St. Mary's Caries: A Comparative Study of Dental Caries Occurrence in the Burial Sites of St. Mary Spital and St. Mary Graces Cemeteries

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Dental caries is a pathological condition common to post-agricultural populations and often used in bioarchaeological studies to assess levels of human health and nutritional status. This study compares caries rates from two Medieval cemeteries from London, England: St. Mary Spital and St. Mary Graces. St. Mary Spital served as a church priory and hospital complex with adjacent cemetery sites to accommodate deaths from the sick and poor. St. Mary Graces cemetery was established in association with the Cistercian Abbey of St. Mary Graces and served mostly common Londoners. Caries prevalence data from both cemeteries were compared to seek differences between the two populations and between sexes, both within and between cemeteries. Adult individuals of known sex and at least one dental caries were utilized as a sample (n=122). Analysis resulted in a statistically significant (t= -11.454 df=120 p=.000) difference between the two cemeteries, with St. Mary Spital having significantly higher overall rates of dental caries, and no significant difference between sexes (t=-1.167 df=120 p=.246). The ill health and likely poor nutrition of those buried at St. Mary Spital should have predisposed them to greater dental caries rates than higher status Londoners buried at St. Mary Graces, and this is reflected in the results of the analysis.

Oral and dental health often speaks a great deal about the overall health status of an individual. As the primary point of entry for the body, the mouth serves as a harbor for many food and waterborne pathogens, as well as frequently reflecting the effects of suboptimal nutritional status, congenital conditions, and infectious conditions of the individual. Tooth enamel (the hardest substance found in the human body) along with dentin and cementum comprise tooth structure, and these three dental tissues preserve the dentition of deceased individuals extremely well, often surviving for millennia. This naturally preservative quality makes dentition a rather reliable resource in the archaeological record, often surviving decomposition, burial, and weathering when other osteological material does not.

Though they are rather impervious to damage once the soft tissue has decomposed, in life, teeth are susceptible to a variety of diseases and can subsequently be damaged or lost for a number of natural and cultural reasons. Because adult teeth are permanent and develop in the craniofacial bones during childhood, an individual's dentition carries a permanent record of their life in their jaws, from childhood through death. Dentition, therefore, is used in many bioarchaeological studies to assess the general health and nutritional status of past populations, as well as to reconstruct dietary patterns and even some cultural patterns and practices.

Of the many afflictions that teeth are vulnerable to during their development and use during life, perhaps the most common and potentially most damaging is dental caries. Hillson (1996), a leading expert in dental anatomy and biology, presents dental caries as an infectious and transmissible disease that can affect any part of the dentition, and as having potentially devastating effects. According to Hillson, caries occurs when bacteria from sugary carbohydrates, such as maize and other agriculturally developed grains, gets lodged in spaces on or around the teeth. These bacteria then begin to ferment, feeding on the residues from food intake that stick in the mouth. As they ferment, the bacteria produce corrosive acids that progressively wear away the enamel surface. Once it pierces all the way through the enamel, this acid can then corrode the dentin and pierce the pulp chamber of the tooth, causing pain and difficulty eating for the affected person. This destructive disease can eventually lead to complete destruction of the tooth if left untreated and is a prominent cause of antemortem tooth loss due to disease. Because caries is caused by bacterial infestation, caries is transmissible throughout the mouth; so one instance of caries in a mouth often correlates with multiple caries within the same mouth. Caries can affect any tooth position, but is most common in the posterior dentition, and primarily on the first molar of both dental arcades (Hillson 1996). Caries can range from nearly imperceptible brown or white "pinprick" spots to complete destruction of the tooth crown, though there are many different methods and scales for grading caries size and severity.

