

Why anthropologists and dentists should work in synergy to improve oral health (in Latin America)

Por qué antropólogos y odontólogos deberían trabajar en coordinación para mejorar la salud bucodental (en América Latina)

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Abstract

Various aspects of the craniomandibular system should be investigated to deepen our understanding of the proximate and evolutionary causes of the most common oral diseases in modern humans. Central American and South American populations are afflicted by a high prevalence of caries and, in general, suffer from poor oral health. Moreover, they have limited access to professional health care, which makes it even more urgent to focus research in these regions.

Given the multifactorial nature of the determinants underlying oral diseases, and considering the complexity of the stomatognathic system, an interdisciplinary approach involving anthropologists, dentists, and orofacial pain specialists, among others, seems to be the most suitable to carry out research addressing the most common oral diseases and their possible functional and social effects on the individual.

Anthropologists and dentists share a common interest in the craniomandibular system, its morphological variation and its diseases, and have traditionally used similar research methods. By combining their different skill sets, these professionals could work synergistically to generate relevant knowledge that may support all those con-

cerned and may reach policymakers in oral health care. Their close collaboration would help identify the most relevant health issues, collect epidemiological data, and understand their implications for individual well-being, thereby addressing the needs of the target populations in compliance with local ethical regulations. *Rev Arg Antrop Biol* 26 (2), 081. <https://doi.org/10.24215/18536387e081>

Keywords: stomatognathic system; craniomandibular disorders; modern humans; function; morphology

Resumen

Varios aspectos del sistema craneomandibular deben ser investigados para profundizar nuestra comprensión de las causas próximas y evolutivas de las enfermedades orales más comunes en poblaciones humanas. Las poblaciones de América Central y América del Sur se ven afectadas por una elevada prevalencia de caries y, en general, padecen una salud bucodental deficiente. Por otra parte, tienen un acceso limitado a la atención sanitaria profesional, lo que hace aún más urgente la necesidad de centrar la investigación en estas regiones.

Dada la naturaleza multifactorial de los determinantes que subyacen a las enfermedades bucodentales, y considerando la complejidad del sistema estomatognático, el trabajo interdisciplinar entre antropólogos, odontólogos, especialistas en dolor orofacial, entre otros, parece ser el más adecuado para llevar a cabo investigaciones que aborden las enfermedades bucodentales más comunes y sus posibles efectos funcionales y sociales en el individuo.

Antropólogos y odontólogos comparten un interés común en el sistema craneomandibular, su variación morfológica y sus dolencias, y tradicionalmente han utilizado métodos similares para su investigación. Combinando los diferentes conjuntos de habilidades que poseen, estos profesionales podrían trabajar sinérgicamente para generar conocimientos relevantes que apoyen a las partes interesadas y puedan llegar a los responsables políticos de la atención de la salud bucodental. Su estrecha colaboración ayudaría a identificar los problemas de salud más relevantes, recopilar datos epidemiológicos y comprender sus implicaciones en el bienestar individual, respondiendo así a las necesidades de las poblaciones de estudio y cumpliendo la normativa ética local. *Rev Arg Antrop Biol* 26 (2), 081. <https://doi.org/10.24215/18536387e081>

Palabras Clave: sistema estomatognático; trastornos craneomandibulares; humanos modernos; función; morfología

The health of the stomatognathic system influences individuals' general well-being since the oral structures are involved in vital functions including respiration, swallowing and mastication, but also speech and stress management. For example, diminished oral function has been associated with oesophageal gastric reflux (Kuze *et al.*, 2023), and missing teeth in children might result in poorer speech quality (Nadelman *et al.*, 2020). Untreated dental decay is a known risk factor for myocarditis (Fung *et al.*, 2016) and has been associated with brain abscess (Kichenbrand *et al.*, 2020). Dental pain and missing teeth might cause functional problems deriving from habitual unilateral mastication, muscle pain and spasms, and compression at the temporomandibular joints (Nguyen *et*

al., 2021). The association between orofacial pain, anxiety and depression is investigated both in the medical (Honda *et al.*, 2018) and in the scientific literature (Barroso *et al.*, 2021).

Clearly, oral hygiene and health are of utmost importance for people's quality of life and the detrimental consequences of poor oral health on the function of the stomatognathic system go beyond the obvious adverse effects of acute pain and infections. Therefore, I maintain that to appreciate the magnitude of the oral health emergency in disadvantaged human groups we need to acquire a deeper knowledge of the stomatognathic system and its functions. Oral health depends on many factors, including anthropological, morphological, historical, cultural and economic variables. Thus, understanding the human stomatognathic system, its functions and ailments is a complex task achievable through the teamwork of specialists from different fields. Improving oral health on a large scale is a challenging task, as oral ailments are deeply rooted in society. Thus, advances in the field of oral care, especially in economically disadvantaged regions, would require the joint effort of authorities and specialists from different sectors and disciplines, including, but not limited to, clinicians, scientists, educators, economists, politicians, industries and benefactors.

