

# Foreword



Smith, B. Holly (2020) Foreword. In: *Dental Wear in Evolutionary and Biocultural Contexts*, Christopher Schmidt and James T. Watson (Eds.), pp xv-xxi. Academic Press, Cambridge. [Indents corrected as much as possible by author after futile struggle with page composer]

All through the 19th century, construction projects and explorations turned up skeletons from across the ages, skeletons that were beginning to go to museums for preservation and study. The most obvious contrast between these earlier human skeletons and living people was the dentition, which often showed remarkable degrees of wear and unusual combinations of wear, occlusion, and dental health (e.g., [Mummery, 1870](#); [Wright, 1909](#)). As the 20th century began, the roster of teeth of the European Paleolithic was expanding rapidly ([Keith & Knowles, 1911](#)), but the 1907 discovery of a primitive mandible in a sand quarry at Mauer, Germany, near Heidelberg, generated extraordinary excitement, both for its massive architecture and for a stratigraphic context that made the new *Homo heidelbergensis* the oldest prehistoric human in Europe ([Shoetensack, 1908](#)).

The Piltdown forgery turned up in 1912, neatly engineered to imitate and enlarge upon the Heidelberg find, flatter British science and promote the social and scientific ambitions of the forger (see [De Groote et al., 2016](#)). It was here that tooth wear took on an additional layer of importance in the history of paleoanthropology. The forger, almost certainly the antiquarian Charles Dawson, combined parts of the jaw of a small female Bornean orangutan with parts of a human cranium to create an ancestor for England to rival those of Europe. The forger broke away the telltale condyle and anterior section, removed the molar teeth, ground them against a hard, abrasive surface, hand polished them and forced two molars back into the jaw ([De Groote et al., 2018](#)). Grinding down the cusps filled two purposes, both disguising cusp morphology and imitating the flat wear characteristic of known fossils. Dawson, who was known to have a cast of the Heidelberg find, probably ground down the orangutan teeth with cast and monograph of the famous fossil at hand. Planted in the Piltdown gravels, even bumbles like glue, fresh breaks and surface-deep stains failed to arouse the suspicions of the scientists called to the site.

Piltdown, with its ape mandible and large human cranium, became a spanner in the works of human evolution for those, like Arthur Keith, who accepted it. Others never did, however, and by midcentury, the British scientists Joseph Weiner, Kenneth Oakley and Le Gros Clark ([1953](#)) came together to examine the finds critically. Under their combined scrutiny, the Piltdown edifice quickly crumbled, exposing the hoax. The wear on the teeth—indeed, as [Weiner \(1955\)](#) said, the only thing that united the jaw with the skull—was central to the problem. Le Gros Clark, fresh off in-depth study of *Australopithecus* ([Clark, 1950](#)), soon showed the artificial nature of the abrasion, but moreover he marshaled observation about tooth wear that would set the agenda for evolutionary studies for decades. He considered the following questions raised by Piltdown ([Clark, 1955](#)).

1. What is the meaning of flat wear?
2. How do large canines effect chewing patterns and tooth wear?

3. What is the meaning of wear gradients between molars? and
4. Can tooth wear help us recognize a human ancestor?

Le Gros Clark's work had wide-ranging influence. In Australia, Thomas Murphy, who was studying humanity's most spectacular tooth wear, responded to Le Gros Clark's study of Piltown by asking:

5. What is the human pattern of dentine exposure and how can it be distinguished from non-human primates?

Murphy went on to map occlusal tooth wear and construct a staged scheme to grade and compare molar wear gradients. His work was widely available in the *American Journal of Physical Anthropology* (Murphy, 1959) and widely influential. Reading Murphy, A.E.W. Miles was struck with an idea: the difference in wear between M1 and M2, teeth separated in emergence time by 5–6 years, must represent 5–6 years of wear, giving a basis for estimating age of death from tooth wear. Miles' method of aging appeared in Brothwell's influential *Dental Anthropology* volume (Miles, 1963). In turn, Alan Mann, in a 1968 thesis and later monograph (Mann, 1975), used Miles' method to construct a demographic profile of the hominin fossils from Sterkfontein and Swartkrans, arguing also that the integration of wear and development pointed to a great antiquity for human growth and development. Even with critiques and corrections, the Miles' method remains a staple in bioarcheology to this day (Gilmore & Grote, 2012). Thus, in the 1960s, tooth wear had led us to the first real evidence-based approach to the questions:

6. Can tooth wear yield a demographic profile for a skeletal sample of unknown age-of-death?
7. What is the time depth of the human life course?