Dental caries is a disease that leaves a permanent mark on the dentition of an affected individual, which makes it relatively easy to identify in the archaeological record. Because caries is a disease that results primarily from dietary factors, it is extremely useful for reconstructing the dietary intake of past populations, in conjunction with any kind of written records, food-related artifacts, and stable isotope analysis of tooth and bone tissue. Nutrition is a highly important variable in overall health, and analysis of dental conditions linked to dietary intake and nutrition can be very informative about the general health of past populations.

The Data Sets: A Brief History of St. Mary Spital and St. Mary Graces Cemeteries

Medieval England was a period of great historical significance that occurred roughly between the end of the 5th Century through to the end of the 15th Century. Marked by the development of the feudal system and the classical depictions of castles, knights, and a primitive struggle for peasant life, this time period encapsulates a long and varied archaeological record of disease and injury. From this time, two cemeteries – St. Mary Spital and St. Mary Graces – serve as excellent snapshots of life and death in medieval England. Both cemeteries contain many significant markers of disease and injury, spanning nearly all ages and including many different social classes and occupations. By examining these two gravesites, it is possible to find patterns of pathology and trauma that can aid in reconstructing the life and health of populations that lived and died while these cemeteries were in use.

The work of Connell et al. (2012) indicates that St. Mary Spital was a priory and hospital established in about 1197 by a group of wealthy merchants from London. St. Mary Spital was created to aid the enlarging population, to extend much-needed aid to the increasing elderly, sick, and injured, and also offered charity to the poor or those otherwise in need, such as pilgrims and women in childbirth. The priory itself was established first, with the hospital not developed or built for roughly another 40 years. At its peak, the hospital at St. Mary

Spital had 180 beds, making it the largest infirmary in all of London. After Henry VIII became king, the priory was dissolved in 1539, and the area was slowly repurposed for housing of the minor aristocracy as well as an artillery ground. (Connell et al. 2012)

Within the site of St. Mary Spital, there are multiple cemetery sites – one an earlier cemetery near a 12th-century building, another made later near a 13th-century building, and the main cemetery that is to the south and east of the church. This main cemetery was the subject of large-scale excavation between November 1998 and August 2001 by the Museum of London Archaeology. The site, having been used and occupied for many years, was assigned time periods and phases by archaeologists when collecting data, and these along with demographic data were used to assess and categorize the individuals recovered. (Connell et al. 2012)

St. Mary Graces cemetery in London was built in association with the Cistercian Abbey of St. Mary Graces. This abbey was established shortly after the end of the Black Death swept through England and was used until the time of the Reformation in the 16th century. While monks and important lay people were buried within the church and chapels on the grounds, the general cemetery at St. Mary Graces was used for the general population – containing individuals of all ages, both sexes, and of both high and low socioeconomic status. Excavation of this site by Museum of London Archaeology in the 1980s revealed the remains of over 300 lay people, in addition to over 100 monks and important people buried in the church and chapels (DeWitte and Bekvalac 2010).

Both of these burial sites contain large and representative samples of the people that they served. However, it is important to note that these two institutions were established and used for very different purposes, and so their respective burial populations may show variation in a number of biological markers because of that. St. Mary Spital was explicitly used as a hospital, and as a charitable housing for the poor and infirm, while St. Mary Graces was simply a burial site for the general lay population. Because of this, it is reasonable to expect a high concentration of disease and injury at St. Mary Spital as compared with St. Mary Graces, consistent with its use as a burial site for the diseased and injured. However, dental caries has no explicit biological predilection toward individuals with other co-infections or concurrent injuries, generally speaking, and can be used as a means to compare the two burial sites without the high probability of spurious relationship or confounding variables.

Methods

Full data sets from the excavations at St. Mary Spital and St. Mary Graces are open sourced and available to the public both in print and as digital copies. The Museum of London Archaeology maintains these data sets on their website through their Centre for Human Bioarchaeology (WORD database 2015, available at http://archive.museumoflondon.org.uk/Centre-for-Human-Bioarchaeology/). By utilizing these rich datasets which contain information about dental pathology, specifically dental caries as well as demographic data, it is possible to make a statistical comparison within and between these two burial populations. These comparisons enable investigation into patterns of dental health and disease, and can allow for estimation of health and nutrition in these people.