In this paper, I aim to discuss how the collaboration between anthropologists and dentists could help improve oral health by identifying and investigating the most relevant problems to address, thereby gathering the necessary evidence to inform the stakeholders. They could also play a crucial role in reaching out to human groups in remote geographical areas with more capillary actions than might be possible through the services of the public health care system. Thus, through a critical narrative review of the anthropological and the clinical literature, I will circumstantiate my claim that a collaboration between anthropologists and dentists shall support advancements in oral health care (see the section "Materials and Methods" for more details). To contextualize this discussion, I will focus on the current understanding of oral health in people from Central and South America for the rest of this introduction.

Oral health in Central and South America is a matter of great interest and concern as the generally poor oral conditions are paralleled by the lack of proper health care (Sampaio *et al.*, 2021), a phenomenon common in low- and middle-income countries and marginalized human groups (see, Poni *et al.*, 2023, in relation to the Baka pygmies of Cameroon, Africa). Malnutrition, combined with insufficient hygienic measures and unavailability of medical assistance, makes the poorest groups, mostly indigenous populations, marginalized groups and individuals living in rural areas, vulnerable to several health conditions (Galante *et al.*, 2022). A recent report highlighted the criticality of oral health in most Latin American countries (Duran *et al.*, 2018; Sampaio *et al.*, 2021) where the prevalence of caries is above 50% in children and 85% in adults, thus approximately 1.5 and 2.5 times higher than in Europe, respectively (<https://www.who.int>).

The case of the Lenca people of Honduras is emblematic due to their condition as an economically disadvantaged and geographically isolated human group. The Lenca represents a marginalized human population living in extreme poverty with a low quality of life. Some Lenca groups inhabit the interior highlands of Honduras where they practice subsistence agriculture while eluding malaria, which is widespread at lower altitudes. Because of the infertile soil of the highlands, they sustain themselves on a monotonous diet lacking proteins and vitamins, consisting of corn, beans, rice, and eggs (Hernández Santana *et al.*, 2019), and thus suffer from malnutrition. The poorest communities count on very limited food resources with insufficient daily calorie intake and, as a result, the stature of the individuals is shorter than the population average. A preliminary oral health

screening in the Lenca, conducted in the 2014 Mixcure community in the Intibucá Forest (Valle Galo *et al.*, 2018), revealed poor oral conditions, a high prevalence of dental decays in children and adults, and, consequently, a high occurrence of missing teeth in older individuals. Dental extraction, usually performed by non-medical operators, is the only available remedy to cure caries that the Lenca living in the forest might receive.

Based on a *Consensus for Dental Caries Prevalence, Prospects, and Challenges for Latin American and Caribbean Countries*, which was summarized in Sampaio *et al.* (2021) and stemmed from work conducted by Latin American oral health experts, Martignon *et al.* (2021) identified caries predisposing factors. Among the recognized etiological determinants, including socioeconomic, cultural and biological (individual) variables, the authors stressed the fact that the socioeconomic context plays a decisive role in the onset of caries and periodontal diseases. Despite regional differences, Latin American countries share similar social and cultural risk factors to caries, namely a high amount of sugar intake — estimated to be about 40 kg per capita per year, over twice the amount consumed in Asia and Africa (Sampaio *et al.*, 2021)— aggravated by deficient oral hygiene. Ricomini Filho *et al.* (2021) discussed the most effective strategies for caries prevention including the use of fluoride and occlusal sealant, and restriction of sugar consumption. They observed that fluoridation programs as well as campaigns for control of sugar intake require effective strategies, regional control and culturally targeted interventions. Along the same lines, Galante *et al.* (2022) discussed the common difficulties in implementing changes in the oral care system, and identified several barriers and facilitators in the improvement of oral health in Latin America. According to the authors, the main fundamental problem is represented by the lack of systematic epidemiological studies or the unavailability of data for research, resulting in a deficit of crucial information for planning further actions. Despite the recent increase in the number of dentists in Latin American countries, the authors expressed concerns about the uneven distribution of oral care professionals across the territory, mostly unwilling to work for the public service and out of the cities. Thus, they concluded that the development and implementation of public policies are necessary, and should be put in place through reinforcing human resources in public settings. For that, Galante *et al.* (2022) stressed the important role that academia should have in supporting this process by informing the stakeholders and, not secondarily, by contributing to population health literacy.

