CHAPTER

The effects of aberrant tooth wear on occlusal relationships 5

Adam Crane[a,b], **James T. Watson**[a,b], **Randy Haas**[c]

[a]*Arizona State Museum, University of Arizona, Tucson, AZ, United States,*
[b]*School of Anthropology, University of Arizona, Tucson, AZ, United States,*
[c]*Department of Anthropology, University of California, Davis, CA, United States*

Introduction

Throughout life, the mechanical and chemical forces resulting from the mastication of food and other extramasticatory behaviors (e.g., the use of teeth as tools, dentistry, aesthetic modification, habitual picking of the teeth, etc.) gradually destroy the tissues that constitute the teeth, a suite of processes known collectively as dental wear (Burnett, 2016). The study of dental wear has a long history in bioarchaeology, owing to the unique kinds of information that can be extracted from patterns observed in individuals or across populations (skeletal samples). Patterns of occlusal wear vary by subsistence regime (e.g., Smith, 1984), and assessments of the degree of dental wear are commonly used by bioarchaeologists to estimate age at death (e.g., Lovejoy, 1985). Furthermore, as the teeth are the only skeletal elements to interface directly with the external environment, data related to diet, food preparation, pathology, idiosyncratic behaviors, and occupational activities that leave few traces elsewhere in the skeleton can often be recovered through careful examination of wear and other features of the dentition (e.g., dental calculus, dental morphology; Irish & Scott, 2016).

In the literature concerning dental wear in archeological populations, considerable attention has been paid to the interpretation of aberrant wear, that is wear inconsistent with the patterns expected to result from the normal mechanical forces of mastication. Numerous forms of aberrant wear have been documented across the world and throughout time in both the archeological and ethnographic records. A recent volume edited by Burnett and Irish (2016) on (largely) intentionally modified teeth highlights this diversity. In these cases, the aberrant wear represents intentional forms of body modification and can be largely attributed to social customs, traditions that form the fabric of signaling embodied messages with deep social meanings. Examples of this type of intentional modification include ablation, filing or notching, drilling and inlays, and staining of tooth surfaces. In contrast, unintentional forms of aberrant tooth wear stem from use-related or pathological wear (Milner & Larsen, 1991). Stojanowki, Johnson, Paul, and Carver (2016) recognize the entire suite of aberrant wear as "idiosyncratic behaviors" in the dentition (Stojanowki et al., 2016, p. 377),

Dental Wear in Evolutionary and Biocultural Contexts. https://doi.org/10.1016/B978-0-12-815599-8.00005-8

recognizing the potentially confounding effects of imposing inferential taxonomies over complex, often interconnected behaviors.

Irrespective of intention, motivations, or ultimate ausation, the form and distribution of aberrant wear can be used in conjunction with archeological, historical, or ethnographic data to identify the behaviors that cause it through proximate causation. Aberrant wear therefore represents a unique source of information about cultural behaviors that are otherwise inaccessible through the analysis human skeletal remains (Stojanowki et al., 2016).

As an illustrative example, lingual surface attrition of the maxillary anterior teeth, or LSAMAT, is manifest as uniquely angled, isolated wear extending from the cingulum to incisal edge across the lingual surfaces of the anterior teeth. The degree of wear (amount of crown loss) is not matched in opposing or adjacent (posterior) teeth. LSAMAT has been documented in numerous archeological populations globally—first by Turner and Machado (1983) among coastal foragers in Brazil and most recently by Watson and Haas (2017) among early foragers from the Lake Titicaca Basin in southern Peru (Fig. 5.1). Given that the steeply-angled lingual wear characterizing LSAMAT is unlikely to result from the normal forces of mastication, researchers have generally concluded that the pattern is likely the result of some extramasticatory force acting on the teeth. LSAMAT is often suggested to result from the use of the front teeth as tools in the processing of fibrous, carbohydrate-rich foods such as tubers. The presence of LSAMAT in archeological contexts thus frequently contributes to interpretations of tuber consumption, as is the case with Watson and

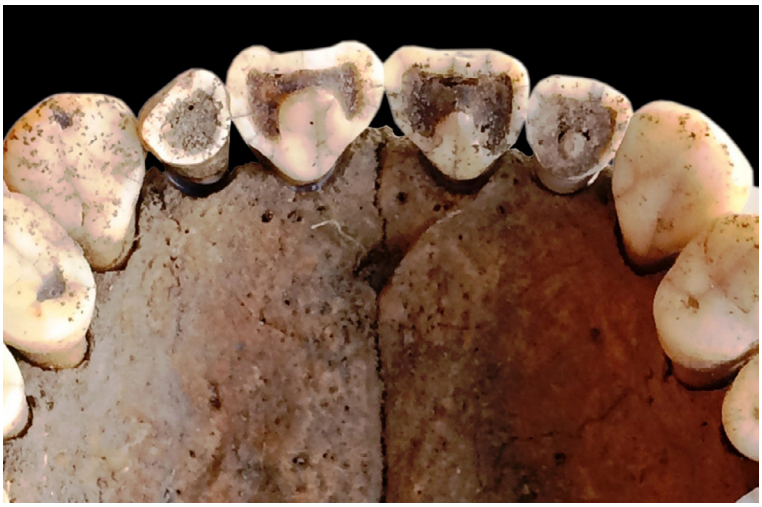

FIG. 5.1

Example of lingual surface attrition of the maxillary anterior teeth (LSAMAT) in an individual from an early forager population from the Titicaca Basin, Peru.

Credit: Dr. James T. Watson and Dr. Randy Haas.

Haas (2017) who interpret it as evidence that the Archaic population of the Lake Titicaca Basin subsisted at least partially on the fibrous tubers native to the Altiplano.

Initially, however, there was little consensus regarding the etiology of LSAMAT. In favor of a dietary explanation for the pattern, Turner and Machado (1983, p. 128) first attributed the ultimate etiology of LSAMAT to behaviors analogous to "the modern way we eat artichokes—by pulling and planning the edible petals across the occlusal surfaces of our anterior teeth." Notably, this interpretation was grounded exclusively in archeological data, with Turner and Machado suggesting that the ubiquity of the aberrant wear in the study population (i.e., affecting men and women equally from a very young age) and the stability of the pattern through time were more consistent with a dietary origin than any productive activity. Meanwhile, Lukacs and Pastor (1988) noted that a similar pattern of wear results from the use of the anterior maxillary teeth as a "third hand" in craft production and food processing, drawing on ethnographic accounts of the practice among Canadian Inuit populations.

Robb, Cruwys, and Smith (1991; reply by Turner, Irish, & Machado, 1991) challenged behavioral explanations that attributed the pattern to mechanical forces (i.e. those resulting from tooth-tooth or tooth-object contact) and instead argued that LSAMAT is more likely a result of chemical erosion—particularly because of pathological conditions leading to chronic regurgitation of gastric acids. This erosion-based explanation was based primarily on observations of LSAMAT-like patterns in modern dentistry patients. Despite these alternatives and decades after Turner and Machado (1983) first proposed tuber-processing as a potential cause of LSAMAT using archeological data, Berbesque et al. (2012, p. 279) observed similar patterns of wear among living Hadza women who "often use their teeth to peel the tough skin from tubers" (Fig. 5.2), which validated the initial dietary interpretation.

The example of LSAMAT and the contention surrounding its etiology is illustrative of the myriad challenges posed by the study of aberrant wear. At the level of gross observation, each of the cases described above is more-or-less consistent with LSAMAT. Yet each of the disparate interpretations of the pattern was ultimately supported by observations of similar wear in living populations. Although some forms of aberrant wear have clearer causes than others—aesthetic modifications such as inlays are not likely to be mistaken for teeth used as tools, for instance—the lesson here is that observation of aberrant wear alone is insufficient to draw conclusions about underlying causes. Given the apparent equifinality of wear patterns, it is only in conjunction with behavioral correlates in the archeological record (e.g., investment in stone milling technologies necessary for the processing of tubers; Watson & Haas, 2017) and historic/ethnographic analogy (e.g., observation of LSAMAT among Hadza women who peel tubers with their teeth; Berbesque et al., 2012) that the analysis of aberrant wear can provide insight into the particular behaviors that cause them.

