

Dental Anthropology

Accessible and engaging, this is the definitive textbook on using teeth to study the demography and ways of life in ancient human communities. Based on extensive laboratory and field experience, this new edition combines archaeological approaches with new technologies and methodologies, covering the key advances in anatomy, forensics, three-dimensional imaging, stable isotopes and proteomics. Hillson provides a biological context for teeth, a guide on key skills, an introduction to current debates, and advice for the excavation, conservation and recording of dental remains. He also showcases the microscopic structure of dental tissues alongside methods of age determination. Discover solutions to problems such as identifying worn, fragmentary human teeth or understanding their condition. This is the ideal reference for advanced courses in anthropology or archaeology, and for everyone interested in dental remains from archaeological sites, museum collections or forensic cases. Online teaching resources include videos of lectures and practicals.

Simon Hillson is Professor of Bioarchaeology at University College London. He has taught dental anthropology for over 30 years and has written key textbooks in bioarchaeology, forensic anthropology and zooarchaeology. He has participated in many archaeological projects in Greece, Peru, Turkey, North Africa, and the UK.

“The field of dental anthropology has evolved rapidly since the first edition of this self-titled book, and this new edition expertly presents updated findings and technological advances across the field. Notably, it was and remains the go-to resource for the macro- and microscopic study of dental development, structure and function, including entire chapters devoted to the principal oral tissues.”

Professor Joel D. Irish, *Liverpool John Moores University*

“I taught dental anthropology at both the graduate and undergraduate levels for 40 years and had to use three textbooks plus supplemental readings to cover the topics I wished to include: morphology, histology, growth, pathology, among others for bioarchaeological and forensic applications. Now with Hillson’s *Dental Anthropology* I would only have to use one.

Hillson challenges the teacher, student, and researcher to think in new directions and consider alternative interpretations of dental data. This book has updated illustrations; an extensive up-to-date bibliography; and further reading sections at the end of each chapter making it an ideal textbook for dental anthropology or for use by students beginning their research careers.

I cannot think of a single topic dealing with teeth from an anthropological, archaeological, or forensic perspective that is not covered in Hillson’s book. I wish I had all this organized information when I started my dental research as a graduate student or, even now, when students begin their own research careers.”

Professor Jerry Rose, *University of Arkansas*

“A well-timed fantastic revised and fully updated edition of a classic book, now including newer analytical techniques. This is an extremely useful text which will be a required staple on every bioarchaeologist’s shelf. The sections on 3D morphological analysis and use of newer methods developed or made more accessible to anthropologists since the first edition are especially valuable.”

Professor Sonia Zakrzewski, *University of Southampton*

“The new second edition of Simon Hillson’s *Dental Anthropology* is a significant revision to the 1996 first edition and is a well-written, well-illustrated, comprehensive, treatment of the subject. Meticulously updated throughout, it reflects the many important recent advancements in the field and is at once primer, guide, textbook, and reference. Hillson’s *Dental Anthropology* delivers in every aspect and will be an important addition to the library of anyone interested in the scientific study of teeth.”

Dr Greg Nelson, *University of Oregon*

“The second edition is certain to become the definitive text on dental anthropology written by the leading expert in the field. Professor Hillson shares his knowledge in an accessible and absorbing manner, a style for which he is well known. The book is comprehensible to those just starting to study teeth; yet, even the most erudite dental anthropologist will come away with new knowledge from this text and will certainly turn to it regularly for reference.”

Dr Marin Pilloud, *University of Nevada, Reno*

“This book is a journey into the fascinating and extravagant world of teeth. It is an essential starting point for the study teeth, but also a bridge to more detailed approaches. It covers a broad range of dental topics such as anatomy, morphology, histology, wear and diseases. It is an indispensable reference work for any dental researcher.”

Professor Ana Maria Silva, *University of Coimbra*

Dental Anthropology

SECOND EDITION

Simon Hillson

University College London





Shaftesbury Road, Cambridge CB2 8EA, United Kingdom
One Liberty Plaza, 20th Floor, New York, NY 10006, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India
103 Penang Road, #05-06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment,
a department of the University of Cambridge.

We share the University's mission to contribute to society through the pursuit of education, learning and
research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/highereducation/isbn/9781108433969

DOI: 10.1017/9781108381550

© Simon Hillson 2024

This publication is in copyright. Subject to statutory exception and to the provisions
of relevant collective licensing agreements, no reproduction of any part may take
place without the written permission of Cambridge University Press & Assessment.