In 2020, the World Health Organization (WHO) published its agenda for the inclusion by 2030 of noncommunicable oral diseases such as caries, tooth loss, periodontitis and oral cancer into primary care acknowledging that “access to prevention, early diagnosis and treatment of oral diseases is far from universal and remains unattainable for millions of people” (p. 4). In the same year, the WHO established the council “Health for all: Transforming economies to deliver what matters” (<https://www.who.int/publications/m/item/health-for-all--transforming-economies-to-deliver-what-matters>), to promote a medium- and long-term economic plan for making health care accessible to the poorest. If financial plans are in the hands of economists and politicians, it is the responsibility of clinicians and researchers to contribute the relevant knowledge necessary to guide policymakers. Here, I will report on the biological and cultural factors relevant to the development of oral pathologies with particular emphasis on craniomandibular dysfunctions, and explain why interdisciplinary research including anthropologists and dentists should join forces for the advancement of oral health care, particularly for the sake of economically disadvantaged groups.

MATERIALS AND METHODS

This work is based on evidence retrieved from the anthropological and clinical literature useful to substantiate my proposal about the need for research collaborations between anthropologists and clinicians for the improvement of oral health, especially in low- and middle-income countries, and with a particular focus on Latin America. By highlighting aspects regarding the epidemiology of craniomandibular dysfunctions, as well as the importance of understanding the functional and clinical implications of human craniofacial variation, I aim to show how anthropologists and dentists are among the most suited professionals to conduct research with biological and medical relevance for the understanding of the stomatognathic system and its pathologies. This point will be developed also from a historical perspective, showing that similar tools and methods for the study of the human stomatognathic system have been in use within both disciplines, showing ample shared ground for research and educational activities.

RESULTS

The epidemiology of craniomandibular dysfunctions

Given their prevalence and burden on society, prevention and treatment of dental caries as well as periodontal diseases and oral cancer have channelled the attention of clinicians and oral health organizations. However, it is also important to acknowledge how the function of the stomatognathic system can be compromised by these ailments. Additionally, other conditions such as malocclusion, which is common to all humans in modern societies (e.g., Cenzato *et al.*, 2021) and partly dependent on socioeconomic factors (Kenessey *et al.*, 2023) have profound functional implications on the stomatognathic system, diminishing its efficiency and affecting the general health and quality of life. Thus, the importance of assessing the prevalence of malocclusion and dysgnathia becomes apparent. While for Brazil the topic is well represented in the literature (see the recent systematic review and meta-analysis by Lombardo *et al.*, 2020), information for other South American countries is sporadic. For Central American populations, accounts of malocclusion are virtually inexistent, but a documentation effort is represented by two related atlases (Andrino *et al.*, 2002a, 2002b) reporting longitudinal, cephalometric evaluation of two groups of children from Guatemala, one focused on populations with admixed origin and the other on the Tzutuhil indigenous group. It follows that the association between malocclusion and dysfunctions is poorly studied in Latin American and Caribbean countries. Not only that, the detrimental effects on stomatognathic function of dental pain and missing teeth –which are the most obvious consequences of dental decay– have been hinted at (e.g., Sampaio *et al.*, 2021; Valle Galo *et al.*, 2018), but to my knowledge, no systematic assessment has ever been performed up to now for Central or South America.

Concerning oral function, a recent work (Slade & Durham, 2020) reported that at least 5% of the US American adults presented signs and symptoms of craniomandibular dysfunction requiring treatment. Based on this assessment, a consensus document was recently published setting priorities and recommendations for addressing the problem of craniomandibular dysfunctions, a set of conditions mainly affecting the face and neck area (National Academies of Sciences, Engineering, and Medicine, 2020). Craniomandibular dysfunctions manifest through muscle and articular pain, and articular degeneration of the temporomandibular joint with consequent functional limitations. A similar effort

should be spent to the benefit of Latin American populations, especially considering that contrary to countries in the Global North, Latin Americans have limited access to oral care, and even more so in rural areas. Endeavors were made to document the prevalence of craniomandibular dysfunctions in a few groups from some Latin American countries (Progiante *et al.*, 2015, Brazil; Restrepo *et al.*, 2021, Colombia; Sandoval *et al.*, 2015, Chile; Thilander *et al.*, 2002, Colombia) which seemed to confirm similar prevalence observed in other regions of the world. Even less documented is the prevalence of craniomandibular dysfunction in indigenous Latin American populations (but see, Jagger *et al.*, 2004, for the Quechua and Colorado Indians of Ecuador). As repeatedly stressed (e.g., Galante *et al.*, 2022; Sampaio *et al.*, 2021; World Health Organization, 2020), epidemiological profiles are essential for planning healthcare policies and, thus, for the advancement of (oral) health. Therefore, efforts should be directed to the assessment of oral health considering other stomatognathic system conditions such as malocclusion, orofacial pain and dysfunction. Differently from acute infections, inflammations or cancerous occurrences, craniomandibular dysfunctions might not be seen as medical emergencies but can be surely appreciated as medical priorities when their profound implications for the general well-being of the patient are understood.

