



Durham E-Theses

WHO CARES?: Examining the biological and social impacts of leprosy on adolescents in Medieval England through clinical and isotopic models of care.

FILIPEK, KORILEA

How to cite:

FILIPEK, KORILEA (2021) *WHO CARES?: Examining the biological and social impacts of leprosy on adolescents in Medieval England through clinical and isotopic models of care.*, Durham theses, Durham University. Available at Durham E-Theses Online: <http://etheses.dur.ac.uk/14018/>

Use policy

The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a [link](#) is made to the metadata record in Durham E-Theses
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

Please consult the [full Durham E-Theses policy](#) for further details.

WHO CARES?:

Examining the biological and social impacts of leprosy on adolescents in Medieval England through clinical and isotopic models of care.



Reproduced with permission from the British Library. © British Library Board: Add. 42130 f186v.

KORI LEA FILIPEK

Submitted for the degree of Doctor of Philosophy

Department of Archaeology,
Durham University

2021

ABSTRACT

Leprosy is a bacterial infection, and although fully treatable, leprosy is commonly associated with negative social perceptions, stigma, and ostracism. Many historical sources cite similar reactions in Medieval England to justify these modern-day views, including a dominant narrative that expulsion and poor treatment was the primary means of medieval eradication. This research employs a novel, cross-disciplinary approach to examine aspects of the life course from adolescents (c. 10-25 years old) who died with leprosy to reveal biological and social impacts of the disease during the Early-Late Medieval transition (9th – 12th centuries AD). This transition is defined by dynamic cultural and population shifts, and runs concurrent with the increase of leprosy in England. The individuals analysed originate from the parish cemeteries of St. John at the Castle Gate (Norwich; 10th – 11th centuries AD) and the St. Mary Magdalen leprosarium (Winchester; 9th – 12th centuries AD). Amelogenin peptide extraction and multi-isotope analyses (strontium, oxygen, carbon, and nitrogen isotopes) determined biological sex, residential origins, and whole-life dietary profiles, which were combined with historical, archaeological, and clinical frameworks to nuance the particulars of these people's lived experience.

The results from this research suggest that the leprosy stigma, as we understand it today, was not present in pre-12th century AD England. Combined data indicate that care (in terms of respect and/or treatment) is evidenced in both archaeological contexts. The majority of adolescents were local to their respective communities and results also reveal the presence of local and non-local females buried within the leprosarium. Dietary isotope profiles evidence early life stress, a 'leprosarium diet' consistent with high-status monastic contexts, and metabolic disruptions likely due to the onset of leprosy. When fully contextualised, these results help to reveal a fuller picture of leprosy in the past using adolescents as a conduit for the biological and social milieu of leprosy in the Medieval period. This line of research is important in understanding and addressing present-day immunological susceptibilities, pathophysiological responses, social inequalities, and treatment of peoples with leprosy, and underscores the important contributions of cross-disciplinary bioarchaeological research to modern understandings of disease histories and dynamics.

TABLE OF CONTENTS

LIST OF TABLES.....	IX
LIST OF FIGURES.....	XI
ACKNOWLEDGEMENTS.....	XVII
STATEMENT OF COPYRIGHT.....	XVIII

CHAPTER 1. INTRODUCTION

1.1 Broad research context.....	1
1.1.1 Contextualising leprosy and medical care in the Early-Late Medieval transition (9th – 12th centuries AD)	2
1.1.2 Leprosy in the Early Medieval period (5 th – 11 th centuries AD)	3
1.1.3 Medical care, hospitals, and the leprosarium in the Early-Late Medieval transition	4
1.2 Aims, hypothetical models, and research questions.....	11
Research Questions and Hypothetical Model 1:	11
Research Questions and Hypothetical Model 2:	12
Research Questions and Hypothetical Model 3:	13
1.3 Structure of the Thesis.....	11
1.4 Research Impact.....	15
1.5 References.....	16

CHAPTER 2. PRESENT, PAST, AND ARCHAEOLOGICAL PERSPECTIVES OF LEPROSY

2.1 Introduction.....	21
2.2 Biological and Clinical Features of Leprosy.....	21
2.2.1 Epidemiology	22
2.2.2. Who it affects today	23
2.2.3 Bacteriology	25
2.2.4 Modes of transmission	27
2.2.5 Ranges in immunity	28
2.2.6 Clinical features and treatment	30
2.2.7 Long-term effects of leprosy.....	31
2.3 Leprosy in the Past – Historical Understandings and Paradigm Shifts.....	32
2.3.1 What’s in a name? - Historical evidence for leprosy	32
2.3.2 The myth of leprosy	34
2.3.3 Leprosy in Leviticus?	36