First published 1996
Second edition 2024

Printed in the United Kingdom by TJ Books Limited, Padstow, Cornwall

A catalogue record for this publication is available from the British Library.

Library of Congress Cataloging-in-Publication Data

Names: Hillson, Simon, author.

Title: Dental anthropology / Simon Hillson.

Description: 2nd edition. | Cambridge, United Kingdom ; New York, NY : Cambridge University Press, 2023. |

Includes bibliographical references and index.

Identifiers: LCCN 2022059460 (print) | LCCN 2022059461 (ebook) | ISBN 9781108433969 (paperback) |
ISBN 9781108381550 (epub)

Subjects: MESH: Tooth—anatomy & histology | Forensic Dentistry | Odontometry

Classification: LCC QM311 (print) | LCC QM311 (ebook) | NLM WU 215 | DDC 611/.314—dc23/eng/20230429

LC record available at <https://lccn.loc.gov/2022059460>

LC ebook record available at <https://lccn.loc.gov/2022059461>

ISBN 978-1-108-43396-9 Paperback

Additional resources for this publication at www.cambridge.org/hillson2e.

Cambridge University Press & Assessment has no responsibility for the persistence
or accuracy of URLs for external or third-party internet websites referred to in this
publication and does not guarantee that any content on such websites is, or will remain,
accurate or appropriate.

For Tony Waldron

Contents

Preface	<i>page</i> xv
What is Dental Anthropology and Who is Interested in It?	xv
What Has Changed in the New Edition?	xvi
The Aims and Contents of This Book	xvii
How Did Dental Anthropology Evolve?	xviii
Dental Anthropology and Destructive Sampling	xix
Abbreviations	xxi
1 Dental Anatomy	1
1.1 Definitions For Dental Anatomy	2
1.1.1 Taxa Included	2
1.1.2 Labels For Teeth	2
1.1.3 Asymmetry and Identifying Left and Right Teeth	16
1.1.4 Measurements of Crown Size	17
1.1.5 General Note On Drawings	17
1.1.6 General Appearance of Teeth in X-Rays	18
1.2 The Dental Arcade in Monkeys and Hominids	20
1.3 Incisors	25
1.3.1 Incisor Crowns	25
1.3.2 Incisor Roots and Pulp Chamber	34
1.3.3 Incisor Wear and Fragmentation	36
1.4 Canines	37
1.4.1 Low Crowned Canines in Humans and Extinct Hominids	37
1.4.2 Tall Crowned Canines in Living Non-Human Primates	47
1.4.3 Canine Roots and Pulp Chamber	47
1.4.4 Canine Wear and Fragmentation	48
1.5 Confusions in Distinguishing Between Human Incisors and Canines	49
1.6 Upper Permanent Premolars	51
1.6.1 Upper Permanent Premolar Crown	51
1.6.2 Upper Permanent Premolar Roots and Pulp Chamber	58
1.6.3 Upper Permanent Premolar Wear and Fragmentation	59

viii Contents

1.7	Lower Permanent Premolars	59
1.7.1	Sectorial Lower Permanent Third Premolars	60
1.7.2	Non-Sectorial Lower Permanent Third and Fourth Premolar Crown Features	62
1.7.3	Lower Permanent Premolar Roots and Pulp Chamber	67
1.7.4	Lower Premolar Wear and Fragmentation	68
1.8	Upper Permanent Molars	68
1.8.1	Upper Permanent Molar Crowns	68
1.8.2	Upper Permanent Molar Roots and Pulp Chamber	73
1.8.3	Upper Permanent Molar Wear and Fragmentation	77
1.9	Lower Permanent Molars	78
1.9.1	Lower Permanent Molar Crowns	78
1.9.2	Lower Permanent Molar Roots and Pulp Chamber	84
1.9.3	Lower Permanent Molar Wear and Fragmentation	84
1.10	Deciduous Premolars	85
1.10.1	Upper Deciduous Premolar Crowns	85
1.10.2	Upper Deciduous Premolar Roots and Pulp Chamber	88
1.10.3	Lower Deciduous Premolar Crowns	91
1.10.4	Lower Deciduous Premolar Roots and Pulp Chamber	93
1.10.5	Upper and Lower Deciduous Premolar Wear and Root Resorption	94
1.11	Conclusions	94
1.12	Further Reading	94
2	Variation in Size and Shape of Teeth	96
2.1	Species, Populations, Sexes and Assemblages	96
2.2	Metrical Variation of the Tooth Outline	98
2.2.1	Simple Caliper Dimensions of the Tooth Crown Outline	99
2.2.2	Geometric Morphometric Approaches to Tooth Form	103
2.2.3	Variability of Measured Tooth Form	105
2.2.4	Sexual Dimorphism	112
2.2.5	Metrical Variation and Hominid Evolution	116
2.3	Non-Metrical Tooth Variants	120
2.3.1	Commonly Recorded Variants	121
2.3.2	Asymmetry and Sexual Dimorphism	136
2.3.3	Development and Inheritance	137
2.3.4	Geographical Patterning and Human Dispersals	139
2.3.5	Biological Profiles in Forensic Cases	142
2.4	Conclusions	143
2.5	Further Reading	144

