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Bruxism as a cause of tooth wear. A demanding physiological activity on the modern human stomatognathic system

El bruxismo como causa de desgaste dental. Una actividad fisiológica demandante en el sistema estomatognático del humano moderno

Miguel Assis[1,2*] | Alejandra Londoño[1,2]

1) Department of Research in Occlusion Medicine, Vienna School of Interdisciplinary Dentistry-VieSID, Klosterneuburg, Austria. **2)** Departamento de Ortodoncia, Universidad San Francisco de Quito, Quito, Ecuador.

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*Correspondencia a: Vienna School of Interdisciplinary Dentistry VieSID, Wasserzeile 35, 3400, Klosterneuburg, Austria. E-mail: miguel.s.assis@gmail.com

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Abstract

Mastication is commonly considered the primary function of the stomatognathic system, and more specifically of the teeth. Studies conducted in the 70s and early 80s revealed that there is almost no contact between teeth during mastication when the bolus is interposed between the dental surfaces, except in the phase of maximum intercuspation. Although mastication is based on an automated muscle activation pattern, it is still a conscious activity. Tooth wear is mostly attributed to abrasion caused by the hardest components of food or by contaminating abrasive materials, such as silica or carbonates. The use of teeth as a tool is also considered a common cause of tooth wear. Differently from mastication, sleep bruxism is an unconscious excursive movement of the lower teeth, which uses the full length of the dental guiding path, and is performed with greater muscular force and in the absence of an interposed bolus. Thus, it might result in heavy tooth contact leading to conspicuous loss of dental material. Since recent modern humans rely on a soft and refined diet, which does not generally account for tooth wear, the possibility of bruxism as a major factor contributing to dental material loss should not be dismissed. In this light, tooth wear patterns in modern-day subjects and past populations should be addressed on the basis of the clinical experience allowing the assessment of bruxism and chewing activities in living subjects. In this paper, clinical know-how on bruxism and the resulting dental wear in contemporary industrialized societies is presented as a possible source of information to be integrated into the most common notion of dental wear in anthropology. Rev Arg Antrop Biol 26(2), 083, 2024. https://doi.org/10.24215/18536387e083

Keywords: stress management; mastication; dental abrasion; occlusion guidance

Resumen
La masticación es considerada la función principal del sistema estomatognático y de los dientes. Estudios realizados en los años 70 y 80, revelaron que practicamente no hay contacto dentario durante la masticación, excepto durante la fase de máxima intercuspidación. Aunque la masticación se basa en un patrón muscular automatizado, es todavía una actividad consciente. El desgaste dental es mayoritariamente atribuido a la abrasión causada por los componentes más duros de la comida o por contaminación de ésta con materiales abrasivos como sílice o carbonatos. En cambio, el bruxismo del sueño es un movimiento excursivo, inconsciente, de los dientes inferiores, que utiliza toda la longitud de las guías oclusales con mayor fuerza muscular y sin la interposición del bolo alimenticio. Por esa razón, puede resultar en contactos dentales de mayor extensión, con el resultado de pérdida de material. Al considerar los humanos modernos que utilizan una dieta blanda y refinada, que generalmente no contribuye para el desgaste dentario, la posibilidad de que el bruxismo sea el mayor contribuyente para la pérdida de material dentario no puede ser descartada. Así, los patrones de desgaste dentario en sujetos modernos y en poblaciones antiguas deberían ser considerados con base en la experiencia clínica del análisis de las actividades de bruxismo y masticación en sujetos vivos. En este artículo se presenta la experiencia clínica en pacientes con bruxismo y con desgaste dental en sociedades industrializadas contemporáneas como una posible fuente de información que se debe integrar al análisis del desgaste encontrado en hallazgos arqueológicos. Rev Arg Antrop Biol 26(2), 083, 2024. https://doi.org/10.24215/18536387e083

Palabras clave: manejo del estrés; masticación; abrasión dental; guía oclusal

Chewing is primarily regarded as the main function of teeth, essential for food intake. However, in humans, the stomatognathic system, of which teeth are a part, performs additional crucial functions, such as speech, respiration, bruxism, and contributing to facial appearance and expression (Slavicek, 2002). The coordination of jaw movements and mastication is largely developed during the first two years of life (Wilson & Green, 2009). The chewing cycle begins with a conscious, cortex-controlled pattern, influenced by the mechanical properties of food (e.g., hardness, toughness, viscosity), followed by subconscious brainstem-controlled actions of the masticatory muscles, tongue, and lips, constantly influenced by sensory inputs (Avivi-Arber *et al.*, 2011). In the frontal view, the path traced by the lower incisors during the masticatory cycle has a drop-like shape (Fuentes *et al.,* 2021). This movement pattern is illustrated in Figure 1, based on the actual jaw movements recorded while a patient chews a small piece of apple, using a condylographic examination performed with a CADIAX 4 device (GAMMA Medizinisch-wissenschaftliche Fortbildungs-GmbH**,** Wasserzeile 35, A-3400 Klosterneuburg, Austria). This type of investigation is routinely performed in clinical practice to assess mandibular kinematics and diagnose dysfunctions. The path traced by the opening movement is typically quite straight, vertical, or slightly oblique, deviating from the midline toward the working side midway through the cycle. The food is maintained between the teeth by the tongue, cheeks (thanks to the buccinator muscles), and lips (through the *orbicularis oris* muscles), and is usually chewed alternatively on one side of the posterior dentition. Consequently, the closing movement starts either to the left or right, depending on the side where the food bolus is positioned. The closing movement occurs more laterally than the opening, with some gliding tooth contact before reaching maximum intercuspation, as can be inferred from the tracings in Figure 1. Thus, the power stroke of the chewing cycle is part of an incursive movement (Slavicek, 2010).

