Revista Argentina de Antropología Biológica

DOSSIER-REVIEW ARTICLE

DOSSIER: "ANTHROPOLOGY MEETS DENTISTRY IN CENTRAL AMERICA: RESEARCH AND EDUCATION IN ORAL BIOLOGY"

Occlusal wear in humans: Anthropological perspective

El desgaste oclusal en humanos: la perspectiva antropológica

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Abstract

Occlusal wear has been present in humans since the beginning of our evolutionary journey. Even considering its intrinsic limitations, its study is central to estimating age at death, making inferences on diet, on the way food was prepared, and on cultural non-masticatory use of teeth. Its study allows us to understand how occlusal wear has responded to the evolutionary changes that characterized human beings from the onset of agriculture up to the more recent Industrial Revolution. This brief review paper focuses on the study of occlusal wear from an anthropological and bioarchaeological perspective. It discusses its importance for understanding past societies, its advantages, and its limitations in anthropological studies of skeletonized individuals, and how different fields of study in odontology, dental anthropology/bioarchaeology focus on occlusal wear from very distinctive and rarely overlapping perspectives, but that can significantly benefit from one another in a multidisciplinary approach. Rev Arg Antrop Biol 26(2), 080, 2024. https://doi.org/10.24215/18536387e080

Keywords: dental wear; bioarchaeology; diet; helicoidal plane; masticatory and extra-masticatory use

Resumen

El desgaste oclusal ha sido parte del camino evolutivo del ser humano desde que apareció el género *Homo*. Desde una perspectiva antropológica, y pese a las limitaciones objetivas que conlleva el estudio del desgaste dental, su análisis es de suma importancia para la estimación de la edad de muerte, para hacer inferencias sobre la dieta, sobre el modo en que los alimentos eran preparados y procesados, y sobre

REVISTA ARGENTINA DE ANTROPOLOGÍA BIOLÓGICA

Volumen 26, Número 2, Artículo 080
Julio -Diciembre 2024

Editado y aceptado por el editor asociado Kornelius Kupczik, Departamento de Antropología, Facultad de Ciencias Sociales, Universidad de Chile, Chile.

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RECIBIDO: 16 de Julio de 2023

ACEPTADO: 1 de Marzo de 2024

PUBLICADO: 13 de Septiembre de 2024

https://doi.org/10.24215/18536387e080

Financiamiento: No se contó con financiamiento en este trabajo.

e-ISSN 1853-6387

https://revistas.unlp.edu.ar/raab

Entidad Editora
Asociación de Antropología Biológica Argentina

el uso cultural de los dientes como tercera mano en actividades extramasticatorias. Su estudio, además, permite reconstruir el modo en que el desgaste ha ido evolucionando debido a los cambios evolutivos que han caracterizado al ser humano desde la revolución Neolítica y la introducción de la agricultura, hasta la Revolución Industrial en tiempos más recientes. Esta breve reseña se centra en el estudio del desgaste oclusal desde la perspectiva antropológica y bioarqueológica. Discute su importancia y relevancia para reconstruir y entender las sociedades del pasado, sus ventajas y limitaciones en el estudio de restos esqueléticos humanos, y cómo diferentes campos de estudio, de la odontología a la antropología dental/bioarqueología, se enfocan en su estudio desde perspectivas diferentes que no siempre se sobreponen, pero que pueden beneficiarse entre sí de un acercamiento multidisciplinario. Rev Arg Antrop Biol 26(2), 080, 2024. https://doi.org/10.24215/18536387e080

Palabras Clave: desgaste dental; bioarqueología; dieta; plano helicoidal; uso masticatorio y extramasticatorio

Occlusion in human beings is of paramount importance when mastication, evolution, as well as restorative applications are involved (Smith, 1986). The contact between opposing maxillary and mandibular teeth leads the occlusal surfaces to wear down in a process called dental attrition (Hillson, 2002). Wear facets form on the occlusal surfaces based on the forces –and their vectors– exerted by the masticatory process (Benazzi *et al*., 2011). At the same time, during mastication, teeth interact with abrasive particles that may be present in the food that is ingested, which favor the abrasion of the occlusal surface (Hillson, 2002). Erosion, instead, depends on the presence of gastric acids or other cultural habits that expose dental enamel and dentine to acidic substances.

