessment of bone change to datasets using CT scans and radiographic images should be treated with caution (Boocock et al., 1995a; Mays et al., 2014), especially since little evidence of sinusitis has been found using radiographs. However, with advancements in medical technology, this is perhaps changing. Casna and Schrader (2022) show that CT scans can identify bone resorption and growth (adapted from Boocock et al. (1995a)) when compared to endoscopic examination, though there was a statistical difference in the identification of bone resorption between these two methods. Further work in this area focusing on the bone changes noted by Boocock et al. (1995a) ought to clarify the efficacy of using CT scans in investigating archaeological sinusitis. Despite the promise of this research, the benefits of employing this method will likely be limited to researchers who have access to equipment, to practitioners with the appropriate expertise to interpret the data, and/or to researchers with funding sufficient to gain access to equipment and associated support.

Finally, the scope of detailed meta-analysis based on the information provided within palaeopathological studies is limited. Different datasets provide differing levels of data, extending from fundamental information provided to readers (e.g., a journal article) to more extensive but possibly more general information offered (e.g., site monographs detailed appendices). Whilst site monographs may provide more extensive information than a journal article, these have historically remained unpublished or have limited accessibility. As such, journal articles are often the main source of comparative data available for palaeopathologists. Other areas of bioarchaeology have benefitted from the production of online datasets (e.g., IsoArcH.eu (Salesse et al., 2018) for archaeological isotope data). However, palaeopathology may be too expansive a field for a similar system to be implemented, though smaller scale databases focusing on singular pathologies do exist (e.g., Cancer Research in Ancient Bodies (CRAB) Database (Hunt et al., 2017)). Journals are increasingly encouraging authors to provide supplementary data. Palaeopathologists should take advantage of this and include supplementary data, similar to a monograph's skeletal catalogue, since more detailed information would be available for comparison. The supplementary data provided by Davies-Barrett et al., (2021) provides a good example by providing the skeletal ID, biological profile (age and sex) of the individual, the sinuses presence, completeness and whether they were observable, alongside information regarding the presence of sinusitis, oroantral fistulae and other pathological bone changes.

5. Conclusions and recommendations

In summary, the study of sinusitis remains a consistent and active area of palaeopathological research. However, its geographic and temporal coverage reflects the colonial roots of biological anthropology and osteoarchaeology. As such, research into sinusitis must be expanded geographically through the southern and eastern hemispheres, must engage local scholars, and extend temporally beyond the last two millennia.

The creation of Boocock et al.'s (1995a) diagnostic criteria has been beneficial in guiding researchers in what bone changes to look for when examining sinusitis. However, this guide does not encompass all the changes witnessed, nor does it provide clear guidance on distinguishing odontogenic and rhinogenic sinusitis. As such, it is time for this diagnostic guide to be revisited and expanded. This expansion must include a contemporary understanding of the pathophysiology of sinusitis informed by clinical literature to better understand the development of bone changes and the indicators of odontogenic sinusitis. Similarly, as medical imaging technologies improve, work extending beyond Casna and Schrader (2022) must be undertaken in order to grapple with the limits of comparisons made between data derived from clinical medical imaging and macroscopic methods.

More generally, palaeopathologists must cautiously use descriptive categories when comparing archaeological populations. Binaries such as "urban" and "rural" are important, but also often reductionist, limiting not only comparisons between data, but our perceptions of the lived environments of the populations being studied. Additionally, more data should be included within publications, as only through this can bigger and more refined statistical modelling of disease factors or histories be undertaken. Palaeopathology is maturing as a discipline, both theoretically and practically, but we must ensure that the work we are producing is of good quality, replicable, and accessible.

CRediT authorship contribution statement

Lee Matthew James: Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Siek Thomas J:** Writing – review & editing, Writing – original draft, Investigation, Data curation. **Hirst Cara S.:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare no competing interests or sources of funding in the production of this work.

Acknowledgements

Sincere thanks go to Dr Jennifer Austen for her contributions to the initial data gathering and drafting of this article. Thanks are also extended to Dr Anwen Caffell, Durham University, for providing helpful thoughts and direction on the first complete draft of this article, as well as to Hannah Leidl and Asan Li, also of Durham University, for their help in ensuring the correct translation of German and Chinese technical labels in the articles found by the authors. Thank you to the reviewers for their time and comments which greatly improved the manuscript.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijpp.2023.11.005.

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