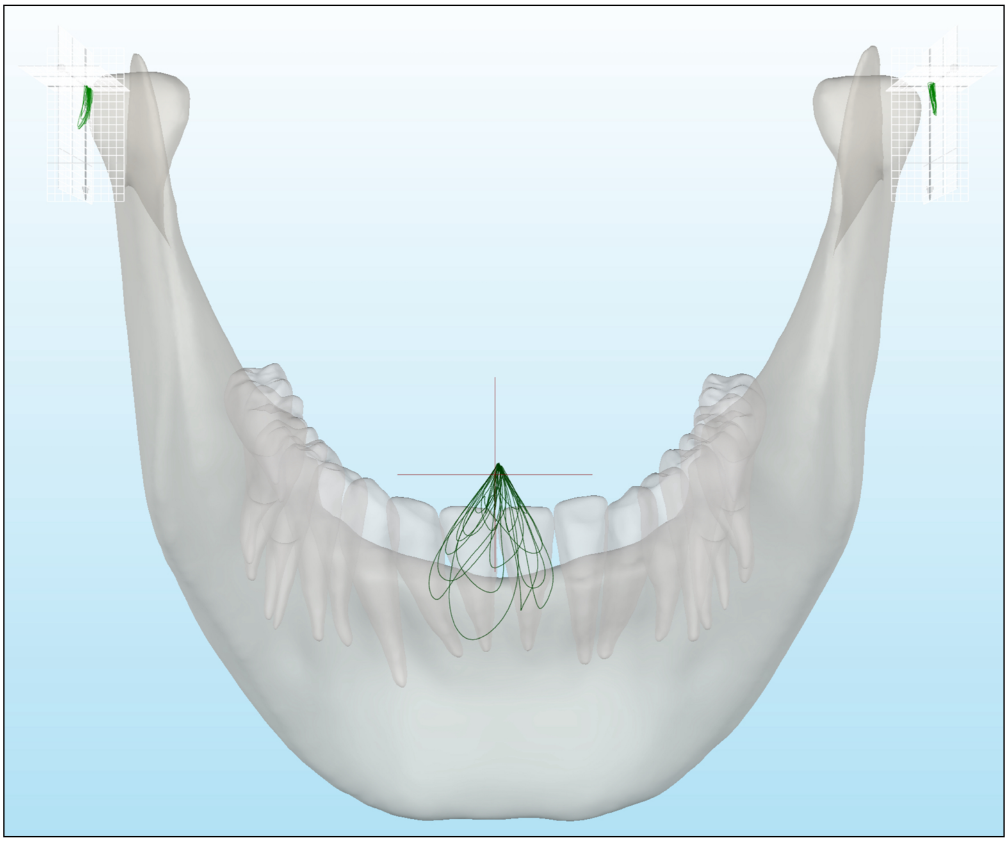

FIGURE 1. Chewing pattern analyzed using a reference point on a lower central incisor traced on the frontal plane. The mastication pattern follows a drop-like shape: the opening occurs roughly in the middle of the shape, after which the mandible moves laterally to the bolus side, and closes in an incursive movement near occlusion.

The inclination of the surface that guides the incursive movement is typically the lingual surface of the upper canines, which is usually the steepest of the upper arch. This steepness determines the lateral amplitude of the chewing movements, or, in other words, the width of the drop-like shape traced by the lower incisor during mastication (Slavicek, 2002). The geometric arrangement of the guidance inclination was first described by Slavicek (1984) and is referred to as "Sequential Guidance with Canine Dominance". This term highlights the fact that, in natural dentition, the canine plays a key role in guiding the lower teeth during the excursive (mediotrusive) movements, allowing the posterior teeth to dis-occlude without interference (i.e., unwanted contacts). The upper canine has the steepest guidance inclination, with an average of 48º measured with the Axis-Orbital Plane (AOP)—the plane formed by the hinge axis (the rotational axis of the lower jaw during the opening) and the left orbitale (for more details, see Piehslinger *et al*., 1991, 1993). The second steepest guidance inclination is at the first premolar, followed by the second premolar, first molar, and second molar, with an average 10º decrease in guidance inclination between each tooth. If the guidance inclination is too steep, particularly if it exceeds the subject's sagittal condylar inclination (SCI) path, it can cause interference, creating a fulcrum and inducing an unwanted transversal lateral condylar movement, known as immediate side shift or Bennett movement (Toubol & Michel, 1983).

Following feeding activities, dental wear is expected due to mastication. Loss of dental material can occur through abrasion, attrition, erosion, or abfraction, as well as chipping of the teeth (Watson & Schmidt, 2020). Archaeological human dental remains show more dental wear, which is mostly related to the harder and more abrasive diets of past populations compared to modern ones (Kaidonis, 2008). In contrast, modern populations in industrialized societies often prepare food extra-orally and cook it, making their diet approximately 10 times softer than that of hunter-gatherers (Dominy *et al*., 2008). This difference in food mechanical properties translates into a generally lower degree of dental wear in modern societies (Corruccini, 1999). Nevertheless, many recent individuals still present moderate to severe dental wear, which is often observed in dental practice (Cunha-Cruz *et al*., 2010; Smith & Robb, 1996).

In this context, we discuss how bruxism, an important physiological and ubiquitous function of the stomatognathic system, characterized by strong tooth contact, might be the primary cause of tooth wear observed in contemporary individuals living in industrialized societies. Drawing from clinical knowledge and observations, we aim to contribute to the ongoing discourse on tooth wear by highlighting bruxism as a significant factor and examining its effects on the stomatognathic system.

MATERIALS AND METHODS

This review is based on clinical and research studies focused on bruxism and mastication. The articles were selected based on the reasoning we sought to develop, without specific limitations regarding publication year or type. The purpose of this article is to strengthen cooperation between biological anthropologists and clinicians. As dentists, we believe we can contribute our knowledge of the functions and dysfunctions observed in our patients to enhance the evaluation of the stomatognathic system and its associated pathologies. Our experience with living subjects is intended to provide a valuable contribution to the field of biological anthropology.

