Illness and Inclusion: Mobility Histories of Adolescents with Leprosy from Anglo-Scandinavian Norwich (Eastern England)

Kori Lea Filipek[1]*, Charlotte A. Roberts[1], Rebecca L. Gowland[1], Janet Montgomery[1], Jane A. Evans[2]

*Corresponding author: k.l.filipek-ogden@durham.ac.uk

1. Department of Archaeology, Durham University (Durham, England)
2. NERC Isotope Geosciences Laboratory, British Geological Survey (Keyworth, Nottinghamshire, England)

Abstract

Leprosy is one of the most notorious diseases in history, widely associated with social stigma and exclusion. This study builds on previous work to re-evaluate the medicohistorical evidence for social stigma in relation to leprosy. This is achieved by isotopic and palaeopathological analyses of adolescent skeletons (10 – 25 years old) from the Anglo-Scandinavian (10^{th} – 11^{th} centuries AD) parish cemetery of St. John at the Castle Gate in Norwich (Eastern England/East Anglia). Core enamel samples from premolar and molar teeth from 10 young individuals with diagnostic lesions for leprosy were selected for radiogenic strontium ($^{87}Sr/^{86}Sr$) and oxygen ($\delta^{18}O$) stable isotope analyses. Isotope data did not exclude anyone from the regional range. Palaeopathological data and archaeological contexts suggest that those with visible signs of leprosy were buried with their local community and in a normative manner, thus challenging the notion of social exclusion experienced by people with leprosy throughout the Medieval Period. This study underscores the importance of bioarchaeological data in challenging broad medicohistorical and archaeological narratives.

Keywords: Infectious disease, Isotope Analyses, Strontium, Oxygen, Stigma, St. John at the Castle Gate/Timberhill

1. Introduction

Leprosy is a chronic bacterial infection caused by the pathogens *Mycobacterium leprae* or *Mycobacterium lepromatosis*. Approximately 250,000 individuals are diagnosed worldwide with leprosy each year, and the condition is associated with low socioeconomic status, a lack of access to medical care, and community stigma (Jacob and Paredes, 2008; Goulart and Goulart, 2008; World Health Organization, 2019). Leprosy has a high infectivity but low pathogenicity, meaning up to 95% of the population is able to successfully fight off the infection through high cell-mediated immunity (CMI) (Walker and Lockwood, 2006; Lastória and Abreu, 2014). If the infection persists within a person, the mycobacteria multiply slowly and leprosy's long incubation period can range from one to over 20 years. However, studies in children reveal the incubation period may be significantly shorter and the impact of leprosy can be exacerbated by endocrine changes during puberty (Davey and Schenck, 1964; Moorthy and Desikan, 2006; Leal and Foss, 2009). The severity of leprosy expressed in a person presents along an immune spectrum. In tuberculoid (paucibacillary) leprosy, individuals show lower numbers of bacilli, few skin lesions, and present a good immune response (Ridley and Jopling, 1966; Ridley, 1974). At the opposite end of the spectrum, lepromatous (multibacillary) leprosy is characterized by low resistance, higher numbers of bacilli, numerous skin lesions, and a poor immune response (Ridley and Jopling, 1966; Ridley, 1974). For those that develop the disease, the severity of the leprous response can have harmful effects on the peripheral nervous system, skin, eyes, testes, and the extremities, and can eventually harm other parts of the body including the skeleton (Walker and Lockwood, 2006; Lastória and Abreu, 2014). Skeletal lesions for leprosy are generally confined to the lepromatous form, and may include destruction and loss of parts of the facial bones (resorption of the anterior nasal spine, remodelling of the nasal margins, abnormal porosity and/ or new bone formation on the oral and nasal surfaces of the palate, destruction of the inferior nasal conchae and vomer, and abnormal porosity and resorption of the alveolar process), and characteristic destruction and remodelling of the hand and foot bones (acro-osteolysis and concentric atrophy of the metacarpals, metatarsals, and associated phalanges) (Møller-Christensen, 1961, Andersen and Manchester, 1987, Andersen and Manchester, 1988; Andersen and Manchester, 1992).

Leprosy has a complex social past both in medicohistorical and archaeological records. Leprosaria, or leprosy hospitals, were very common in Medieval Europe (12^{th} – 14^{th}

centuries AD) leading scholars to interpret leprosy as an endemic disease during this time (Manchester and Roberts, 1989; Richards, 2000: 83-97; Rawcliffe, 2006: 1-12; Demaitre, 2007: 42-80; Roberts, 2018, 2020; Filipek et al., 2021). Many medical and historical sources repeatedly cite that people with leprosy in the past were treated poorly and excluded from their communities, including experiencing measures of forced transportation away from cities and towns, and execution (Covey, 1998: 97-103; Watts, 1997: 61-63; Rawcliffe, 2006: 40-42; Moore, 2008: 56-59). However, critical evaluations of this oft-cited narrative (Rawcliffe, 2006: 6-29; Edmond, 2006; Touati, 2000) propose that this deleterious perception of leprosy is largely a by-product of colonialist perspectives and medical racism in the 19th and 20th centuries AD, which in turn influenced Medieval and modern perceptions of leprosy and its associated stigma.

