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Visualising Mastoiditis

with a Portable X-Ray System–A Preliminary Analysis

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Background

In spite of the high prevalence and severity of the disease even today (Flohr and Schultz, 2009; Groth et al., 2012; Wilson et al., 2017), mastoiditis is rarely studied archaeologically. Where mastoiditis is examined, it is studied in isolation and is seldom integrated into broader explorations of population health. Fixed and inaccessible imaging systems, and/or destructive sectioning methods are often the limiting factors (e.g., Flohr and Schultz, 2009).

The aim of this preliminary analysis was to develop a new method for diagnosing archaeological cases of mastoiditis that was grounded in modern clinical practices, non-destructive, and accessible; to expand the understanding of mastoiditis' epidemiology and etiology and its impact on public health. This preliminary analysis 1) assessed the diagnostic quality of the X-rays generated and 2) compared the frequency of mastoiditis in the sample with that of other chronic respiratory infections, specifically maxillary sinusitis and lower respiratory tract infection.

Methodology

A sample from Black Gate cemetery, Newcastle-upon-Tyne, England (8th–12th century C.E.) were studied (see Table 1 for the demographic distribution). Only individuals with at least one complete mastoid process were included in the preliminary analysis (see Table 2 for observability and diagnosis criteria). Digital X-rays were taken (see Figure 1) in an appropriate laboratory and following the health and safety guidelines established by the University of Sheffield.

Males	Females	Non-adults
15	12	13

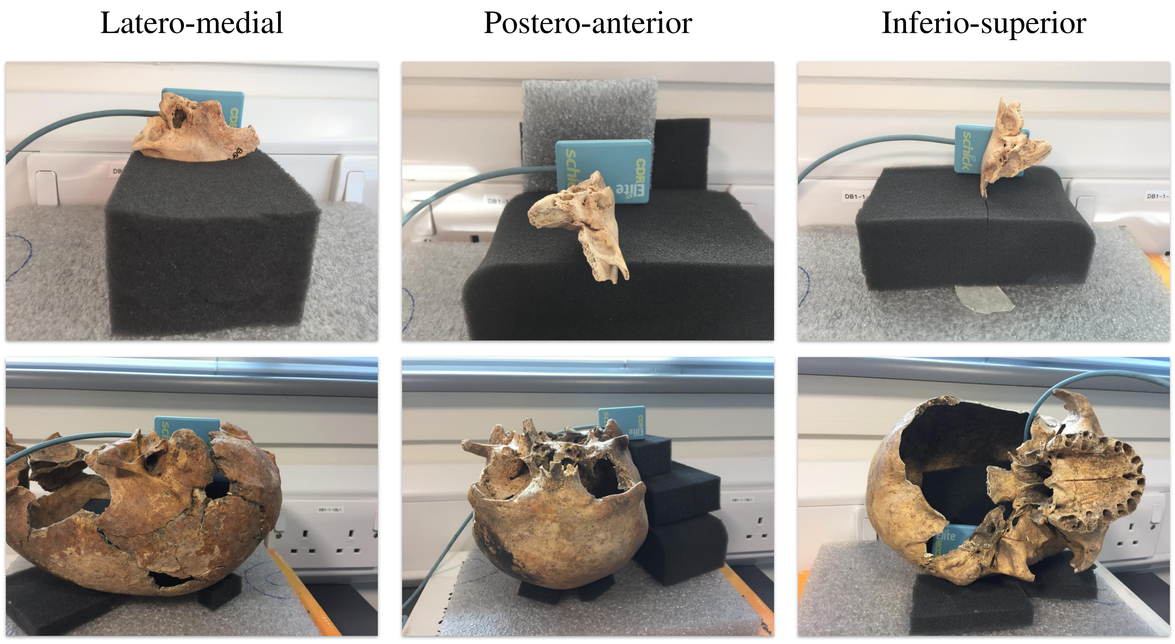
Young child (1–5 years)	Older child (5–10 years)	Adolescent (10–15 years)	Young adult (15–25 years)	Prime adult (25–35 years)	Mature adult (35–45 years)	Senior adult (45+ years)
4	4	5	6	8	7	6

Table 1. Biological sex and age at death distribution within the sample.