From within this large population dataset, individuals were chosen for inclusion in this project if they had at least one or more caries present in their dentition (N=122). In selecting the sample, subadults, individuals of undetermined sex, and individuals with no caries present were eliminated from the total population. Because caries can only be detected by examining the teeth left in the jaw and skull at the time of death, this selection and overall counts from this sample likely underestimate true prevalence due to antemortem tooth loss.

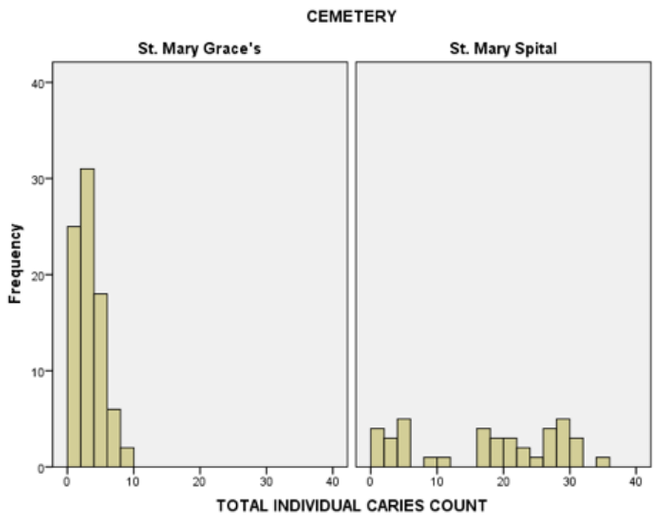
For the purposes of this study the variables sex, cemetery, mandibular caries count by individual, maxillary caries count by individual, and total caries count by individual from each data set were used in independent sample T-tests of means for significance, seeking the strength and direction of any existing relationship between them. Because some statistical testing within the sites is already given in Museum of London Archaeology's published material about the two sites, when available this information was used as provided in conjunction with independent testing.

Primarily, this study seeks to examine differences between sexes, both within each burial site as well as between the two as separate and aggregate categories. Additionally, this study will look to find differences between the two cemeteries overall, to determine whether there were significantly greater or fewer incidences of dental caries between two burial populations from comparable time periods and very similar locations, though used in different ways.

Results

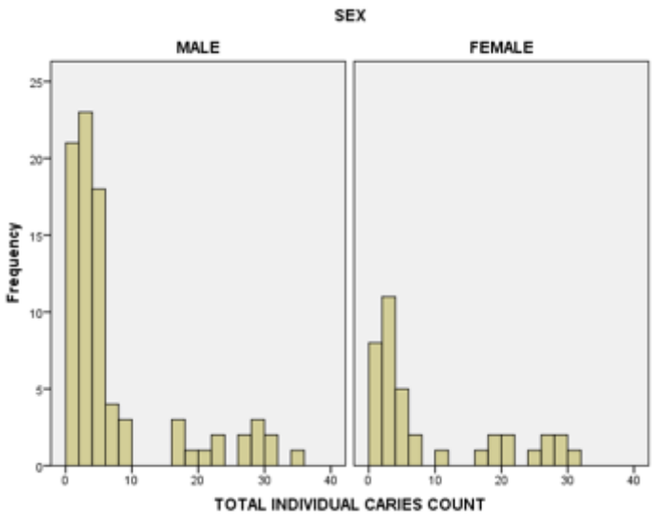
Of the total population (N=122), 82 individuals were buried in the cemetery of St. Mary Graces and 40 were from St. Mary Spital. Of the aggregate number of individuals, 84 were male (68.9%) and 38 were female (31.3%). All individuals had at least one caries in the permanent dentition that remained intact within the mandible or skull. The mean number of maxillary caries and mandibular caries was roughly similar (3.66 mean maxillary caries and 3.84 mean mandibular caries). Of the whole mouth, the mean total individual caries count was 7.48, with a median of 3.00. Total caries counts ranged from 1 to 35 per individual. For more detailed information about the frequencies and descriptions of the sample, see Appendix A.