	Contents	ix
3 Occlusion		145
3.1 Definitions and Methodology		145
3.1.1 Normal Occlusion		145
3.1.2 Malocclusion		146
3.1.3 Methods of Recording Occlusion		146
3.1.4 Variations Within Jaws		148
3.1.5 Relationship Between Teeth of Different Jaws		152
3.2 The Development of Malocclusion		153
3.2.1 The Role of Inheritance		153
3.2.2 The Role of Jaw Remodelling in Response to Forces Acting On Them		154
3.3 Conclusions		155
3.4 Further Reading		156
4 Sequence and Timing of Dental Growth		157
4.1 Initiation and Development of Tooth Germs		158
4.1.1 The Crown and Root Formation Pattern		158
4.1.2 Intrauterine Tooth Formation Sequence		160
4.1.3 Postnatal Development Sequence		162
4.2 Methods of Study		165
4.2.1 Size Measurements of Developing Teeth		165
4.2.2 Whole Jaw Sections		167
4.2.3 Histology of Fully Developed Teeth		167
4.2.4 Dissection of Foetal Tooth Germs		167
4.2.5 Radiography of Living Children		168
4.2.6 Appropriateness of Clinical Standards		171
4.3 Estimating Age-at-Death from Tooth Development		173
4.3.1 The Dentition at Birth		173
4.3.2 Moorrees, Fanning and Hunt Stages		174
4.3.3 Demirjian, Goldstein and Tanner Stages		178
4.3.4 Third Molar Development Standards		179
4.3.5 Measurement of Developing Tooth Height		180
4.3.6 Enamel Histology and Chronology		181
4.3.7 Which Age Estimation Method is Best?		183
4.4 The Development of Tooth-Supporting Structures		184
4.4.1 Dental Eruption		184
4.4.2 Timing and Sequence of Dental Eruption		186
4.4.3 Deciduous Tooth Root Resorption		188
4.5 The Development Atlas Or Chart Approach		190
4.5.1 The Schour and Massler and Ubelaker Charts		190
4.5.2 The London Atlas		193
4.5.3 Gustafson and Koch Charts		195
4.6 Dental Development and Human Evolution		195

x	Contents	
	4.7 Conclusions	200
	4.8 Further Reading	201
	5 Dental Enamel	202
	5.1 Enamel Cells and Matrix	202
	5.1.1 Ameloblasts	203
	5.1.2 Enamel Matrix and Maturation	203
	5.1.3 Enamel Crystallites	204
	5.2 Prismatic Structure of Enamel	205
	5.2.1 The Course of Prisms Through the Enamel	210
	5.3 Incremental Structures in Enamel	212
	5.3.1 Prism Cross Striations	212
	5.3.2 Brown Striae of Retzius	213
	5.3.3 The Neonatal Line in the Enamel	217
	5.3.4 Pathological Bands, Wilson Bands, Stress Lines	218
	5.3.5 Incremental Lines On the Crown Surface	219
	5.3.6 Other Features of the Enamel Surface	222
	5.4 Enamel Development Chronology	224
	5.4.1 Matching Tooth Crowns	224
	5.4.2 Estimation of Crown Formation Schedule and Age-at-Death	226
	5.5 Enamel Defects	228
	5.5.1 Amelogenesis Imperfecta	229
	5.5.2 Defects Relating to Local Disturbances	229
	5.5.3 Developmental Defects Related to Systemic Disturbances	229
	5.5.4 Methods For Scoring Hypoplasia and Hypomineralisation	237
	5.5.5 Anthropological Studies	242
	5.6 Enamel Thickness in Living and Fossil Hominids	247
	5.7 Archaeological Preservation of Enamel	247
	5.8 Conclusions	248
	5.9 Further Reading	249
	6 Dentine	250
	6.1 Dentine Cells, Tubules and Matrix	250
	6.1.1 Odontoblasts	250
	6.1.2 Dentinal Tubules	251
	6.1.3 Dentine Matrix	253
	6.2 Mineralisation of Dentine	254
	6.3 Peripheral Dentine of the Root and the Cement–Dentine Junction	257
	6.4 Incremental Structures in the Dentine	258
	6.4.1 Dentine Lines	259
	6.4.2 Interglobular Spaces	262
	6.4.3 Periradicular Bands	265