Similarly, evaluations of archaeological evidence also provides evidence to challenge these embedded notions of leprosy stigma in the past (Roberts, 2020:280; Lee, 2006; Filipek et al., 2021). Archaeological reviews of leprosy from prehistory to the 12th century AD in Asia, Africa, and Europe, often reveal no differential burial treatment of those with the disease (Roberts, 2020:280; Filipek et al., 2021). This suggests that the evidence for social exclusion should be re-evaluated further. Evaluating the mobility of people with leprosy is critical to understanding disease transmission and potential stigma. In recent years, palaeopathological and aDNA research have helped to verify the presence of leprosy in time and space, as well as the treatment of people with leprosy during their lives, at the time of their deaths, and, by extension, the perception of the disease by their communities (Donoghue et al., 2018; Roberts, 2013). This study's primary objective is to explore evidence of mobility that may support or refute the hypothesis that people with leprosy in Early Medieval England were expelled from their local areas. To achieve this objective, archaeological and palaeopathological evidence is integrated with isotopic data ($^{87}Sr/^{86}Sr$ and $\delta^{18}O$) to evaluate whether individuals with leprosy buried at the St. John at the Castle Gate/Timberhill parish cemetery (10th – 11th centuries AD) were raised locally in the area, or buried far from "home", potentially as a consequence of leprosy stigma.

2. Background

Early Medieval Norwich (Norfolk, Eastern England) developed from a series of communal settlements in the earlier Medieval period (5th – 7th centuries AD) to a more centralised mercantile centre concentrated around the tributary streams and valleys of the River Wensum in the Middle Saxon Period (c. 7th – 9th centuries AD)(Ayers, 2011; Shepherd Popescu, 2009; Figure 1). From the 9th century AD, Norwich was ruled under Danelaw and vacillated between Danish and Anglo-Saxon rule until the 11th century AD.

Excavations at the South Bailey of Norwich Castle for a retail centre (Castle Mall) were undertaken by Norfolk Archaeological unit from 1987-1991. During the course of the excavations, upwards of six cemeteries were discovered, with two (Farmer's Avenue and St. John at the Castle Gate/Timberhill) radiocarbon dated to the Late Saxon Period (c. 850-1060 AD) (Bayliss et al., 2009). Shepherd Popescu (2009:257) suggests that the term 'Anglo-Scandinavian' should be used to denote this period in Norwich, based on artefactual evidence consistent with a sustained Viking presence in the area. Of particular note is the evidence for leprosy in skeletons within the parish cemetery site of St. John at the Castle Gate/Timberhill.

[FIGURE 1]

St John at the Castle Gate/Timberhill

The church of St. John at the Castle Gate (known as St John the Baptist, Timberhill after the 12th century AD) is estimated to have an 11th century AD foundation date based on stylistic similarities to other structures with known dates (Shepherd Popescu, 2009; Popescu, 2016). The earliest documentary mention of this site was in 1157 in the *Liber Cartarum et Placitorum*, which noted a church called 'St John at the Castle Gate', but an extant structure was most likely in place before that time (Shepherd Popescu, 2009; Popescu, 2016). Excavations of a small part of the original cemetery revealed the articulated remains of 184 skeletons with at least 149 adults (59 males, 76 females, and 14 undetermined), and 35 non-adults buried in a "fan shape" along the northernmost part of the churchyard, with graves aligned south-west to north-east in the western part of the cemetery, east-to-west at its

centre, and north-east to south-west in the eastern part (Norfolk Archaeological Unit, 2009; Figure 2).

[FIGURE 2]

Previous radiocarbon dating of 17 individuals from the site reveal that the cemetery was in use for a very short time period, commencing cal AD 980-1030 (95% probability) and ceasing in cal AD 990-1050 (95% probability), likely representing one or two generations (Bayliss et al., 2009: 237-247). The site is largely contemporaneous with the adjacent Farmer's Avenue cemetery (cal AD 890-1060, 95% probability), with St. John at the Castle Gate potentially serving as an extension to the Farmer's Avenue cemetery (Shepherd Popescu, 2009: 236-268). Prior analysis of carbon and nitrogen stable isotope data from bone collagen of individuals from both cemeteries are consistent with each other (Table 1), indicating a diet based on plants with a C_3 photosynthetic pathway, terrestrial protein, and possible incorporation of a marine component (Bayliss et al., 2004; Bayliss et al., 2009). This is substantiated by the discovery of a large number of pig, cattle, and sheep remains from the Late Saxon period of the site (Albarella et al., 2009).