2.3.4 Entangled Terminology – Medical traditions of ‘leprosy’ in the Classical, Islamic, and Early Medieval periods.....	38
2.4 Bioarchaeology of Leprosy.....	48
2.4.1 Skeletal changes in leprosy.....	48
2.4.2 Leprosy in human remains through time and space	52
(I) Prehistoric to Early Medieval evidence from Asia and the Middle East.....	52
(II) Prehistoric to Early Medieval evidence from Africa	56
(III) Prehistoric to Early Medieval evidence from Continental Europe	59
2.4.3 Bioarchaeology of Leprosy in Prehistoric to Early Medieval Britain	70
2.4.4 Summary of the bioarchaeology of leprosy from Prehistory to the Early Medieval period	74
2.5 References.....	75

CHAPTER 3. APPLICATIONS OF ISOTOPE ANALYSES IN PALAEOPATHOLOGY

3.1 Introduction.....	88
3.2 Fundamentals of isotope biogeochemistry.....	88
3.2.1 Isotopic Fractionation	89
3.2.2 Assumptions of equifinality and ‘stress’	90
3.2.3 Isotope Notation.....	91
3.2.4 Tissues used in archaeological analyses of stable isotopes	92
(I) Bone apatite and collagen.....	93
(II) Dental tissues	94
3.3 Measurement by mass spectrometry.....	96
3.4 Isotope applications in bioarchaeology and palaeopathology.....	98
3.5 Carbon stable isotopes.....	99
3.5.1 C ₃ and C ₄ biomes.....	99
(I) European Plants	100
3.5.2 Dietary carbon and collagen.....	102
3.5.3 Carbon in aquatic and terrestrial food webs.....	103
3.6 Nitrogen stable isotopes.....	104
3.6.1 Nitrogen uptake and variability.....	105
3.6.2 The consideration of nitrogen in aquatic and terrestrial food webs.....	107
3.6.3 Trophic-level effects in dietary carbon and nitrogen	109
(I) Trophic level effects of dietary carbon.....	109
(II) Trophic level effects of nitrogen	110
3.6.4 Nitrogen metabolism	111
3.7 Beyond the food chain.....	113

3.7.1 Breastfeeding and weaning processes	114
3.7.2 Water stress	115
3.7.3 Nutritional stress	116
3.7.4 Pathophysiological stress	118
3.8 Carbon and nitrogen stable isotopes in palaeopathology.....	120
3.8.1 What is stress? The importance of distinguishing between starvation and disease	125
3.9 The use of oxygen and strontium in bioarchaeology.....	127
3.10 Oxygen isotopes.....	127
3.10.1 Pathophysiological and anthropogenic variations in $\delta^{18}\text{O}$ values	130
3.10.2 The use of oxygen isotopes in palaeopathology	133
3.11 Strontium isotopes.....	135
3.11.1 Developing local $^{87}\text{Sr}/^{86}\text{Sr}$ baselines	138
3.11.2 Environmental and anthropogenic factors affecting radiogenic strontium ratios.....	140
(I) Maritime environments and precipitation.....	141
(II) Atmospheric Dust	141
(III) Fertiliser	142
(IV) Diet.....	142
3.11.3 Strontium metabolism in humans	143
3.11.4 Strontium ratios in enamel: biomineralisation and developmental timings	144
3.12 Strontium and oxygen isotope analyses in palaeopathology.....	147
3.13 Summary and future directions in isotope analyses and palaeopathology.....	153
3.13.1 Conclusions and interpretive considerations	155
3.14 References.....	156

CHAPTER 4. MATERIALS AND METHODS

4.1 Introduction.....	173
4.2 Materials.....	173
4.2.1 Broad Archaeological Context	173
4.2.2 St. Mary Magdalen leprosarium (Winchester, Hampshire, England)	174
(I) Location	174
(II) Excavations.....	175
4.2.3 St. John at the Castle Gate/ Timberhill (Norwich, Norfolk, England).....	181
(I) Location	181
(II) Excavations.....	183
4.2.4 Individuals Selected for Study and Sampling Strategies	190
4.3 Methods.....	194

4.3.1 Overview of the methods used.....	194
4.3.2 Osteological Methods.....	194
(I) Sex estimation	195
(II) Age at death estimation	196
(III) Other osteological data	199
(IV) Palaeopathological analysis	199
4.3.3 Index of Care Methods	201
4.3.4 Isotope Methods.....	204
(I) Initial isotope sampling	204
(II) Radiogenic strontium and stable oxygen isotope methods	205
(III) Carbon and Nitrogen Isotope Analyses	213
(IV) Establishing timings of tooth growth and development	220
(V) Additional quality controls for carbon and nitrogen stable isotopes	221
4.3.5 Amelogenin Peptide Methods.....	224
4.3.6 Summary Statistics and Data Presentation.....	220
4.4 References.....	225