When dealing with dental wear, we must distinguish between its macroscopic (macrowear, i.e., the one that can be analyzed with a naked eye), and microscopic form (microwear, i.e., the microscopic striations produced by the interaction between the tooth and microscopic particles, and whose shape and direction allows to infer the kind of food ingested – Ungar *et al.*, 2008). In this paper, the term dental wear will only refer to its macroscopic form, because its microscopic one would require a whole publication on its own.

Occlusal tooth wear (interproximal wear will not be discussed in this article) receives different attention, depending on the interested disciplines. Alongside being a physiological phenomenon, occlusal wear may also result from occlusion problems, which is of interest for odontologists in general, and orthodontists and periodontists in particular, who need to "fix" them, or lead to periodontal problems deriving from the exposure of the root as a consequence of the need to maintain dental occlusion between isomers in a process of continuous dental eruption. Problems at the temporo-mandibular joint, for example, heavily affect the way teeth tend to occlude, resulting in abnormal and/or anomalous wear patterns. At the same time, stress-related problems like grinding and bruxism, whether conscious or unconscious, result in excessive wear and occlusal problems that lead the patient to search for medical attention for her/his health and well-being. In this perspective, the intervention of the specialist aims at correcting potential problems as to restore a healthier oral status in the patient and grant better living conditions.

Specialists in odontology have the advantage of having every piece of information in hand so to provide the best and most effective way to correct the chewing plane when it is not in a normal occluding position and solve the patients' needs. In this perspective, normal occluding position is analyzed by odontologists by means of a set of planes and curves of the whole occlusal surface, which respond to functional geometric patterns, like the Curve of Spee, the Curve of Monson, or the Helicoidal Plane.

On the contrary, physical and forensic anthropologists in general and, even more so, bioarchaeologists, deal with archaeological human remains, which undergo taphonomic processes that commonly deteriorate them. Preservation is an issue in many parts of the world, particularly the tropical ones (Tiesler & Cucina, 2008), and Central America is not the exception, so bioarchaeologists frequently deal with scattered and partially preserved remains. It is not uncommon for bioarchaeologists to handle a few scattered teeth from each individual (if not secondary, mixed remains), and they do not always have the advantage to analyze a whole and complete dentition. Despite this objective limitation, their goal is to get as much information as possible to understand the biocultural evolutionary and adaptative process in the past and reconstruct ancient lives both at population (Buikstra, 1997; Saul, 1972; Tiesler & Cucina, 2008) and at an individual level (Hosek & Robb, 2019).

Given the nature of teeth, which are the most durable parts of the human skeleton (the enamel in particular), they are often the only anatomical elements that preserve and provide information on ancient individuals and populations. Based on the above issues and the differences that exist between specialists in various fields of odontology and dental anthropology, this paper aims to provide a general but brief view of the way dental anthropologists and bioarchaeologists deal with occlusal wear from a macroscopic perspective, and how it can be informative of biological and cultural aspects in archaeological human populations. It will not deal with wear facets formation and forces exerted during mastication (for such topic see Benazzi *et al*., 2011, 2016; Yang *et al*., 2022, and see also Kullmer in this journal's Dossier), nor microwear (see Ungar *et al.,* 2008), both of which would require a separate contribution.

Occlusal wear

As mentioned above, macroscopic occlusal wear (also known as gross dental wear – Brothwell, 1963) results from attrition, abrasion, and erosion. While erosion can be detected in some cases because it commonly affects the whole tooth, or specific parts of the crown, in skeletonized individuals distinguishing between attrition and abrasion can be complex (Larsen, 2015). Thus, the term "occlusal wear" is commonly reported as a combination of various factors (Larsen, 2015, p. 277). However, as Molnar (2011) stated, an experienced eye should be able to differentiate between the causes of wear in archaeological dental assemblages, at least in adequately preserved skeletonized individuals.