In the absence of supporting lines of evidence, aberrant wear is often indicative only of some nonspecific extramasticatory force acting on the teeth. That said, it should be noted that while the observation of aberrant wear of known cause in living/historic populations may be the strongest foundation for the interpretation of similar

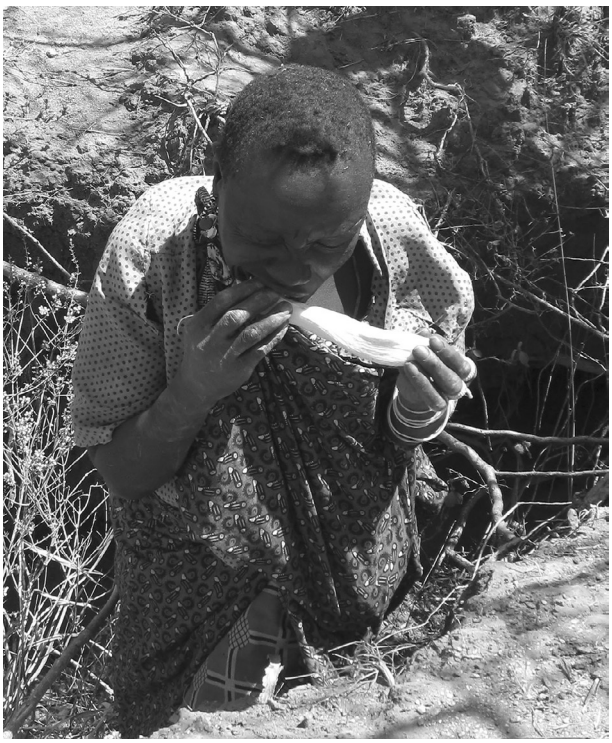

FIG. 5.2

Photograph depicting a Hadza woman peeling tubers with her maxillary anterior teeth.

Credit: Dr. Colette Berbesque.

patterns in skeletal populations, Turner and Machado's (1983) successful assessment of LSAMAT in the absence of ethnographic/historic analogy demonstrates the viability of archeological data for interpreting the underlying causes of aberrant wear. The case of LSAMAT further demonstrates the importance of assessing not just the ultimate etiology of a pattern of wear (e.g., the use of the teeth to peel tubers) but also the proximate etiology—that is, the mechanism underlying the destruction of dental tissues (i.e., attrition, abrasion, abfraction, or erosion)—acting on the teeth. While the LSAMAT described by Turner and Machado (1983) and the pattern described by Robb et al. (1991) are broadly similar, the cases are the products of distinct proximate etiologies. Given that proximate etiologies can be differentiated through careful analysis of worn surfaces (see Burnett, 2016), the contention surrounding the dietary or pathological origins of LSAMAT could have been circumvented through more careful documentation of those proximate etiologies.

Although the examples above depict the study aberrant wear as fraught, they are also illustrative of the unique research opportunities presented by the phenomena. Aberrant wear patterns may also reflect the breadth of human behaviors that can

be embodied in the teeth. Solely within the literature concerning a single pattern of aberrant wear, the LSAMAT studies above convincingly identify and describe three distinct underlying behaviors (or pathology in the case of Robb et al., 1991). In each case, the analysis of aberrant wear allows for the identification of human behavior in the archeological record at the level of individual practices, an interpretive resolution rarely accessible through observations of the human skeleton. It takes only a brief survey of the broader literature to demonstrate the wide variety of other aberrant wear forms that have been documented in archeological contexts, each a similarly valuable source of insight into human behavior (Table 5.1).

The state of the field

It is clear from the discussion above that the interpretation of aberrant wear is contingent on the ability of researchers to identify behavioral correlates, either in the archeological record or in populations with similar patterns of wear of known cause. Thus, one might expect that analyses of aberrant wear would be highly systematic, such that the inter- and intra-population comparisons necessary to establish relationships between study populations and known populations are consistently possible.

Table 5.1 Sample of aberrant wear studies in the literature.

Wear type	References
Occlusal	
Dietary inclusions	Eshed, Gopher, and Hershkovitz (2006) and Kieser et al. (2001)
Bruxism	Nugent (2013)
Malocclusion	Helm and Prydsö (1979), Rose and Roblee (2009), and Varrela (1990)
Behavioral	
Use of teeth as tools	Hinton (1981), Irish and Turner (1987, 1997), Lukacs and Pastor (1988), Turner and Machado (1983), Wallace et al. (1975), and Watson and Haas (2017)
Filing/grooving	Geller (2006), González, Perea Pérez, Sánchez Sánchez, and Mar Robledo Acinas (2010), and Williams and White (2006)
Inlays	Fastlicht (1962), Geller (2006), Linné (1940, 1948), and Williams and White (2006)
Ablation	Cook (1981), Hrdlička (1940), Kangxin and Nakahashi (1996), and Pietrusewky and Douglas (1993)
Therapeutic fillings	Bertrand, Colard, Lacoche, Salomé, and Vatteoni (2009) and Wols and Baker (2004)
Pipe facets	Walker and Henderson (2010) and Pfieffer, Dudar, and Austin (1989)
Interproximal grooves	Brown and Molnar, 1990, Formicola (1988), Ubelaker, Phenice, and Bass (1969), and Ungar, Grine, Teaford, and Pérez-Pérez (2001)
Chronic regurgitation	Robb et al. (1991)

Unfortunately, this is not the case (Stojanowki et al., 2016). Despite the potential value of aberrant wear as a source of information concerning human behavior, the phenomenon tends to be obscured by the standard scoring approaches that are widely used in the analysis of dental wear. These approaches—among them the methods first developed by Murphy (1959), Scott (1979), and Smith (1984) and later made ubiquitous by their use in Buikstra and Ubelaker's (1994) *Standards for Data Collection from Human Skeletal Remains*—typically assess dental wear on the occlusal surface using simple ordinal systems, wherein wear is scored in terms of severity (Fig. 5.3).

In these systems, each tooth (or tooth quadrant for the molars) is assigned a numeric score corresponding to a standardized stage of wear progression developed from observations of normal occlusal wear in a reference population. While such approaches are useful to the extent that they facilitate intra- and inter-population comparison of normal occlusal wear, ordinal systems obfuscate the variety of aberrant

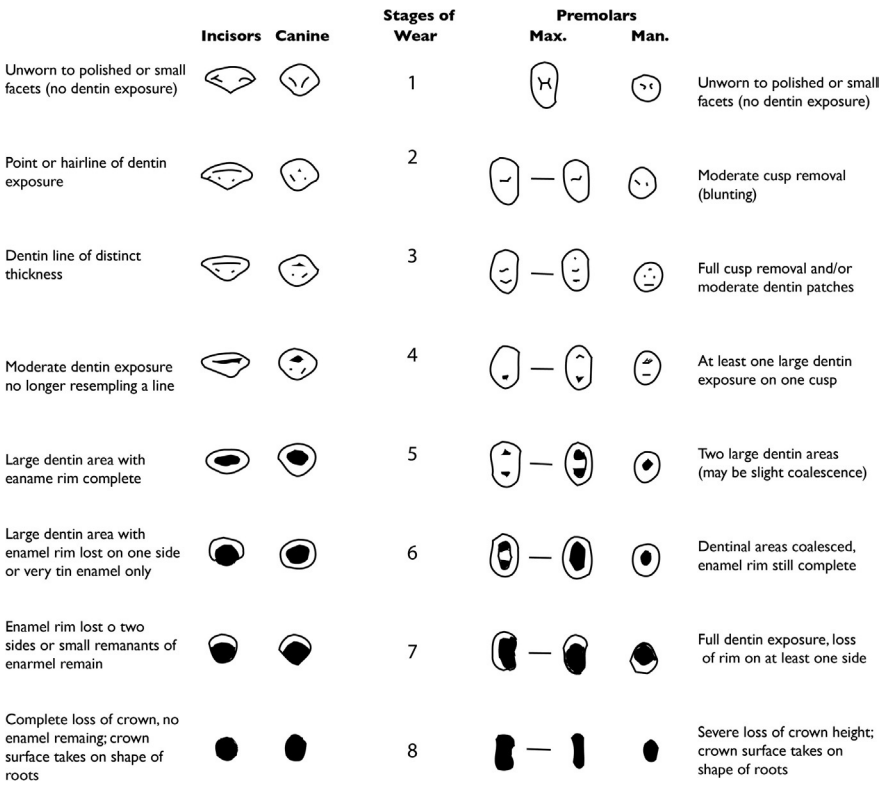

FIG. 5.3

Example of an illustrated ordinal scale used for the scoring of normal occlusal wear.