[TABLE 1]

Evidence for leprosy in skeletons excavated from St. John at the Castle Gate

Success in diagnosing evidence for leprosy in the skeleton depends on several factors, including chronicity and severity of the disease (e.g. tuberculoid vs. lepromatous), and the presence of characteristic skeletal lesions on the bones of the face, hands and feet (Møller-Christensen, 1961; Andersen et al., 1992; 1994; Andersen and Manchester, 1992). Out of the 184 individuals excavated, 92 had foot bones, 101 had hand bones, and 103 had facial bones available for assessment (Anderson, 1996; Anderson, 2009). Only 48 individuals had all three skeletal regions preserved (Anderson, 1996; Anderson, 2009). Anderson (2009) reported lesions consistent with a diagnosis of leprosy in 35 individuals (34% of the observable population), with 24 individuals (23.3 % of the observable population) reported

to have skeletal lesions pathognomonic of the condition (Anderson, 2009: 228-231). Of particular note is the archaeological context associated with the St. John's cemetery. St. John at the Castle Gate/Timberhill lies within the boundaries of the developing town, and was considered a parochial cemetery rather than a leprosarium cemetery (Anderson 2009: 231; Popescu 2016:8). The prevalence rate for those at St. John's with lesions diagnostic of leprosy (c. 34% of the observable burial population) is the highest for any parish cemetery not associated with a leprosarium (Anderson 2009: 231; Popescu 2016:8) and comparable with the approximate 24% suggested for the skeletons excavated from the cemetery associated with the site of St. James and Mary Magdalen leprosy hospital in Chichester (12th – 15th centuries AD) (Magilton et al., 2008).

3. Using Strontium and Oxygen isotopes to study movement of people with disease

The mobility of people throughout time and space is linked to major drivers related to forced or voluntary migration due to prevailing disease, conflict situations, and natural disasters (e.g. earthquakes), factors related to economy or settlement (e.g. famine, food insecurity, the need for work, better health, safety), and seeking marriage and kinship, but also ethnicity, identity and agency (e.g. ethnic enclaves, prior kinship, individual choice), etc. (Castelli, 2018).

Analyses of radiogenic strontium ($^{87}Sr/^{86}Sr$) and stable oxygen ($\delta^{18}O$) isotopes applied to bioarchaeological questions help to identify people's mobility histories and contextualise the impetus for these types of mobility drivers in the past at both the individual and population levels (see Evans et al., 2006; Evans et al., 2010; Chenery et al., 2010; Montgomery, 2010; Evans et al., 2012). Strontium and oxygen isotope ratios are subsumed into forming tooth enamel from the ingestion of food and water, and remain relatively unmodified throughout a person's lifetime (Montgomery and Evans, 2006; Evans et al., 2010; Montgomery, 2010; Evans et al., 2012). Strontium isotope ratios ($^{87}Sr/^{86}Sr$) are related to the underlying geology of an area and therefore provide a geographic signal for the origin of a person's food and water during tooth crown development (Bentley, 2006). Oxygen isotope ratios ($^{18}O/^{16}O$) of tooth enamel are related to the ingestion of drinking water, and therefore indirectly reflect an area's isotopic composition of its precipitation, which varies

according to climate, proximity to the coast, altitude, and region (Darling et al., 2003; Chenery et al., 2010; Evans et al., 2012). Unlike strontium, oxygen undergoes a fractionation process once subsumed, and therefore regression formulae must be applied to values in order to make comparisons with modern data (Daux et al., 2008; Chenery et al., 2010, 2012). Based on these principles, the use of both isotope systems can reveal whether a person's strontium ($^{87}Sr/^{86}Sr$) and oxygen isotope ratios ($\delta^{18}O$) are consistent with their burial location, and by extension used to interpret whether individuals were raised locally or not.

Few studies have examined the mobility histories of individuals with skeletal lesions diagnostic of specific infectious diseases like leprosy. This is despite stigma being a key factor that can be a consequence of having a specific disease (stigma) and the potential impact of mobility on its transmission. This is in part due to the difficulty in ascertaining whether a person was infected with the disease before, during, or after movement to an area from their birthplace/where they were raised (Roberts et al., 2013; Filipek-Ogden et al., 2016; Quinn, 2017; Roffey et al., 2017). However, by examining isotope ratios from younger individuals, the likelihood increases that their geographic origins during childhood overlap with the location where they were infected with leprosy. This is because of the long incubation period associated with the disease. A critical but key limitation to understanding these isotope systems is that they function on a discriminatory basis, meaning they can only show whether a person's strontium and oxygen isotope ratios are consistent with their burial locations; they cannot provide a definitive place of origin, such as a modern-day townor city (Montgomery, 2010; Evans et al., 2012). This is because, large swathes of regions with the same geology and climate patterns can produce similar isotope data, and some culturally-mediated behaviours (e.g. breastfeeding, brewing of liquids), certain diseases (e.g anaemia), and issues of equifinality can alter the isotopic composition of human tissues. Therefore, caution and consideration of these issues should be exercised in interpretations of mobility isotope data (Montgomery, 2010; Brettell et al., 2012; Bogaard and Outram, 2013; Reitsema, 2013).