6.5	Dentine Development Chronology	266
6.5.1	Matching Teeth from One Individual	266
6.5.2	Schedule of Dentine Formation	266
6.6	Dentine Sclerosis	267
6.7	Secondary Dentine and Dead Tracts	269
6.7.1	Regular (Physiological Or Senile) Secondary Dentine	270
6.7.2	Irregular (Reparative) Secondary Dentine	270
6.8	Pulp Stones	270
6.9	Archaeological Preservation of Dentine	272
6.10	Conclusions	273
6.11	Further Reading	273
7	Dental Cement	274
7.1	Cement Function, Cells and Development	274
7.2	Components and Related Elements of Cement	275
7.2.1	The Organic Matrix of Cement	275
7.2.2	The Mineral Component of Cement	276
7.2.3	Cells of the Cement and Periodontal Ligament	277
7.3	Types of Cement	279
7.3.1	Acellular Afibrillar Cement	279
7.3.2	Acellular Extrinsic Fibre Cement	280
7.3.3	Cellular Intrinsic Fibre Cement	280
7.3.4	Cellular Mixed Stratified Cement	281
7.3.5	The Cement–Dentine Junction	282
7.3.6	The Cement–Enamel Junction	282
7.4	Cement Layering	282
7.5	Resorption and Remodelling	285
7.6	Hypercementosis and Cementicles	285
7.7	Archaeological Preservation of Cement	286
7.8	Conclusions	286
7.9	Further Reading	287
8	Histological Methods of Age Determination in Adults	288
8.1	How Accurate Do Adult Age Estimates Need to Be?	288
8.2	Counts of Layers in Cement	289
8.2.1	TCA in Non-Humans	290
8.2.2	TCA in Humans	291
8.3	The Gustafson Technique and Its Derivatives	293
8.3.1	Gustafson's Original Technique	293
8.3.2	Multiple Regression Derivatives	294
8.4	Root Dentine Sclerosis	295
8.5	Secondary Dentine	297

xii Contents

8.6	The Forensic Context	298
8.7	Conclusions	300
8.8	Further Reading	301
9	Chemistry of Dental Tissues and Calculus	302
9.1	The Inorganic Component	302
9.1.1	Calcium Phosphate Minerals	302
9.1.2	Secondary Minerals	303
9.1.3	Gradients of Inorganic Components	304
9.1.4	Fluoride Chemistry	305
9.2	The Organic Component	305
9.2.1	Organic Component of Dentine, Cement and Calculus	306
9.2.2	The Organic Component of the Enamel	307
9.2.3	Racemisation and Epimerisation of Amino Acids	309
9.2.4	Nucleic Acids	310
9.3	The Chemistry and Physics of Isotopes	311
9.3.1	Stable Isotopes, Diet and Mobility	311
9.3.2	Radiocarbon Dating and Date of Birth	314
9.3.3	Lead Pollution	314
9.3.4	Dating by Uranium Series and Electron Spin Resonance	315
9.4	Conclusions	316
9.5	Further Reading	317
10	Tooth Wear and Modification	318
10.1	Tooth Wear Terms	319
10.2	Wear That Does Not Produce Matching Facets Where Teeth Meet	320
10.2.1	General Ante-Mortem Loss of Surface Detail	320
10.2.2	More Focused Loss of Dental Tissue and Teeth	320
10.3	Wear That Produces Matching Facets Where Teeth Meet	333
10.3.1	Occlusal Wear Facets	333
10.3.2	Angles of Wear Facets and the Helicoidal Occlusal Plane	334
10.3.3	Scoring and Measuring Occlusal Wear Facets	337
10.3.4	Patterns and Gradients of Occlusal Facet Wear	341
10.3.5	Occlusal Facet Wear and Age Estimation	343
10.3.6	Approximal (Interproximal Or Interstitial) Facet Wear	346
10.4	Macro-Scale Pattern of Wear Facets	348
10.4.1	The Chewing Cycle and Early Stage Wear Facets	348
10.4.2	Occlusal Fingerprint Analysis	351
10.4.3	Dental Topography Approaches to Wear	353