From his student days, C. Loring Brace used tooth size as a window onto both human variation and evolutionary change (see Ferrie, 1997). He had a life-long interest in tooth wear, food and food preparation, as factors that influenced the face and teeth, and he was especially inspired by the Australian record. The use of teeth as tools would figure into his explanation of the large, forward-jutting Neanderthal face (Brace, 1962). Brace mentored first Stephen Molnar, who would engineer an early chewing machine "CANIBAL" (Brace & Molnar, 1967) and later pull together a generation of work on tooth wear and culture (Molnar, 1972). Chewing machines, which today have a sophistication almost unimaginable in those early days, continue to isolate factors in a way not possible with living subjects.

By the late 1970s, Brace would supervise three more students with independent approaches to prehistoric diet: Ryan (1980) with "microwear," Schoeninger (1979) with stable isotopes, and myself, with patterns of tooth wear (Smith, 1983), the latter a level of focus that would come to be called "macrowear." We Brace students tackled, at least, these questions:

8. How were teeth used as tools in fossil hominins and did it especially impact the Neanderthal face?
9. What did extinct human populations eat?

10. Can we discriminate important human economic groups such as foragers vs agriculturalists by tooth wear?

Like all “macrowear” students, Molnar and I faced the same basic problem: Whatever the question, we were searching for Factor II in a setup where Factor I was subject age—the underlying determinant that remained a frustrating unknown in almost all skeletal samples. We all developed work-arounds, comparing wear on one tooth versus another or scaling wear against another dental dimension. Another limitation came from measuring a continuous phenomenon with a ranked scale. [Scott \(1979\)](#) provided a scale that itself recorded pattern with wear scores per cusp, scores which could be sorted out or summed over all, a method that produced a variable more amenable to parametric statistics. My own eight-stage scale, most similar to Murphy’s, was largely designed to work as a “blocking” variable that grouped comparable degrees of wear despite pattern differences, so that another more parametric variable could be studied ([Smith, 1984](#)).

“Microwear” came into archeology early in the context of use-wear on lithics, a subject that could be reviewed as early as 1974 ([Keeley, 1974](#)). Lithic use-wear shares the many of the same concerns dental microwear studies would focus on, processing of plants versus animals, hide working and the contribution of environmental grit among them. The adoption of microwear into paleontology owes some debt to the increasing availability of the scanning electron microscope in the 1970s ([Grine, 1977](#)), but the practice of examining tooth wear facets and striations in fine detail had a long history in paleontology. [Butler \(1952\)](#) and [Butler and Mills \(1959\)](#) used it to map out the buccal phase of chewing, an important mammalian innovation. Facet mapping remains a basic tool in reconstructing jaw movement in extinct species, where recent advances in technology allow a detailed automated “occlusal fingerprint analysis” ([Kullmer et al., 2009](#)). Both old and new approaches address:

11. How to we move from wear facet maps to jaw movement, mastication and food properties?

With roots in both mammalogy and archeology, perhaps it is no wonder that paleoanthropology made microwear its own. The initial paper that inspired many was by [Walker, Hoeck, and Perez \(1978\)](#), a study that contrasted microwear on teeth of browsing versus grazing hyraxes—a beautifully matched and balanced case study. Microwear studies now held out the promise that they might diagnose meaningful categories of dietary adaptations relevant to early hominins. Microwear studies had real advantages: Age-at-death collapsed as a problem because microwear was primarily observed on occlusal enamel, a tissue with a limited time window in a life span and, as a shorter-term phenomenon, more amenable to experimentation. At Johns Hopkins, Alan Walker gathered graduate students, postdocs and young professors, among them Kathleen Gordon ([Gordon, 1982](#)) and [Teaford \(1982\)](#). Teaford, who had worked on gradients of tooth wear in

cercopithecoid primates, quickly saw the promise of the new field (Teaford & Walker, 1984). About the same time, Fred Grine brought his experience of the paleontology of South Africa to Stony Brook (Grine, 1984). He took up microwear with his early graduate student Peter Ungar, who would, in turn, take the field as far as anyone.