Credit: Buikstra, J. E., & Ubelaker, D. H. (1994). Standards for Data collection from human skeletal remains: proceedings of a seminar at the field museum of natural history. Arkansas Archeological Survey Research Series 44 (p. 52). Fayetteville: Arkansas Archeological Survey, with the permission of the Arkansas Archeological Survey.

wear observable within and across populations. In the analysis of aberrant wear, it is typically not the severity of wear but rather its morphology, orientation, and distribution—often at the level of individual tooth surfaces rather than whole tooth. The features that render LSAMAT distinct from normal occlusal wear for instance, the steep angle of wear across the lingual surface of the maxillary anterior teeth, would be scored as minimal wear in an occlusal wear system because it doesn't contribute directly to the vertical loss of crown height. Similarly, the many forms of aberrant wear that do not affect occlusal surfaces (e.g. interproximal grooves, inlays, etc.) are likely to be excluded entirely from standard scoring approaches.

Perhaps because of the inadequacy of current standard scoring approaches, there is a tendency among problem-oriented studies of aberrant wear to treat the phenomena as independent of other processes acting on the teeth. For instance, in Lukacs and Pastor's (1988) analysis of aberrant dental wear at the Harappa and Mehrgarh sites in Pakistan, interpretations of interproximal grooving and LSAMAT present in the populations—and even co-occur in at least one individual—are compartmentalized. Although dental wear may originate from multiple discrete etiologies, the phenomena ultimately cascade into complex inter-connected relationships that vary across the arch and between jaws. Interactions between wear etiologies are further complicated by the effects of non-wear processes. For example, pain related to oral pathology can lead an individual to favor one side of the mouth for mastication, leading to changes in normal occlusal wear that in turn alter other co-occurring wear processes. Thus, the analysis of aberrant wear cannot be undertaken without first parsing relationships among co-occurring etiologies and other non-wear processes (Kaidonis, Ranjitkar, Lekkas, Brook, & Townsend, 2014).

While complex oral interactions may complicate problem-oriented studies of tooth wear, the composite intermingling of wear types reflects the value of teeth as a site for holistic interpretations of embodiment (e.g., of subsistence and other cultural activity). In anthropology, theories of embodiment concern the tendency of social and environment phenomena to become imprinted on the body is various ways (Krieger, 2005). Within this framework, an individual's patterns of wear—the product of the myriad processes acting on the teeth and their complex interactions—can be understood as a coalescence of embodied social and environmental phenomena.

To address some of the problems outlined above, here we propose a model for the description and interpretation of aberrant dental wear that allows for the assessment of both proximate (e.g., attrition, abrasion, erosion, abfraction) and ultimate etiologies (i.e., behavioral vs. occlusal). Unlike current standard recording methods for dental wear, which are framed primarily in terms of wear severity at the level of whole teeth, the model developed here approaches wear in terms of its distribution and morphology at the level of individual tooth surfaces. Further, the model attempts to reckon with the etiological relationships that shape an individual's overall pattern of wear. The goal of this model is to apply a systematic approach to the analysis of aberrant wear, such that the varied cultural phenomena embodied in the teeth can be defined with greater clarity. Further, we argue that the holistic assessment facilitated by this model creates new opportunities to investigate the social dimensions aberrant wear, particularly as aberrant wear can be considered an embodiment of social phenomena and a proxy for communities of practice.

Recognizing interacting etiologies

Central to this our model of aberrant wear is a recognition of the tendency for multiple etiologies of wear to co-occur and interact in any given individual. This co-occurrence is easily demonstrated at the level of ultimate etiologies, as any given individual is likely to engage in several different behaviors beyond normal mastication that have the potential to destroy dental tissues. For instance, one can imagine an individual living today who would simultaneously exhibit abrasive wear caused by lip/tongue piercings (Plessas & Pepelassi, 2012), attritional wear caused by bruxism (Carvalho, Cury, & Garcia, 2007), and erosive wear caused by acidic foods (Kaidonis, 2008). Abrasion caused by a lip/tongue piercing might damage or otherwise alter the occlusal surface of one or more teeth, thereby altering the occlusal relationships between teeth during episodes of bruxism and affecting the subsequent patterns of wear. In addition, decay in dental tissues related to changes in pH could further destabilize tissue structures resulting in more damage and further alterations to wear patterns.

Co-occurring wear etiologies, and the interactions among them can be understood as occurring either directly or indirectly. Direct interactions refer to instances where multiple etiologies of wear act on a single tooth surface, such that the final pattern of wear on that surface is a product of all contributing etiologies. For instance, in an archeological context, the occlusal surface of a tooth might be worn simultaneously by an abrasive diet and using that tooth as a tool, such that the final pattern does not resemble what one might expect of either etiology in isolation.

Indirect interactions among wear etiologies comprise instances where wear caused by one etiology mitigates or otherwise alters the potential of another etiology to destroy the tissues of a tooth surface without itself affecting that surface. For instance, aberrant wear that reduces the surface area of an occlusal surface will indirectly mitigate future occlusal wear affecting the opposing tooth surface. It should be noted that multiple etiologies of wear do not have to act on the same tooth surface simultaneously for one form to directly affect the manifestation of the other. Rather, a pattern of wear resulting from one etiology can emerge in isolation only later to be altered or destroyed entirely by subsequent forces acting on the teeth. This sort of interaction is already acknowledged in the field of microwear analysis, where microscopic wear patterns are generally understood as a reflection of only the last few "days, hours, or even minutes" of wear depending on the rate of tissue destruction (Teaford & Oyen, 1989). The observation that microwear patterns typically reflect only the most recent source of wear points to one of the barriers to the analysis of relationships among wear etiologies. While the final pattern of wear ultimately observed in the archeological record may be a product of multiple contributing etiologies, the wear process itself can create ambiguity in the identification of each discrete etiology. That is, the wear process acting on the teeth closest to the time of death may obscure evidence of the other etiologies that contributed to that overall pattern.

Perhaps a greater challenge in the assessment of etiological interactions is simply the delineation of discrete forces acting on the teeth. While some wear etiologies

act on only a few teeth and result in highly visible, well-bounded wear (e.g., inlays, interproximal grooves), rendering them relatively easy to identify, other forms of aberrant wear documented in archeological contexts tend to be distributed across numerous teeth and contiguous with surfaces also typically affected by normal occlusal wear. In cases of bruxism, for instance, aberrant wear is limited to the occlusal surfaces of the teeth, and thus the pattern can be difficult to differentiate from normal occlusal wear in the absence of microwear analyses (Kaidonis, 1995; Xhonga, 1977). Identifying wear etiologies in these circumstances requires careful documentation at the level of individual tooth surfaces, where morphology and orientation (relative to the normal occlusal surface) can aid in the differentiation of contiguous wear etiologies. Identification of discrete etiologies can then be facilitated further by observations of patterns at the level of the total dentition, including incongruities between adjacent teeth in the arch, asymmetries in wear across the total dentition, or any other pattern spanning multiple teeth that indicates the presence of extramasticatory forces acting on the teeth.