An initial T-test sought to find a relationship between total individual caries count and cemetery location. The results (t= -11.454 df=120 p=.000) showed a strong negative relationship between these two variables. That is, an individual was much more likely to have a higher incidence of dental caries if they were found in one cemetery over the other. In this case, individuals buried in St. Mary Spital had significantly higher caries counts per individual, as shown in the histogram below. For full statistical information, see Appendix B.



A secondary pair of tests looked for differences between the cemeteries within the maxillary or mandibular arcades separately. In concordance with the prior results of total caries counts per cemetery, each dental arcade also showed significant differences. In both instances, individuals from St. Mary Spital had significantly higher rates of maxillary and mandibular caries. (Mandibular caries t=-10.358 df=120 p=.000; maxillary caries t=-10.337 df=119 p=.000) Full testing information can be found in Appendix C.

Another T-test looked for a similar relationship, if any, between total individual caries count and the sex of the individual. The results (t=-1.167 df=120 p=.246) showed no significant relationship between sex and total caries count. Additional testing compared maxillary and mandibular counts to sex to see if there were significant differences between the different arcades based on sex. Maxillary caries counts showed no significant relationship (t=-1.238 df=120 p=.218), and mandibular caries counts failed to produce any kind of relationship as well (t=-1.107 df=120 p=.270). The graph below displays a comparison of frequencies of total caries counts between males and females. For further detail on these tests, see Appendix D.



Discussion & Conclusion

Considering their respective histories, it is unsurprising to see that St. Mary Spital had significantly higher caries rates than St. Mary Graces. St. Mary Spital was used explicitly as a hospital and charitable shelter for the poor and infirm, whereas St. Mary Graces was simply a burial site for lay people. In a locale with highly concentrated amounts of disease and poverty, it would only make sense to see higher rates of illness and malnutrition left on skeletal remains, and this is exactly the kind of record that individuals from St. Mary Spital show. Caries rates at St. Mary Graces are comparable to other similar burial sites of the Medieval period. (DeWitte and Bekvalac 2010) Knowing this, it is reasonable to assume that St. Mary Spital, having significantly higher caries rates than St. Mary Graces, is also likely to have significantly higher rates of dental

caries than most other typical Medieval burial sites.

In their work on St. Mary Graces, DeWitte and Bekvalac utilize Usher's multistate model of morbidity and mortality to determine that individuals suffering from dental and periodontal diseases, such as caries, are more likely to die than their unaffected peers (DeWitte and Bekvalac 2010, Usher 2000). If this model holds true, then individuals at St. Mary Spital would have been more likely to die than individuals from other sites because of their high rates of dental and periodontal disease or because of co-infections and conditions associated with dental and periodontal diseases.

Future research examining the association of caries with mortality rates should be conducted. Similar comparison studies could be undertaken on other burial sites, in an effort to identify areas of high mortality risk. These areas of high risk likely represent regions of great poverty, due to the likelihood of the poor having inadequate access to nutrition and suffering more often from disease and injury. Knowing this, it is possible to examine different burial sites for the standard of living and socio-economic status of the burial population during their lifetimes. This aids in the reconstruction of past societies and furthers knowledge about historical and pre-historic populations, adding to the growing body of knowledge about health and the human past.

Ultimately, statistical testing can only provide information on the population, not the individual. Compelling information can be garnered from a case study of individual remains from within these two populations, as well as historical and cultural research about the kinds of people who would have lived and died in these places.