CHAPTER 5. RESULTS

Manuscript 5.1: Alloparenting Adolescents: Evaluating the Social and Biological Impacts of Leprosy on Young People in Early-Late Medieval England (9th – 12th centuries AD) through Cross-Disciplinary Models of Care.....	233
Introduction	234
Considering the role of alloparenting in the leprosarium	235
Medical care for medieval children – An index of effort	237
Medieval leprosaria- Care or confinement?	238
Leprosy in young people – Present and past.....	240
Identifying leprosy in the past	242
Bodies of evidence - Archaeological examples of leprosy in young people	243
Adolescents in Medieval leprosaria.....	244
The leprosy hospital of St. Mary Magdalen (Winchester, UK).....	245
Handled with care – The burial contexts	246
Skeletal indicators of lepromatous leprosy in the adolescents at St. Mary Magdalen	247
Bioarchaeological Interpretations of care and treatment of leprosy	250
Facing lepromatous leprosy – An index of care.....	251
Discussion and Conclusions	261
Acknowledgements	263
References	263

Manuscript 5.2: Health at home: Mobility analyses of adolescents with leprosy from the Late Saxon (10th – 11th centuries AD) cemetery of St. John at the Castle Gate/Timberhill (Norwich, England)	271
Abstract	271
Keywords	271
Key Summary points	271
Introduction	271
Background	274
Historical Background of the area	274
Norwich Castle Mall Cemetery Excavations	274
Using Strontium and Oxygen isotopes to study movement of people with disease	279
Geological Context and Meteorological Context	280
Materials and Methods	281
Osteological Methods	281
Isotope methods	285
Results	286
Discussion	288
Conclusion	291
Acknowledgments	292
References	292
Manuscript 5.3: Disease at the Doorstep: Sex and mobility histories of adolescents buried in the cemetery of St. Mary Magdalen leprosarium (Winchester, England)	300
Abstract	300
Keywords:	301
Introduction	301
Leprosy in the Present and Past	301
Archaeological Context	303
Evidence for leprosy in the young people buried at St. Mary Magdalen	306
Isotopic Background	310
Characterizing the Strontium and Oxygen isotope ranges for Winchester	311
Osteological analyses and biomolecular methods	312
Individuals	313
Age and Sex	313
Sample Preparation	314
Amelogenin peptide extraction methods	314
Isotope Methods	315
Results	316

Discussion	318
Individuals with $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{18}\text{O}_{(\text{P})\text{VSMOW}}$ values consistent with the study area (Winchester)	319
Individuals with non-local $^{87}\text{Sr}/^{86}\text{Sr}$ but $\delta^{18}\text{O}_{(\text{P})\text{VSMOW}}$ values consistent with British ranges	320
Individuals with $\delta^{18}\text{O}_{(\text{P})\text{VSMOW}}$ values inconsistent with British ranges	320
Social reactions to leprosy	323
Conclusions	324
Acknowledgments	325
References	325
Manuscript 5.4: Feeding the body and soul: isotopic evidence of diet and pathophysiological stress in adolescents with leprosy buried at the St. Mary Magdalen Leprosy Hospital (Winchester, Hampshire, England)	334
Abstract	334
Key findings:.....	334
Keywords:	335
Introduction	335
Leprosy care and diet in the past	336
Incremental dentine	337
The St. Mary Magdalen Leprosarium	337
Sampling and methods	339
Skeletal analyses and tooth selection.....	339
Isotope preparation and methods.....	344
Results	345
Broad trends in diet and potential movement to the leprosarium	361
Potential indicators of pathophysiological stress	364
Discussion	367
Were adolescents fed a poor diet in the leprosarium?	367
Pathophysiological stress near the end of life in nitrogen isotope profiles	368
Discrepancies in bone and dentinal collagen	369
Linking early life stress in enamel and the manifestation of leprosy in the dentinal collagen profiles.....	370
Physiological disruptions in co-forming teeth	370
Conclusions.....	371
Acknowledgements:	372
References	373

CHAPTER 6. DISCUSSIONS, FUTURE DIRECTIONS, AND FINAL CONCLUSIONS

6.1 Mobility and Identity analyses	381
6.2 Care in the leprosarium	383

6.3 Life histories and 'stress'	384
6.4 Limitations of the research	385
6.5 Future Directions	386
6.5.1 Disease related mobility and mortuary treatment.....	386
6.5.2 Synergistic relationships between isotopes and disease.....	387
6.5.3 Identity and Kinship	388
6.6 Final conclusions	389
6.7 References	391
APPENDIX:DATA	396

