Dental Perspectives on Human Evolution: State-of-the-Art Research in Dental Paleoanthropology. 2007. Edited by Shara E. Bailey and Jean-Jacques Hublin. Vertebrate Paleobiology and Paleoanthropology Series. Dordrecht, The Netherlands: Springer (403 pages + index). $129.00, ISBN: 978-1-4020-5844-8

This is the third book in Springer's series on Vertebrate Paleobiology and Paleoanthropology; it consists of the proceedings of the first symposium on Human Evolution held at the Max Planck Institute for Evolutionary Anthropology (Leipzig, Germany). The volume illustrates the diverse and innovative ways that teeth inform our understanding of human evolution. Recent advances in the analysis of dental morphology, microstructure, development, and wear are showcased with respect to how they have increased knowledge of hominin phylogeny, ontogeny, and adaptation to changing dietary environments. An introduction to the volume by Simon Hillson provides a synopsis of key themes and unique perspectives presented in each chapter. The four main sections of the volume begin with an introductory chapter by scholars that have made a significant impact on the field. These introductions provide useful analytical summaries of each contribution and place them in the broader context of research in dental anthropology and paleoanthropology. Some, such as Fred Grine's introduction to Part IV: 'Dentition and Diet', which focuses on dental macro- and micro-wear, is comprehensive, historical, and well referenced - with 135 citations. Others, including Wood's introduction to Part III: 'Dental Development' are brief, yet highlight key features of each chapter in the section. A bit perplexing is Macchiarelli and Bailey's introduction to Part II: 'Dental microstructure and life history', where on several occasions the reader is uncertain which author's observations and opinions are being presented ('in my view', 'I would also like to note', 'in my personal view'). A brief synopsis of each of four section of the volume follows.

Part I: 'Dental evolution and dental morphology', contains seven chapters, and begins with Pilbrow's analysis of occlusal odontometric variation in great ape molar teeth. Results indicate that great ape molar metrics exhibit patterns of inter-species and sub-species taxonomic diversity. Despite small sample sizes, lack of understanding of inter-trait associations, and use of a classification system designed for scoring modern human tooth crown morphology, Bailey and Wood explore the evolutionary divergence of the Homo and Paranthropus lineages using post-canine morphometric variation. They find that increased dental crown complexity in Paranthropus is not a primitive retention and that dental trends said to be characteristic of Homo actually appear relatively late in human evolution. Maxillary molar cusp morphology of South African australopithecines is analyzed by Moggi-Cecchi and Boccone who find similarities (in crown base areas) and significant differences (in relative area of anterior cusps and molar size sequences) between A. africanus and A. robustus. Crown morphology of fossil samples from Gran Dolina (TD-6) and Sima de los Huesos are used by Martinón-Torres and colleagues, to assess phylogenetic issues related to the early colonization of Europe. They conclude that a coordinated assessment using biological and cultural evidence holds promise.

An innovative technique—neural network analysis using Self Organizing Maps—for describing dental morphology is used by Manni and colleagues to evaluate the relationship between archaic and modern Homo sapiens. Though it has some advantages, this new technique may have limitations that preclude its adoption by other investigators. The final two chapters in Part I focus on exciting new, non-destructive advances in imaging dental structures and tissues. Olejniczak and associates discuss methodological aspects of 3D data acquisition by micro-computed tomography of primate molar teeth. Precise and reliable portrayal of the enamel-dentine junction and measures of enamel cap thickness are tightly linked to methodological parameters such as slice thickness and pixel resolution. The advantages of high resolution X-ray computer tomography (HRXCT) for obtaining digital 3D data and volumetric properties of dense tissues, is reviewed by Gantt and colleagues.

Five chapters comprise Part II: 'Dental microstructure and life history.' This section begins with an analysis of dental microstructure, growth and life history of Megaladapis, providing estimates of gestation length, molar crown initiation, formation and completion times and minimum emergence ages for M1 and M2. Schwartz and colleagues find that molar development is rapid and poorly explained as a function of adult body mass. Microstructural indicators of dental development in a single female specimen of Pan paniscus are described by Ramirez-Rozzi and LaCruz. Preliminary results from the analysis of perikymata and striae counts reveal high appositional rates and short crown formation time for I1 while molar crown formation time is similar to that of the common chimpanzee.

New data on chimpanzee and human molar crown development are presented by Tanya Smith and associates, who document variation in incremental features within and between genera. Within cusp types humans show greater average cusp formation times than chimpanzees due either to thicker cuspal enamel and/or higher mean periodicity values. High variability in cusp formation times and overlapping ranges raise concerns for interpreting small samples. Enamel microstructure of Australopithecus africanus

is documented by Bromage and colleagues, who employed a portable confocal scanning optical microscope to circumvent analytic issues such as limited magnification and specimen preparation. Cross-striation periodicity and data on striae-EDJ angles are presented and crown formation time for a single molar (STW 284, M2) is estimated at between 3.0 and 3.2 years. In the final paper in this section, Guatelli-Steinberg and associates compare imbricational enamel growth in the anterior teeth of Neandertals and three modern human groups from diverse eco-geographic settings. While no significant difference was found in imbricational enamel formation times for anterior teeth, differences were evident in the shape of growth curves (from cusp tip to cervix) and in mean perikymata numbers across anterior tooth types.