RESULTS

Mastication studies

Gibbs and Lundeen conducted extensive experimental studies on mastication during the 1970s and 1980s (Gibbs *et al*., 1971, 1981a, 1981b, 1982; Suit *et al*., 1976; Wickwire *et al*., 1981). In collaboration with Messerman (1967), they developed a device called the "gnathic replicator", which was capable of recording and reproducing the subject's chewing cycles in real-time. This device allowed for the direct recording of mandibular movements, simultaneously plotted at both the tooth and condylar levels. The recorded data could then be reproduced on an articulator or a sample mandibular model. From these studies, it was found that the mastication pattern begins with an opening movement to position the food between the occlusal surfaces of the teeth, followed by an incursive movement without tooth contact as the bolus is positioned between the teeth, ultimately leading to tooth contact near maximum intercuspation (ICP) when the food is nearly comminuted. The recordings of mandibular movements during mastication revealed an average tooth glide length of 1 mm near the point of ICP (Suit *et al*., 1976). This suggests that only a small portion of the canine guiding path, which has the steepest guidance inclination, is utilised during mastication.

In another experimental study on mastication (Tscharre-Zachhuber & Riedl, 1988), patients with total prostheses were fitted with full dentures that had different canine guidance inclinations. Their mastication pattern was recorded. The results showed that the chewing path varied according to the guidance inclination, indicating that the muscular pattern of each patient adapted to the different full dentures within minutes to perform chewing movements and avoid unwanted tooth contacts during mastication (Fig. 2). Given that there is limited tooth contact during mastication, and considering that we do not use the full extent of the guidance, coupled with the fact that modern human diets are less abrasive than those of pre-industrial times, one could speculate that bruxism may play a more significant role than mastication in tooth wear (Sato *et al*., 2002).

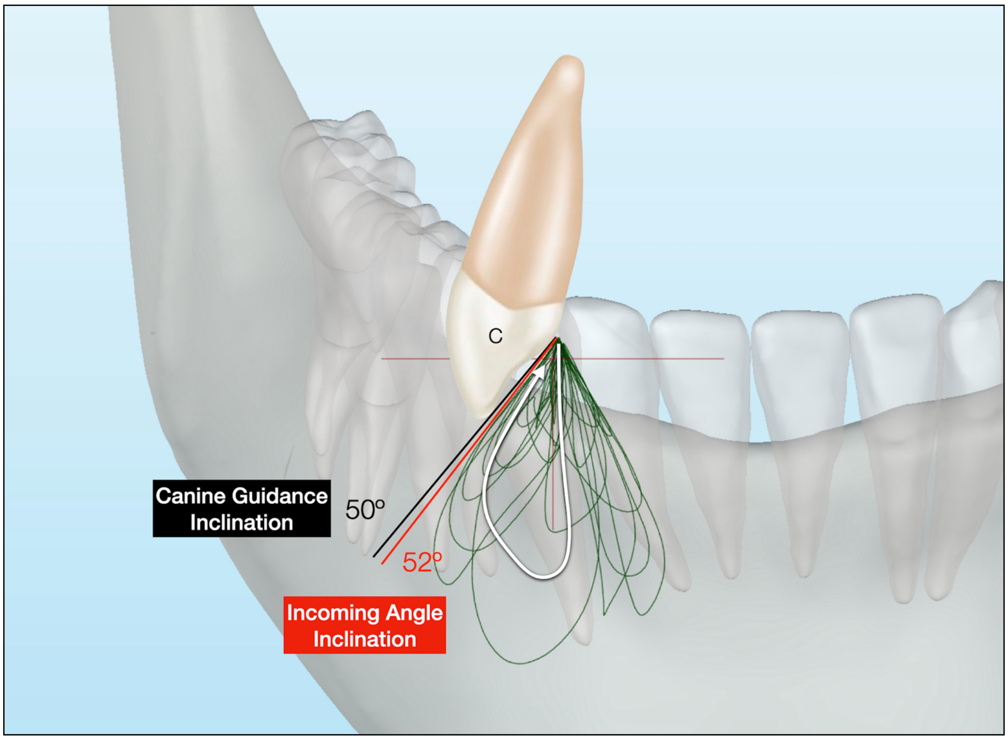

FIGURE 2. Chewing pattern analyzed using the cusp of tooth 44 as a reference, traced on the frontal plane by the CADIAX 4 condylographer on a sample patient. Throughout the mastication cycle, the incoming angle is 2º steeper than the upper canine guidance inclination (usually the steepest), indicating that tooth contact is avoided during mastication. If canine guidance is made steeper or flatter, the muscular pattern changes accordingly, maintaining a freedom space of 2º.

Bruxism studies

Nowadays, bruxism is no longer considered a parafunction but rather a physiological function of the masticatory system (Andrisani & Andrisani, 2021). Polysomnographic studies have shown that sleep bruxism is always accompanied by cardiac and respiratory activation, and, most importantly, by activation of brain function. It stimulates the ARAS (Ascending Reticular Activating System) nuclei, which in turn activate the production of ARAS neurotransmitters. When bruxism no longer works properly, individuals may be at risk of developing dementia. Bruxism consists of Rhythmic Masticatory Muscle Activity (RMMA), resulting in clenching, grinding, and tapping of the teeth, and it can occur during wakefulness and sleep. Sleep bruxism is very common, occurring during the most profound phase of sleep (Lavigne *et al*., 2008). We unconsciously brux for 45 to 50 minutes each night, in several separate episodes, with muscular activity reaching up to 223% of maximum voluntary contraction (Yoshimi *et al*., 2009).

