

# Archaeological oral health: a comparison of post-medieval and modern-day dental caries exposure of adults in East London

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## Key points

Over the last 300 years, sugar consumption in the UK has increased from 1.8 kg to 23 kg per person per year.

Reports dental decay rates were significantly lower in the sampled post-medieval burials.

Suggests 'teeth' were a leading cause of death in post-medieval London.

## Abstract

Modern levels of dental decay worldwide are on the rise. This study aimed to calculate historical rates of decay and compare them with recent figures. To compare the rate of dental decay in East Londoners from a post-medieval burial ground and a published modern sample, a database of human remains held at the Museum of London Archaeology (MOLA) was interrogated. The resulting numbers of decayed and missing teeth were analysed and compared to the East London Oral Health Inequality study initially undertaken in 2010. A lower decayed/missing/filled teeth (DMFT) score was seen in the post-medieval burials.

## Introduction

Oral health remains a global public health concern in the twenty-first century, and while the prevalence of dental decay (caries) has decreased in the United Kingdom recently, poor oral health continues to impact on the quality of life of those affected.<sup>1</sup>

The oral health profile has shifted over the past 500 years. In the pre-modern era, bread made from wheat ground by millstone contained small stone particles resulting in increased abrasive tooth surface loss.<sup>2</sup> Industrialisation dramatically increased the availability of food and abundance of dietary free sugars, and with that, increased dental decay. A recent study of the oral health of modern-day East London shows the average East Londoner has around 12 teeth that are

affected by decay.<sup>3</sup> East London is generally defined as a geographical area lying to the east of the gates of the ancient City of London, with poorly defined external boundaries. For the purpose of this study, the narrowest definition of the historic core of East London, the area colloquially known as 'the East End' is used. This restricts the area to residences within the modern-day London Borough of Tower Hamlets.

Historically, East London has been a socially and materially deprived area, and social deprivation has a well-established association with poor oral health.<sup>4</sup> Historical attempts to study and map out areas of poverty and deprivation such as Charles Booth's 1889 'Map of London' illustrate well the levels of poverty surrounding the City of London. A modified excerpt of his map with the modern day borough of Tower Hamlets overlaid in red can be seen in Figure 1. Charles Booth concluded from his survey that more than a third of London lived in poverty at the time. Today, deprivation indices mirror this. A 2015 report entitled *The English indices of deprivation*, published by the Department for Communities and Local Government placed Tower Hamlets

as the 24th most deprived area in the England, out of 326 local authorities.<sup>5</sup>

In 1700, the estimated sugar consumption per adult per year in the UK was 1.8 kg.<sup>6</sup> Recent nutritional surveys put the modern-day figure as high as 23 kg of dietary free sugars per adult per year, with low-income groups consuming the most sugar.<sup>7,8</sup> In 2015, as part of the 'Crossrail' project, an archaeological excavation of a post-medieval burial ground, known as the New Churchyard, was undertaken. The site is situated 1.3 metres beneath modern day London Liverpool Street station, a major East London railway terminus. This cemetery was in use between 1569 and 1739, and an estimated 25,000 burials took place here.<sup>9</sup> An extensive and thorough investigation commenced and the removal and meticulous cataloguing of the condition of the remains provides a unique insight into the health of East Londoners from this period.

This project aims to compare the rates of dental decay of those buried at the site with the current rates in East London today. This study hypothesises that modern day East Londoners will have higher levels of dental decay than their predecessors, owing to the change in dietary free sugar consumption.

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## Materials and methods

The decayed/missing/filled teeth index (DMFT) is a well-established tool in oral epidemiology and dental public health for measuring caries exposure and has been in use for over 75 years.<sup>10</sup> The DMFT index counts the number of teeth that have decay, are missing or have a filling. Most DMFT studies exclude third molars (wisdom teeth) due to varying rates of third molar presence. This gives a maximum DMFT score of 28 (or 32 if wisdom teeth are included), if all teeth of the individual are affected. Dietary carbohydrates combined with poor oral hygiene will result in decay (D), treated decay will result in a filling (F), or untreatable decay may result in an extraction (M). In population studies the mean DMFT is, therefore, a good indicator of the dental decay rates of the population.