Other intervening processes

Beyond the interactions among co-occurring etiologies of wear, is it also necessary to consider the impact that non-wear processes (e.g., oral pathology) can have on the manifestation of dental wear. As an example, Fig. 5.4 depicts an early farming individual from southern Arizona where dental trauma (i.e., a chipped tooth) led to changes in wear. By removing a substantial portion of the occlusal surface and surrounding enamel in 1st mandibular molar, dental trauma in this individual disrupted wear processes affecting the occlusal surface of the opposing dentition and the interproximal surface of the adjacent distal tooth. Beyond dental trauma, other oral pathology—particularly those that remove tooth surfaces from occlusion (e.g., large carious lesions, antemortem tooth loss, etc.)—are likely to intervene in wear processes indirectly, as considered in the case of a painful lesion causing an individual to favor one side of the mouth during mastication. If the painful tooth in question was lost, attributing the resulting asymmetrical wear to oral pathology could only be inferred.

It should be noted that while the interactions above are described in a way the might suggest dyadic relationships between wear etiologies or between wear and non-wear processes, any such interactions can lead to complex, cascading effects on the manifestation of the overall pattern of dental wear. While some direct interactions can be relatively easy to identify (e.g., the co-occurrence of multiple kinds of wear on single teeth, the removal of occlusal surface through dental trauma, etc.), these secondary or tertiary interactions may be virtually impossible to define with any certainty. As such, the priority in the documentation of aberrant wear must be a comprehensive recording of wear characteristics present on each tooth surface. In the absence of a means to parse these more complex interactions, a full accounting of the wear acting on each surface will at minimum allow for systematic comparison among individuals/populations and potentially facilitate the development of more refined methods in the future.

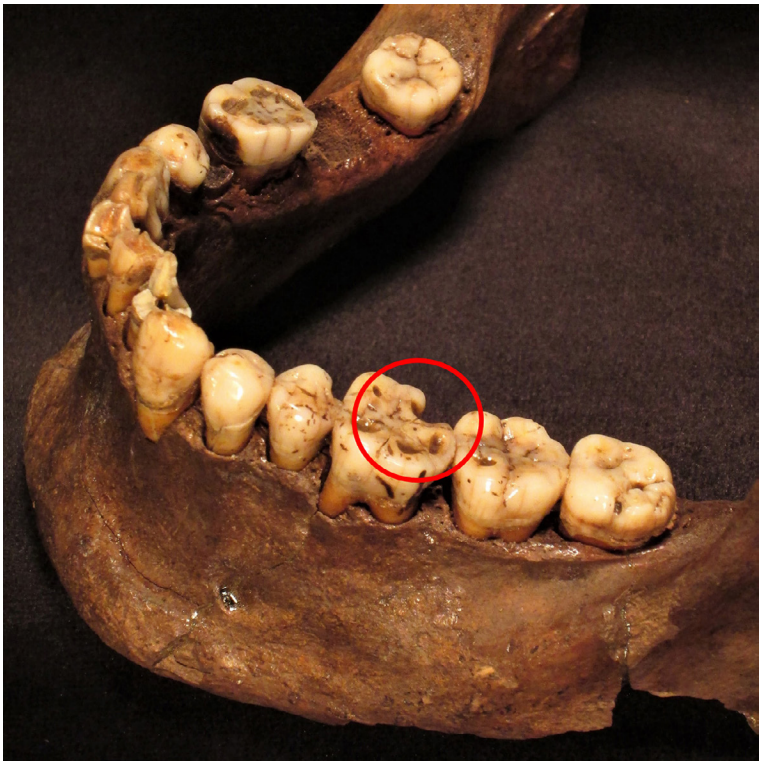

FIG. 5.4

Individual from the Los Ojitos site in southern Arizona where dental trauma (chipped tooth, *circled*) likely intervened in the manifestation of wear.

Credit: Adam Crane.

A new model of aberrant wear

As a means of parsing out these complex interactions and to address the inadequacies of current standard scoring approaches, here we propose a model for the documentation and interpretation of aberrant tooth wear that integrates wear observed at the level of individual tooth surfaces with the overall pattern of wear that emerges at the level of the total dentition. Rather than attempting to apply standard, quantitative criteria to aberrant wear—as in many ordinal scoring systems—this model constitutes a relatively open-ended framework of observations. This is due in part to the lack of established criteria for the identification of aberrant wear, but it is also a reflection of the degree of variation among the types of aberrant wear that have been documented in the archeological record, which together defy a singular system of quantification. That is, the model represents an attempt to bring together and systematize the myriad lines of evidence that can contribute to the identification/interpretation of aberrant wear in its many forms.

The model divides the analysis of aberrant wear into four stages, representing a general progression from the description of wear to the interpretation of etiology (Fig. 5.5). It begins with documentation of the form of wear at the level of individual tooth surfaces and the distribution of wear at the level of the total dentition. Observations of wear form include documentation of the gross morphology of wear facets, micropatterns, the angle of wear facets relative to the occlusal plane, and articulations with wear facets on opposing/adjacent teeth. Where relevant wear facets are contiguous with the occlusal surface, an appropriate ordinal scoring system (e.g., Murphy, 1959; Scott, 1979; Smith, 1984, etc.) should also be applied. While such systems are not especially useful for the interpretation of aberrant wear itself, the availability of these data creates opportunities for comparison within and across populations.

Observations of wear distribution are recorded in terms of permanent/deciduous dentition, tooth class, and tooth surface. Using these observations of wear form and distribution, it should then be possible to classify wear by the proximate etiologies acting on each tooth surface, differentiating among attrition (tooth-tooth interaction), abrasion (tooth-object interaction), erosion (chemical destruction of dental tissue), and abfraction (indirect destruction of dental tissue by mechanical loading). Detailed descriptions of each of these different proximate etiologies are available in the literature, though in some cases they may only be differentiated with confidence through microwear analyses (see Burnett, 2016; Kaidonis, 2008).

Given the potential for co-occurring etiologies of wear, any potential relationships between the proximate etiology resulting in aberrant wear and other forces acting on the dentition are recorded with an emphasis on interactions with wear on adjacent teeth in the arch and with wear on opposing occlusal surfaces. Additionally, as non-wear processes can intervene in the manifestation of wear, the presence of oral pathology, dental trauma, and observations of the broader masticatory apparatus (e.g., TMJ morphology/pathology) are also recorded (Kaidonis, 2008; Kaidonis et al., 2014).

After describing the form/distribution of wear, identifying proximate etiologies, and describing potential etiological relationships the model concludes with the interpretation of the ultimate etiologies underlying aberrant wear. Etiologies are broadly classified as either behavioral or occlusal, differentiating between wear resulting from alterations to the normal forces of mastication (e.g., the inclusion of grit in the diet, the consumption of acidic foods, etc.) and wear resulting from activities unrelated to mastication (e.g., the use of teeth as tools). It is critical at this stage to acknowledge that while broad classes of behavior can be identified from observations of wear alone (e.g., aesthetic/cultural modification, the insertion of abrasive objects into the interproximal spaces, etc.), the interpretation of aberrant wear as a product of particular cultural activities is highly contingent on the correlation of the skeletal data with observation of analogous wear of known cause in the ethnographic/historical records or behavioral correlates in the archeological record (Molnar, 2011). While the literature concerning aberrant wear is rife with such speculation, to assign a specific behavior as the cause of wear in the absence of supporting ethnographic/historical/archeological data would be an overstatement of the evidence.