Homeostasis, a term introduced in the 1930s by the physiologist Walter Cannon, refers to a self-regulating process by which an organism maintains internal stability while adjusting to changing external conditions. In her 1986 PhD thesis, supervised by Prof. Rudolf Slavicek (1928-2022), Karin Kail, a psychologist at the Medical University of Vienna, Austria, proposed that bruxism might serve as a mechanism for humans to release stress, thus viewing the masticatory system as a fundamental component of the allostatic process. Allostasis (McEwen & Gianaros, 2010) is a more recent regulatory model, building on the concept of homeostasis. This updated concept differs from homeostasis by emphasising the role of brain activity in interpreting environmental stress and coordinating changes in neurotransmitters, hormones, and other mechanisms, including immune system regulation. The involvement of the brain allows errors to be remembered and used to reduce future errors, anticipating needs and preparing to satisfy them before they arise.

According to Sato and Slavicek (2008), emotional and behavioral responses, along with our most basic instincts, are regulated by the limbic system, the most primitive part of the brain that we share with other species in the phylum *Chordata*. The amygdala, a key component of the limbic system, is responsible for detecting and processing threats and regulating the body's response to stress. When stressful events occur, the amygdala releases hormones that trigger the body's "fight or flight" response —preparing the body for survival by increasing heart rate, blood pressure, pupil dilatation, and breathing rate, all while placing the body in a state of heightened alertness. The amygdala receives sensory input from the mouth and controls the oral muscles. The neocortex, which governs conscious social behavior, suppresses socially unacceptable or aggressive instincts. However, if stress is not released immediately through aggressive behavior, then it must be addressed later through other mechanisms.

Sato's research team in Japan (Hori *et al*., 2004; Miyake *et al*., 2012; Nukazawa *et al*., 2018; Ono *et al*., 2008, 2009; Sasaguri *et al*., 2005; Sato & Slavicek, 2008; Sato *et al*., 2002, 2008, 2010), further investigated the biochemical relationship between stress and bruxism using animal models to explore the hypothesis that the masticatory system plays a role in stress management. Their findings indicated that bruxism-like activity has beneficial effects on stress-induced reactions. These include an increase in the expression of Fos protein, neuronal nitric oxide synthase, phosphorylated extracellular signal-regulated kinase 1/2, corticotropin-releasing factor, and free radicals in the paraventricular nucleus of the hypothalamus. The studies also showed changes in the blood neutrophil-to-lymphocyte ratio and adrenocorticotropic hormone levels, as well as the formation of stomach ulcers in animal models. In humans, increased amygdala neuronal activity and elevated salivary chromogranin A levels were observed. The researchers concluded that the masticatory system, through bruxism activity, functions as a cybernetic negative feedback control system. This system helps to prevent allostatic overload and reduces the risk of disease at a somatic level. Bruxism activity regulates not only hormones, neutrophils, lymphocytes, free radicals, blood pressure, blood temperature, and blood glucose, but also influences brain function, particularly attenuating the amygdala activity.

Bruxism as a double-edged sword

Bruxism is considered a necessary physiological function that supports cardiac and respiratory activities and plays a role in awakening mechanisms (Andrisani & Andrisani, 2021). However, various factors, such as alcohol, drugs, diet, and certain medical conditions, can influence the intensity and frequency of bruxism (Frosztega *et al*., 2022; Montastruc, 2023; Ohayon *et al*., 2001; Toyama *et al*., 2023). Excessive bruxing forces can lead to significant tooth wear and other dental issues, such as non-carious cervical lesions (NCCL), abfractions, enamel chipping, crown failure, tooth sensitivity, and periodontal tissue damage, which may require clinical intervention (Benazzi *et al*., 2013; Bustos *et al*., 2020; Miranda *et al*., 2017). Sato *et al*. (2002) emphasised the importance of maintaining proper dental occlusion to buffer the strain and stress generated during bruxing activity. They argued that sleep bruxism, being largely involuntary, should be managed by designing oral rehabilitations that allow for biomechanically efficient occlusion, thereby minimising the negative effects of bruxism on dental structures.

Unlike mastication, bruxism involves excursive movements with tooth contact, significant muscular force, and the full utilisation of the guidance path. Yoshimi *et al*. (2009) developed a new system for analysing sleep bruxism, combining a 2-axis accelerometer with electromyography and encephalography. This system allowed for easy identification and quantification of the three basic bruxism patterns: grinding, clenching, and tapping. Their research revealed that grinding and clenching were more predominant than tapping in a sample of 19 volunteers. Building on Yoshimi's work, Sugimoto *et al*. (2011) investigated the role of occlusion, and specifically of canine guidance, in bruxism activity. They found a direct correlation between sagittal condylar inclination—the path the condyle follows on the anterior slope of the articular eminence—and canine guidance: the steeper the canine guidance relative to the sagittal condylar inclination, the more intense bruxing activity. This led to more grinding behavior and increased cusp abrasion on the canines, contributing to dental wear. In contrast, subjects with a shallower guidance inclination relative to their sagittal condylar inclination showed less bruxism activity, with a predominance of clenching over the grinding pattern and less pronounced wear facets. These observations on the functional geometry of occlusion and its relationship to mandibular kinematics offer valuable insights into the effects of bruxism on teeth and the broader stomatognathic system.

To assess the effects of bruxism in living subjects, it is essential to use proper tools for objective quantification of bruxing activities. The combined use of polysomnography and electromyography is considered the gold standard for evaluating sleep bruxism activity (Manfredini *et al*., 2014). However, sleep laboratories are not widely available to most clinicians, and these tests can be costly. As a result, many published clinical studies rely on questionnaires, asking individuals whether they perceive themselves as bruxers, which leads to a subjective assessment of bruxism.

D'Incau *et al*. (2012) reported that when a third moving body (such as hard food) is interposed between two bodies (the opposing teeth), each tooth wears separately. When the third body is removed, the contact surfaces of the teeth no longer align. In contrast, when two-body abrasion predominates, which is more characteristic of tooth grinding (as seen in bruxism) than mastication, the wear facets are well-defined, smooth, and shiny. This distinct pattern of wear could serve as a feature to help differentiate whether the wear facets are caused by mastication or bruxism.