The human remains excavated from the New Churchyard were examined and recorded by osteologists at the Museum of London Archaeology (MOLA). The number of teeth present were recorded along with any signs of dental pathology, including periodontal disease (dental calculus or bone height loss), tooth loss and cavities. Each tooth 'space' was coded for, and entered into, MOLA's Oracle 9i (v 9.2.0) relational database system.

A search query of the Oracle database was made for entries of human remains with jaw bones present. The result of the query returned left or right maxillae (total 845) and left or right mandibles (total 1,070). To ensure the sample was as anatomically complete as possible, these results were filtered into individual skeletons with bilateral upper and lower jaws present (total 364).

There was decay evident in all ages of remains, for example in subadult<sup>11</sup> (380) (aged between 6–11 years old) (Fig. 2). However, the data were filtered by those estimated to be aged over 18, to ensure full development of adult dentition in the remains sampled. Therefore, the inclusion criteria for the remains studied required individuals to be estimated to be over the age of 18, identifiable as male or female, and who had a complete mandible and maxilla in a good enough condition to identify the presence or absence of a minimum of 28 'possible' teeth, including third molars. This resulted in a total of 224 adult individuals with a total number of 6,868 possible coded teeth; on occasion, some third molar teeth were not coded for, resulting in an average of 30.7 possible teeth per individual. The DMFT score per individual was then calculated.



Fig. 1 An excerpt from Charles Booth's 'Descriptive Map of London Poverty'



Fig. 2 Left mandible of subadult (380) with dental decay in molar tooth. Reproduced with permission from © Crossrail, courtesy of MOLA

A total number of 'missing teeth' (MT) per individual was recorded. Only teeth that can be identified as ante-mortem (before death) loss were counted, meaning only those with an absent socket, indicating bony infill, were counted as 'missing' teeth. Occasionally, teeth are separated from the jaw during the excavation process or not found. In the event a socket was present without signs of healing these were assumed to be post-mortem loss, and therefore counted as 'present' to the individual at the time of death.

The total number of teeth with carious lesions per individual were counted as 'decayed teeth' (DT). The teeth that were lost post-mortem were not counted as decayed, since it is not possible to ascertain if they had experienced decay during life. Teeth lost post-mortem numbered 739 out of a possible 6,868 teeth.

## Results

Of the 224 adult burials with complete jawbones, only 30 individuals had no evidence of any decayed teeth and only 19 had neither missing nor decayed teeth. Of the 5,195 teeth present, the decay rate was 18.9%. Of a total of 6,868 possible teeth, 982 (14.3%) showed decay and 934 (13.6%) were missing ante-mortem. Therefore 27.9% of teeth had been damaged by dental caries and/or lost before death (Table 1).

Females in this sample had both higher rates of decay and missing teeth, having an average of 4.5 decayed teeth and six missing teeth, compared with men having 4.3 decayed and three missing teeth. Combined, the 224 adult burials had a mean DMFT score of 8.55, indicating the average of this sample had 8.55 teeth that had been afflicted by poor oral health before their death (Table 2).