Infection	Observability	Lesion appearance	Examples
Childhood mastoiditis	Individuals over 16 years of age with at least one complete mastoid process.	Hypocellular internal structure of the mastoid process resulting from disruption to the pneumatization process prior to puberty.	Chien et al., 2012; Robinson et al., 1993
Active/healing mastoiditis	Individuals with at least one complete mastoid process.	At least one area of bone destruction contained within a layer of sclerotic bone which interrupts the structure of the natural pneumatized bone.	Bluestone, 1998; Flohr and Schultz, 2009; Gregg et al., 1981; Titche et al., 1981
Chronic maxillary sinusitis	At least half of the floor of one maxillary sinus and no evidence of dental fistula(e).	Proliferative and/or sclerotic sub-periosteal and/or lytic bone lesions.	Boocock et al., 1995; Lewis et al. 1995
Chronic lower respiratory infection	An individual must have at least six observable ribs (at least one third of the visceral surface of the blade observable) to be considered observable themselves.	Proliferative and/or sclerotic sub-periosteal and/or lytic bone lesions.	Davies-Barrett, 2019

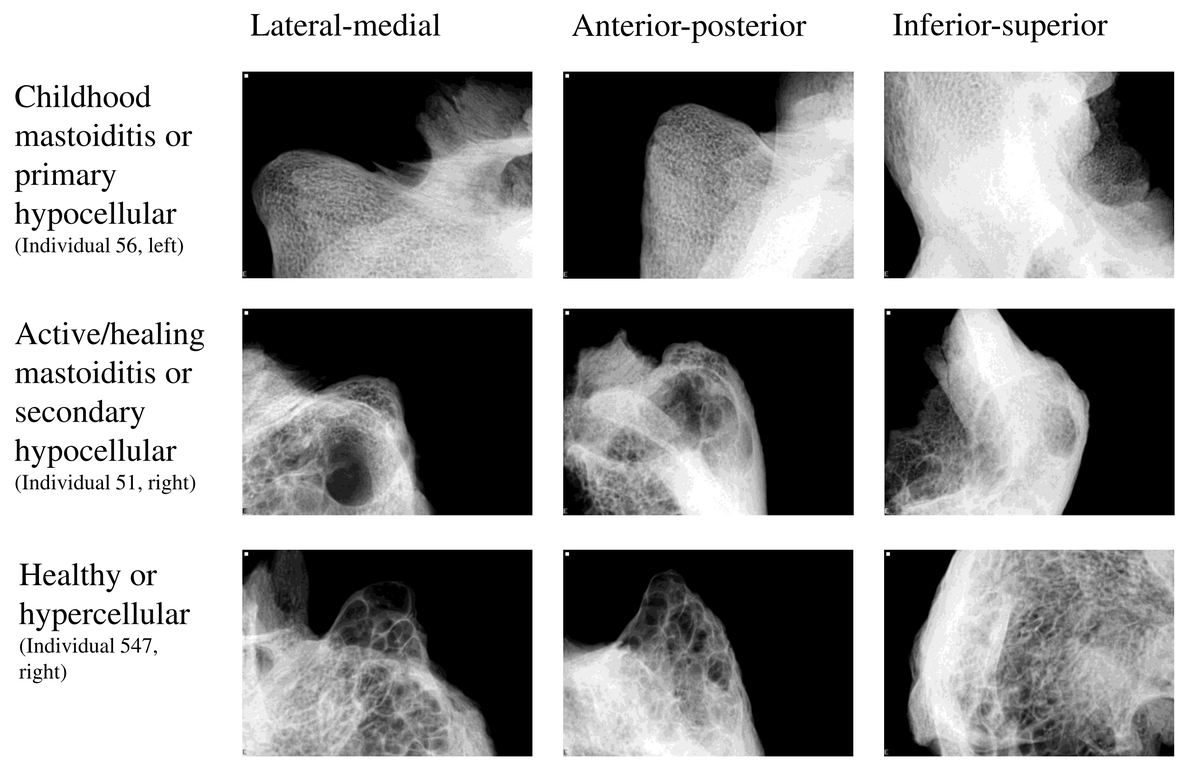
Table 2. Criteria used to determine the observability of structures, bones, and individuals; and for the diagnosis of infections from lesion appearance.