Onodera *et al*. (2006) developed the Brux Checker®, a thin (0.1 mm) polyvinyl foil pressure-formed on plaster casts of the subject's teeth. The exposed side is tinted with a red food colorant that peels off when it comes into contact with opposing teeth (Fig. 3). This innovative tool has revolutionized the study of bruxism because it is effective, inexpensive, and most importantly, it objectively shows the bruxism pattern of the subject, even if the patient is unaware of their bruxing activity. The Brux Checker® revealed that nearly 100% of the subjects exhibit some form of bruxism. More importantly, the tool can detect the type of bruxism activity and identify the occlusal surfaces engaged during bruxing. It allows for the measurement of the extent of the tooth contact points and grinding areas, either from 2D images (i.e., photos) or, more accurately, through a 3D surface scan of the Brux Checker®. With this tool, it is possible to differentiate between "old" wear facets that are no longer in use and current wear facets still being used. Additionally, new grinding areas which have not yet formed visible wear facets can be identified. The Brux Checker® thus provides an objective and comprehensive functional evaluation of the occlusion in relation to bruxing activities.

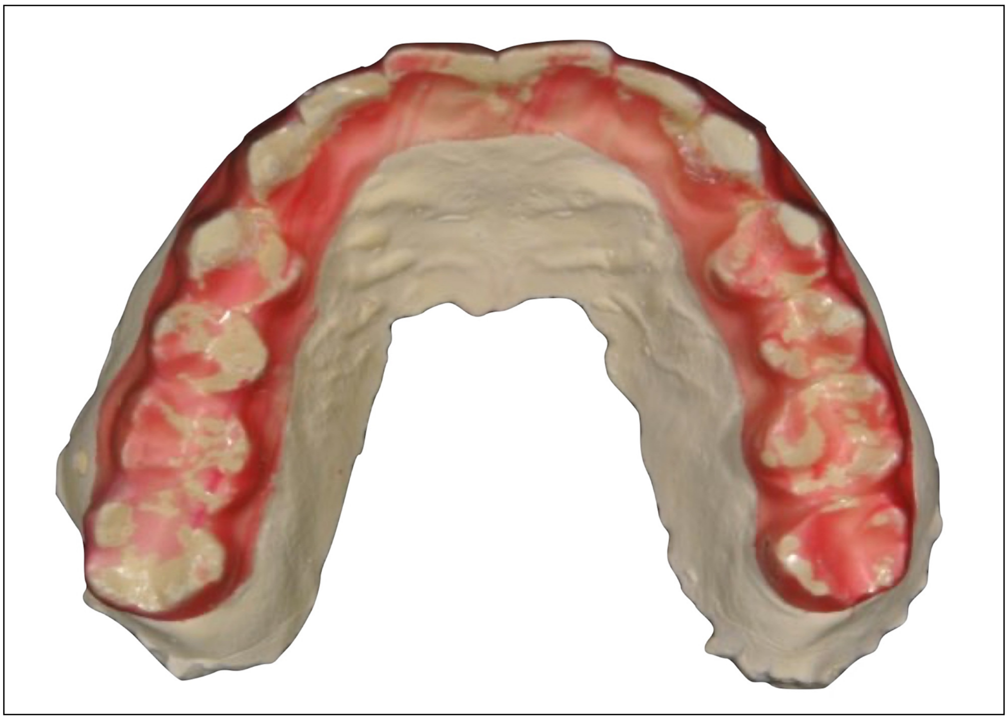

FIGURE 3. Occlusal view of a Brux Checker® after one night of use, showing the contact areas and the patient's bruxism activity pattern. The red colour of the 0.1 mm polyvinyl foil is removed by tooth contact during sleep bruxism, objectively demonstrating how the patient uses their occlusal surfaces. The correctness or absence of a guidance system can be easily assessed.

A clinical case

A 38-year-old female patient presented to our dental office with severe tooth wear, generalized toothache, and TMJ pain. The anterior teeth showed significant structure loss, to a point where the pulp was compromised in one of the lower incisors (Fig. 4). She reported consuming a "regular" 21st-century diet. The use of the Brux Checker® confirmed intense bruxing activity, indicating that the majority of her tooth wear was likely caused by bruxism.

Interestingly, the patient presented both *torus mandibularis* and *torus maxilaris*. The formation of a *torus mandibularis* is typically considered a result of overload on the mandibular bone (Park & Ahn, 2020). A Paleodontology study on 48 crania from Viking Age Icelanders older than 1,140 AD (Richter & Eliasson, 2012), found that 50% of the cases exhibited *torus mandibularis*. This type of mandibular bony growth has been linked to bruxism activity and a particular occlusion characterized by group function during lateral movements. In such oclussions, disocclusion is guided by the posterior teeth rather than solely by the canines (Park & Ahn, 2020).

FIGURE 4. Intraoral photographs of a 38-year-old female patient showing severe dental abrasion, as well as the presence of *torus mandibularis* and *torus maxilaris*.

Based on these clinical observations, as well as supporting information from the anthropological literature, it was hypothesized that the patient was generating significant intense occlusal forces due to bruxism. Furthermore, an examination of the patient's occlusogram waxes (Fig. 5) confirmed that she exhibited group function in lateral movements, as well as simulated (voluntary) awake bruxism activity. This comprehensive assessment helped corroborate the idea that bruxism was a significant factor contributing to the patient's dental issues.