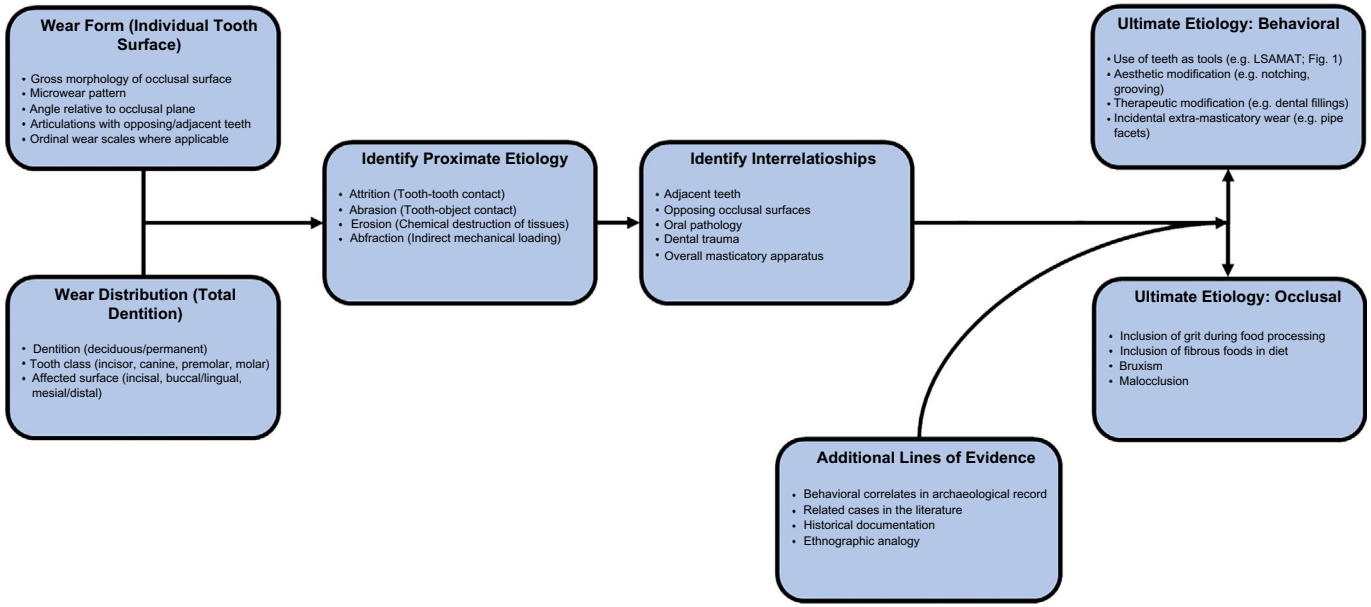

FIG. 5.5

Model for the identification and interpretation of aberrant dental wear.

As discussed above, the open-ended nature of this model is strategic—reflecting a recognition of the variability of aberrant wear in the archeological record—but it also a product of necessity. Until enough empirical analyses of aberrant wear can demonstrate predictable, generalizable relationships from which statistical models can be developed, the analysis of aberrant wear can only be systematic insofar as the sorts of data collected are standardized and the logic underlying their interpretation are consistent among researchers. That said, at the time of writing this chapter we have begun to explore the viability of network analyses as a means of assessing aberrant wear. Early applications of Multilayer Perceptron (MLP), a neural networks analysis that produces a predictive model for one or more dependent (target) variables based on the values of the predictor variables, have shown promise for the identification of variables that best predict wear across the sample (Crane, Watson, & Haas, 2018).

Standard ordinal recording methods for the documentation of attritional wear fail to capture the wide variety of aberrant wear observed in the archeological record (Stojanowki et al., 2016). On the other hand, the subsequent unsystematic treatment of aberrant wear in the literature fails to facilitate comparison within and between populations (Molnar, 2011). In both cases, little attention is paid to the complex etiological interactions that produce observed patterns of aberrant wear. Through the model developed here, we attempt to address these deficiencies. By beginning with comprehensive data collected from the whole dentition as a foundation for interpretation, the model allows for aberrant wear to be integrated into broader studies of attritional dental wear in a systematic way, thereby facilitating comparative study.

By recognizing aberrant wear as a product of the total forces acting on the teeth, the model actively confronts the interactions between etiologies such that the cultural activities underlying aberrant wear might be interpreted with greater clarity. The model is thus particularly valuable for the interpretation of aberrant wear manifesting on or adjacent to occlusal surfaces, as the etiologies underlying such wear are likely to interact with normal occlusal wear. Conversely, by situating aberrant wear in the context of the total masticatory apparatus, the model allows for more consistent interpretation of the effects of aberrant wear on the morphology and health of the dentition as a whole. Further, the holistic assessment facilitated by this model—that is, its consideration of the total forces acting of the teeth and their interactions-creates new opportunities to investigate the social dimensions of aberrant wear, both as embodiment of social phenomena and as a proxy for communities of practice.

Social dimensions of aberrant wear

The aim of the model outlined above is in part to direct researchers toward a more holistic treatment of aberrant wear. That is, it is an attempt to recognize that the phenomena cannot be studied as if they were isolated from other processes acting on the dentition. Rather, patterns of aberrant wear must be recognized as emerging in the context of numerous direct and indirect forces acting on the teeth and interpreted as such. This recognition of aberrant wear as a product of complex interactions among

co-occurring etiologies other intervening forces further positions the field as an ideal site for the application of theories of embodiment, through which the social dimensions of aberrant wear can be explored. Below, the viability of embodiment as an interpretive framework for the study of aberrant wear is explored. Further, by interpreting aberrant wear as an embodiment of social phenomena (i.e., of subsistence activities, of cultural norms and aesthetics, of medical interventions, etc.) we argue that patterns of aberrant wear observed at the population level might serve as a proxy for communities of practice heretofore only examined in terms of material culture.

Aberrant wear as embodied social phenomena

As defined by Krieger (2005, p. 352), the concept of embodiment "[refers] to how we literally incorporate, biologically, the material and social world in which we live, from in utero to death; a corollary is that no aspect of our biology can be understood in the absence of knowledge of history and individual and societal ways of living". Within this framework, observations of the body are taken to represent direct manifestations of the physical or cultural environment. For instance, Gravlee (2009) draws on embodiment theory to demonstrate how health disparities among racially-defined groups in the United States—attributed to social isolation, economic disadvantage, and systemic violence—constitute an embodiment of Western racial ideology. While the framework has typically been the purview of medical anthropologists, embodiment is among the theoretical domains to receive greater attention from bioarchaeologists in recent years (e.g., Torres-Rouff, 2018).

Given the tendency for information related to subsistence, health, and cultural activities to become embedded in the teeth through calculus, pathology, and wear, the teeth are particularly well-suited for the application of embodiment as an interpretive approach (Stojanowki et al., 2016). These relationships are already widely recognized by bioarchaeologists, as evident in the long history of research drawing on dental wear as evidence for the reconstruction of subsistence patterns. For instance, Sciulli (1997) draws on observations of dental wear and oral pathology to define three "dental cultural ecological environments," such that high levels of wear with low frequencies of oral pathology correspond to foraging subsistence patterns, low levels of wear with low frequencies of oral pathology correspond to foraging subsistence where ceramic technologies have been developed, and low levels of wear with high frequencies of oral pathology correspond to agricultural subsistence. These observations can easily be reframed through an embodiment framework, with the different patterns of wear and oral pathology understood as embodiments of the underlying subsistence systems. To the extent that the approach employed by many bioarchaeologists in the study of aberrant wear frames the phenomena as evidence of underlying behaviors, such research can likewise be interpreted as an application of embodiment theory, if not explicitly recognized as such in the literature.

We cannot claim to be the first to apply an explicitly embodiment-based framework to the interpretation of aberrant dental wear, however. Geller's (2006) assessment of intentional body modification among the pre-Columbian Maya, the

aesthetic modification of teeth (via notching, grooving, inlays, etc.) is framed as an embodiment of social identity. Given the tendency toward embodiment-like observations in much of the literature concerning aberrant wear, here we propose that researchers in the field would benefit by following suit after Geller and adopting an explicitly embodiment-based framework for the interpretation of aberrant wear. Furthermore, the model outlined above facilitates precisely such a framework by acknowledging the myriad social and environmental phenomena that can coalesce in the dentition of a single individual. In other words, the subsistence pattern, environmental conditions, health, and cultural activities experienced by an individual can be understood as coming to be embodied in an that individual's dentition as the overall pattern of wear observed. This application of embodiment theory to aberrant dental wear—specifically the recognition that cultural practices can become embodied in the teeth as recognizable patterns of wear—is central to the use of aberrant wear as a proxy for communities of practice explored below.