Geological and Meteorological Context of Norwich

The local geology of Norwich (c. 30km) lies at the intersection of two lithologies: Cretaceous chalk to the immediate south and west, which is abutted by undifferentiated Neogene-Pleistocene gravels, sands, and clay sediments (British Geological Survey, 2007). Norwich lies at the lowest fording point above the confluence of the River Wensum with the River Yare, about 33 km west of the North Sea coast. Deposits of alluvium extend to the east and were widely used for animal grazing at the time of the compilation of the Domesday Book (11th century AD), and heavier, more fertile soils to the west and northwest suggest the area was extensively wooded in the past (Shepherd Popescu, 2009:37). The city is enveloped by Mousehold Heath to the north-east, and the archaeological site of St. John's lies at the end of the Ber Street ridge to the south, which is underlain by the gravels, sands, and clays of the Norwich Crag and the Beeston chalk (Shepherd Popescu, 2009:37). Expected biosphere ratios ($^{87}Sr/^{86}Sr$) for the Norwich area lie between 0.708 – 0.710 (Evans et al., 2010). A previous study on Medieval and post-Medieval faunal remains recovered from the Norwich Castle Mall excavations by Madgwick et al. (2012) provide a dentine ratio of 0.7098, which is consistent with predicted values.

The $\delta^{18}O_{(P)VSMOW}$ for archaeological humans excavated in Britain has a mean value of 17.7‰ ± 1.4 (2σ), with west-coast higher rainfall areas producing a mean delta value of 18.2‰ ± 1 (2σ, n=40), and the east coast having lower rainfall areas producing a mean delta value of 17.2‰ ± 1.3 (2σ, n=83) (Evans et al., 2012). Individuals raised local to the Norwich area should fall within the east-coast, lower rainfall range (<700mm/year) (Darling and Talbot, 2003). Evans et al. (2012) provide a conversion of $\delta^{18}O$ to drinking water values ($\delta^{18}O_{DW}$) based on Daux et al. (2008; Eqn. 6), and estimate a mean a drinking water value of -7.5‰ ±1.8 (2σ, n=83) for lower rainfall areas, which is consistent with data produced by Darling et al. (2003).

[FIGURE 3]

4. Materials and Methods

Sample selection and osteological methods

Using the previously published skeletal report (Anderson, 1996), skeletons were selected and re-evaluated for macroscopic evidence of leprosy at the Norwich Castle Museum. In order to analyse the individuals from this site and take tooth samples for subsequent isotopic analyses, permission with ethical justification for the study was sought and acquired firstly from the Ethics Committee of the Department of Archaeology, Durham University and secondly from Norwich Castle Museum. The Code of Ethics (2010) and the Code of Practice (2010) published by the British Association for Biological Anthropology and Osteoarchaeology (BABAO)(https://www.babao.org.uk/publications/ethics-and-standards) were strictly adhered to in sampling the individuals selected and during their study. Individuals with bones/teeth showing lesions with diagnostic indicators of lepromatous leprosy were selected for further analyses (for lesions, see Møller-Christensen, 1961; Andersen and Manchester, 1987; Andersen and Manchester, 1988; Andersen and Manchester, 1992; Ortner, 2008). These included specific lesions associated with rhinomaxillary syndrome, including resorption of the anterior nasal spine, remodelling of the nasal margins, abnormally porosity and/or new bone formation on the oral and nasal surfaces of the palatal bones, destruction of the inferior nasal conchae and vomer, and abnormal porosity and resorption of the alveolar process; Figure 4). Acro-osteolysis and concentric atrophy of the hand and foot bones (destruction and remodelling of the metacarpals, metatarsals, and phalanges), mediolateral remodelling of the metatarsal shafts, and other nonspecific lesions consistent with, but not wholly diagnostic of leprosy, were also evaluated, including resorptive grooves on the palmar surfaces of the hand phalanges (‘volar grooving’) caused by flexion contractures (Andersen and Manchester, 1987), tarsal fusion and dorsal exostoses (Andersen and Manchester, 1988), and subperiosteal new bone formation on the distal shafts of the tibiae and fibulae (Ortner, 2008). As observation of the distribution pattern of these pathological lesions is important to consider a diagnosis of leprosy, this was carried out and differential diagnoses were generated for all individuals. However, the presence of rhinomaxillary syndrome, which is pathognomonic for leprosy (Møller-Christensen, 1961; Andersen and Manchester, 1992; Ortner, 2008), was required for a skeleton to be included in this study.