**Table 1** New Churchyard sample results

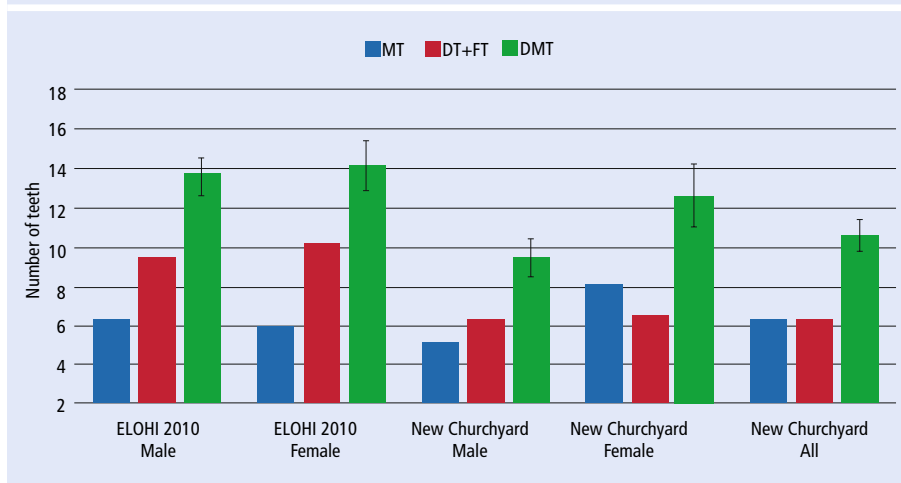
	Skeletons (n)	Possible teeth	Decayed (DT)	Missing ante-mortem (MT)	Filled (FT)	DMFT
Male	143	4,396	615	441	0	1,056
Female	81	2,472	367	493	0	860
<b>Total</b>	<b>224</b>	<b>6,868</b>	<b>982</b>	<b>934</b>	<b>0</b>	<b>1,916</b>

**Table 2** New Churchyard caries experience measures (DMFT)

	n	DT Mean (95% CI)	MT Mean (95% CI)	FT	DMFT Mean (95% CI)
Male	143	4.30 (3.70–4.89)	3.08 (2.22–3.95)	0	7.38 (6.39–8.38)
Female	81	4.53 (3.71–5.35)	6.09 (4.56–7.61)	0	10.62 (9.02–12.21)
<b>Total</b>	<b>224</b>	<b>4.38 (3.90–4.87)</b>	<b>4.17 (3.37–4.97)</b>	<b>0</b>	<b>8.55 (7.67–9.43)</b>

**Table 3** ELOHI study 2015. Reproduced with permission from Delgado-Angulo E K, Bernabé E, Marceles W. Ethnic inequalities in dental caries among adults in East London. *J Public Health (Oxf)* 2016; 38: e55–e62, Oxford University Press

	n	DT Mean (95% CI)	MT Mean (95% CI)	FT Mean (95% CI)	DMFT Mean (95% CI)
Male	638	0.91 (0.55–1.26)	4.23 (3.82–4.65)	6.48 (5.74–7.23)	11.62 (10.71–12.53)
Female	1375	1.08 (0.79–1.37)	4.01 (3.31–4.72)	7.02 (5.89–8.15)	12.12 (10.84–13.39)
“White British” M + F	565	1.20 (0.67–1.73)	5.10 (4.62–5.59)	7.17 (6.44–7.90)	13.47 (12.52–14.42)

**Fig. 3** Comparison of DMFT scores. Standard error bars for DMFT marked**Table 4** Age distribution of samples

Age range	NC (%)	ELOHI 2010 (%)
Young adult ~ 18–25	67 (30%)	163 (8%)
Middle adult ~ 26–45	136 (60%)	1,486 (74%)
Mature adult ~ 45 +	21 (9%)	364 (18%)
<b>Total</b>	<b>224</b>	<b>2013</b>

Data from recently published DMFT scores from the East London Oral Health Inequality study (ELOHI) (Table 3) were used as a modern comparison.<sup>3</sup> The article published male and female results separately. Comparing the two studies, post-medieval males had an average

of 4.24 fewer decayed teeth than modern male east Londoners, while post-medieval females had an average of 1.5 fewer decayed teeth. As none of the post-medieval teeth had fillings, the mean decayed and mean filled teeth from the ELOHI were combined in order to fairly compare ‘decay experience’ of the two groups (Fig. 3).