	Contents	xiii
10.5 Micro-Scale Wear Facet Texture		353
10.5.1 Introduction to Microwear		353
10.5.2 Browsers, Grazers, Folivores, Frugivores and Hard Object Feeders		356
10.5.3 Buccal Surface Microwear		358
10.5.4 Mechanisms of Tooth Wear		359
10.6 Conclusions		364
10.7 Further Reading		365
11 Dental Disease		367
11.1 The Tooth and the Periodontium		367
11.2 The Oral Microbiome		368
11.3 Dental Calculus		372
11.3.1 Mineralisation and Microstructure of Calculus		373
11.3.2 DNA, Starch Granules and Phytoliths in Calculus		374
11.4 Dental Caries		376
11.4.1 Introduction to Dental Caries		376
11.4.2 Enamel Caries		377
11.4.3 Cement Caries		379
11.4.4 Dentine Caries		380
11.4.5 Categories and Patterns of Carious Lesion		381
11.4.6 Scoring and Counting Carious Lesions		385
11.4.7 Paleoepidemiology of Dental Caries		388
11.5 Periodontal Disease		396
11.5.1 Aetiology of Periodontal Disease		396
11.5.2 Epidemiology of Periodontal Disease		400
11.6 Periapical Inflammation		403
11.6.1 Pulpitis		403
11.6.2 Periapical Or Lateral Periodontitis		403
11.7 Archaeological Signs of Periodontal Disease and Periapical Inflammation		404
11.7.1 Periapical Bone Loss		406
11.7.2 Vertical and Horizontal Bone Loss		408
11.8 Conclusions		410
11.9 Further Reading		411
Appendix A Field and Laboratory Methods		412
A.1 Excavation, Cleaning and Storage of Dentitions		412
A.1.1 Excavation		412
A.1.2 Cleaning		413

xiv Contents

A.1.3 Support, Consolidation and Reconstruction	414
A.1.4 Packing and Storage	415
A.1.5 Labelling	416
A.2 Surface Impressions and Replicas	416
A.2.1 Impression Materials	416
A.2.2 Procedures	417
A.3 Sectioning	418
A.3.1 Equipment and Materials	418
A.3.2 Procedure	418
A.4 Etching, Coating and Allied Techniques	419
A.4.1 Equipment	419
A.4.2 Etching	419
A.4.3 Coating	420
A.5 Photography of Museum and Archaeological Specimens	420
A.5.1 Equipment and Procedures	420
A.6 Radiographic Techniques	422
A.6.1 Equipment	422
A.6.2 Principles	422
A.6.3 Procedure	423
A.7 Calipers and Measurements	424
Appendix B Microscopy	426
B.1 Light Microscopy	426
B.1.1 The Limits of Simple Observation	426
B.1.2 Compound Microscopes	426
B.1.3 Transmitted Light Microscopes	426
B.1.4 Reflected Light Microscopes	427
B.1.5 Confocal Microscopy	427
B.1.6 The Factors That Form Images in Light Microscopy	428
B.1.7 Images in the Polarising Microscope	428
B.2 Scanning Electron Microscopes	429
B.2.1 How the Scanning Electron Microscope Works	429
B.2.2 The Everhart–Thornley Detector	430
B.2.3 Backscattered Electron Detector	431
Appendix C Age Estimation Tables and Charts For Dental Development	432
References	436
Index	504

Colour plates can be found between pages 194 and 195.

Preface

What is Dental Anthropology and Who is Interested in It?

Dental anthropology can be defined as a study of people and their close primate relatives from the evidence provided by teeth. Teeth have a distinct anatomy and physiology all their own and wholly different to the biology of the bones that make up the skeleton. Strictly speaking, teeth together form the dentition, which is not part of the skeleton at all. They are also unique amongst the resistant parts of archaeological and fossil remains in having been exposed on the surface of the body throughout life. Dental anthropology can therefore be studied in the mouths of living people, as well as in museum collections, archaeological sites and fossil assemblages. It is thus not surprising that practising dentists have always been prominent amongst dental anthropologists, with anatomists and other oral biologists from schools of dentistry, in addition to researchers whose training lies more in biological anthropology. The exposure of teeth in the living mouth is also very useful when training anthropologists, as everyone carries their own reference material with them – students can just open their mouths and look in a mirror.