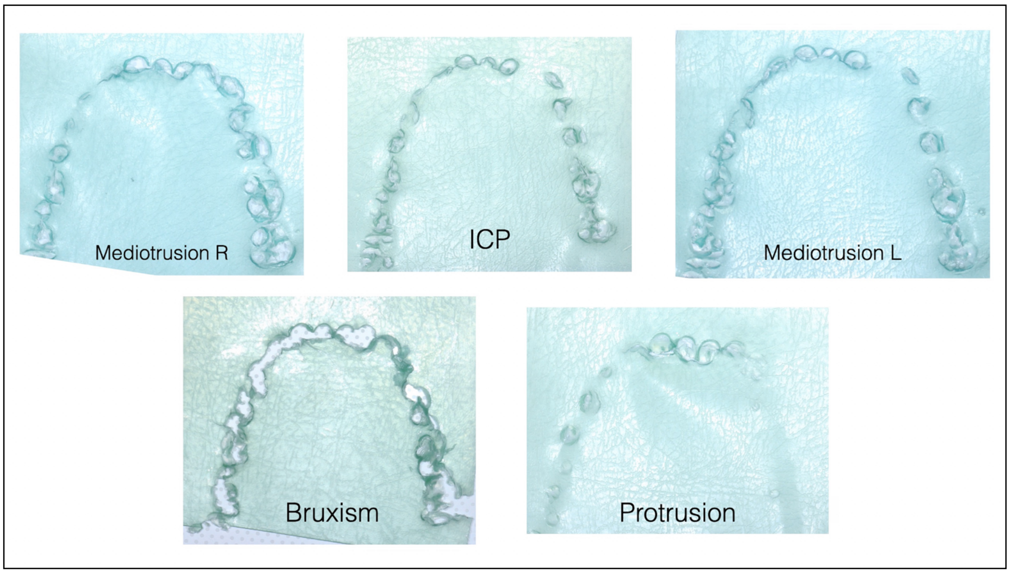

FIGURE 5. Occlusogram waxes are 0.3 mm-thin wax sheets used to evaluate occulsal dynamics. The patient bites in maximum intercuspation (ICP) to establish a baseline record, followed by using new wax sheets to register each excentric movement with tooth contact, starting from ICP. This tool is highly effective for clinically assessing dynamic contacts during protrusion, right (R) mediotrusion, left (L) mediotrusion, and bruxism (grinding).

CONCLUSIONS

Bruxing activity is a physiological phenomenon, and thus it is reasonable to assume its presence in past populations, contributing to overall dental wear through attrition. However, current methods for assessing attrition specifically caused by bruxing activities in skeletal remains are not part of the anthropologist´s toolkit. Investigating the contribution of bruxism to dental wear in archaeological human remains could reveal valuable insights into the lifestyles and stress levels of past populations.

We propose that close collaborations between clinicians and biological anthropologists could greatly enhance the understanding of this aspect of dental wear. Techniques such as Occlusal Fingerprint Analysis (Kullmer *et al*., 2009) and micro-abrasion studies could be applied to assess whether occlusal wear facets result from two-body or three-body abrasion mechanisms. Moreover, comparing findings from Occlusal Fingerprint Analysis with a Brux Checker® on the same patient could provide both qualitative and quantitative data on wear facets.

The functional interpretation of dental wear patterns could yield a deeper understanding of how bruxism reshaped the occlusal surfaces of dental crowns. Such research might also offer further insights into the life histories of past populations by estimating potential stress levels they experienced.

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INFORMED CONSENT STATEMENT

Informed consent was obtained from the subject involved in the clinical study.

AUTHORS CONTRIBUTIONS

Miguel Assis: Conceptualization; writing – original draft; writing – review and editing. Alejandra Londoño: Conceptualization; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

LITERATURE CITED

Andrisani, G., & Andrisani, G. (2021). The neurophysiological basis of bruxism. *Heliyon*, *7*(7), e07477. https://doi.org/10.1016/j.heliyon.2021.e07477

Avivi-Arber, L., Martin, R., Lee, J.-C., & Sessle, B. J. (2011). Face sensorimotor cortex and its neuroplasticity related to orofacial sensorimotor functions. *Archives of Oral Biology*, *56*(12), 1440-1465. https://doi.org/10.1016/j.archoralbio.2011.04.005

Benazzi, S., Nguyen, H. N., Schulz, D., Grosse, I. R., Gruppioni, G., Hublin, J.-J., & Kullmer, O. (2013). The evolutionary paradox of tooth wear: Simply destruction or inevitable adaptation? *PLOS One*, *8*(4), e62263. https://doi.org/10.1371/journal.pone.0062263

Bustos, A. J., Al-Talib, T., & Abubakr, N. H. (2020). Retrospective analysis of the association of non-carious cervical lesions with bruxism. *Open Journal of Stomatology*, *10*(2), 11-18. https://doi.org/10.4236/ojst.2020.102002

Corruccini, R. S. (1999). *How anthropology informs the orthodontic diagnosis of malocclusion's causes*. Edwin Mellen Press.

Cunha-Cruz, J., Pashova, H., Packard, J. D., Zhou, L., & Hilton, T. J. for Northwest PRECEDENT. (2010). Tooth wear: Prevalence and associated factors in general practice patients. *Community Dentistry and Oral Epidemiology*, *38*(3), 228-234. https://doi.org/10.1111/j.1600-0528.2010.00537.x

d'Incau, E., Couture, C., & Maureille, B. (2012). Human tooth wear in the past and the present: Tribological mechanisms, scoring systems, dental and skeletal compensations. *Archives of Oral Biology*, *57*(3), 214-229. https://doi.org/10.1016/j.archoralbio.2011.08.021

Dominy, N. J., Vogel, E. R., Yeakel, J. D., Constantino, P., & Lucas, P. W. (2008). Mechanical properties of plant underground storage organs and implications for dietary models of early hominins. *Evolutionary Biology*, *35*(3), 159-175. https://doi.org/10.1007/s11692-008-9026-7

Frosztega, W., Wieckiewicz, M., Nowacki, D., Michalek-Zrabkowska, M., Poreba, R., Wojakowska, A., Kanclerska, J., Mazur, G., & Martynowicz, H. (2022). Polysomnographic assessment of effects of tobacco smoking and alcohol consumption on sleep bruxism intensity. *Journal of Clinical Medicine*, *11*(24), 7453. https://doi.org/10.3390/jcm11247453