Identifying communities of practice through aberrant wear

In anthropology, practice theory can be defined generally as a framework for understanding the intersection of individual agency and broader social structure (Bourdieu, 1977; Ortner, 2006). In brief, the theory concerns how the decisions and practices of individuals constitute broader society while simultaneously being defined and limited in scope by the structure of that society (i.e., Bourdieu's concept of the *habitus*). While this framework encompasses a broad range of research in anthropology, one of the main applications of the theory of practice in archeological contexts has concerned the identification and interpretation of communities of practice. This concept was first defined by Lave and Wenger (1991) as a social network constituted by shared participation and knowledge-transfer in an activity. In other words, the concept reflects the assumption that shared participation in any given activity requires a shared understanding of that activity, such that some degree of social interaction in the form of knowledge-transfer can be inferred (Wendrich, 2012a, 2012b). While the form of social interaction required for this knowledge-transfer may be direct (e.g., apprenticeships) or indirect (e.g., traditions passed down over multiple generations), the existence of a community of practice nonetheless reflects a continuity of knowledge among multiple individuals.

The concept is particularly well-suited to archeological research given the wide variety of productive practices that would have been necessary to create the material culture observed in the archeological record. For instance, Sassaman and Rudolphi (2001) use communities of practice as a framework to parse out variation among stylistically similar ceramic traditions in Late Archaic period contexts across three settlement clusters in the southeastern United States. They note that while ceramic decoration and cooking techniques were more-or-less consistent across the three clusters, production techniques used to create the pottery were unique in each location. The authors argue that potters in this context participated in two distinct communities of practice: the first representing a cognatic community, in which

knowledge of ceramic production techniques was transferred generationally from mother to daughter and thus rendered regionally specific due to the populations' matrilocal organization, and the second representing an affinal community, in which the exchange of knowledge and symbols among related communities (i.e., through intermarriage) led to a pan-regional suite of decorative traits and cooking techniques. While the identification of discrete patterns in ceramic techniques is by no means a novel approach in archeology, the interpretation of such patterns through the communities of practice framework allows for production techniques to be situated within the broader social organization of the archeological population.

Archeological studies of communities of practice that rely on material culture such as this have been extremely effective at identifying contexts where communities of practice existed in the past; however, where such studies fall short is in relating the material culture representing a community of practice to the people that constitute that community. For instance, Minar (2001) detected subtle differences among textile production techniques in the southeastern United States through an analysis of subtle differences in the twisting of cordage, and through reference to literature concerning handedness and the material properties of the fibers used in the textiles she makes a convincing argument that these differences constitute distinct cultural traditions (i.e., communities of practice). Yet simply identifying that distinct communities of practice existed in this archeological context leaves some questions unanswered. Within the archeological population, who were the individuals that participated in each tradition? Perhaps more pressing, are the people who participated in a community of practice for textile production the same people who used those textiles and ultimately deposited them in the archeological record? That these questions remain unaddressed in Minar's discussion of communities of practice demonstrates a broader problem in artifact-centered approaches to the concept. That is, studies that define communities of practice solely in terms of the material products of those communities necessarily divorce material culture from the individuals that produced it.

As the studies described above illustrate, such an approach can delineate communities of practice with impressive resolution, but they require us to assume a relationship between the material culture representing a community of practice and the archeological context where that material culture is excavated. Given the wide body of literature demonstrating the existence of extensive exchange networks in prehistory (e.g., Earle & Ericson, 1977), the assumption that an artifact was produced by the same population that ultimately deposited it in the archeological record cannot stand without justification. It is here that we propose aberrant wear to be an effective supplement to material culture in the study of communities of practice.

As discussed above, aberrant wear can be interpreted through embodiment theory as a manifestation of the forces in the physical and cultural environment that produce it. Among the wide variety of aberrant wear forms published in the literature, a considerable proportion of cases have been interpreted as the direct result of cultural practices that destroy dental tissues, including incidental wear (e.g., pipe

facets; Walker & Henderson, 2010), wear secondary to productive activities (e.g., the use of teeth as tools; Lukacs & Pastor, 1988), and intentional dental modification (e.g., filing, grooving, etc. González et al., 2010). Here we propose that—just as distinct patterns identified in the production of material culture can be related to communities of practice in archeological assemblages—distinct patterns of aberrant wear might likewise be interpreted as an embodiment of behaviors constitutive of communities of practice in skeletal populations.

Returning once more to the example of LSAMAT, Watson and Haas (2017) recognize the pattern of wear as a manifestation of tuber processing among early foragers in highland Peru, and this observation contributes primarily to the authors' interpretation of subsistence in the population. Here, we would take this interpretation further and argue that the consistent pattern of wear identified in the population is evidence not just for diet composition (i.e., the consumption of tubers), but also evidence of a tradition of subsistence *practice*. That is, a community of practice in which knowledge related to tuber processing was shared among its constitutive members. Much like continuity in ceramic form implies shared production techniques in the context described by Sassaman and Rudolphi (2001), the similarity of aberrant wear among individuals in Watson and Haas' (2017) case suggests continuity in practices related to the processing of tubers for consumption. Unlike the material culture studies described above, however, deriving this interpretation from the dentition does not require assumptions about the relation of the practice to the archeological context. That is, rather than basing the interpretation on analyses of the ultimate products of a practice, which will inevitably possess complex use-histories that may divorce an object from the community that produced it, the use of aberrant wear as a proxy for communities of practice locates practice in the bodies of the community itself as an embodied phenomenon.

In addition to the direct link aberrant wear provides between practices and practitioners, patterns of aberrant wear also allow some parameters of a community of practice to be defined that would otherwise be inaccessible—or at least only indirectly accessible—through the analysis of material culture. Whereas communities of practice as identified through material culture are generally nebulous—that is, the identities of their constituting members are more-or-less indeterminate except to the extent that they can be inferred from ethnographic analogy (e.g., the inference that ceramics were typically produced by women as observable in descendent groups in the Southwest US; Sassaman & Rudolphi, 2001). In contrast, the identification of communities of practice through aberrant dental wear is accompanied by the full suite of identifying data accessible through skeletal analysis. In the LSAMAT example described by Watson and Haas (2017) for instance, the set of individuals exhibiting the pattern of wear consistent with tuber processing can be defined unambiguously in terms of age and sex (Table 5.2). To these features we might add further observations of health, diet, and social status to the extent that these are illuminated by skeletal data and the burial context of the body. We can imagine further opportunities still through archaeogenetic analyses, which could potentially shed light on the consanguineous pathways of knowledge transfer.

Table 5.2 Age and sex distribution of individuals exhibiting LSAMAT in early foraging population of Titicaca Basin, Peru.

Burial no.	Sex	Age	Maxilla		Mandible		Caries	Pathology AMTL	Mean occlusal wear score (Smith, 1984)	LSAMAT
			Anterior	posterior	Anterior	posterior				
3	Female	18–20	4	8	5	10	0	0	2.5	No
4	?	12–15	6	8	6	7	0	0	1.9	Yes
5	Male	40–50	0	2	1	3	0	3	7.4	Unobs.
6	Female	40–50	6	8	4	8	0	6	6.8	Unobs.
7	Female	18–20	6	10	6	10	0	0	2.8	Yes
8	Female	30–40	0	3	5	6	0	1	5.3	Unobs.
9	Male	20–25	4	10	6	9	0	0	4.2	Yes
10	Female	20–25	6	10	6	10	0	0	3.2	No
11	Female	25–35	0	7	4	9	0	0	5.0	No
12	Male	35–45	1	8	1	8	0	0	5.8	Unobs.
16	Male	35–45	0	2	5	7	1	2	6.8	No

Credit: Reproduced after 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), 120.

Although this discussion might imply that the use of aberrant wear as a proxy for communities of practice would entail a relatively straightforward interpretation (i.e., practice leads to aberrant wear➔ practice becomes embodied in the teeth➔ wear pattern at the population level delineate the community of practice), the approach is not without problems. Among them are the same issues discussed previously that hinder the study of aberrant wear more generally. As the overall pattern of wear in any given individual is potentially a product of multiple wear and non-wear processes that interact in complex ways, the pattern of aberrant wear ultimately observed in the archeological record may vary among individuals in a population despite resulting from shared practice. Given that the identification of communities of practice is contingent on the identification of continuity in practice, this variation poses a problem for the use of aberrant wear as proxy to the extent that it obscures that continuity. Researchers could attempt to circumvent this problem by analyzing aberrant wear systematically—as through a model like the one we outline above—such that etiological relationships can be parsed, and shared etiologies can be identified despite individual variability.