Part III is devoted to 'Dental development' and consists of four chapters spanning dental genetics and tooth size, dental development sequences, inter-group variation in calcification stages and new methods for reconstructing dental ontogeny. Tooth size variation in outbred pedigreed populations of baboons and mice were used by Hlusko and Mahaney to test expectations derived from dental field theory. In mice, incisor size appears to be genetically independent of molar size, and circumstantial evidence from fossils suggests that some level of independence exists in the expression of anterior and post-canine tooth size in primates. Braga and Heuze introduce the concept of modularity to assess interactions between inter-dependent elements in growing dentitions. They observe considerably greater plasticity and variability in development timing of incisors than of other teeth and advise caution in using incisor teeth as a reliable substitute for other permanent teeth in the interpretation of fossils. Preliminary results from an on-going analysis of permanent molar calcification stages (M1 and M2) in African-American and European-American children are presented by Monge and associates, who find evidence of earlier maturation among children born in the 1990s. A re-evaluation of what constitutes 'normal' dental development and greater appreciation for the range of plasticity in dental calcification is encouraged.

Serial micro-CT scans are used by Smith and colleagues to reconstruct the topography of the dento-enamel junction and quantify cusp volume and relationships during successive stages of development. This research suggests that spatial relationships consist of shape differences that are established early in morphogenesis by differential development within the tooth germ, and that differences in cusp size and proportions are modified at the crown surface by enamel apposition.

Dental wear and elemental ratios in fossil hominin and modern human teeth are addressed by five diverse contributions to Part IV, entitled 'Dentition and diet". An innovative method known as laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) was used by Humphrey and colleagues to determine changes in Sr/Ca ratios across the neonatal line in deciduous teeth of formula-fed and breast-fed children. Marked reduction in Sr/Ca ratios were detected across the neonatal line in breast-fed children but not in formula-fed children, a result that holds promise for interpreting the chronology of dietary transitions in infancy and early childhood. Tooth crown topography, a landmark-free, 3D method of describing crown morphology, is employed by Ungar to show that differences in diet can be inferred from worn teeth in extant apes, that species-specific wear patterns allow inferences of function from form in worn teeth, and that differences in molar crown topography in Paranthropus and Australopithecus suggest differences in diet and fallback foods.

A retrospective review of past accomplishments and vision of future developments in the field of dental microwear is provided by Teaford, who regards 'low magnification' methods and scale-sensitive fractal analysis as 'next steps' in this rapidly developing field. Ulhaas and colleagues employ 3-D analysis of occlusal surface wear to comparatively assess variation in three hominin taxa: *A. afarensis*, *A. africanus*, and *Paranthropus robustus*. Using a portable optical triangulation scanner, inter-specific differences in the mode of reduction in occlusal relief was responsible for enhancing variation in wear facet orientation, an observation that implies low levels of interspecies competition for food. In the final chapter of the book, Estebaranz and associates use micrographs (SEM) and 3-D topographic images of molar buccal surfaces to characterize striation density and enamel surface roughness in three extant and three fossil hominin taxa. Postmortem surface damage and automated data acquisition were considered in this study which found a clear and significant association between some measures of enamel roughness and microwear pattern, a finding of value in inferring diet.

Overall, I found the volume a valuable review of emerging methods and new approaches to the use of dental morphology, microstructure, development, and wear in unraveling critical issues in human evolution. The hominin focus of the volume, made some chapters (Part II, chapter 2: lemur dental development; Part III, chapter 2: quantitative genetics of mice and monkeys) seem either out-of-place, or a refreshing departure from the main theme. The book is top-heavy with introductions (to the volume and then again to each individual section), yet lacking in summary, synthetic or integrative perspectives either by section, or for volume as a whole. This is an unfortunate omission. Though diverse in their objectives and methods, the contributions to this volume exhibit significant overlap in the questions posed and the results derived. A

comparative assessment of contributions, followed by a summary of the issues and themes that were consistently affirmed, as well as those on which divergent interpretations exist, would have been a valuable service to the reader.

As with many edited volumes, contributions are variable though in different ways; some chapters fail to yield definitive conclusions due to limitations of either sample size or methodology or both; while others present innovative and potentially useful analytical methods that suffer from operational complexity limiting their adoption by other investigators. Finally, it's sad that a volume devoted to cutting-edge technology contains so many annoying errors. For example, some text citations are missing from the References in the introduction to Part I (page 5, Martin-Torres *et al*., 2007; and Kono, 2004). Elsewhere (Part I, chapter 5), text references to illustrations are incorrect: a) on page 70, in discussing lower second premolar morphology, the reader is referred to Figure 3, which illustrates lower second molar occlusal surfaces. Again on page 73, in discussing molar cusp number, the reader is referred to Figure 5 which illustrates lower first premolar teeth. Sloppy editing, or inept use of the spell-checker, results in some awkward sentences; for example, on page 188, we read "... when discussing variation in enamel developmental, ..." and "In light if this, ...", and page 189, "... If is unclear why this population ...."

Researchers, teachers and graduate students in human and dental evolution, and possibly in allied clinical fields, will find the volume an indispensable and essential aid in keeping abreast of current developments in dental anthropology. However, given the rapid rate of change in method and theory in dental paleoanthropology, I'm concerned about the shelf-life of books devoted to cutting-edge issues and technology that require a significant financial investment.

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