[FIGURE 4]

[TABLE 2]

Age at death for each individual was reassessed, based on tooth development according to methods set out in AlQahtani et al. (2010). This was undertaken to target adolescents, defined socially and biologically as ranging from ages 10 – 25 years (World Health Organization, 1993; Patton et al., 2016; Sawyer et al., 2018). Adolescent individuals were specifically selected because of their unique liminal status in the Early Medieval Period; i.e. not a 'child' and not yet an 'independent adult' (Gilchrist, 2012: 34; Cochelin, 2013; Lewis, 2016), and because their potential for moving their location is more limited due to their younger age, i.e. the older a person is the more opportunity they may have to move (Montgomery, 2010). This is not to say individuals who died in adolescence did not have the opportunity to move, but prior to the establishment of adolescent apprenticeships in the 13th century AD (Lewis, 2016), adolescents would likely be contributing their labour to local agriculture (Kroll 1977; Kroll and Bachrach 1986). When compared to adults, younger people also offer a crucial insight into social attitudes towards disease in the past and provide a 'pivotal conduit' for understanding the social and physical impacts of disease within a population as a whole (Redfern and Gowland, 2011: 111).

A total of 10 tooth samples from the selected adolescents were selected for radiogenic strontium and stable oxygen isotope analysis (Table 3). Either molars or premolars were selected for each individual, representing the most recently formed teeth for this age group, and only teeth without pathological lesions were selected. Teeth were removed from their alveolar sockets by hand and photographed occlusally, mesially, distally, buccally, lingually and apically before sample preparation for isotopic analyses. The images were sent to Norwich Castle Museum for archival purposes.

Isotope methods

Sections of core enamel were extracted in the Sample Preparation Laboratory in the Department of Archaeology, Durham University. Tooth sample preparation followed the guidelines of Montgomery (2002). Tooth surfaces were abraded using tungsten carbide burrs to remove exogenous material, and 15-25mg of enamel were sectioned using

diamond edged dental saws. All surface enamel and any adhering dentine were mechanically removed from the enamel sections. Processed chips of core enamel were sealed in Eppendorf microtubes and transferred to the laboratory facilities at the NERC Isotope Geosciences Laboratory (NIGL: class 100, HEPA-filtered) at the British Geological Survey, Keyworth, Nottinghamshire, England) for further preparation.

For strontium isotope analyses, the sections of core enamel were then further prepared and measured according to Evans et al. (2006). In a clean laboratory, the enamel sample was first cleaned ultrasonically in high purity water to remove dust, rinsed twice, dried down in high purity acetone and then weighed into pre-cleaned Teflon beakers. A known amount of ^{84}Sr tracer solution was added to each sample, which was dissolved in Teflon distilled 8 M HNO_3. The sample was converted to chloride using quartz distilled 6M HCl and then taken up in 2.5M HCl. The strontium was extracted using Eichrom Dowex AG50X8 resin. The samples were loaded onto Rhenium filaments (Birck 1986) and the isotope composition and concentrations were determined by Thermal Ionization Mass spectroscopy (TIMS) using a Thermo Triton multi-collector mass spectrometer. The international standard for $^{87}Sr/^{86}Sr$, NBS-987, gave a value of 0.710251 ± .000005 (n = 19, 2sd) during the analysis of these samples. Procedural blank values were less than 100pg.

For oxygen isotope analyses, approximately 3 mg of powdered enamel were placed into a glass vial and sealed with septa. The vials were transferred to a hot block at 90°C on a GV Multiprep system. The vials were evacuated and 4 drops of anhydrous phosphoric acid added. The resultant CO_2 was collected cryogenically for 14 minutes and transferred to a GV IsoPrime dual inlet mass spectrometer. The resultant isotope values are reported as delta (δ) values, in parts per thousand (per mil; ‰) normalized to the VPDB scale using a within-run calcite laboratory standard (Keyworth Carerra Marble, KCM), and calibrated against SRM19, NIST reference material. These ratios are converted to the VSMOW scale using the published conversion equation of Coplen (1988): VSMOW = (1.03091 x $\delta^{18}O_{VPDB}$) +30.91. Analytical reproducibility for this run of laboratory standard calcite (KCM) is 0.09‰ (1σ, n = 6) for $\delta^{18}O_{VSMOW}$, and ± 0.05‰ (1σ, n = 6) for $\delta^{13}C_{VPDB}$. The reproducibility of the enamel, based on the average of five duplicate pairs is ± 0.07‰, 1σ. The carbonate oxygen results ($\delta^{18}O_{(C)VSMOW}$) were converted to phosphate values ($\delta^{18}O_{(P)VSMOW}$) using the regression

equation $\delta^{18}O_P = 1.0322 \times \delta^{18}O_C - 9.6849$ (Chenery et al., 2010, 2012), with an associated error of ±0.29 ‰, 1σ. The conversion to phosphate values was carried out to make the data more comparable to oxygen isotope data and baselines reported in other studies (e.g. Evans et al., 2012).