Dental caries is one of the most common dental affectations, but it is by no means the only one. Dental calculus, enamel hypoplasia, periodontal diseases, other dental and oral lesions, dental wear or modification, and antemortem tooth loss are all valid alternatives that can speak a great deal about the health and nutrition of an individual long after their remains have been buried. Further study of these factors in a similar way as given in this study could potentially provide a great deal of useful comparative information about these past populations.

Both the St. Mary Graces and St. Mary Spital cemeteries contained unique and varied burial populations that displayed a range of dental and skeletal affectations specific to their individual health, nutrition, and life experiences. Common Londoners buried at St. Mary Graces, though affected by dental caries, had much lower rates of affectation than the poor and infirm buried at the hospital at St. Mary Spital. These differences are statistically significant and can be used to differentiate between these populations in terms of the diseases and illnesses they suffered during life.

Literature Cited

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Appendix A: Frequencies

Statistics

		CEMETERY	SEX
N	Valid	122	122
	Missing	0	0
Mode		0	0

SEX

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	MALE	84	68.9	68.9	68.9
	FEMALE	38	31.1	31.1	100.0
	Total	122	100.0	100.0	

CEMETERY

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	St. Mary Grace's	82	67.2	67.2	67.2
	St. Mary Spital	40	32.8	32.8	100.0
	Total	122	100.0	100.0	

Statistics

		MAXILLARY CARIES COUNT	MANIBULAR CARIES COUNT
N	Valid	121	122
	Missing	1	0
Mean		3.66	2.84
Median		2.00	1.00
Std. Deviation		4.400	5.288
Range		16	21
Minimum		0	0
Maximum		16	21
Percentiles	25	1.00	.00
	50	2.00	1.00
	75	4.00	5.00

Statistics

TOTAL INDIVIDUAL CARIES COUNT

N	Valid	121
	Missing	0
Mean		7.48
Median		3.00
Std. Deviation		9.218
Range		34
Minimum		1
Maximum		35
Percentiles	25	2.00
	50	3.00
	75	7.25

TOTAL INDIVIDUAL CARIES COUNT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	29	23.8	23.8	23.8
	2	19	15.6	15.6	39.3
	3	15	12.3	12.3	51.6
	4	15	12.3	12.3	63.9
	5	8	6.6	6.6	70.5
	6	5	4.1	4.1	74.6
	7	1	.8	.8	75.4
	8	2	1.6	1.6	77.0
	9	1	.8	.8	77.9
	10	1	.8	.8	78.7
	16	1	.8	.8	79.5
	17	3	2.5	2.8	82.0
	18	2	1.6	1.6	83.6
	19	1	.8	.8	84.4
	20	1	.8	.8	85.2
	21	2	1.6	1.6	86.9
	22	1	.8	.8	87.7
	23	1	.8	.8	88.5
	25	1	.8	.8	89.3
	26	2	1.6	1.6	91.0
	27	2	1.6	1.6	92.6
	28	3	2.5	2.5	95.1
	29	2	1.6	1.6	96.7
	30	2	1.6	1.6	98.4
	31	1	.8	.8	99.2
	35	1	.8	.8	100.0
	Total	122	100.0	100.0	

MAXILLARY CARIES COUNT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	20	16.4	16.5	16.5
	1	31	25.4	25.6	42.1
	2	24	19.7	19.8	62.0
	3	9	7.4	7.4	69.4
	4	9	7.4	7.4	76.9
	5	4	3.3	3.3	80.2
	6	1	.8	.8	81.0
	7	2	1.6	1.7	85.1
	8	1	.8	.8	83.5
	9	2	1.6	1.7	85.1
	10	1	.8	.8	83.5
	11	5	4.1	4.1	90.1
	12	2	1.6	1.7	91.7
	13	1	.8	.8	92.6
	14	4	3.3	3.3	95.9
	15	3	2.5	2.5	98.3
	16	2	1.6	1.7	100.0
	Total	121	99.2	100.0	
Missing	System	1	.8		
Total		122	100.0		