Patterns of occlusal wear depend on a variety of factors. The quality of food ingested (i.e., softer versus more abrasive and fibrous foods) is fundamental in assessing the speed and extent cusps are abraded, and how occlusal wear advances; the way food is prepared (with the potential inclusion of external abrasive particles) also affects how it interacts with the occlusal surfaces. However, in bioarchaeology, the macroscopic extent of occlusal wear (normalized by age) is only informative in a very general way of the kind of diet (Hillson, 2002; Smith, 1984); more detailed and precise information can instead be obtained when microwear is analyzed (Ungar *et al*., 2008). In this case, the analysis of microscopic striations (grooves) produced by the texture of food allows us to recognize patterns indicative of the kind of food ingested (Ungar *et al*., 2008). Yet, human beings spend a relatively short amount of time feeding every day so that, for the rest of the time, tooth-to-tooth contact (attrition) is responsible for occlusal wear at much greater force and speed because of bruxism, grinding or tapping (Johansson, 1992).

As mentioned above, while diagnosing this stressful condition in living patients is easier (for a medical review see Azouzi *et al*., 2018), the same cannot be done in archaeological remains. Therefore, specific research questions are much more limited when archaeological remains are the focus of the investigation. In fact, any search in the literature shows how papers dealing with such topics appear in orthodontic and more specialized journals, but not in osteological and bioarchaeological ones. For example, in a search in the International Journal of Osteoarchaeology, when the word "bruxism" is typed in, none of the nine papers that showed up focuses on bruxism. On the contrary, other conditions appear, like lingual surface attrition of the maxillary anterior teeth (LSAMAT) (Wasterlain *et al*., 2022), general oral problems (Buzon & Bombak, 2010), or dental wear as an adaptive process to specific environmental situations (Xiong *et al*., 2022).

The study of occlusal wear in bioarchaeology

Occlusal wear has been the object of anthropological research from an adaptative and evolutive perspective since mid-20th century (see among others Brothwell, 1963; Dahlberg, 1963; Greene *et al*., 1967; Molnar, 1971; Moorrees, 1957; Smith, 1984, just to cite a few). In 1971, Stephen Molnar published one of the landmarks on occlusal wear for the bioarchaeological literature, resting on the theoretical and methodological approaches employed in previous studies (Brothwell, 1963; Greene *et al*., 1967).

The main contribution for which Molnar's paper is usually referred to in the literature is the scale of degree of occlusal wear in anterior teeth, premolars and molars. Molnar adapted his new standard scale from Brothwell's (1963) with hints from Murphy's (1959) classification (Molnar, 1971, p. 177). Eight categories are presented for each tooth type, ranging from grade 1 (unworn, pristine tooth) to grade 8, which considers the root functioning as an occlusal surface with no traces or remnants of enamel. Though the latter is very uncommon, if non-existent at all in studies about modern extant populations – with few exceptions like the Australian Aboriginals still living in the Outback (Brown *et al*., 2011), it is a feature that occurred quite frequently in archaeological human populations (Fig. 1), without being considered a pathological expression as usually interpreted in modern times (Azouzi *et al.,* 2018).

FIGURE 1. Severe degree of occlusal wear in a prehistoric fisher-gatherer from southern United States of America (photo by A. Cucina).

Alongside the degree of occlusal wear, however, Molnar's paper describes and also standardizes the kind of wear, i.e., the form of the occlusal surface (natural, flat, rounded and more), as well as the direction of surface wear (wear plane is flat or tilted both along the mesio-distal and the bucco-lingual vectors of the tooth or vice versa). By that time, Molnar's paper (1971) filled a gap in the bioarchaeological literature by providing a novel approach that was not just centered on the degree of wear, but also on the type and vectors of dental wear.

Following previous publications that noted that occlusal wear changed based on the populations' economy (Greene *et al*., 1967; Moorrees, 1957), Molnar comparatively explored the above features among three archaeological populations from North America. He noted that hunter-gatherers presented heavier occlusal wear than the agriculturalists and explained it with the "wide assortment of food used by H&G plus a difference in tool assemblage may have been responsible for the heavier tooth function and more rapid rate of wear" (Molnar, 1971, p. 187).