LIST OF TABLES

Table 1.1 – Chronological list of Early-Late Medieval hospitals and leprosaria in England founded before 1150 AD.....	9
Table 2.1 - Translations of treatments for leprosy and elephantiasis from Bald’s Leechbook I.....	46
Table 2.2 - Common skeletal expressions of leprosy.....	49
Table 2.3 - Differential diagnoses to consider for leprosy bone.....	50
Table 2.4 - Current Skeletal Evidence for leprosy in Asia (Prehistory to Early Medieval periods).....	55
Table 2.5 - Current Skeletal Evidence for Leprosy in Africa (Prehistory to Early Medieval periods).....	58
Table 2.6 - Current Skeletal Evidence for Leprosy in Continental Europe (Prehistory to Early Medieval periods).....	69
Table 2.7 - Current and Possible Skeletal Evidence for Leprosy in Britain (Prehistory to Early Medieval periods).....	73
Table 3.1 - Stable isotopes of elements used in this thesis, their abundance in nature, and the reference standards of known isotopic composition they are measured relatively to.....	92
Table 3.2 - Types of mass spectrometers used to analyse isotope ratios in this study.....	98
Table 3.3 - Ranges in $\delta^{13}\text{C}$ values for C_3 plants reported in literature.....	100
Table 3.4 – The effects of protein catabolism and anabolism on $\delta^{15}\text{N}$ values.....	118
Table 3.5 - Average $^{87}\text{Sr}/^{86}\text{Sr}$ ratios sampled from material with varying chronological lithologies.....	138
Table 3.6 – Median developmental timings of deciduous and permanent dental crowns.....	147
Table 4.1 - Individuals from the North cemetery with skeletal evidence for leprosy.....	177
Table 4.2 - Calibrated radiocarbon dates and SNP types for individuals buried at the St. Mary Magdalen leprosy hospital site.....	179
Table 4.3 - Individuals buried at St. John at the Castle Gate/Timberhill with skeletal evidence of leprosy.....	185
Table 4.4 - Brief summary of the sites and individuals selected for study.....	191
Table 4.5 - Individuals and teeth sampled in this study with revised ages and sexes.....	198
Table 4.6 - Summary of osteological methods.....	199
Table 4.7 - Step-by-step guidance for recording based on Roberts and Connell (2004).....	200
Table 4.8 - Individuals from St. Mary Magdalen leprosarium selected for carbon and nitrogen stable isotope analyses of incremental dentine.....	213

Table 4.9 - Carbon and nitrogen isotope ratios for international and in-house standards used in this thesis.....	219
Table 4.10 - Growth and development rates of teeth (both sexes) used in this research.....	221
Table 4.11 - Collagen yields from tooth samples.....	222
Table 5.1.1 – Adolescents excavated from the North Cemetery of the St. Mary Magdalen Leprosarium (c. 9 th – 12 th centuries AD; Winchester, UK).....	244
Table 5.1.2 – Impact of Leprous Bone Changes on Aspects of Daily Living for Sk. 19 and individuals with similar bone changes when they were alive.....	257
Table 5.1.3 – Model of care considering the probability of need for direct support required from other people to survive with the bone changes present in Sk. 19.....	258
Table 5.1.4 – Model of care considering the probability of need for accommodation and support across multiple divisions.....	259
Table 5.2.1 – 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).....	278
Table 5.2.2 – Individuals selected for strontium and oxygen isotope analysis. Radiocarbon dates and carbon and nitrogen isotope values from Bayliss et al. (2009: 239). Tooth development timing based on Moorees et al. (1963) and AlQahtani et al. (2010).....	283
Table 5.2.3 – Strontium and oxygen isotope data, including $\delta^{18}\text{O}_P$ calculated from Chenery et al. (2012), and $\delta^{18}\text{O}_{DW}$ calculated from Daux et al. (2008) eqn. 6, in accordance with Chenery et al. (2012).....	287
Table 5.2.4 – British sites reporting skeletons with possible and confirmed leprosy prior to the 12 th century AD.....	290
Table 5.3.1 – Radiocarbon dates and SNP types for individuals buried at St. Mary Magdalen (Winchester, England).....	306
Table 5.3.2 – Adolescents selected for study with resultant amelogenin peptide data, and strontium and oxygen isotope data. $\delta^{18}\text{O}_P$ calculated from Chenery et al. (2012), and $\delta^{18}\text{O}_{DW}$ calculated from Daux et al. (2008) equation 6, in accordance with Chenery et al. (2012).....	316
Table 5.4.1 - Calibrated radiocarbon dates and SNP types for individuals buried at the St. Mary Magdalen leprosy hospital site.....	338
Table 5.4.2 - Individuals from the St. Mary Magdalen leprosarium selected for carbon and nitrogen stable isotope analyses of incremental dentine. Geographic origins previously estimated by Filipek et al. (<i>in prep</i>) and Roffey et al. (2017).....	342
Table 5.4.3 - Data and quality parameters for this study.....	345
Table 6.1 – Research questions revisited.....	381