In paleoanthropology, microwear studies were (and are) aimed primarily at australopiths, especially at explaining the massive adaptations to chewing forces evident in *Paranthropus* species (Grine, 1986; Peterson, Abella, Grine, Teaford, & Ungar, 2018). The focus on early hominins meant that cooking and all but the simplest food preparation dropped out of the picture, reducing variables. Still, in the early days, little was known about the correspondence of microwear to food and food properties or environmental grit. To begin to parse out factors, Teaford and colleagues turned to living primate species where the food repertoire was known and more limited (Peterson et al., 2018; Teaford & Walker, 1984). Technical questions for the field of microwear were often big questions:

12. Can we interpret the microwear of anterior teeth vs posterior teeth to understand food acquisition vs mastication?
13. What kinds of categories of feeding behavior or diet can microwear determine for any mammal? Browser/grazer? Frugivore/folivore? Carnivore/Omnivore? Ground feeder/arboreal feeder? Hard/soft Tough/brittle?
14. Can microwear help explain the craniofacial adaptation of *Australopithecus* sp. and especially, *Paranthropus bosei*?

Microwear as a field faced its other hurdles. No one knew the time depth of a scratch on enamel, something that had to be established experimentally. The answer—that they might represent only days or a week (Teaford & Oyen, 1989)—was astounding. Hand-counting and categorizing pits and scratches was demanding and tedious work and counts of features were difficult to duplicate across observers. Over time, use of simpler light microscopy tended to replace the scanning electron microscope, simplifying procedures. Ungar and colleagues made a major innovation by turning to engineering for concepts and methods, distinguishing 3D properties like texture, “complexity” and “anisotropy” and automating measurement (Peterson et al., 2018; Ungar, Brown, Bergstrom, & Walker, 2006). A new era of repeatability dawned, and once messy scatterplots snapped into new order (DeSantis et al., 2013), also enabling microwear to reveal distinctions among human economies (El Zaatari, 2010; Schmidt, Beach, McKinley, & Eng 2015).

The growing number of new hominin species turned up in the last 40 years greatly increased the arena for, and importance of, questions about early hominin diet because niche divergence is likely crucial to diversification (Ryan & Johanson, 1989; Ungar, Scott, Grine, & Teaford, 2010). Yet, microwear often did not easily slot into our expectations based on facial architecture (Walker, 1981), something we continue to struggle with (Ungar, Grine, & Teaford, 2008). Primatology, however, introduced us to “fallback foods” (Altmann,

1998), a concept that accounts for some of the difficulty synthesizing all lines of evidence.

Although microwear studies blossomed after 1978, “macrowear” studies didn’t die off. Over this same 40 years, bioarcheology and zooarcheology have kept up a solid tradition of tooth wear studies, one that encompasses both micro- and macro-scale (Schmidt, 2010). Scoring methods for macrowear based on Smith (1984) and Scott (1979) appeared in Buikstra and Ubelaker’s (1994) “Standards,” thus becoming part of the work up of skeletal material. Technical advances also aided macrowear studies, making it possible to digitize areas of dentine exposure and tooth area to create precise measurements (Clement, Hillson, & Aiello, 2012).

Several macrowear studies speak to diet in transitional periods in the Old and New Worlds (Eshed, Gopher, & Hershkovitz, 2006; Kaifu, 1999; Watson, 2008). Domesticated and game animals are frequent topics, as is ecological change and changing cultural horizons (Pechenkina, Benfer, & Zhijun, 2002) and wear continues as a tool to age mammals in any setting (Anders, von Koenigswald, Ruf, & Smith, 2011). Special wear patterns have been noted that correspond to underground storage organ foods in examples from around the world (Turner & Machado, 1983; Watson & Haas, 2017), something of particular interest as an early adaptation in the hominins (Dominy, Vogel, Yeakel, Constantino, & Lucas, 2008). Among the many questions being asked, we might add:

15. Can mammal (human or nonhuman) tooth wear track aridification and/or other climate changes?
16. Can wear illuminate transitions in diet or economy such as the steps toward agriculture and/or the domestication of animals?
17. Can the growing body of tooth wear scores contribute to paleodemography?
18. In what circumstances does mastication of underground storage organs produce special wear on teeth?