## Discussion

The limitations of using the ELOHI published results without the raw data made statistical comparison to the New Churchyard data unreliable. The use of the data collected by human osteologists from the New Churchyard burials has its own practical problems; the data were not collected for the purpose of DMFT analysis and DMFT-specific data collection training was not undertaken and may lead to inaccuracy. Clinical scoring of DMFT is known to have inter-examiner reliability issues and regular training has been shown to have high levels of sensitivity, therefore examiner calibration with the World Health Organisation guidelines may improve sensitivity.<sup>12</sup>

The very nature of using archaeological finds may result in an incomplete data set. The teeth that were lost post-mortem (intact sockets showing no signs of healing), numbered 739, a mean of four teeth per skeleton. For the purposes of this study, the lost teeth were counted as neither ‘missing’ nor ‘decayed’. This could lead to an underestimating of the decay rate. Applying the 18.9% measurable decay rate among examined teeth to the 739 lost post-mortem, would indicate an extra 139 uncounted decayed teeth. This would increase the mean DMFT of the New Churchyard sample to 9.17.

Estimating the age of death from adult remains once dentition has developed is problematic due to variability in skeletal age changes, giving wider age range estimations. The New Churchyard sample can be split into young adult (18–25 years), middle adult (26–45), and mature adult (>46). Using similar age ranges, the ELOHI group included a much lower proportion of young adults (16–24), and a higher proportions of middle adults (25–44) and mature adults (>45) (Table 4).

As the raw data from the ELOHI study was not attainable, the published results for all males and all females was used for comparison. A more ethnically comparable group of males and females of ‘White British’ background from the ELOHI study may have permitted a more



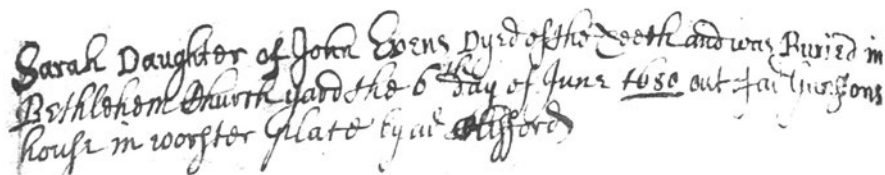
accurate comparison. Using the published average DMFT of combined males and females from the 'White British' category of the ELOHI study, the post-medieval burials had nearly five fewer decayed teeth than their modern counterparts (ELOHI White British combined DMFT 13.47 [12.52–14.42], New Churchyard combined DMFT 8.55 [7.67–9.43]).

DMFT scores naturally increase with age, as teeth have had more exposure to the decay process over time. With the distribution of age of the New Churchyard sample being younger than the ELOHI 2010 sample, this could account for some of the lower DMFT rates. Life expectancy at birth in the early seventeenth century was between 33 and 40 years, and very few deaths were attributed to age.<sup>13,14</sup> It could be argued that the population of post-medieval East London may not have lived long enough to experience the DMFT levels seen in the ELOHI study.

The comparatively lower rate of dental decay demonstrated in this study does not necessarily imply better oral health than in post-modern East London. While decay rates may have been lower, only rudimentary dental care was available and oral health was a major cause of morbidity and mortality. Parish burial records frequently attribute 'teeth' as the cause of death (Fig 3 and Fig 4).

The Bedlam Burial Ground Register is an extensive database of over 5,000 recorded burials at the New Churchyard ground, populated from historical parish burial records.<sup>15</sup> From the records, 2,669 of the entries have a recorded cause of death, 148 of these deaths were attributed to 'teeth', making it the seventh most common of the 60 unique causes of death recorded.<sup>16</sup> The cause of death would have been recorded by non-medical parish clerks, as there was no requirement for a medical practitioner to provide a certification of death until the Birth and Deaths Registration Act 1874.<sup>17</sup> This may result in an over reporting of teeth as a cause of death, possibly an umbrella term used for many oral pathologies.