LIST OF FIGURES

Figure 2.1 Worldwide prevalence of leprosy based on 2017 data.....	23
Figure 2.2 Immune spectrum of leprosy based on Ridley and Jopling (1966) and Jopling and McDougall (1988) classifications.....	29
Figure 2.3 Picture of a living person’s hand showing ‘λεύκη’ or vitiligo.....	35
Figure 2.4 Location of the ancient city Lepreum superimposed onto modern-day Greece.....	36
Figure 2.5 An early illustrated work depicting Constantine the African lecturing to the school of Salerno.....	44
Figure 2.6 Coronal CT scan from male patient with leishmaniasis infection, showing similar bone changes to rhinomaxillary syndrome. Note: maxillary changes in leishmaniasis are often asymmetric.....	51
Figure 2.7 A right foot showing skeletal changes consistent with Madura foot, or mycetoma, which can be confused for bone changes associated with leprosy.....	52
Figure 2.8 Dorsal aspects of metatarsals showing bone changes that may be caused by leprosy or a secondary infection subsequent to a crushing injury from Individual 416 KA.....	53
Figure 2.9 Image of Individual 1997 showing nasal and alveolar resorption and pitting on the hard palate of the maxilla.....	54
Figure 2.10 Cranium of a middle-aged female from Uzbekistan with bone changes consistent with rhinomaxillary syndrome.....	55
Figure 2.11 Skull of Individual B6 from the Kellis 2 cemetery in the Dakhleh Oasis (Egypt) displaying signs of rhinomaxillary syndrome.....	57
Figure 2.12 The cranium of the individual from El Biga (Sudan) demonstrating resorption of the anterior nasal spine, remodelling of the nasal aperture, and changes to the hard palate associated with the rhinomaxillary changes consistent with leprosy.....	58
Figure 2.13 Image of a young-adult male from the Copper Age (c. 3780-3650 BC) Carpathian Basin displaying maxillary porosity possibly due to leprosy.....	59
Figure 2.14 Right (top row) and left (bottom row) metatarsals from individual t. 74 buried at the necropolis of Casalecchio di Reno.....	61
Figure 2.15 Skull of Individual GM162 (4 – 5 years old) from Martellona (c. 2nd – 3rd centuries AD) showing possible skeletal changes associated with lepromatous leprosy.....	63
Figure 2.16 Individual 23 from Vaison La Romaine (Southern France, c. 500 AD) showing complete resorption of the phalanges and most of the metatarsals, tarsal coalition, and tarsal exostoses.....	64
Figure 2.17 The maxilla of an Avar-period (6th – 8th centuries AD) adult male from Morrione (Central Italy) showing bone changes diagnostic of lepromatous leprosy.....	66

Figure 2.18 Facial and foot skeletal changes diagnostic of lepromatous leprosy from an older adult female (aged 50-60) excavated from Sárrétudvari-Hízófold (10th century AD).....	66
Figure 2.19 Skull of Individual 188 from Prušánky 1 (Czechia) displaying rhinomaxillary changes associated with lepromatous leprosy.....	68
Figure 2.20 Cranium of a child from Scotland (c. 2000 BC) showing widening of the nasal aperture and resorption of the maxilla.....	72
Figure 3.1 Schematic drawing of a typical isotope ratio mass spectrometer. Modified from United States Geological Survey.....	97
Figure 3.2 Average $\delta^{13}\text{C}$ values of modern C_3 and C_4 plants.....	102
Figure 3.3 Diagram of the terrestrial nitrogen cycle.....	106
Figure 3.4 – Approximations of $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values of various taxa based on enrichment and trophic level effects.....	111
Figure 3.5 Diagram of amino acid metabolism, major metabolic pathways, and end products.....	112
Figure 3.6 Flow chart of the cachexia process.....	120
Figure 3.7 Schematic diagram of the biological interdependence between nutrition and disease.....	126
Figure 3.8 Diagram of the Rayleigh fractionation system and the variables that will affect $\delta^{18}\text{O}$ values in evaporation, condensation, and precipitation.....	129
Figure 3.9 Enrichments in ^{18}O above drinking water, precipitation, or source water.....	133
Figure 3.10 Diagram illustrating the relatively static nature of strontium ratios through biochemical processes.....	136
Figure 3.11 Map of biosphere strontium isotope variation across Britain.....	140
Figure 3.12 Biomineralisation of enamel highlighting a prismatic structure during formation.....	146
Figure 4.1 Location map of the sites selected for study in England, with London marked for geographical reference.....	174
Figure 4.2 Location of Winchester and underlying bedrock geology.....	175
Figure 4.3 Aerial view of the excavations of the St. Mary Magdalen leprosarium. The North Cemetery is located in the centre, and underlies most of the later masonry phases.....	176
Figure 4.4 Sk. 27 in situ with associated scallop shell signifying his pilgrimage to the St. James Shrine at the Santiago de Compostela Cathedral in Spain.....	177
Figure 4.5 The local geology of Norwich within a 30 km radius.....	182
Figure 4.6 Plan showing St. John the Baptist Church and cemetery location.....	183
Figure 4.7 The Church of St. John the Baptist/Timberhill as it stands today.....	184