Perhaps the most exciting development in recent years is the interdisciplinary teams that are tackling the big question the field began with:

19. Can we combine the study of morphology, pathology, macrowear, isotopes, microwear and paleoecology to bring to life the food habits of extinct hominins and prehistoric populations?

All these of lines of evidence together may lead us to actual food sources, something that may inform us about grouping patterns, seasonality, feeding posture and energy availability of the hominins that fed on them. One fascinating aspect of combined approaches is that isotopes, microwear, and macrowear tell us respectively, what the subject ate while growing up, what it ate the last week of its life, and how tooth use averaged over a lifetime, a diversity of evidence we must learn to exploit.

It was always clear that tooth wear tells the story of a life as lived and, despite a notorious attempt to fake one, scientists ultimately saw through the hoax to build a productive field from what they learned.

By 2018, 40 years after microwear blossomed, 65 years after Piltdown was exposed, and 106 years after a forger sat at a worktable grinding down orang-utan teeth, it is time for some synthesis. I thank James Watson and Christopher Schmidt for putting this volume together and inviting me to comment. These 19 questions are just a sample of what has been addressed with the evidence of tooth wear. We might as well make it 20, hoping this field will contribute more to the evolution of the genus *Homo* (see [Wrangham, 2009](#)):

20. Can tooth wear at ANY level help track the growing importance of cooking during human evolution and help define its time depth in the Pleistocene?

I'll leave you to it.

**B. Holly Smith**  
Ann Arbor, Michigan

---

## References

- Altmann, S., 1998. Foraging for survival. University of Chicago, Chicago.
- Anders, U., von Koenigswald, W., Ruf, I., Smith, B.H., 2011. Generalized individual dental age stages for fossil and extant placental mammals. *Paläontologische Zeitschrift*, 85 (3), 321–339.
- Brace, C.L., 1962. Cultural factors in the evolution of the human dentition. In: Montagu, M.F.A. (Ed.), *Culture and the evolution of man*. Oxford University Press, Oxford.
- Brace, C.L., Molnar, S., 1967. Experimental studies in human tooth wear: I. *American Journal of Physical Anthropology*, 27 (2), 213–221.
- Buikstra, J.E., Ubelaker, D.H. (Eds.), 1994. Standards for data collection from human skeletal remains. Research series No. 44, Arkansas Archaeological Survey, Fayetteville, AR.
- Butler, P.M., 1952. The milk-molars of *Perissodactyla*, with remarks on molar occlusion. *Proceedings of the Zoological Society of London*, 121, 777–817.
- Butler, P.M., Mills, J.R.E., 1959. A contribution to the odontology of *Oreopithecus*. *Bulletin of the British Museum (Natural History), Geology*, 4, 1–26.
- Clark, W.E.L.G., 1950. Hominid characters of the australopithecine dentition. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland*, 80, 37–54.
- Clark, W.E.L.G., 1955. An anatomical study of the Piltdown teeth and the so-called turbinial bone. *Bulletin of the British Museum (Natural History), Geology*, 2 (6), 234–242.
- Clement, A.F., Hillson, S.W., Aiello, L.C., 2012. Tooth wear, Neanderthal facial morphology and the anterior dental loading hypothesis. *Journal of Human Evolution*, 62, 367–376.
- De Groote, I., Flink, L.G., Abbas, R., Bello, S.M., Burgio, L., Buck, L.T., et al., 2016. New genetic and morphological evidence suggests a single hoaxer created “Piltdown man”. *Royal Society Open Science*, 3, 160328.
- DeSantis, L.R.G., Scott, J.R., Schubert, B.W., Donohue, S.L., McCray, B.M., Van Stolk, C.A., et al., 2013. Direct comparisons of 2D and 3D dental microwear proxies in extant herbivorous and carnivorous mammals. *PLoS ONE*, 8, e71428.
- Dominy, N.J., Vogel, E.R., Yeakel, J.D., Constantino, P., Lucas, P.W., 2008. Mechanical properties of plant underground storage organs and implications for dietary models of early hominins. *Evolutionary Biology*, 35, 159–175.
- El Zaatari, S., 2010. Occlusal microwear texture analysis and the diets of historical/prehistoric hunter-gatherers. *International Journal of Osteoarchaeology*, 20, 67–87.