The carbonate oxygen results ($\delta^{18}O_{(C)VSMOW}$) were converted to drinking water values ($\delta^{18}O_{DW}$) using Daux et al.'s (2008) equation 6 in accordance with Chenery and colleague's (2012) calculation: $\delta^{18}O_{DW} = 1.590 \times \delta^{18}O_C - 48.634$. The calculation of drinking water values can involve larger uncertainties (± 1 ‰, 2σ) (Chenery, 2012; Pollard et al., 2011) and therefore drinking water values are used only as general guidance.

5. Results

Strontium and oxygen isotope data and strontium concentrations for the 10 samples are presented in Table 3 and Figure 5. Strontium isotope ratios range from 0.7090 to 0.7101 (mean 0.7095, ± 0.0008 2σ). Strontium concentrations range between 71 ppm and 193 ppm (mean 105, ± 38 ppm, 2σ), which are consistent within previously reported archaeological and modern teeth from Britain (98 ± 130 ppm) (Eckardt et al., 2009; Chenery et al., 2010; Evans et al., 2012; Hemer et al., 2014), suggesting good preservation. One individual (Sk. 13044) failed to produce a strontium isotope ratio. The remaining nine individuals provide strontium isotope ratios compatible with the predicted ratios for the Norwich area (~0.708 – 0.710).

The $\delta^{18}O_{(P)VSMOW}$ values for the individuals range from 17‰ to 19.3‰ (mean 17.8 ± 0.6‰ 1σ), with corresponding $\delta^{18}O_{DW}$ values ranging from -7.6‰ to -4.1‰ (mean -6.3 ± 0.9‰ 1σ). Nine of the 10 individuals show $\delta^{18}O_{(P)VSMOW}$ (mean 17.7 ± 0.4‰ 1σ) and $\delta^{18}O_{DW}$ (-6.5 ± 0.6‰ 1σ) values that fall within the predicted values for the study area. One individual (Sk. 13121) is a clear outlier from the group with a high $\delta^{18}O_{(P)VSMOW}$ (19.3‰; $\delta^{18}O_{DW}$ = -4.1‰).

[TABLE 3]

[FIGURE 5]

6. Discussion

One individual (13121) has an oxygen isotope ratio outside of the expected range for the burial location. The latest forming tooth available for sampling from 13121 was the left maxillary first molar, the crown of which develops between the ages of 1.5 months and 3.5 years (AlQahtani et al., 2010). Therefore, this result is likely due to an additional metabolic alteration in their $\delta^{18}O$ values from breastfeeding. It is important to note that this was the only individual with an M1 sampled, and therefore we would expect the $\delta^{18}O$ values for this individual to show some form of ^{18}O enrichment due to breastfeeding. The tissues of breastfed infants are often enriched in ^{18}O relative to $\delta^{18}O$ body water values of the mother instead of from drinking water directly derived from precipitation. This relative enrichment can result in an increase in an individual's $\delta^{18}O_{DW}$ by as much as 2-3‰ within tissues developing during the breastfeeding period (Fuller et al., 2006; Tsutaya and Yoneda, 2015). Given that their strontium isotope ratio aligned well with others within the cemetery, the most likely explanation is that this individual was raised locally and that their higher oxygen isotope ratio is a by-product of breastfeeding.

This study's main objective was to view whether any evidence of exclusion of these adolescents from their place of origin existed to support or refute the hypothesis that people with leprosy in Early Medieval England were segregated from their local communities. The results indicate that all of these young people with lesions diagnostic of lepromatous leprosy were buried in a normative manner within a parish cemetery within the boundaries of the town, and have isotope profiles consistent with the Norwich area and other broadly contemporaneous burials from the region (Haraldsson, 2016). Our sampling strategy does acknowledge that younger people would have had less time (shorter lives) or ability to move from their original communities, particularly if they were ill, but if they were expelled as many medicohistorians have suggested (Browne, 1975; Brody, 1975: 147-157; Dols, 1979; Kealey, 1981:104-105; Conrad et al., 1998: 187-189; Covey, 1998: 95-103; Porter, 1999:121-122; Richards, 2000: 48; Moore, 2008: 43-60), we would expect them to be found beyond the confines of their local area and excluded from local community cemeteries.

It is worth noting that inclusion within the local geographical confines of the area does not necessarily reflect social inclusion (Hadley 2010). However, if they were socially stigmatised but not expelled from the area, we would expect their burials to show some degree of deviancy or otherness. Moore (2008:59) argues that individuals with leprosy in Medieval England were subject to such stigma that their bodies, residences, and belongings were incinerated upon their deaths. This is not supported by the archaeological and skeletal evidence at St. John's at the Castle Gate, which shows that individuals with leprosy were buried with care, including with earthen pillows, head supports made of flint, wooden coffins, burial shrouds, grave goods, and beds of pebbles. This shows parity in burial practice with individuals without skeletal evidence of lepromatous leprosy at St. John's, as well as with nearby, largely contemporaneous cemeteries (Shepherd Popescu, 2009:266-269). This pattern of burial inclusivity is further illustrated by Roberts in her consideration of the global evidence for skeletons with leprosy within their funerary context (2020:280). Furthermore, isotope data from the affected individuals in the current study are consistent with the local area, indicating that notions of stigma and exclusion have been overstated in medical and historical literature.