This book (and the first edition that preceded it) has, however, been written mainly for biological anthropologists, amongst whom there are several different groups with an interest in teeth. Bioarchaeologists (the term is used differently in the UK to include remains of all living things) focus on collections of human remains that have been excavated from archaeological sites, aiming to reconstruct the demography, biological affinities, diet, health and general way of life of past populations from a range of skeletal and dental evidence. Teeth are particularly resistant to the destructive effects of long burial in the ground and thus occupy an important place. They often yield most of the bioarchaeological findings from a site. Archaeological collections may be compared directly with similar studies of living people. For this reason, collaboration with dentists and oral biologists is an important element in bioarchaeological research. Forensic anthropologists provide another focus of interest in teeth. Their aim is to identify fragmentary remains and the teeth become important when the remains are so damaged as to make identification difficult by any other means. Forensic anthropology is usually considered to be distinct from forensic dentistry, also known as forensic odontology. This specialism concentrates particularly on the matching of patients' dental records with evidence of dental surgery on the body but, as this requires clinical training and experience, it falls outside the scope of this book. Several forensic odontology textbooks have been published (Senn & Stimson, 2009; Taylor & Kieser, 2016; David & Lewis, 2018). In a forensic case, anthropological methods only come

xvi Preface

into their own where the remains have no evidence of dental treatment or it is not possible to find dental records for matching purposes – still a common enough occurrence in many parts of the world amongst those unable to afford treatment. Palaeoanthropology is another large specialisation with dental interests, because teeth and jaws make up the bulk of primate fossil finds. This interest overlaps with that of primatology, which is concerned with the biology and behaviour of both living and fossil representatives of this order of mammals. Full consideration of teeth in these fields would have expanded the book out of reasonable bounds, so the focus has been restricted to humans and our closest relatives.

What Has Changed in the New Edition?

It is many years since the publication of the first edition of this book and much about dental anthropology has changed. Most of this second edition has therefore been rewritten completely, even though the overall headings and organisation remain the same. It is also a larger book. Some changes relate to new instrumentation, new approaches and new findings. This includes, for example, the availability of much higher resolution scanners and X-ray machines with associated software and computing power, which have given rise to highly innovative three-dimensional approaches to tooth morphology and wear. There has also been an enormous growth in published studies, not only in dental anthropology itself, but also in cognate disciplines, such as developmental biology, clinical dentistry and even the engineering of bearing surfaces. The biological and clinical context of dental anthropology is better established and the new edition aims to make this clear. The passage of time has also allowed a change of mind in some areas, following the teaching of many dental anthropology students, much further reading, wider practical experience around the world and time for thought. Other changes and expansions relate to a growing conviction that things might not be as simple as they once seemed. In places, therefore, one of the aims is to challenge widely held assumptions in a way that stimulates discussion and provokes questions. This complicates things and may not make comfortable reading for those who would prefer a straightforward answer, but it should make students and teachers think. Everything about teeth is complex and extravagantly multifactorial. That is their whole interest. They are information dense. Much complicated detail is packed into a small, durable package, which is hard work to unpack but amply repays the effort spent on it. It is futile to simplify all this for convenience of recording, to chase an assumed clarity which is not really warranted, or to fit an independently conceived social or evolutionary theory. For example, many published archaeological studies of dental decay and at least one well-established database did not record the full range of information necessary to tabulate proper epidemiological statistics that would have allowed them to be compared or interpreted meaningfully in a context of modern clinical understanding of the disease. This is sad, not only because of the wasted effort, but also because the work will need to be done again or, worse, the necessary information may be lost forever when the material has been reburied. With a forensic investigation, simplification may be positively dangerous. It could well lead to over-

confident evidence that might mislead police or even affect a court verdict. This second edition therefore makes no apology for exploring dental complexity in even more detail than the first.

The illustrations have also changed considerably in the new edition, although some may look superficially similar. The original line drawings have been completely redrawn, with others added (some charts are in colour for clarity), and many new photographs have been included. This is because of hard lessons learned in computer graphics, experience in teaching practical classes and continued study of a wide range of archaeological collections around the world with much more effective camera equipment.

The Aims and Contents of This Book

The purpose of this book is to provide readers with the tools required for planning and carrying out a study of dental anthropology. It is also intended to provide a framework within which to understand published studies, not only from anthropology but also from biological and clinical research. Many readers are likely to be students and the format and contents of the book have evolved from almost 50 years' teaching experience. The level of explanation is appropriate for postgraduate classes but could nevertheless support undergraduate teaching. Text and diagrams provide preparation for practical classes and act as a handbook while in the laboratory or the field. Researchers in anthropology, archaeology, oral biology and dentistry also found the first edition to be a useful reference and it is intended that the same will be true of the second edition. Current issues of dental anthropology raised in the book provide background and starting points for discussions, essays and papers.