There is certainly evidence in the New Churchyard of severe pathology relating to teeth, notably in the case of males (5,820). Estimated to have been 25–36 years old, the maxilla shows significant bony destruction and loss of the left molar teeth (Fig. 5).<sup>11</sup> This would have undoubtedly caused significant pain to the individual, and most likely have resulted from dental decay. Furthermore, 29.4% (148/503) of one sample of adults from



*Sarah Daughter of John Evens dyed of the tooth and was Buried in Bethlehem Churchyard [The New Churchyard] the 6th day of June 1680 out of Mr Gunstons house in worster place by Mr Clifford*

Fig. 4 'Cause of death' from Parish of St James Garlickhithe. Reads: 'Sarah Daughter of John Evens dyed of the tooth and was buried in Bethlehem Churchyard [The New Churchyard] the 6th day of June 1680 out of Mr Gunstons house in Worster place'. Reproduced with permission from: London Metropolitan Archives, City of London P69/JS2/A/001/MS09140;<sup>22</sup> Saint James, Garlickhithe, City of London collection; and the Genealogy Society of Utah



Fig. 5 Male 5820 left maxillary dental abscess. Reproduced with permission from © Crossrail, courtesy of MOLA

the excavation were affected by macroscopic periapical lesions of the bone.<sup>11</sup>

Post-medieval dentistry was far from what we are used to today. Rudimentary dental 'fillings' have been discovered in prehistoric man and materials such as beeswax or bitumen have been found packed into cavitated teeth as early as 13,000 years ago.<sup>18</sup> Dental fillings comprising of packed gold leaf were in use in Europe in the early sixteenth century. Giovanni d'Arcoli, Professor of Medicine and Surgery at Bologna, wrote in his book *Practica seu Exposito* in 1480 that 'teeth could

be filled with gold leaf after cleansing of the cavity with acid'.<sup>19</sup> The earliest book published about dentistry *Artzney Buchlein* in Germany, in 1530, confirms the procedure in further detail;<sup>20</sup> however, these restorative procedures involving precious metals would have been reserved for the wealthiest in society. None of the teeth found at the New Churchyard excavation had any evidence of dental filling materials.

Dentistry in post-medieval London was far less regulated than today. Extractions could be performed by any number of 'tooth-drawers';

from barber-surgeons to blacksmiths, many occupations would remove the teeth of those desperate enough.<sup>21</sup> Samuel Pepys wrote of minimally invasive charlatan dentists who would pretend to remove the ‘tooth worms’, believed to be the source of toothache, from their victims’ mouths.<sup>11</sup>

## Conclusion

The meticulous recording of the condition of skeletal remains from the New Churchyard allow a unique insight into the oral condition of those buried and provide a sample of the oral health of East Londoners from the post-medieval time period.

Comparing the calculated pre-modern DMT scores with the results from the recently published DMFT scores from the East London Oral Health Inequality study indicates that, of the burials sampled, there were significantly lower rates of dental decay in post-medieval London than there are today. While this does not imply better oral health of the inhabitants of post-medieval London, it challenges the ‘normal’ levels of decay experience we see in East London today. The reduced life expectancy in post-medieval London provides some explanation for the reduced decay exposure in the sampled burials and warrants further exploration, however the difficulty in accurately ageing adult skeletal remains precludes accurately age-matched comparisons.

Despite the lack of dental care in post-medieval times, the sampled population experienced less decay than the modern-day sample. Increased modern-day access to processed food with

higher levels of dietary free sugars may explain the significantly higher levels of decay seen today.