- Eshed, V., Gopher, A., Hershkovitz, I., 2006. Tooth wear and dental pathology at the advent of agriculture: new evidence from the Levant. *American Journal of Physical Anthropology*, 130 (2), 145–159.
- Ferrie, H., 1997. An interview with C. Loring Brace. *Current Anthropology* 38 (5), 851–869.
- Gilmore, C.C., Grote, M.N., 2012. Estimating age from adult occlusal wear: a modification of the Miles method. *American Journal of Physical Anthropology*, 149, 181–192.
- Gordon, K.D., 1982. A study of microwear on chimpanzee molars: implications for dental microwear analysis. *American Journal of Physical Anthropology*, 59 (2), 195–215.
- Grine, F.E., 1977. Postcanine tooth function and jaw movement in the gomphodont cynodont *Diademodon*. *Palaeontologica Africana*, 20, 123–135.
- Grine, F.E., 1986. Dental evidence for dietary differences in *Australopithecus* and *Paranthropus*: a quantitative analysis of permanent molar microwear. *Journal of Human Evolution*, 15 (8), 783–822.
- Kaifu, Y., 1999. Changes in the pattern of tooth wear from prehistoric to recent periods in Japan. *American Journal of Physical Anthropology*, 109 (4), 485–499.
- Keeley, L.H., 1974. Technique and methodology in microwear studies: a critical review. *World Archaeology*, 5, 323–336.
- Keith, A., Knowles, F.H.S., 1911. A description of teeth of palaeolithic man from Jersey. *Journal of Anatomy and Physiology*, 46, 12–27.
- Kullmer, O., Benazzi, S., Fiorenza, L., Schulz, D., Bacso, S., Winzen, O., 2009. Technical note: occlusal fingerprint analysis: quantification of tooth wear pattern. *American Journal of Physical Anthropology*, 139 (4), 600–605.
- Mann, A.E., 1975. Paleodemographic aspects of the South African australopithecines. University of Pennsylvania, Philadelphia.
- Miles, A.E.W., 1963. Dentition in the assessment of individual age in skeletal material. In: Brothwell, D.R. (Ed.), *Dental anthropology*. Pergamon Press, Oxford, pp. 191–209.
- Molnar, S., 1972. Tooth wear and culture: a survey of tooth functions among some prehistoric populations. *Current Anthropology*, 13, 511–526.
- Mummery, J.R., 1870. On the relations which dental caries (as discovered amongst the ancient inhabitants of Britain, and amongst existing aboriginal races) may be supposed to hold to their food and social condition. Wyman and Sons, London.
- Murphy, T., 1959. The changing pattern of dentine exposure in human tooth attrition. *American Journal of Physical Anthropology*, 17 (3), 167–178.
- Pechenkina, E.A., Benfer, R.A., Zhijun, W., 2002. Diet and health changes at the end of the Chinese Neolithic: the Yangshao/Longshan transition in Shaanxi province. *American Journal of Physical Anthropology*, 117 (1), 15–36.
- Peterson, A., Abella, E.F., Grine, F.E., Teaford, M.F., Ungar, P.S., 2018. Microwear textures of *Australopithecus africanus* and *Paranthropus robustus* molars in relation to paleoenvironment and diet. *Journal of Human Evolution*, 119, 42–63.
- Ryan, A.S., 1980. Anterior dental microwear in hominid evolution: Comparisons with human and nonhuman Primates. (Doctoral dissertation) The University of Michigan, Ann Arbor.
- Ryan, A.S., Johanson, D.C., 1989. Anterior dental microwear in *Australopithecus afarensis*: comparisons with nonhuman primates. *Journal of Human Evolution*, 18 (3), 235–268.
- Schmidt, C.W., 2010. On the relationship of dental microwear to dental macrowear. *American Journal of Physical Anthropology*, 142 (1), 67–73.
- Schmidt, C.W., Beach, J.J., McKinley, J.I., Eng, J.T., 2015. Distinguishing dietary indicators of pastoralists and agriculturalists via dental microwear texture analysis. *Surface Topography*, 4, 014008.