Chapter 1 outlines the essential anatomical detail for identifying, siding and classifying teeth in various states of development, wear and damage. It includes a range of normal variation in form, which is considered in more detail in Chapter 2, covering metrical and non-metrical morphology. This includes methods for measuring and recording variation, with a discussion of the anthropological issues that have been addressed, including variation between sexes and populations, and the evidence which this provides for the dispersals of modern humans throughout the world. Chapter 3 deals in a similar fashion with occlusion, or the way in which teeth fit together. In Chapter 4, the highly complex development of teeth is introduced, including the basic biology, the methods of study, the clinical reference standards which are available and the possibilities for estimating age-at-death in children. Chapters 5, 6 and 7 introduce the histology of the three dental tissues, enamel, dentine and cement. They include methods for establishing detailed developmental chronologies, as well as a discussion of irregularities in these sequences, such as enamel hypoplasia. One of the key issues for bioarchaeology and forensic anthropology is estimation of age and sex from human remains. Part of this is outlined in Chapters 2 and 4 but, in forensic odontology, dental histology has also long been employed in estimates of age-at-death in adults. This is reviewed in Chapter 8. The chemistry and physics of dental tissues has been a major focus of

xviii Preface

research and an introduction is provided in Chapter 9, suitable for further reading in more specialist books and papers. Chapter 10 deals with the complex issue of tooth wear: the mechanisms that produce it, the great variety of different forms it takes at different scales of examination, the relationship with occlusion and the possibilities for estimating age-at-death from it. Finally, Chapter 11 introduces the most common dental diseases seen in ancient dentitions. These are dental caries, periodontal disease and periapical inflammation. All are ultimately related to dental plaque, which is represented in archaeological remains by calculus or tartar. The chapter outlines plaque and calculus biology, and the aetiology and epidemiology of the diseases. Archaeological evidence shows that profound epidemiological changes have taken place, particularly in dental caries. Each chapter has its own introduction and conclusion, highlighting suggestions for further reading, although the citations throughout link to a large bibliography.

How Did Dental Anthropology Evolve?

‘Show me your teeth and I will tell you who you are,’ Baron Georges Cuvier, the great eighteenth- and nineteenth-century zoologist and anatomist, is supposed to have said. This comment was really in the context of comparative anatomy and refers to Cuvier’s delight in reconstructing whole extinct animals from fossil fragments of their dentitions, but it will do just as well for human teeth. One of the main themes of dental anthropology has been a study of variation in size and shape of the teeth, as recorded in casts of living mouths or seen in the skulls of archaeological and fossil collections. This research is founded on a series of classic ‘odontographies’: dental studies of particular ethnic groups or fossil collections such as those of Robinson (1956) on the australopithecines from South Africa, Weidenreich (1937) on the Chinese *Homo erectus* fossils, Campbell (1925) on Aboriginal Australians, Moorrees (1957) on the Aleuts and Pedersen (1949) on the East Greenland Inuit. It was particularly brought to prominence during the second half of the twentieth century by the late Al Dahlberg, who amassed a large collection of casts from his work as a dentist with living Native Americans. He acted as a focus for the development of dental anthropology through his graduate training programme at the University of Chicago and his role in the establishment of a series of Dental Morphology Symposia, which still runs regularly to this day. The widespread use of the phrase ‘dental anthropology’ probably dates to the forerunner of these symposia, a meeting held in London during 1958 (Brothwell, 1963a), celebrated 30 years later at a conference of the American Association of Physical Anthropologists in Kansas City (Kelley & Larsen, 1991). In 1986, a Dental Anthropology Association was formed during a conference at Albuquerque, New Mexico, and now numbers amongst its membership most of the active researchers in the field. It publishes *Dental Anthropology Journal*.

Dental anthropology is, however, a much wider subject than just morphology. It includes a study of the development of teeth in relation to age, their appearance in the mouth, and the processes of wear and other changes that occur once they are in place. It also includes the

microscopic traces, preserved inside the tissues of the teeth, of the growth and ageing processes. Yet another area of interest is the study of dental diseases, in relation to diet and other factors, and the most recent development is a study of the biochemistry of dental tissues. These ideas and techniques have entered anthropology from oral biology, whose roots lie in odontology, a term that is little mentioned nowadays but which has formed the scientific basis for modern dental surgery and forensic investigation. Odontology has its origins in the eighteenth and nineteenth centuries, with one major focus at the Royal College of Surgeons of England, in London. The museums of the College were founded with the personal collections of the extraordinary surgeon polymath John Hunter (1771, 1778). Successive curators included Sir Richard Owen (1845), Sir John Tomes (1894) and Sir Frank Colyer (Miles & Grigson, 1990), who, between them, published the founding texts of odontology. At the time of writing, the College is being rebuilt, but its museums were scheduled to open in 2023. Oral biology continues to be taught and researched in dental schools and has provided the basis for the dental histology and pathology, which have been incorporated into dental anthropology and are covered in this book.