Molnar (1971) stated that standardizing occlusal wear in the molars was much easier than in anterior teeth and premolars, the latter being the most difficult ones. As said, his 1971 standard rested on Brothwell's (1963) and Murphy's (1959), and all of them describe wear patterns in molars based on how they appear on the whole occlusal surface. The same was done by Smith (1984). Differently from them, Scott (1979) published a new standardized method specifically designed to score occlusal wear on the molar teeth. This system divides the molars' surface into four quadrants, each ranging from grade 1 to 10. The distribution of wear is similar to Molnar's but is spread on a scale of ten instead of eight grades. Therefore, the overall final grade ranges from 4 to 40. According to the author, this approach provides a more reliable scoring, because teeth tend to wear off differently by quadrant, providing a more reliable reflection of the amount of enamel on the occlusal surface (1979, p. 216). Because it focuses on quadrants, the system allows the observer to pin-point wear in a more specific and reliable way; yet, on the other hand, since this system is designed specifically for molars, researchers interested in occlusal wear in the whole dentition face the difficulty of having to use two different scoring systems (see Lagan & Ehrlich, 2021).

Molnar's and Scott's are not the only scoring systems in the bioarchaeological literature. Hillson (2002) reports Murphy's system (1959), but in general they are the standards more frequently used in archaeological studies. Today, modern technologies allow to implement detailed analyses based on 3D scans (Gkantidis *et al*., 2020), or using computer apps, which permit a better assessment of the extent and the distribution of occlusal wear in bioarchaeological human populations (Lagan & Ehrlich, 2021).

Despite Molnar's description of the direction of the occlusal planes, their effective use by modern odontologists has not been truly replicated in dental anthropological studies. The Curve of Spee (Smith, 1986; Spee, 1890) and the Curve of Monson (Osborn, 1982) are almost never referred to in such studies (Herrera-Atoche *et al.,* 2022; Osborn, 1982). On the contrary, the helicoidal plane received some attention during the last decades of the 20^{th} century. Strictly speaking, the helicoidal plane is a wear pattern in which the lower first molar presents an occlusal and wear pattern that is sloped outward in the mandibular first molar (M1) (i.e., the lingual side is less worn out than the buccal one). Then, the pattern tends to flat down horizontally when the second molar (M2) is involved, and it is reversed at the third molar (M3) level (the opposite occurs for the maxillary molars). That pattern was called a "helix" (Smith, 1986), is typical in the whole *Homo* genus (Schwartz, 2000), and has relevance for understanding the distribution of the forces during mastication (Benazzi *et al*., 2011; Yang *et al*., 2022).

The development of all these planes and curves varies depending on a wide set of variables that can modify tooth presence, position, and occlusion (Hall, 1976), and can be fully appreciated in a complete and well-preserved skull and dentition. Unfortunately, preservation of skeletal and dental remains is no doubt an issue for the correct application and understanding of these curves in human archaeological collections, forcing to analyze vectors in specific teeth only (see for example Watson, 2008); though it may not be the only reason for dental anthropologists not to focus their attention to this matter, it is for sure a strong limiting factor.

On the other hand, anthropology is interested in the biocultural evolution of dental wear (see Hillson, 2002; Smith, 1984). With the introduction of agriculture and processed food sometime between 10,000 and 5,000 years b.C. –depending on the regions in the world in which it evolved– the whole orofacial structure, and the extent of occlusal wear changed. Occlusal wear is a physiological continuous process throughout an individual's lifetime. It was particularly evident in pre-agricultural societies, where the quality of the food (and the way it was prepared) was different from modern times. Nowadays, occlusal wear in modern, industrialized societies, tends to be minimal and it is not unusual that individuals still maintain evidence of occlusal cusps even later in life (Brown *et al*., 2011).

Late Pleistocene/Early Holocene individuals (ca. 13,000-8,000 B.P.) (Chatters, 2014) were hunter-gatherers, and regardless of whether their subsistence relied on big-game or other animal sources, they presented very severe degrees of occlusal wear, regardless of their respective ages at death. Cucina *et al*. (2021) extensively analyzed dental morphology in the available sample of Late Pleistocene and Early Holocene individuals from North America (including Mexico). Though their study case (Naia) presented an almost immaculate dentition when she died at about age 16, they noted that, with very few exceptions, most of the individuals during that time presented a very severe degree of occlusal wear that permitted to score very few traits (same that was reported also by Turner II & Scott, 2014). The estimation of age-at-death is an issue when occlusal wear is concerned, yet Buhl Woman from Idaho (Green *et al*., 1998) was just 17-21 years old when she died, and her teeth were all flat down by occlusal wear. Those big-game hunters used to cover the meat with sand to protect it from flies infesting it with their eggs (Fenton, T.D., Michigan State University, personal communication, November 2019). Such a cultural habit implied that, despite cleaning meat for consumption, grainy particles likely remained embedded into meat and contributed to worn down teeth.