A second problem facing the use of aberrant wear for the interpretation of communities of practice is the absence of the products of those practices in the analysis. Whereas the material culture approaches to communities of practice described above are one degree removed from the people who constitute the community, in that they focus on the products of practices to the exclusion of the people performing them, the aberrant wear approach we are advocating here is one degree removed from the practices themselves. While the analysis of aberrant wear can identify and describe the forces that cause the phenomenon (e.g., mechanical vs. chemical forces, tooth-tooth contact vs. tooth-object contact, etc.), and thus identify shared cause among individuals through population-level patterns of wear, it is often not possible identify specific activities as the cause of aberrant wear without additional lines of evidence (Molnar, 2011). In Watson and Haas' (2017) case, this was achieved through reference to ethnographic contexts with similar patterns of wear (i.e., Berbesque et al., 2012); however, additional lines evidence like this are not likely to be as accessible or unambiguous in all cases. That said, this is a problem that the study of aberrant wear shares with studies that attempt to identify communities of practice via material culture.

The material culture studies above likewise rely on data from living/historic peoples to interpret the significance of production techniques. For instance, Sassaman and Rudolphi's (2001) assessment of communities of ceramic production in the Southwest US relies both on ethnographic/ethnohistoric data to interpret the gendered dimensions of ceramic production in archeological contexts. Likewise, Minar's (2001) analysis of textile production in the Southeast US is run-through with comparison to ethnographic contexts. Given the shortcomings of both material culture-based and aberrant wear-based approaches to the interpretation of communities of practice, here we propose that in ideal cases—however rare they might be—the two lines of evidence should be wedded, such that analysis of material culture informs interpretations of practice while the dentition informs interpretations of the practitioners.

Conclusions

In the first half of this chapter, we attempted to address some of the methodological problems hindering the study of aberrant dental wear. As direct evidence of cultural activities otherwise unobservable in human skeletal remains, aberrant wear represents a particularly valuable source of data for the interpretation of past behavior. Yet the lack of standard scoring methods that adequately capture the wide variety of aberrant wear observed in the archeological record has kept researchers from documenting the phenomena systematically. Moreover, the tendency of researchers to treat the phenomena as isolated from other processes acting on the dentition overlooks the complex interactions that inevitably contribute to the final pattern of wear observed in the archeological record. To correct these problems, the model outlined here represents a holistic documentation of wear characteristics, with observations ranging from individual tooth surfaces to the level of the total dentition. By situating wear observed at the level of individual tooth surfaces in the context of the total dentition, the model allows for the proximate and ultimate etiologies underlying aberrant wear to be parsed from co-occurring forms with greater clarity. While at this stage the model is necessarily open-ended relative to standards used for the documentation of normal occlusal wear, we believe it will facilitate the sort of intra- and inter-population comparison necessary to develop more refined empirical models.

Whereas the first half of this chapter reckons with the problems of past and current research concerning aberrant wear, the second half is an attempt to explore future theoretical opportunities for the field. If aberrant wear is understood as a direct manifestation of the behaviors that cause it, then it is only a short step to reframe the study of the phenomena in terms of theories of embodiment. While this framework fits well with the model advanced earlier in the chapter—to the extent that it benefits from an understanding of wear patterns as a coalescence of multiple social and environmental factors—it also facilitates the adoption of aberrant wear as a proxy for communities of practice. That is, if aberrant wear is framed as an embodiment of the underlying practices, then a shared pattern of aberrant wear at the population level can be understood as evidence of a community of practice, thereby allowing for inferences concerning the social interactions and knowledge transfer necessary to maintain such a community. The example cases presented throughout this chapter are at most proofs of concept for the proposed model and theoretical applications, and the approach advanced here remains to be tested on novel cases. At a minimum, the study of aberrant wear in archeological contexts will surely benefit from a greater focus on systematic documentation.

References

Berbesque, J. C., Marlowe, F. W., Pawn, I., Thomson, P., Johnson, G., & Mabulla, A. (2012). Sex differences in Hadza dental wear patterns. *Human Nature*, *23*, 270–282.

Bertrand, B., Colard, T., Lacoche, C., Salomé, J. F., & Vatteoni, S. (2009). An original case of tin dental fillings from 18th century northern France. *Journal of Dental Research*, *88*(3), 198–200.

Bourdieu, P. (1977). *Outline of a theory of practice*. Cambridge: Cambridge University Press.

Brown, T., & Molnar, S. (1990). Interproximal grooving and task activity in Australia. *American Journal of Physical Anthropology*, *81*, 545–553.

Buikstra, J. E., & Ubelaker, D. H. (1994). Standards for data collection from human skeletal remains: Proceedings of a seminar at the field museum of natural history. *Arkansas Archeological Survey research series 44*. Fayetteville: Arkansas Archeological Survey.

Burnett, S. E. (2016). Crown wear: identification and categorization. In J. D. Irish & G. R. Scott (Eds.), *A companion to dental anthropology* (pp. 415–432). West Sussex: Wiley Blackwell.

Burnett, S. E., & Irish, J. D. (2016). *A world view of bioculturally modified teeth*. Gainesville: University Press of Florida.

Carvalho, A. L., Cury, A. A., & Garcia, R.C.M.R. (2007). Prevalence of bruxism and emotional stress and the association between them in Brazilian police officers. *Brazilian Oral Research*, *22*(1), 31–35.

Cook, D. C. (1981). Koniag Eskimo tooth ablation: was Hrdlička right after all? *Current Anthropology*, *22*(2), 159–163.

Crane, A. T., Watson, J. T., & Haas, R. (2018). *The interplay of behavioral and occlusal etiologies in aberrant tooth wear*. In *Poster presented at the annual meeting of the American Association of Physical Anthropologists, Austin, TX*.

Earle, T. K., & Ericson, J. E. (1977). *Exchange systems in prehistory*. New York: Academic Press.

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*, 145–159.

Fastlicht, S. (1962). Dental inlays and fillings among the Ancient Mayas. *Journal of the History of Medicine and Allied Sciences*, *17*(3), 393–401.

Formicola, V. (1988). Interproximal grooving of teeth: additional evidence and interpretation. *Current Anthropology*, *29*(4), 663–671.

Geller, P. L. (2006). Altering identities: body modifications and the pre-Columbian Maya. In R. Gowland & C. Knüsel (Eds.), *The social archaeology of funerary remains* (pp. 279–291). Oxford: Oxbow Books.

González, E., Perea Pérez, B., Sánchez Sánchez, J. A., & Mar Robledo Acinas, M. (2010). Dental aesthetics as an expression of culture and ritual. *British Dental Journal*, *208*(2), 70–80.

Gravlee, C. C. (2009). How race becomes biology: embodiment of social inequality. *American Journal of Physical Anthropology*, *139*, 47–57.

Helm, S., & Prydsö, W. (1979). Prevalence of malocclusion in medieval and modern Danes contrasted. *European Journal of Oral Sciences*, *87*(2), 91–97.

Hinton, R. J. (1981). Form and patterning of anterior tooth wear among aboriginal human groups. *American Journal of Physical Anthropology*, *54*, 555–564.

Hrdlička, A. (1940). Ritual ablation of front teeth in Siberia and America. In *Smithsonian miscellaneous collection, 99(3)*. Baltimore: The Lord Baltimore Press.

Irish, J. D., & Scott, G. R. (2016). Introduction to dental anthropology. In J. D. Irish & G. R. Scott (Eds.), *A companion to dental anthropology* (pp. 3–6). West Sussex: Wiley Blackwell.