It is also important to note, that leprosy would not have been unknown in this time and place. Several Early Medieval cemetery sites around Norfolk, as well as the remainder of Britain (England, Scotland and Wales), have revealed skeletal remains of people with leprosy, including high-status burials (see Roberts, 2020 – Appendix 3; Filipek et al. 2021). Documentary evidence such as the *Leechbooks* (c. 9th - 10th centuries AD) give advice for the care and treatment of individuals with leprosy (Cockayne, 1865; 1866; Doyle, 2017), and Fursey, an Irish missionary, specifically spoke about the presence leprosy in East Anglia (Eastern England) as early as the 7th century AD (Shepherd Popescu, 2009: 270). Textual evidence from Later Medieval contexts indicates that in some instances people with leprosy were glorified for their suffering, rather than stigmatized (Rawcliffe, 2006:44-102). Although this study cannot tell us how individuals with lepromatous leprosy were treated in life as a direct consequence of their disease, their inclusion within a local parochial cemetery, and not outside the town, demonstrates that their disease status did not exclude them from the normal community burial customs at the times of their deaths. It may be argued that the presence of individuals with leprosy at St. John at the Castle Gate and not at Farmer's

Avenue suggests some degree of separation, but the latter cemetery has an earlier start date (c. 890 AD), and archaeological evidence suggests it was likely an overflow cemetery for Farmer's Avenue (Shepherd Popescu, 2009: 236-268).

Notwithstanding, we cannot fully exclude the possibility that St. John's served in some part as an early *leprosarium*. Although there is a lack of infirmary structures associated with the cemetery, both the conspicuous location of the parish and its access to a secure freshwater source is mirrored in *leprosaria* established after the expansion of the Norwich Castle walls in the 12th century AD (Rawcliffe 2006: 312-313; Shepherd Popescu 2009: 269). Therefore it is possible that expansion of the Castle walls could have also destroyed any timber infirmary buildings associated with St. John's.

7. Conclusions

This study aimed to ascertain the mobility histories of people with leprosy buried at St. John at the Caste Gate in Norwich, with the objective of evaluating evidence for stigma in Early Medieval Norwich. The analysis of strontium and oxygen isotopes combined with the burial evidence suggests that young individuals with leprosy in Norwich were included in community cemeteries consistent with their place of birth/upbringing in the Anglo-Scandinavian period. Future studies ascertaining and comparing leprosy strain type and individual haplotypes will further aid in understanding leprosy and the particulars of migration and transmission in Early Medieval England. This study also reports the first strontium and oxygen isotope data from people with leprosy in East Anglia. Although the study sample was small, this contributes to a growing body of research interrogating the social impacts of leprosy and challenges to oft-cited narratives about the treatments of people with leprosy in the past, and perceptions of those with the disease in present.

8. Acknowledgments

Special thanks are given to Tim Pestell from the Norwich Castle Museum for allowing access to the skeletal collection, and Hilary Sloane and Carlyn Stewart from the NERC Isotope Geosciences Laboratory for their additional support. Additional thanks are given to Harald Haraldsson, Dr. Sophie Beckett, and the Sedgeford Historical and Archaeological Research

Project (SHARP) for permitting the use of their data for comparison and to the anonymous reviewers for their time and helpful comments. KLF would also like to thank Drs. Joanna Moore and Lucie Johnson from Durham University for their helpful comments. The authors declare that they have no conflict of interest.

Data Availability Statement:

The data that supports the findings of this study are available within the text of this article

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Table 1 – Radiocarbon dates and mean carbon and nitrogen isotope values from bone collagen from Farmer's Avenue and St. John's at the Castle Gate, Norwich (UK). Data compiled from Bayliss et al. (2009: 239).

Cemetery	**^{14}C (95% confidence)**	**δ^{13}C‰**	**δ^{15}N‰**
Farmer's Avenue	890 – 1060 cal AD	-19.3	10.7
St. John's	990 – 1050 cal AD	-19.3	11.1

Table 2 – Individuals selected for strontium and oxygen isotope analysis. Radiocarbon dates and carbon and nitrogen isotope values compiled from Bayliss et al. (2009: 239). Tooth development timing based on Moorees et al. (1963) and AlQahtani et al. (2010).