### Declaration of interests

*The author has no conflicts of interests to declare. This project was self-funded, no external organisations provided financial support.*

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## References

- White D A, Tsakos G, Pitts N B. Adult Dental Health Survey 2009: common oral health conditions and their impact on the population. *Br Dent J* 2012; **213**: 567–572.
- Lanfranco L P, Eggers S. Caries through time: an anthropological overview. In Lanfranco L P, Eggers S (eds) *Contemporary approach to dental caries*. pp 3–34. London: IntechOpen, 2012.
- Delgado-Angulo E K, Bernabé E, Marcenes W. Ethnic inequalities in dental caries among adults in East London. *J Public Health (Oxf)* 2016; **38**: e55–e62.
- Bower E, Gulliford M, Steele J, Newton T. Area deprivation and oral health in Scottish adults: a multilevel study. *Community Dent Oral Epidemiol* 2007; **35**: 118–129.
- Ministry of Housing, Communities & Local Government. English indices of deprivation. 2015. Available at <https://www.gov.uk/government/collections/english-indices-of-deprivation> (accessed September 2019).
- Mant M, Roberts C. Diet and dental caries in post-medieval London. *Int J Hist Archaeol* 2015; **19**: 188–207.
- Public Health England. National Diet and Nutrition Survey. 2019. Available at <https://www.gov.uk/government/collections/national-diet-and-nutrition-survey> (accessed September 2019).
- Public Health England. *Sugar reduction: the evidence for action*. London: Public Health England, 2015. Available at [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/470179/Sugar\\_reduction\\_The\\_evidence\\_for\\_action.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/470179/Sugar_reduction_The_evidence_for_action.pdf) (accessed September 2019).
- Hartle R. Burial practice. In Hartle R (ed) *The New Churchyard: From Moorfields Marsh to Bethlem Burial Ground, Brokers Row and Liverpool Street*. p 44. London: Museum of London Archaeology, 2017.
- Broadbent J M, Thomson W M. For debate: problems with the DMF index pertinent to dental caries data analysis. *Community Dent Oral Epidemiol* 2005; **33**: 400–409.
- Knox E. Diet and dental health. In Hartle R (ed) *The New Churchyard: From Moorfields Marsh to Bethlem Burial Ground, Brokers Row and Liverpool Street*. pp 171–185. London: Museum of London Archaeology, 2017.
- World Health Organization. *Oral health surveys: basic methods*. 5th ed. Sao Paolo: World Health Organization, 2013.
- Galor O, Moav O. Natural selection and the evolution of life expectancy. *Minerva Center for Economic Growth* 2005; 02-05. Available at [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=563741](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=563741) (accessed September 2019).
- Livi-Bacci M. *A concise history of world population*. Abingdon: John Wiley & Sons, 2017.
- Crossrail. Bedlam Burial Ground Register. 2018. Available at <http://www.crossrail.co.uk/sustainability/archaeology/bedlam-burial-ground-register> (accessed September 2019).
- Hartle R. The burial population: burial registers and the excavated sample. In Hartle R (ed) *The New Churchyard: From Moorfields Marsh to Bethlem Burial Ground, Brokers Row and Liverpool Street*. p 88. London: Museum of London Archaeology, 2017.
- Legislation.gov.uk. Births and Deaths Registration Act 1874. Available at <http://www.legislation.gov.uk/ukpga/Vict/37-38/88/enacted> (accessed September 2019).
- Oxilia G, Fiorillo F, Boschin F et al. The dawn of dentistry in the late upper Paleolithic: an early case of pathological intervention at Riparo Fredian. *Am J Phys Anthropol* 2017; **163**: 446–461.
- d’Arcoli G. *Practica seu Expositio*. Padua, 1480.
- Donaldson J A. The use of gold in dentistry. *Gold Bull* 1980; **13**: 117–124.
- British Dental Association. Barber-surgeons and toothdrawers. Available at <https://bda.org/museum/the-story-of-dentistry/ancient-modern/barber-surgeons-and-toothdrawers> (accessed September 2019).
- London Metropolitan Archives. LMA ref: P69/J52/A/002/MS09140, p 296. 1680.