An interdisciplinary team including anthropologists, morphologists and clinicians such as dentists and orofacial pain specialists would be better suited to carry out such studies. While the contribution of clinicians is fundamental for patients' diagnosis and their adequate treatment, anthropologists and morphologists possess complementary competencies suited to better address the associated or causal factors leading to the disease. Cultural and social anthropologists play a crucial role in the interaction with indigenous groups, to facilitate effective communication with the population in focus taking into account their traditions and beliefs. Understanding the socioeconomic background is of crucial importance to contextualize a disease and identify viable solutions. Retrieving information from past populations represents one of the ways to inform oral health, as, for example, Carvalho *et al.* (2019) showed based on archaeological findings, providing evidence that diet overpowers the effects of sexual hormones on oral health. Biological anthropologists and clinicians share an interest in the study of malocclusion and facial morphology as demonstrated in the iconic book by Corruccini (1999) "*How Anthropology Informs the Orthodontic Diagnosis of Malocclusion's Causes*", and reflected in numerous other works by this and other authors (see section "The role of culture and technological advancement", below). Morphometric competencies are required to analyse and interpret shape variation of the cranial and stomatognathic structures for its biological and clinical implications. This kind of morphometric research has a long tradition in anthropology and is as well established within the field of dentistry, as it will be discussed in the next section.

The importance of craniofacial variation

By now, it might be evident to the reader that the challenges in oral health care go beyond the ordeal of caries. Corrections of malocclusion and oral rehabilitations should be performed taking into account the shape of the face and the vertical, sagittal, and transversal relationships between the jaws. These key elements should be assessed before developing a treatment plan. The importance of facial growth and proportions for dentistry was recognized already in the 1940s when cephalometric evaluation was performed to support the diagnosis and treatment of malocclusion and dysgnathia or predict their

progress in children. In clinical settings, especially in the field of orthodontists, morphometric parameters mostly consisting of linear distances and angles are usually collected from lateral radiographic images and compared against population-specific reference values. The implementation of cephalometry into the dental practice was possible following the discovery of x-rays and the use of landmarks for morphometric analysis (Martin & Saller, 1957), and rested upon knowledge derived from growth and development studies (Björk & Skieller, 1977, 1983; Enlow & Harris, 1964). Works by the University of Michigan in the 1960s and 1970s deepened discussion on the suitability of cephalometric variables for evaluating vertical and horizontal facial growth (Enlow *et al.*, 1969), and identified possible deviations from the expected facial proportions at various developmental ages. In Moyers *et al.* (1979), a distinction was made between variables such as angles and ratios reflecting growth – thus showing changes through time - from those that instead represented craniofacial patterns, namely the constraints preserving integration of the craniofacial elements during growth. Although cephalometric evaluation based on linear distances and angles from 2D images has been criticized for their inherent methodological limitations (Moyers & Bookstein, 1979; but see also, Bookstein, 2016) the analyses developed by Ricketts (1961), McNamara (1984), and Slavicek (1984) are among the most popular and are still currently used, providing variables as well as reference values for the clinical interpretation of the patient's parameters.

The shape of the cranial and stomatognathic structures depends on several factors, including population and family history determining eventually the individual's unique morphology. Recent studies have contributed to the reconstruction of the complex population history of the Americas (Hubbe *et al.*, 2015; Menéndez *et al.*, 2015; Moreno-Mayar *et al.*, 2018) which is reflected also in high craniofacial variation (Bonfante *et al.*, 2021; Cramon-Taubadel *et al.*, 2017; Quinto-Sánchez *et al.*, 2015). Central America, a populations' crossroad, is currently home to various human groups with indigenous, Hispanic, and African genetic history backgrounds, living in different environments and with heterogeneous socio-economic conditions (Herrera-Paz, 2019). These topics are treated to a greater extent in other papers that are part of the current Dossier (Baldi & Herrera-Paz, 2024; Hubbe, 2024). It is clear then, that an assessment of cranial and especially facial variation in Central and South American populations is relevant for the sake of orthopaedic treatment and oral rehabilitation.