Individual	Sex	Age at death (± 0.5)	Tooth sampled	Age range of crown formation (± 0.5)	Bones affected by leprosy	^{14}C dates (2σ)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Sk. 11117	Male	16.5-18.5	Mandibular RM3	7.5 – 17.5 years	Facial bones, hands, feet, distal lower limbs	cal AD 990-1050	-18.2	11.4
Sk. 11287	Male	22.5-23.5	Maxillary LM3	7.5 – 16.5 years	Facial bones, hands, distal lower limbs, feet unavailable for observation			
Sk. 13009	Ambiguous	15.5-16.5	Maxillary RM2	2.5 – 8.5 years	Facial bones, hands, possible feet, distal lower limbs	cal AD 980-1030	-17	11.7
Sk. 11518	Ambiguous	10.5 - 11.5	Mandibular RM2	2.5 – 9.5 years	Facial bones, hands, feet, distal lower limbs	cal AD 990-1040	-19.2	11.5
Sk. 13121	Female	18.5-23.5	Maxillary LM1	1.5 months – 3.5 years	Facial bones, all other skeletal elements unavailable for observation at time of analysis			
Sk. 11526	Ambiguous	12.5-13.5	Mandibular RM3	7.5 – 17.5 years	Facial bones, distal lower limbs			
Sk. 13035	Female	18.5-20.5	Maxillary LM2	2.5 - 8.5 years	Facial bones, hands, distal lower limbs, feet unavailable for observation			
Sk. 13044	Male	15.5-16.5	Mandibular RM2	2.5 - 9.5 years	Facial bones, hands			
Sk. 13101	Ambiguous	14.5-16	Maxillary LM3	7.5 – 16.5 years	Facial bones, feet, distal lower limbs, hands unavailable for observation			

Sk. 13146	Male	18.5-20.5	Mandibular LM3	7.5 – 17.5 years	Facial bones, feet, distal lower limbs, hands unavailable for observation at time of analysis

Table 3 – Strontium and oxygen isotope data, including $\delta^{18}O_P$ calculated from Chenery et al. (2012), and $\delta^{18}O_{DW}$ calculated from Daux et al. (2008) eqn. 6, in accordance with Chenery et al. (2012).

Skeleton	**Sr ppm**	**$^{87}Sr/^{86}Sr$**	**$\delta^{13}C_{VPDB}$ (‰)**	**$\delta^{18}O_{(C)VSMOW}$ (‰)**	**$\delta^{18}O_{(p)vSMOW}$ (‰)**	**$\delta^{18}O_{DW}$ (‰)(Eqn 6)**
13101	120	0.7098	-12.35	26.73	17.9	-6.1
13009	193	0.7095	-12.45	25.82	17.0	-7.6
11117	81	0.7090	-12.68	26.38	17.6	-6.7
11518	87	0.7100	-12.98	26.76	17.9	-6.1
13121	71	0.7096	-12.83	28.03	19.3	-4.1
11526	128	0.7097	-13.26	26.51	17.7	-6.5
13035	84	0.7090	-13.01	26.83	18.0	-6.0
13044	FAILED	FAILED	-13.22	26.98	18.2	-5.7
13146	100	0.7101	-13.44	26.31	17.5	-6.8
11287	84	0.7090	-12.61	26.25	17.4	-6.9

Figure Captions

Figure 1. Map of Norwich and area of settlement for Late Saxon Norwich with St. John at the Castle Gate (starred). (Modified from Norfolk Archaeological Unit (2009) Norwich, Castle

Mall [data-set]. York: Archaeology Data Service [distributor] https://doi.org/10.5284/1000173; Open Access and Shepherd Popescu 2009:51).

Figure 2. Distribution and leprosy presence in individuals buried at St. John at the Castle Gate as given in Shepherd Popescu 2009:120. Leprosy status determined by Anderson 1996:22-23, based on criteria from Møller-Christensen 1961(Modified from Norfolk Archaeological Unit (2009) Norwich, Castle Mall [data-set]. York: Archaeology Data Service [distributor] https://doi.org/10.5284/1000173; Open Access).

Figure 3. Oxygen contour and strontium biosphere maps with Norwich starred. Modified from Darling et al. (2003:189), and Evans et al. (2010:2).

Figure 4. Facial bones of Sk. 13009 displaying evidence of rhinomaxillary syndrome including 1.) Resorption of the anterior nasal spine, 2.) Widening and remodelling of the nasal aperture, 3.) Widening and flattening of the nasal bones, and 4.) Pitting on the nasal floor.

Figure 5. Strontium and oxygen isotope data from St. John at the Castle Gate (Norwich, Norfolk, Eastern England). Also plotted are the estimated predicted ranges for Norwich from Evans et al. (2010, 2012), and comparative data from Early Medieval (7^{th}-9^{th} centuries AD) local burials from nearby Sedgeford, Norfolk, Eastern England (Haraldsson, 2016). Sk. 13121 presents as an outlier likely due to an enrichment in ^{18}O from breastfeeding during tooth formation.