Figure 4.8 Schematic layout of burials of Cemetery 4 at the Church of St. John at the Castle Gate/Timberhill. Burials in black denote skeletons with skeletal lesions diagnostic of leprosy and shaded burials represent possible leprosy.....	185
Figure 4.9 St. John at the Castle Gate/Timberhill in relation to other leprosaria surrounding the city from the 12th century AD.....	189
Figure 4.10 Skeleton 28, aged 12.5-13.5 years old, from the St. Mary Magdalen leprosarium exhibiting evidence of rhinomaxillary changes, including 1.) flattening of the nasal bones, 2.) widening and remodelling of the nasal aperture, 3.) resorption of the anterior nasal spine, and 4.) resorption of the maxillary alveolar process. This individual also shows leprogenic odontodysplasia (encircled), or arrested development of the maxillary anterior dentition, which may occur in individuals with the disease.....	194
Figure 4.11 Diagrammatic representations of dental development and eruption patterns from AlQahtani 2010.....	197
Figure 4.12 Skull of Sk. 19 demonstrating advanced rhinomaxillary changes including widening and fusion of nasal bones, widening and remodelling of the nasal aperture, resorption of the anterior nasal spine and alveolar process of the maxilla, and complete resorption of the hard palate.....	202
Figure 4.13 The structure and methods within the Index of Care framework.....	203
Figure 4.14 Cleaning the tooth crown and root with a dental hand piece and tungsten carbide dental burr (Left), and removing a chip of enamel along the enamel-dentine junction with a diamond circular saw (Right).....	205
Figure 4.15 Ultrapure water added to enamel samples (Left) and samples on heated block in the laminar flow hood (Right).....	206
Figures 4.16 Parafilmed enamel samples in the ultrasonic bath.....	207
Figures 4.17 Weighing clean enamel samples in Teflon beakers (Left) followed by adding strontium spike solution (Right).....	208
Figure 4.18 Enamel samples in Teflon beakers within on the hot plate following the addition of 8M ultrapure nitric acid.....	209
Figure 4.19 Eichrom AG 50w-X8 resin columns for column chemistry. Strontium samples were collected in the beakers below.....	210
Figure 4.20 Loading isolated strontium onto rhenium filaments (Left), and loading filaments into the turrets for thermal ionisation mass spectrometry (Right).....	211
Figure 4.21 Powdering enamel with mortar and pestle for oxygen stable isotope analysis, protected by Parafilm.....	212
Figures 4.22 The bisected right mandibular third molar of Sk. 18 demineralising in 0.5M of cold HCl (Left), and the left maxillary second molar of Sk. 8 after the demineralisation process (Right).....	216
Figure 4.23 Longitudinal sectioning of a canine tooth with a scalpel following Method 2 of Beaumont et al. (2013a).....	217

Figure 4.24 Samples within microtubes denaturing within a heated block (Left), before being centrifuged to separate any further debris (Right).....	217
Figure 4.25 Placing collagen within a tin capsule (Left), and weighing the tin capsule on a microbalance to ensure an adequate sample weight (Right).....	218
Figure 5.1.1 Impaired young person being moved by cart and receiving charity.....	233
Figure 5.1.2 Direct and indirect costs involved with seeking medical or surgical care for children in the Early Medieval period.....	238
Figure 5.1.3 a) Location of St. Mary Magdalen Leprosy Hospital (Winchester) and b) aerial view of the excavations of the North Cemetery.....	247
Figure 5.1.4 Skull of Sk. 52 from the St. Mary Magdalen Leprosy Hospital (Winchester) displaying evidence of rhinomaxillary syndrome including rounding of the nasal aperture, resorption of the anterior nasal spine, recession of the alveolar margin, and widening and flattening of the nasal bones.....	249
Figure 5.1.5 Skull of Sk. 19 demonstrating advanced rhinomaxillary syndrome including widening and fusion of nasal bones, widening and remodelling of nasal aperture, and complete loss of the anterior nasal spine, alveolar process of the maxilla, and hard palate.....	252
Figure 5.1.6 Hand phalanges of Sk. 19 showing volar grooving likely indicative of long-term flexion contractures.....	253
Figure 5.1.7 Right foot of Sk. 19 demonstrating bone resorption to proximal metatarsals and fusion of tarsals.....	254
Figure 5.1.8. Left lower limb of Sk. 19 showing amputation at the distal end.....	255
Figure 5.1.9 Biological consequences of having lepromatous leprosy, including skeletal changes and body systems affected.....	256
Figure 5.1.10. 'Decision Path' in the health-related caregiving process for a group agency infrastructure (From IndexofCare.org).....	261
Figure 5.2.1 Map of Norwich with location of Norwich Castle Mall excavations of Farmer's Avenue and St. John at the Castle Gate (starred).....	276
Figure 5.2.2 Distribution of individuals with skeletal evidence of leprosy at St. John at the Castle Gate.....	277
Figure 5.2.3 Oxygen contour and strontium biosphere maps with Norwich starred.....	281
Figure 5.2.4 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.....	283
Figure 5.2.5 Strontium and oxygen isotope data from St. John at the Castle Gate (Norwich, Norfolk, UK). Also plotted are the estimated predicted ranges for Norwich from Evans et al. (2010) and Evans et al. (2012), and comparative data from the Early Medieval period (7 th -9 th centuries AD) local burials from nearby Sedgeford, Norfolk, UK (Haraldsson 2016). Sk. 13121 presents as an outlier likely due to an enrichment in ¹⁸ O from breastfeeding during tooth formation.....	288