The same pattern of dental wear was found in other Paleoindians, like Spirit Cave (Jantz & Owsley, 1997), Wizards Beach (Edgar, 1997), and the older male from Horn Shelter no. 2 (Young, 1988). An amazing and very detailed description and photographic representation of the extent and severity of occlusal wear in a Paleoindian individual is that one presented by Owsley *et al*. (2014) for Kennewick Man. This individual, dated to 8,690-8,400 cal. B.P. (Stafford Jr., 2014), died at about 40 years of age (Owsley *et al*., 2014). By that age, Kennewick Man presented only a few, tiny portions of enamel in his permanent dentition. The degree of wear (according to Smith, 1984) ranges between 6 and 8 (though most of them fell into the 7-8 categories), corresponding to grade 6-7 according to Molnar's scale. Only his mandibular right M3 shows stage 3 of wear, but that's due to the premature loss of his isomeric, antagonistic tooth. Interestingly, the very high level of $\delta^{15}N$ suggests that Kennewick Man's diet was based on salmon, plus residues of fish or animals that fed on fish (Schwarcz *et al*., 2014). This kind of food does not seem tough and fibrous; however, the habitat in which the Kennewick Man skeleton was encountered was windy and sandy, which might suggest that external particles entered his food contributing to wear down his teeth. Yet, as Teaford & El Zaatari (2014) showed, Kennewick Man´s pattern of microwear does not seem to indicate chewing of fibrous food. Nonetheless, his degree of wear is undeniably severe. As mentioned above, severe wear was not limited to older people, as Buhl Woman shows. Owsley *et al*. (2014) also present the case of a 9-year-old child from the Grimes Shelter, Nevada, dated to 9,470 cal. years B.P., showing its deciduous molars to be severely worn out despite the child's young age.

As Smith (1984) correctly stated, in this perspective tooth wear study is an important tool to reconstruct moments in human biocultural evolution, which comprise a set of cultural variables like cooking, use of fire, food processing, use of grinding tools (like the widespread *metates* and *manos* in Mesoamerica), pottery and "other refinements in the way food is processed" (Smith, 1984, p. 39). She cites milestone publications (for that time) like Molnar (1971), Pedersen (1949), and Walker *et al*. (1978) that represented the primary literature for the reconstruction of the way food might have been prepared in ancient populations. One important aspect the author focused on is the main macroscopic difference in the wear patterns of molar dentitions between hunter-gatherers and agriculturalists.

The introduction of agriculture (the Neolithic Revolution), which led to a more sedentary lifestyle, represented one of the epic cultural changes in human societies that would change social structure leading to complex societies, and that would radically change the way food was obtained and prepared (Weisdorf, 2005). Human beings no longer acquired their food through hunting and recollecting, but they produced their own food. This meant a dramatic increase in the intake of refined carbohydrates (whether maize, corn, rice, depending on the cultures and regions in the world), gradually reducing and eventually eliminating from the diet the intake of more abrasive tougher-to-chew foods like tubers (Smith, 1984). Sedentism, the development of pottery and different ways of processing food led to the intake of softer substances (the outside-the-mouth processing) (Smith, 1984) and an increase in the frequency of pathologies such as caries, little known by hunter-gatherers (Cohen & Armelagos, 1984).

Molnar (1971) noticed that hunter-gatherers displayed a different degree of occlusal wear than agriculturalists. Based on this evidence, Smith (1984), in her comparative analysis of hunter-gatherers and agriculturalists from many different parts of the world and from different periods, reached twofold conclusions. Firstly, the wear plane in hunter-gatherers is always flatter than in agriculturalists, which on the other hand presents molars' wear resembling the helicoidal plane. Though Smith did not reference it, papers dealing with the helicoidal plane are cited in the references of her article. According to the author, the indirect reason for more sloping wear is that softer food requires less lateral mandibular excursion (1984, p. 53), which is the process that flattens down occlusal wear. Secondly, molar wear is distributed more homogeneously in hunter-gatherers, while agriculturalists tend to display a more restricted pattern of wear (see also Eshed *et al*., 2016).