Fuentes, R., Farfán, C., & Arias, A. (2021). Characteristics of chewing: An update of the literature. *International Journal of Odontostomatology*, *15*(4), 873-881. http://dx.doi.org/10.4067/S0718-381X2021000400873

Gibbs, C. H., Lundeen, H. C., Mahan, P. E., & Fujimoto, J. (1981a). Chewing movements in relation to border movements at the first molar. *The Journal of Prosthetic Dentistry*, *46*(3), 308-322. https://doi.org/10.1016/0022-3913(81)90220-1

Gibbs, C. H., Mahan, P. E., Lundeen, H. C., Brehnan, K., Walsh, E. K., & Holbrook, W. B. (1981b). Occlusal forces during chewing and swallowing as measured by sound transmission. *The Journal of Prosthetic Dentistry*, *46*(4), 443-449. https://doi.org/10.1016/0022-3913(81)90455-8

Gibbs, C. H., Messerman, T., Reswick, J. B., & Derda, H. J. (1971). Functional movements of the mandible. *The Journal of Prosthetic Dentistry*, *26*(6), 604-620. https://doi.org/10.1016/0022-3913(71)90085-0

Gibbs, C. H., Wickwire, N. A., Jacobson, A. P., Lundeen, H. C., Mahan, P. E., & Lupkiewicz, S. M. (1982). Comparison of typical chewing patterns in normal children and adults. *Journal of the American Dental Association*, *105*(1), 33-42. https://doi.org/10.14219/jada.archive.1982.0073

Hori, N., Yuyama, N., & Tamura, K. (2004). Biting suppresses stress-induced expression of corticotropin-releasing factor (CRF) in the rat hypothalamus. *Journal of Dental Research*, *83*(2), 124-128. https://doi.org/10.1177/154405910408300208

Kaidonis, J. A. (2008). Tooth wear: The view of the anthropologist. *Clinical Oral Investigations*, *12*(S1), 21-26. https://doi.org/10.1007/s00784-007-0154-8

Kullmer, O., Benazzi, S., Fiorenza, L., Schulz, D., Bacso, S., & Winzen, O. (2009). Occlusal fingerprint analysis: Quantification of tooth wear pattern. *American Journal of Physical Anthropology*, *139*(4), 600-605. https://doi.org/10.1002/ajpa.21086

Lavigne, G. J., Khoury, S., Abe, S., Yamaguchi, T., & Raphael, K. (2008). Bruxism physiology and pathology: An overview for clinicians. *Journal of Oral Rehabilitation*, *35*(7), 476-494. https://doi.org/10.1111/j.1365-2842.2008.01881.x

Manfredini, D., Ahlberg, J., Castroflorio, T., Poggio, C. E., Guarda-Nardini, L., & Lobbezoo, F. (2014). Diagnostic accuracy of portable instrumental devices to measure sleep bruxism: A systematic literature review of polysomnographic studies. *Journal of Oral Rehabilitation*, *41*(11), 836-842. https://doi.org/10.1111/joor.12207

McEwen, B. S., & Gianaros, P. J. (2010). Central role of the brain in stress and adaptation: Links to socioeconomic status, health, and disease. *Annals of the New York Academy of Sciences*, *1186*(1), 190-222. https://doi.org/10.1111/j.1749-6632.2009.05331.x

Messerman, T. (1967). A means for studying mandibular movements. *The Journal of Prosthetic Dentistry*, *17*(1), 36-43. https://doi.org/10.1016/0022-3913(67)90048-0

Miranda, J. S., Barcellos, A. S. de P., Oliveira, A. de S., Paradella, T. C., Kimpara, E. T., & Chaves, M. das G. A. M. (2017). Are non-carious cervical lesions more frequent in sleep bruxism patients? *Brazilian Dental Science*, *20*(4), 49-54. https://doi.org/10.14295/bds.2017.v20i4.1445

Miyake, S., Yoshikawa, G., Yamada, K., Sasaguri, K., Yamamoto, T., Onozuka, M., & Sato, S. (2012). Chewing ameliorates stress-induced suppression of spatial memory by increasing glucocorticoid receptor expression in the hippocampus. *Brain Research*, *1446*, 34-39. https://doi.org/10.1016/j.brainres.2012.01.011

Montastruc, J.-L. (2023). Drugs and bruxism: A study in the World Health Organization's pharmacovigilance database. *British Journal of Clinical Pharmacology*, *89*(12), 3765-3768. https://doi.org/10.1111/bcp.15884

Nukazawa, S., Yoshimi, H., & Sato, S. (2018). Autonomic nervous activities associated with bruxism events during sleep. *CRANIO®: The Journal of Craniomandibular & Sleep Practice*, *36*(2), 106-112. https://doi.org/10.1080/08869634.2017.1287232

Ohayon, M. M., Li, K. K., & Guilleminault, C. (2001). Risk factors for sleep bruxism in the general population. *CHEST*, *119*(1), 53-61. https://doi.org/10.1378/chest.119.1.53

Ono, Y., Kataoka, T., Miyake, S., Cheng, S.-J., Tachibana, A., Sasaguri, K., & Onozuka, M. (2008). Chewing ameliorates stress-induced suppression of hippocampal long-term potentiation. *Neuroscience*, *154*(4), 1352-1359. https://doi.org/10.1016/j.neuroscience.2008.04.057

Ono, Y., Kataoka, T., Miyake, S., Sasaguri, K., Sato, S., & Onozuka, M. (2009). Chewing rescues stress-suppressed hippocampal long-term potentiation via activation of histamine H1 receptor. *Neuroscience Research*, *64*(4), 385-390. https://doi.org/10.1016/j.neures.2009.04.011

Onodera, K., Kawagoe, T., Sasaguri, K., Protacio-Quismundo, C., & Sato, S. (2006). The use of a BruxChecker in the evaluation of different grinding patterns during sleep bruxism. *CRANIO®: The Journal of Craniomandibular & Sleep Practice*, *24*(4), 292-299. https://doi.org/10.1179/crn.2006.045

Park, J.-M., & Ahn, J.-M. (2020). Association between torus mandibularis, self-reported bruxism and occlusion. *Oral Biology Research*, *44*(1), 32-36. https://doi.org/10.21851/obr.44.01.202003.32

Piehslinger, E., Čelar, A. G, Čelar, R. M., Jäger, W., & Slavicek, R. (1993). Reproducibility of the condylar reference position. *Journal of Orofacial Pain*, *7*(1), 68-75.