Figure 5.3.1 Location of Winchester with aerial view of excavations of St. Mary Magdalen leprosarium (inset).....	305
Figure 5.3.2 Skull of Sk. 28 (aged 12.5-13.5) from St. Mary Magdalen Leprosy Hospital (Winchester, England) displaying evidence of rhinomaxillary syndrome (black arrows) including 1.) Rounding of the nasal aperture, 2.) Resorption of the anterior nasal spine, 3.) Recession of the alveolar process, and 4.) Widening and flattening of the nasal bones.....	308
Figure 5.3.3 Leprogenic odontodysplasia (arrested development of the teeth) in the maxillary incisors of Sk. 56 due to an infiltration of <i>Mycobacterium leprae</i> (encircled). Based on dental development (Moorrees et al. 1963; AlQahtani et al. 2010), this arrested growth would have occurred between 6.5-7.5 years of age.....	309
Figure 5.3.4 Strontium and oxygen isotope ratios showing mobility histories of 19 adolescents from the St. Mary Magdalen leprosy hospital, Winchester. The dashed line represents the strontium isotope ratio for modern seawater (0.7092) (Veizer 1989), and therefore the upper limit for the predicted strontium isotope ratios for the Winchester area.....	318
Figure 5.3.5. Oxygen isotope drinking water values from Western Europe with Winchester (starred).....	322
Figure 5.4.1 a) Location of Winchester, England, and b) aerial view of St. Mary Magdalen excavations.....	339
Figure 5.4.2 Skull of 16.5-17.5 year old male (Sk. 56) displaying facial signs of lepromatous leprosy. These include 1) resorption of the maxillary alveolar process, 2) resorption of the anterior nasal spine, 3) widening and remodelling of the nasal aperture, and 4) widening and flattening of the nasal bones. Sk. 56 also displays evidence for leprogenic odontodysplasia, with constriction and arrested development of the maxillary incisors (encircled).....	343
Figure 5.4.3 Life history incremental dentine profiles of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from canine (triangles) and molar (circles) teeth from adolescents with lepromatous leprosy buried at St. Mary Magdalen Leprosy Hospital (Winchester, England). $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ from rib collagen (Cameron 2014; Roffey et al. 2017) are plotted for Sk. 8, Sk. 18, and Sk. 27. Also plotted are concurrent periods of linear enamel hypoplasia formation, estimated from Primeau et al. (2015).....	358
Figure 5.4.4 A) Scatterplot showing initial (circle) and terminal (triangle) molar increments of dentine collagen from adolescents buried at the St. Mary Magdalen leprosarium (SMM). Also plotted are comparative data, including an 'Anglo-Saxon' (6 th – 11 th centuries AD) faunal baseline data from Hampshire (O'Connell and Hull 2011), the average 'Anglo-Saxon' mean diet from Hampshire (<i>ibid</i>), the SMM adult rib mean (Roffey et al. 2017), and the adult rib mean from the nearby high-status St. Mary's Abbey (12 th – 16 th century AD) mean diet (<i>ibid</i>). B) Scatterplot detail showing a general pattern of enrichment in ^{15}N and ^{13}C from the initial molar increment to the terminal molar increment of 10 adolescents buried at SMM. The end member values also differ to the average adult $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ rib values for the leprosarium, potentially indicating a more accurate reflection of diet at the time of death for adolescents (Beaumont et al. 2018; Beaumont 2020). The shift is likely due to increased access to higher quality foodstuffs, including animal products and marine resources. This would be in line with monastic prescriptions on diet, or a consequence of pathophysiological alterations of carbon and nitrogen metabolism due to systemic disruption as a consequence of leprosy or other diseases.....	363
Figure 5.4.5. Scatterplot of incremental $\delta^{13}\text{C}$ values from molars of non-locals showing shifts towards the dietary average for people buried at St. Mary Magdalen leprosy hospital (boxed) These shifts may potentially signify entry into the leprosarium and how long the individuals remained there before death.....	364