Dental Anthropology and Destructive Sampling

This is a general issue of responsibility, affecting several chapters in the book, so it is addressed here at the start. Studies of ancient DNA, proteins, dating and stable isotopes are together some of the fastest growing aspects of bioarchaeology. To a large extent, they require destructive sampling, sometimes a very small etched area or fragment, but sometimes a whole tooth. The effects of this are added to tooth sectioning for microscopic studies of histology. Curators of collections are under constant pressure for access and, when visiting as a researcher, gaps in the dentitions due to sampling are increasingly evident. There are many stakeholders in this issue. Some do not want the remains to be disturbed in any way, or even reburied, while others feel that the greatest possible use should be made of a valuable resource. Museums and other curators of these collections have difficult decisions to make and, increasingly, strict guidelines are followed when considering requests for study and destructive sampling. I feel the need for some general principles for dental anthropology and these are my own views. Firstly, the default position should be that no destructive sampling of any kind should take place, unless a strong research case is made that the investigation would potentially have a wide enough impact to outweigh the loss of material for potential future study and the concerns of those opposed to sampling. Secondly, pilot studies need to have shown that there is a high probability of success – a small group of specimens should be tested before sampling a larger group. Thirdly, the sampled tooth should always have an antimere, the equivalent tooth from the other side, which remains unsampled. That way, at least something is left. Fourthly, the sample size should be the absolute minimum possible for the planned research. Finally, if a tooth is to be sampled, the maximum possible amount of information should result from its destruction, combining different studies and techniques in a collaboration. So, for example, sectioning for histology

xx Preface

could combine with stable isotope and trace element studies, ancient DNA and proteomics. Ideally, all potential stakeholders in the collection should be consulted and collaboration invited. In any case, this type of broad approach is exactly what funding bodies look for – they ask who will benefit from the project.

Abbreviations

AAC	acellular afibrillar cement
aDNA	ancient DNA
AEFC	acellular extrinsic fibre cement
AI	amelogenesis imperfecta
<i>AMELX</i>	amelogenin gene on X chromosome
<i>AMELY</i>	amelogenin gene on Y chromosome
ASUDAS	Arizona State University Dental Anthropology System
B	buccal
BP	years Before Present (defined as AD 1950)
BSE	backscattered electron mode scanning electron microscopy
CDJ	cement–dentine junction
CEJ	cement–enamel junction
CEJ–AC	CEJ–alveolar crest distance
CIFC	cellular intrinsic fibre cement
CMSC	cellular mixed stratified cement
CO	centric occlusion
CR	centric relation
D	distal
DGT	Demirjian, Goldstein and Tanner dental development stages
DNE	Dirichlet normal energy
EDJ	enamel–dentine junction
ESED	environmental secondary electron detector
ESEM	environmental scanning electron microscope
ET	scanning electron microscopy with Everhart–Thornley detector
GCF	gingival crevice fluid
ICM	inhibitory cascade model
ICP	intercuspatation position
ka	thousands of years
kD	kiloDaltons (a measure of atomic mass)
La	labial
LHPC	localised hypoplasia of primary canines
Li	lingual
LSAMAT	lingual surface attrition of the maxillary anterior teeth
M	mesial
Ma	millions of years
MFH	Moorrees, Fanning and Hunt dental development stages
mg l ⁻¹	milligrams per litre
mRNA	messenger RNA
MWTA	microwear texture analysis

xxii List of Abbreviations

NCP	non-collagenous proteins
nm	nanometres (millionths of a millimetre)
O	occlusal
OFA	occlusal fingerprint analysis
OMIM	Online Mendelian Inheritance in Man
OPCR	orientation patch count rotated
PAC	periapical cavity
PCA	principal components analysis
PC1	first principal component
PC2	second principal component
PC3	third principal component
PG	proteoglycan
PME	probable mutation effect
RFI	occlusal relief index
RI	refractive index
SE	secondary electron mode (alternative name for ET) scanning electron microscopy
SEM	scanning electron microscopy
TCA	tooth cementum annulation
TMJ	temporomandibular joint
w/v	weight for volume (weight of solute as percentage of solution volume)
‰	per mil (parts per thousand)
µm	micrometres (thousandths of a millimetre)