As mentioned above, however, the analysis of macroscopic vectors and patterns of wear surged in the last decades of the 20th century. More recent times have witnessed less interest in the anthropological analysis of occlusal wear planes (see Watson, 2008), using wear as a tool to explore oral health of archaeological human groups in relation to diet, social status and living conditions (see for the American continent, Deter, 2009; Hubbe *et al*., 2012; Watson, 2008; Watson *et al*., 2013, among others). Alongside their analysis of the pathological impact on oral health (which is not the topic of this paper), these studies stress the concept that occlusal wear is multifactorial and age dependent. Even within culturally homogeneous groups, differences existed because of different environmental conditions, food availability, and cultural habits (see, among others, Larsen, 2015, p. 277; Smith, 1984). At the same time, the direct relationship between occlusal wear and age is one topic that has always caught the attention of bioarchaeologists and is briefly explored in the following section.

Occlusal wear as an indicator of age at death

Occlusal wear is age dependent. As such, it can only increase from pristine, unworn teeth to the root functioning as occlusal surface (Molnar, 1971). As mentioned above, teeth are the most durable structures in the human body, and they are often the only part of the skeletonized individuals that provide some sort of information. One of the most important variables within bioarchaeological studies, together with biological sex, is the age at death. Several morphological or histological indicators are analyzed in the skeleton to estimate the age of an individual (see Larsen, 2015 for a general review of the many different methods). However, in cases of poor skeletal preservation, teeth are the only pieces that can be informative of age.

Brothwell (1963) was one of the first scholars to create a standardized comparative scale in which the degree of occlusal wear is correlated to biological age. Despite his system not providing specific information on the way it was developed, it is one of the most widely used standards in bioarchaeological research. It focuses on molars and shows four age categories (17-25, 25-35, 35-45, and above 45 years). In each category, the wear patterns of the three molars are visually described. A different approach was taken by Lovejoy (1985). In his study of the prehistoric Libben population, the author describes 10 stages of wear, with associated age at death for the maxillary dentition, and nine for the mandibular one. Like Brothwell's (1963), Lovejoy's standard (1985) relies on a visual representation of the degree of occlusal wear, which is based on the extent of exposure of the dentine. This standard is also widely used in bioarchaeological studies.

Usually, because of the anatomy of teeth, molars are considered the most reliable teeth to score dental wear and correlate it to age at death (Mays *et al*., 2022). This happens because molars have a larger occlusal surface that grants a more precise evaluation, and wear is more regularly distributed. Moreover, because of the relatively stable sequence of eruption between first, second, and third molar (approximately six years between M1 and M2, and between M2 and M3), the observer can quantify the extent of wear (and the related age), assess and correct potential discrepancies in the sequence of wear in molars (Mays *et al*., 2022). This is particularly important during the initial stages of wear because dental eruption grants a precise age at death that can be contrasted to occlusal wear age, and from there correlate occlusal wear by age in more advanced wear stages (Mays *et al*., 2022). Figure 2 shows the degree of wear in a juvenile from a prehistoric site in Pakistan. Based on occlusal wear in the mandibular first molar (Lovejoy, 1985), the individual would be in a D stage, between 20 and 24 years old. However, the more reliable stage of formation and eruption of the M2 suggests an approximate age of 13-15 years (Hillson, 2002, pp. 144-145 reproducing Ubelaker's chart).

As we can see, occlusal wear is population-specific, and its rate may change based on the kind of food, the way it is prepared, and the environment in which it is obtained (see the Late Pleistocene cases described above). So, wear must be calibrated to age, depending on a wide range of possible factors. While the rate of wear was relatively stable in prehistoric populations that are culturally similar (Mays *et al*., 2022), it has decreased significantly in the last couple of centuries, at least in industrialized societies. In fact, Mays

FIGURE 2. Occlusal wear in the first molar of a ca. 14 years of age subadult from Mesolithic Pakistan (photo by A. Cucina).

(2015) noted that the average correlation coefficient between occlusal wear and age was 0.52; however, when excluding the low dental wear values of European populations from the 19th and 20th centuries, such average was as high as 0.9.