Figure 1. Imaging set-up for disarticulated and articulated temporal bones.



Preliminary Results

Figure 2. Radiographs of mastoid processes in various stages of health.



The digital X-rays had high fidelity: excellent resolution, contrast, and detail (see Figure 2). This allowed for the detailed examination of bone macrostructure. It was possible to differentiate hypocellular, pathological destroyed/sclerotic bone, and various natural patterns of healthy pneumatized bone (Bitar et al., 1996); and to diagnose childhood mastoiditis and active/healing mastoiditis. Table 3 presents the results of the study. Of those diagnosed with active/healing mastoiditis, 33.3% (2/6) were also diagnosed with chronic maxillary sinusitis and 16.7% (1/6) were also diagnosed with chronic lower respiratory infection.

Childhood mastoiditis	Active/healing mastoiditis	Chronic maxillary sinusitis	Chronic lower respiratory infection
48.1% (13/27)	15.0% (6/40)	60.0% (12/20)	7.1% (2/28)

Table 3. The true prevalence of the conditions observed in the sample.

The sample was too small to warrant statistical analysis, but some trends stand out. Firstly, the percentage of individuals with childhood mastoiditis was high. Mastoiditis is most often a disease of childhood; thus, this finding was consistent with the clinical literature (Bluestone, 1998; Groth et al., 2012; Wilson et al., 2017). The percentage of active/healing mastoiditis was low, but within the broad range reported from other archaeological populations: 11.1% (Schultz et al., 2007)–83.4% (Flohr and Schultz, 2009). Secondly, while over half of the sample was diagnosed with chronic maxillary sinusitis, only a third of the individuals with mastoiditis also had chronic maxillary sinusitis. This suggests that they did not co-occur significantly within the wider population, but that their etiologies may have involved shared risk factors. Thirdly, of the two individuals diagnosed with lower respiratory tract infection, only one also had mastoiditis. This neither spoke to the co-occurrence of these infections within the larger population, nor ruled out them sharing an etiology. Broad environmental risk factors (Bluestone, 1998) appeared to influence the sample's morbidity while other risk factors influenced individual susceptibility to each type of infection.

Next Steps

This study served as a preliminary analysis for a PhD research project. Here, the fidelity of the X-ray system was analysed, the methodology was tested, and some preliminary data was explored. This also served to identify areas requiring refinement or augmentation within the wider project, such as:

1) To establish standardised planes for imaging the mastoid process to promote accurate reproduction of radiographs and to facilitate comparisons within and between studies.
2) Refinement of the method to enable imaging of incomplete (fractured post-mortem) mastoid processes to compare the bone structure visible in the fractured cross-section to the radiograph and to test if fractured mastoid processes are diagnostic.
3) To follow the rigorous guidelines established recently by Anna Davies-Barrett and colleagues (2019) for recording lesions on the visceral surface of ribs to allow for inter-study comparison.

The larger project examines the skeletal remains of 2000+ individuals from Roman to post-Industrial Britain held within the Department of Archaeology, University of Sheffield's Human Osteological Collection. Its aim is to develop a new method of diagnosing middle ear infection in human skeletal remains that is grounded in modern clinical practices, non-destructive, and accessible. Its objectives are as follows: 1) to compile a comparative collection of radiographs that illustrate each clinically-defined stage of mastoid infection; 2) to characterize the epidemiology of mastoiditis in the sample; 3) to characterize the etiology of mastoiditis in relation to other chronic respiratory infections (maxillary sinusitis and lower respiratory tract infection) in the sample; and 4) to better understand the lifeways of those living with respiratory infections and their public health impact during the urbanisation and industrialisation of Britain.

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