Irish, J. D., & Turner, C. G. (1987). More lingual surface attrition of the maxillary anterior teeth in American Indians: prehistoric Panamanians. *American Journal of Physical Anthropology*, *73*, 209–213.

Irish, J. D., & Turner, C. G. (1997). Brief communication: first evidence of LSAMAT in non-native Americans: historic senegalese from West Africa. *American Journal of Physical Anthropology*, *102*, 141–146.

Kaidonis, J. A. (1995). *An experimental study of the wear characteristics of human enamel during tooth grinding* [Ph.D. dissertation]. The University of Adelaide.

Kaidonis, J. A. (2008). Tooth wear: the view of the anthropologist. *Clinical Oral Investigations*, *12*, S21–S26. Suppl. 1.

Kaidonis, J. A., Ranjitkar, S., Lekkas, D., Brook, A. H., & Townsend, G. C. (2014). Functional dental occlusion: an anthropological perspective and implications for practice. *Australian Dental Journal*, *59*(1), 1–12.

Kangxin, H., & Nakahashi, T. (1996). A comparative study of ritual tooth ablation in Ancient China and Japan. *Anthropological Science*, *104*(1), 43–64.

Kieser, J. A., Dennison, K. J., Kaidonis, J. A., Huang, D., Herbison, P. G. P., & Tayles, N. G. (2001). Patterns of dental wear in the early maori dentition. *International Journal of Osteoarchaeology*, *11*, 206–217.

Krieger, N. (2005). Embodiment: a conceptual glossary for epidemiology. *Journal of Epidemiology and Community Health*, *59*, 350–355.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Linné, S. (1940). Dental decoration in aboriginal America. *Ethnos*, *5*, 2–28.

Linné, S. (1948). Dental decoration in ancient Mexico. *Ethnos*, *13*, 190–193.

Lovejoy, C. O. (1985). Dental wear in the Libben population: its functional pattern and role in the determination of adult skeletal age at death. *American Journal of Physical Anthropology*, *68*, 47–56.

Lukacs, J. R., & Pastor, R. F. (1988). Activity-induced patterns of dental abrasion in prehistoric Pakistan: evidence from Mehrgarh and Harappa. *American Journal of Physical Anthropology*, *76*, 377–398.

Milner, G. R., & Larsen, C. S. (1991). Teeth as artifacts of human behavior: intentional mutilation and accidental modification. In M. A. Kelley & C. S. Larsen (Eds.), *Advances in dental anthropology* (pp. 357–378). New York: Wiley-Liss.

Minar, C. J. (2001). Motor skills and the learning process: the conservation of cordage final twist direction in communities of practice. *Journal of Anthropological Research*, *57*(4), 381–405.

Molnar, P. (2011). Extramasticatory dental wear reflecting habitual behavior and health in past population. *Clinical Oral Investigations*, *15*, 681–689.

Murphy, T. R. (1959). Gradients of dentine exposure in human tooth attrition. *American Journal of Physical Anthropology*, *17*, 179–185.

Nugent, S. E. (2013). *Death on the imperial frontier: An osteobiography of Roman burial from Oğlanqala, Azerbaijan* [MA thesis]. Ohio State University.

Ortner, S. B. (2006). *Anthropology and social theory: Culture, power, and the acting subject*. Durham: Duke University Press.

Pfieffer, S., Dudar, J. C., & Austin, S. (1989). Prospect hill: skeletal remains from a 19th-century methodist cemetery, Newmarket, Ontario. *Northeast Historical Archaeology*, *18*, 29–48.

Pietrusewky, M., & Douglas, M. T. (1993). Tooth ablation in old Hawai'i. *The Journal of Polynesian Society*, *102*(3), 255–272.

Plessas, A., & Pepelassi, E. (2012). Dental and periodontal complications of lip and tongue piercing: prevalence and influencing factors. *Australian Dental Journal*, *57*, 71–78.

Robb, N. D., Cruwys, E., & Smith, B. G. N. (1991). Is "lingual surface attrition of the maxillary teeth (LSAMAT)" caused by dental erosion? *American Journal of Physical Anthropology*, *85*, 345–351.

Rose, J. C., & Roblee, R. D. (2009). Origins of dental crowding and malocclusions: an anthropological perspective. *Compendium of Continuing Education in Dentistry*, *30*(5), 292–300.

Sassaman, K. E., & Rudolphi, W. (2001). Communities of practice in the early pottery traditions of the American Southeast. *Journal of Anthropological Research*, *57*(4), 407–425.

Sciulli, P. W. (1997). Dental evolution in prehistoric Native Americans of the Ohio Valley Area. I. Wear and pathology. *International Journal of Osteoarchaeology*, *7*(5), 507–524.

Scott, E. C. (1979). Dental wear scoring technique. *American Journal of Physical Anthropology*, *51*, 213–218.
Smith, B. H. (1984). Patterns of molar wear in hunter-gatherers and agriculturalists. *American Journal of Physical Anthropology*, *63*, 39–56.
Stojanowki, C. M., Johnson, K. M., Paul, K. S., & Carver, C. L. (2016). Indicators of idiosyncratic behavior in the dentition. In J. D. Irish & G. R. Scott (Eds.), *A companion to dental anthropology* (pp. 377–395). West Sussex: Wiley Blackwell.
Teaford, M. F., & Oyen, O. J. (1989). In vivo and in vitro turnover in dental microwear. *American Journal of Physical Anthropology*, *80*(4), 447–460.
Torres-Rouff, C. (2018). *Embodying intimacy: cranial vault modification as child rearing practice*. In Podium presentation given at the annual meeting of the American Association of Physical Anthropologists, Austin, TX.
Turner, C. G., Irish, J. D., & Machado, L. M. C. (1991). Reply to Robb, Cruwys, and Smith, with additional remarks on LSAMAT. *American Journal of Physical Anthropology*, *85*(3), 348–351.
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*, 125–130.
Ubelaker, D. H., Phenice, W., & Bass, W. M. (1969). Artificial interproximal grooving of the teeth in American Indians. *American Journal of Physical Anthropology*, *30*, 145–150.
Ungar, P. S., Grine, F. E., Teaford, M. F., & Pérez-Pérez, A. (2001). A review of interproximal wear grooves on fossil hominin teeth with new evidence from Olduvai Gorge. *Archives of Oral Biology*, *46*, 285–292.
Varrela, J. (1990). Occurrence of malocclusion in attritive environment: a study of a skull sample from southwest Finland. *European Journal of Oral Sciences*, *98*(3), 242–247.
Walker, D., & Henderson, M. (2010). Smoking and health in London's East End in the first half of the 19th century. *Post-Medieval Archaeology*, *44*(1), 209–222.
Wallace, J. A., Barrett, M. J., Brown, T., Loring Brace, C., Howells, W. W., Kortizer, R. T., et al. (1975). Did La Ferrassie I use his teeth as a tool? [and comments and reply]. *Current Anthropology*, *16*(3), 393–401.
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.
Wendrich, W. (2012a). Archaeology and apprenticeship: body knowledge, identity, and communities of practice. In W. Wendrich (Ed.), *Archaeology and apprenticeship: Body knowledge, identity, and communities of practice* (pp. 1–19). Tucson: University of Arizona Press.
Wendrich, W. (2012b). Recognizing knowledge transfer in the archaeological record. In W. Wendrich (Ed.), *Archaeology and apprenticeship: Body knowledge, identity, and communities of practice* (pp. 255–262). Tucson: University of Arizona Press.
Williams, J. S., & White, C. D. (2006). Dental modification in the postclassic population from Lamanai, Belize. *Ancient Mesoamerica*, *17*, 139–151.
Wols, H. D., & Baker, J. E. (2004). Dental health of elderly confederate veterans: evidence from the Texas State Cemetery. *American Journal of Physical Anthropology*, *124*, 59–72.
Xhonga, F. (1977). Bruxism and its effects on teeth. *Journal of Oral Rehabilitation*, *4*, 65–76.

Further reading

Tayles, N. (1996). Tooth ablation in prehistoric southeast Asia. *International Journal of Osteoarchaeology*, *6*, 333–345.