MANDIBULAR CARIES COUNT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	33	27.0	27.0	27.0
	1	29	23.8	23.8	50.8
	2	22	18.0	18.0	68.9
	3	5	4.1	4.1	73.0
	4	2	1.6	1.6	74.6
	5	3	2.5	2.5	77.0
	6	2	1.6	1.6	78.7
	7	2	1.6	1.6	80.3
	8	1	.8	.8	81.1
	10	1	.8	.8	82.0
	11	2	1.6	1.6	83.6
	12	2	1.6	1.6	85.2
	13	4	3.3	3.3	88.5
	14	5	4.1	4.1	92.6
	15	4	3.3	3.3	95.9
	16	3	2.5	2.5	98.4
	17	1	.8	.8	99.2
	21	1	.8	.8	100.0
	Total	122	100.0	100.0	

Appendix B: T-Test

Group Statistics

	CEMETERY	N	Mean	Std. Deviation	Std. Error Mean
TOTAL INDIVIDUAL CARIES COUNT	St. Mary Grace's	82	2.84	1.809	.200
	St. Mary Spital	40	16.98	10.916	1.726

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
TOTAL INDIVIDUAL CARIES COUNT	Equal variances assumed	166.257	.000	-11.454	120	.000	-14.134	1.234	-16.577	-11.691
	Equal variances not assumed			-8.135	40.048	.000	-14.134	1.737	-17.645	-10.622

Appendix C: T-Test

Group Statistics

	CEMETERY	N	Mean	Std. Deviation	Std. Error Mean
MANDIBULAR CARIES COUNT	St. Mary Grace's	82	1.32	1.481	.164
	St. Mary Spital	40	9.03	6.423	1.016

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MANDIBULAR CARIES COUNT	Equal variances assumed	216.402	.000	-10.358	120	.000	-7.708	.744	-9.181	-6.234
	Equal variances not assumed			-7.493	41.037	.000	-7.708	1.029	-9.785	-5.631

Group Statistics

	CEMETERY	N	Mean	Std. Deviation	Std. Error Mean
MAXILLARY CARIES COUNT	St. Mary Grace's	81	1.54	1.295	.144
	St. Mary Spital	40	7.95	5.286	.836

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MAXILLARY CARIES COUNT	Equal variances assumed	169.648	.000	-10.337	119	.000	-6.407	.620	-7.634	-5.180
	Equal variances not assumed			-7.554	41.327	.000	-6.407	.848	-8.119	-4.694

Appendix D: T-Test

Group Statistics

	SEX	N	Mean	Std. Deviation	Std. Error Mean
TOTAL INDIVIDUAL CARIES COUNT	MALE	84	6.82	8.777	.958
	FEMALE	38	8.92	10.098	1.638

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
TOTAL INDIVIDUAL CARIES COUNT	Equal variances assumed	4.255	.041	-1.167	120	.246	-2.100	1.800	-5.663	1.463
	Equal variances not assumed			-1.107	63.318	.273	-2.100	1.897	-5.891	1.692

Group Statistics

	SEX	N	Mean	Std. Deviation	Std. Error Mean
MAXILLARY CARIES COUNT	MALE	84	3.33	4.272	.466
	FEMALE	37	4.41	4.652	.765

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MAXILLARY CARIES COUNT	Equal variances assumed	1.279	.260	-1.238	119	.218	-1.072	.866	-2.787	.643
	Equal variances not assumed			-1.197	63.893	.236	-1.072	.896	-2.861	.717

Group Statistics

	SEX	N	Mean	Std. Deviation	Std. Error Mean
MANDIBULAR CARIES COUNT	MALE	84	3.49	5.029	.549
	FEMALE	38	4.63	5.814	.943

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MANDIBULAR CARIES COUNT	Equal variances assumed	4.821	.030	-1.107	120	.270	-1.143	1.033	-3.189	.902
	Equal variances not assumed			-1.048	63.060	.299	-1.143	1.091	-3.324	1.037