- Schoeninger, M.J., 1979. Diet and status at Chalcatzingo: some empirical and technical aspects of strontium analysis. *American Journal of Physical Anthropology*, 51 (3), 295–309.
- Scott, E.C., 1979. Dental wear scoring technique. *American Journal of Physical Anthropology*, 51 (2), 213–217.
- Shoetensack, O., 1908. Der Unterkiefer des Homo heidelbergensis aus den Sanden von Mauer bei Heidelberg. Ein Beitrag zur Paläontologie des Menschen. Wilhelm Engelmann, Leipzig.
- Smith, B.H., 1983. Dental attrition in hunter-gatherers and agriculturalists. (Doctoral dissertation) The University of Michigan, Ann Arbor.
- Smith, B.H., 1984. Patterns of molar wear in hunter-gatherers and agriculturalists. *American Journal of Physical Anthropology*, 63, 39–56.
- Teaford, M.F., 1982. Differences in molar wear gradient between juvenile macaques and langurs. *American Journal of Physical Anthropology*, 57 (3), 323–330.
- Teaford, M.F., Oyen, O.J., 1989. In vivo and in vitro turnover in dental microwear. *The American Journal of Physical Anthropology*, 80 (4), 447–460.
- Teaford, M.F., Walker, A., 1984. Quantitative differences in dental microwear between primate species with different diets and a comment on the presumed diet of *Sivapithecus*. *American Journal of Physical Anthropology*, 64, 191–200.
- Turner, C.G., Machado, L.M.C., 1983. A new dental wear pattern and evidence for high carbohydrate consumption in a Brazilian Archaic skeletal population. *American Journal of Physical Anthropology*, 61 (1), 125–130.
- Ungar, P.S., Brown, C.A., Bergstrom, T.S., Walker, A., 2006. Quantification of dental microwear by tandem scanning confocal microscopy and scale-sensitive fractal analyses. *Scanning*, 25, 185–193.
- Ungar, P.S., Grine, F.E., Teaford, M.F., 2008. Dental microwear and diet of the Plio-Pleistocene hominin *Paranthropus boisei*. *PLoS ONE*, 3 (4), e2044.
- Ungar, P.S., Scott, R.S., Grine, F.E., Teaford, M.F., 2010. Molar microwear textures and the diets of *Australopithecus anamensis* and *Australopithecus afarensis*. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 365, 3345–3354.
- Walker, A., 1981. Diet and teeth: dietary hypotheses and human evolution. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 292, 57–64.
- Walker, A., Hoeck, H.N., Perez, L., 1978. Microwear of mammalian teeth as an indicator of diet. *Science*, 201, 908–910.
- Watson, J.T., 2008. Changes in food processing and occlusal dental wear during the early agicultural period in Northwest Mexico. *American Journal of Physical Anthropology*, 135, 92–99.
- Watson, J.T., Haas, R., 2017. Dental evidence for wild tuber processing among Titicaca Basin foragers 7000 ybp. *American Journal of Physical Anthropology*, 164 (1), 117–130.
- Weiner, J.S., 1955. An outline of the Piltdown problem. *Bulletin of the British Museum (Natural History), Geology*, 2 (6), 229–233.
- Weiner, J.S., Oakley, K.P., Clark, W.E.L.G., 1953. The solution of the Piltdown problem. *Bulletin of the British Museum (Natural History), Geology*, 2 (3), 141–146.
- Wrangham, R.W., 2009. *Catching fire: How cooking made us human*. Basic Books, New York.
- Wright, W., 1909. The teeth of early man. *Proceedings of the Royal Society of Medicine*, 2 (Odont Section), 3–8.