Over the years, the number of studies aiming at solving the population-specific issue associated with dental wear has increased, which stresses the importance of analyzing occlusal wear to estimate age at death in skeletal individuals. Studies range from adjusting specific methods to specific archaeological populations (see, for example, Mays *et al*., 1995; Oliveira *et al*., 2006), to updating previous charts (Mays *et al.*, 2022), to figure out which method is most suited to be adapted (calibrated) to each archaeological population (see for example Gilmore & Grote, 2012; Mays, 2002).

Culturally induced extra-masticatory wear

Though occlusal wear results from attrition and abrasion during mastication, and from stress-related tooth-to-tooth contact, in past societies human beings tended to use their teeth in the so-called "extra-masticatory" activities, or "using teeth as tools", or as teeth used as "third-hand" (Molnar, 2011). This generates extra mechanical stress on the crowns, resulting in additional wear, as well as notching, grooving, tilting, and traumas, based on the kind of activities performed (Neves *et al*., 2022). Teeth used for this extra-masticatory activity vary depending on the activity itself. Extra-masticatory activities range from stripping bark from a freshly cut branch, chewing animal or vegetable fibers to soften them for different purposes, using anterior teeth as a clamp to keep objects steady and firm (to make a knot in a fishing line, for example) (Brown *et al*., 2011; Hillson, 2002; Molnar, 2011) or to stretch and scratch animal hides (Lozano *et al*., 2008).

Because of their intrinsic nature and the limited availability of culturally induced wear, the anthropological literature commonly presents them as case studies (Molnar, 2011). Nonetheless, their analysis allows a better understanding of cultural habits and behaviors, and the extent to which teeth were (intentionally or unintentionally) used as necessary "tools" for past people. Unfortunately, as Molnar (2011) stated, while we can figure out gross, general activities based on the kind, type, and extent of extra-masticatory wear, we can hardly typify them based on the specific activities that used to be carried out (Molnar, 2011, p. 682). In fact, there is not a standardized methodology to classify this type of wear, because it depends on the kind of activities that were carried out. As Brown *et al*. (2011) correctly stated, in skeletonized human materials it can be challenging to distinguish activity-induced wear from physiological one when preservation is poor, unless patterns of wear are very distinctive and difficult to misinterpret.

However, general patterns at population level can provide hints of extra-masticatory activities, in particular in the absence of diagnostic features that would lead to assess occlusal wear as due to masticatory or paramasticatory activities. For example, Cucina *et al.* (2019) noted that in Late Pleistocene/Early Holocene individuals from North America, occlusal wear in the anterior teeth was always higher than in the rest of the dentition. This was particularly true in the specific case study they were investigating, a young adolescent with no occlusal wear in the posterior teeth but with noticeable wear in the incisors. Although the authors could detect notches only in the young individuals (for the other individuals published the images did not allow detection of these tiny details), the general pattern highlighted in their study suggests the use of anterior teeth for extra-masticatory functions.

In 1983, Turner II & Machado reported an anomalous wear pattern on the lingual surface of the maxillary anterior teeth. It was labeled "lingual surface attrition of the maxillary anterior teeth" (LSAMAT), which is known as Anterior Clinical Erosion in odontology (Azouzi *et al*., 2018). It appears as a patch of dentine close to the cervical portion of the lingual surface without corresponding wear in the antagonistic mandibular teeth. It can affect only one portion of the lingual side of the crown, or the whole lingual surface. The location and pattern of this kind of wear were not the result of masticatory or paramasticatory activities. A few years later, Irish & Turner II (1987) provided further evidence of this anomalous kind of wear when they analyzed prehistoric populations from Panama. According to the authors, LSAMAT might have been caused by the processing of manioc. More precisely, raw roots might have been shredded in the mouth by placing the piece of root between the tongue and the lingual side of the maxillary anterior teeth.

Watson & Hass (2017) considered tuber processing responsible for LSAMAT among a forager community in the Titicaca basin. Similarly, abrasion because of manioc processing was considered the reason for LSAMAT in a Puerto Rico archaeological population (Turner II *et al*., 1991). On the other hand, based on clinical studies Robb *et al*. (1991) criticized the attribution of LSAMT to abrasion, and instead considered that it was caused by chemical erosion of the lingual surface (but see Turner II *et al*., 1991 for a reply). In this perspective, LSAMAT was attributed to processing starchy items in enslaved individuals from Portugal by Wasterlain *et al*. (2022), who, on the other hand, ruled out the possibility that chemical erosion might have caused it.