Piehslinger, E., Čelar, A. G., Čelar, R. M., & Slavicek, R. (1991). Computerized axiography: Principles and methods. *CRANIO®: The Journal of Craniomandibular & Sleep Practice*, *9*(4), 344-355. https://doi.org/10.1080/08869634.1991.11678382

Richter, S., & Eliasson S. T. (2012). Prevalence of torus mandibularis in Viking Age Icelanders. *Bulletin of the International Association of Paleodontology*, *6*(2), 40-50.

Sasaguri, K., Kikuchi, M., Hori, N., Yuyama, N., Onozuka, M., & Sato, S. (2005). Suppression of stress immobilization-induced phosphorylation of ERK 1/2 by biting in the rat hypothalamic paraventricular nucleus. *Neuroscience Letters*, *383*(1-2), 160-164. https://doi.org/10.1016/j.neulet.2005.04.011

Sato, C., Sato, S., Takashina, H., Ishii, H., Onozuka, M., & Sasaguri, K. (2010). Bruxism affects stress responses in stressed rats. *Clinical Oral Investigations*, *14*(2), 153-160. https://doi.org/10.1007/s00784-009-0280-6

Sato, S., Sasaguri, K., Ootsuka, T., Saruta, J., Miyake, S., Okamura, M., Sato, C., Hori, N., Kimoto, K., Tsukinoki, K., Watanabe, K., & Onozuka, M. (2008). Bruxism and stress relief. In M. Onozuka & C.-T. Yen (Eds.), *Novel Trends in Brain Science* (pp. 183-200). Springer. https://doi.org/10.1007/978-4-431-73242-6_11

Sato, S., & Slavicek, R. (2008). The masticatory organ and stress management. *International Journal of Stomatology and Occlusion Medicine*, *1*, 51-57. https://doi.org/10.1007/s12548-008-0010-8

Sato, S., Yuyama, N., Tamaki, K., Hori, N., Kaneko, M., Sasaguri, K., Lee, M.-C.-i., Onozuka, M., & Slavicek, R. (2002). The masticatory organ, brain function, stress-release, and a proposal to add a new category to the taxonomy of the healing arts: Occlusion medicine. *Bulletin of Kanagawa Dental College*, *30*(2), 117-126.

Slavicek, G. (2010). Human mastication. *International Journal of Stomatology and Occlusion Medicine*, *3*, 29-41. https://doi.org/10.1007/s12548-010-0044-6

Slavicek, R. (1984). *Die funktionellen Determinanten des Kauorgans.* Verlag Zahnärztlich-Medizinisches Schrifttum.

Slavicek, R. (2002). *The Masticatory Organ. Functions and Dysfunctions*. GAMMA Medizinisch-wissenschaftliche Fortbildungs-AG.

Smith. G. N., & Robb, N. D. (1996). The prevalence of toothwear in 1007 dental patients. *Journal of Oral Rehabilitation*, *23*(4), 232-239. https://doi.org/10.1111/j.1365-2842.1996.tb00846.x

Sugimoto, K., Yoshimi, H., Sasaguri, K., & Sato, S. (2011). Occlusion factors influencing the magnitude of sleep bruxism activity. *CRANIO®: The Journal of Craniomandibular & Sleep Practice*, *29*(2), 127-137. https://doi.org/10.1179/crn.2011.021

Suit, S. R., Gibbs, C. H., & Benz, S. T. (1976). Study of gliding tooth contacts during mastication. *Journal of Periodontology*, *47*(6), 331-334. https://doi.org/10.1902/jop.1976.47.6.331

Toubol, J. P., & Michel, J. F. (1983). Le mouvement initial de Bennett. Expérimentation clinique, conséquences thérapeutiques. *Les Cahiers de Prothèse*, *42*, 69-87.

Toyama, N., Ekuni, D., Fukuhara, D., Sawada, N., Yamashita, M., Komiyama, M., Nagahama, T., & Morita, M. (2023). Nutrients associated with sleep bruxism. *Journal of Clinical Medicine*, *12*(7), 2623. https://doi.org/10.3390/jcm12072623

Tscharre-Zachhuber, C., & Riedl, M. A. (1988). Kaumusteruntersuchungen von Totalprothesenträger. *Zeitschrift* Für *Stomatologie*, *85*(7), 423-428.

Watson, J. T., & Schmidt, C. W. (2020). An introduction to dental wear in evolutionary and biocultural contexts. In C. W. Schmidt & J. T. Watson (Eds.), *Dental Wear in Evolutionary and Biocultural Contexts* (pp. 1-10). Elsevier. https://doi.org/10.1016/B978-0-12-815599-8.00001-0

Wickwire, N. A., Gibbs, C. H., Jacobson, A. P., & Lundeen, H. C. (1981). Chewing patterns in normal children. *The Angle Orthodontist*, *51*(1), 48-60.

Wilson, E. M., & Green, J. R. (2009). The development of jaw motion for mastication. *Early Human Development*, *85*(5), 303-311. https://doi.org/10.1016/j.earlhumdev.2008.12.003

Yoshimi, H., Sasaguri, K., Tamaki, K., & Sato, S. (2009). Identification of the occurrence and pattern of masseter muscle activities during sleep using EMG and accelerometer systems. *Head & Face Medicine*, *5*(1), 7. https://doi.org/10.1186/1746-160X-5-7