Figure 5.4.6 Box and whisker plots of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ showing a reduced variability towards a “leprosarium diet”. The last two molar increments illustrate decreased variation in $\delta^{13}\text{C}$ values and increased variation in $\delta^{15}\text{N}$ values, possibly due to pathophysiological stress caused by leprosy.....365

Figure 5.4.7 Scatterplots of individuals showing isotopic disparities in $\delta^{15}\text{N}$ (all) and $\delta^{13}\text{C}$ values (Sk. 18, Sk. 54, 56) in concurrently forming canines (triangles) and molars (circles).....367

ACKNOWLEDGEMENTS

I would first like to thank my incredible team of supervisors, **Professor Charlotte Roberts**, **Professor Janet Montgomery**, and **Professor Becky Gowland**. It has been *such a privilege* to work with you. Your academic mentorship, knowledge, advice, patience, support, and encouragement has been the guiding light during this process, and for that, I am eternally grateful.

I would like to thank **Tim Pestell** from Norwich Castle Museum and **Dr. Simon Roffey** from the University of Winchester for access to the individuals analysed for this research. I would also like to extend a special thank you to **Dr. Katie Tucker** for her assistance, access to unpublished data, and the wonderful friendship that has developed from this endeavour.

I am extremely grateful to my external collaborators, **Professor Jane Evans** from British Geological Survey, and **Dr. Julia Beaumont** from University of Bradford for taking me under their wings in their isotope labs. Your expertise, kindness, and friendship is such a gift, and I am so appreciative of your willingness to take a chance on me. Thank you also to **Carlyn Stewart** and **Hilary Sloane** from British Geological Survey, and **Marise Gorton**, **Tommy Morgan**, and **John Henry Jackson** from University of Bradford for their assistance. I am truly relieved that I did not accidentally blow up your respective labs.

I am indebted to **Dr. Beth Upex** and **Dr. Steve Robertson**, for their hard work to make the Department of Archaeology and the labs more accessible after that I may continue my research after becoming physically disabled. Additionally, I would like to thank and Department Heads **Professor Sarah Semple** and **Professor Robin Skeates** for approving and helping to put in place this support. It would have been easy to give up at such a low point, but you all facilitated an environment that was welcoming, encouraging, and allowed me to flourish. The impact of that kindness and acceptance will always resonate within me.

I am thankful and very grateful to **Dr. David Petts** and **Dr. Sarah Inskip** for serving as my examiners. I hope you didn't find it too dull.

I would also like to take this opportunity to thank my colleagues and friends. First to my office mate, dear friend, neighbour, and overall genius smarty-pants, **Dr. Joanna Moore**. I could not have finished this without your encouragement, support, knowledge, tea and coffee, biscuits/cake, laughs, hugs, pub quizzes, and your ability to tell me when I was being an idiot during my imposter syndrome moments. I look forward to all of the work we will (hopefully) get to do in future and the G&Ts we will share after the pandemic (preferably somewhere sunny). Thank you to my inspiring and brilliant colleagues **Dr. Kendra Quinn**, **Dr. Lucie Johnson**, **Dr. Ellen Kendall**, and **Tessi Loeffelmann** for always giving great advice, conversation, and encouragement, suggesting references, and just being wonderful people. To my BFFs, **Dr. Joshua Jowitt** and **Megan Oliverson**. Thank you for always being there to lift my spirits, provide a steady supply of chocolate and memes, taking me dancing, to drag shows, and ballets, for providing constant support, and the best hugs. This PhD would have been so much more stressful without you, so thank you.

Lastly, I would like to thank my family. Thank you to my dad, **Charly Filipek** his wonderful wife, **Sandy Luedke**, and my sisters, **Melissa** and **Shannon Shank** for always believing in me. Thank you so much to my partner, **Matthew Crowther**. Your unwavering love, support, and encouragement to keep going through all of the hardships we have endured has given me the motivation to accomplish this feat. You are such a special person. I am so looking forward to sharing the rest of my life with you and taking on whatever else life throws at us. Finally, to my brilliant, insane, and utterly hilarious son, **Dorian**. You give me countless reasons to smile and play every day, and inspire me to keep going. This research would have definitely been finished two years ago without you, but I would not trade it for the world. Mummy loves you so so much.

STATEMENT OF COPYRIGHT

“The copyright of this thesis rests with the author. No quotation from it should be published without the author's prior written consent and information derived from it should be acknowledged.”