CONCLUSIONS

Teeth form during infancy and childhood and do not remodel through life (Hillson, 2002). Therefore, they provide a wide range of evolutionary, developmental, dietary, and adaptive information (among others) about the individual regardless of age (Hillson, 2014; Teaford *et al*., 2000). Leaving aside erosion, taphonomic processes or pathological conditions like extensive carious lesions that destroy dental pieces (Hillson, 2002), from an anthropological perspective tooth wear is the only physiological process that removes information from dental elements, like tooth morphology, morphometry, linear enamel hypoplasia and others (Hillson, 2014).

Occlusal wear develops as a result of different activities. Except for extra-masticatory use of teeth, an activity that in some cases can be detected based on the distribution and shape of wear itself, it is oftentimes difficult in skeletonized individuals to assess whether occlusal wear was due to mastication or to paramasticatory stressful conditions.

There is little doubt that pronounced and severe occlusal wear has accompanied humankind in its evolutionary journey since the appearance of the genus *Homo*. Humankind has always dealt with occlusal wear and adjusted to it. Today, occlusal wear is very limited in industrialized societies because of the softer and more processed kind of food ingested (Brown *et al*., 2011; Larsen, 2015). As mentioned above, however, severe occlusal wear is still evident in recent or extant human populations like the Australian Aboriginals, which are often referred to because of their extensive use of teeth for masticatory and extra-masticatory functions (see Brown *et al*., 2011; Hillson, 2002; Larsen, 2015; Neves *et al*., 2022; Smith, 1986).

Anthropologically, the study of occlusal wear (alone or in combination with other skeletal indicators) is a useful tool to estimate age at death, at least on a large scale, assess diet and the way food was prepared, and to reconstruct evolutionary paths in human life history. Today, people in Western societies do not wear down their teeth, but from an evolutionary perspective, this is a highly recent trend, which has not characterized humankind through time. So, one question arises spontaneously: What's the function of cusps in human evolution if they are removed and flattened down by wear within a few years after the tooth has erupted? According to Brown *et al*. (2011), the concept that cusps function to stabilize upper and lower dental arches and grant maximum intercuspation does not hold when we look at the evolutionary path of human dentitions. Unless affected by some pathological condition, they state that mastication has always been very efficient in humans, even in individuals with teeth lacking cusps due to occlusal wear. Citing Campbell (1956), they consider that cusps and *fossae* are necessary structures in the occlusal surface to guide opposing teeth in the process of eruption so as to reach a proper alignment. Cusps' interdigitation maintains teeth into position until the whole bony and root structures are fully formed. As Brown *et al*. (2011) say, "at about this stage intercuspation is no longer essential in the naturally functioning dentition and tooth wear is already changing cuspal morphology" (p. 165).

As we have seen, occlusal wear has always been part of *Homo sapiens'* evolutionary journey and, as such, is an excellent source of information for bioarchaeologists and dental anthropologists on past societies and our evolutionary voyage. It is informative on diet, food processing, age at death, para-masticatory, and non-masticatory activities. Nonetheless, it is very complex, and it can be very difficult to be fully appreciated when it is analyzed under one single lens or from one single frame of reference, be it the odontological or the dental anthropological ones. Today, despite their common interest (teeth), odontology and dental anthropology are still academically very distant from each other, for an array of reasons that go beyond the scope of this paper. However, only the combined holistic and multidisciplinary effort of specialists in dental anthropology and in odontology can provide a better and greater understanding of occlusal wear (as well as the other topics in dental anthropology). The "evolutionary medicine" approach has already started to throw down that wall; hopefully, the same step will be taken in "evolutionary dentistry" or "evolutionary odontology".

ACKNOWLEDGMENTS

The author thanks Cinzia Fornai and Karol Ramirez Chan for organizing the round table "Anthropology Meets Dentistry in Central America: Research and Education in Oral Biology" (Costa Rica) from which this paper originates. Thanks also go to one anonymous reviewer and the journal's editor for constructive comments.

AUTHOR CONTRIBUTIONS

Andrea Cucina: Conceptualization, Visualization, Writing – original draft, Writing – re- view & editing.

CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

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