Similarly, cranial and facial proportions have been the focus of traditional anthropology since the 19th century. Human craniofacial morphology is of interest within biological anthropology, anatomy and genetics for the understanding of human growth and development, morphological variation and evolution. Craniofacial morphology is the outcome of genetic and developmental factors with a complex reciprocal influence on function. For example, wider and shorter faces have been associated with stronger masticatory muscles than narrow and elongated faces in anthropological (Sella-Tunis *et al.*, 2018) and clinical studies (Bonakdarchian *et al.*, 2009; Ingervall & Helkimo, 1978). It is also known that muscle fiber composition of the masseter changes depending on facial vertical dimensions, in relation to skeletal class II (namely, showing retrognathic mandible) and III (showing prognathic mandible), with a higher percentage of fatigue-resistant type I fibers than type II fibers in subjects with higher vertical dimension (Sciote *et al.*, 2012; 2013). Similarly, the rate of type I to type II fibers in the masseter changes between sides of the same individual when facial asymmetries are present, with the lower side of the face presenting a masseter muscle with a higher percentage of fast-twitching, non-fatigue-resistant muscle fibers type II (Rowlerson *et al.*, 2005). Certain pathologies are also

associated with characteristic facial shapes. For example, conditions that cause facial muscle weakness, such as airway obstruction or Duchenne muscular dystrophy result in abnormally elongated face and open bite (Eckardt & Harzer, 1996; Tourne, 1990). From this brief overview of the importance of craniofacial morphology in biology and medicine, it is clear that research exploring craniofacial variation and its functional implications would inform both anthropology and dentistry alike.

The role of culture and technological advancement

Because of its plasticity, the growth and development of the stomatognathic system are influenced by exogenous in addition to endogenous factors, including trauma, pathologies, malocclusions, but also oral behaviors and diet. Accordingly, understanding the contributions of these variables in shaping the masticatory system is of clinical relevance. Modern diet has been indicated as one of the main determinants for an increased prevalence and severity of malocclusion, especially after the Industrial Revolution (Wrangham, 2009). Through the interpretation of the effects of technological changes in the extraoral preparation of food, resulting in refined, easy-to-chew aliments, both proximate and ultimate explanations for the high rate and marked expression of malocclusions can be provided (see Fornai, 2023, for a recent account on this topic). In short, it can be said that modern food does not require high or prolonged masticatory effort which means that it does not challenge the masticatory system during growth, thus resulting in less-than-ideal development of the face and altered dental eruption.

On the other hand, malocclusions and dysgnathia do not seem to reduce fitness in modern societies because of a relaxed natural selection on phenotypes performing with lower chewing efficiency. This concept was corroborated by Eyquem *et al.* (2019) who, by studying crania from recent and past Chilean and Argentinean populations, confirmed that presence of strong morphological covariation between the maxilla and the upper face, although the degree of variation in the recent populations was higher most probably due to decreased developmental constraints. The same group of research (Toro-Ibacache *et al.*, 2019) also showed a very clear distinction in mandibular morphology (rather than mandibular size) between past and recent populations. Similarly, through biomechanical simulations, Stansfield *et al.* (2018) interpreted the morphological differences between recent and prehistoric human mandibles as the result of reduced loading history during ontogeny in recent humans. The effects of soft food on craniomandibular development and masticatory performance have been investigated in various ways through observational studies comparing human populations with different diets, from rural and urbanized areas (Corruccini *et al.*, 1985), and animal experimental models (Corruccini & Beecher, 1982; Fujishita *et al.*, 2015; Lieberman *et al.*, 2004), consistently demonstrating reduced masticatory forces and dexterity.

Reduced occlusal and interproximal dental wear is another obvious consequence of the modern diet. While biological anthropologists are familiar with the concept of progressive dental wear as a physiological process resulting from the regular usage of teeth in a highly abrasive environment (Cucina, 2024), pronounced dental wear usually raises the concerns of clinicians because, in modern societies, it might be indicative of excessive bruxing activity (Assis & Londoño, 2024), which causes an overload of the masticatory muscles and supporting dental structures. When interpreting the stomatognathic condition of modern humans, these two perspectives reconciled in works carried out by dentists contributing knowledge about the evolutionary and secular changes of the hu-

man stomatognathic system (Begg, 1954; Jonke *et al.*, 2008; Ricketts *et al.*, 2004; Türp, 2019), and anthropologists exploring the condition of contemporary humans and the challenges faced in clinical settings (Alt *et al.*, 2017; Carvalho *et al.*, 2019; Kaidonis *et al.*, 2014). Through the detailed study of occlusal microwear, precious information can be acquired from teeth providing indications about the individual's diet and environment (e.g., El Zaatari & Hublin, 2014), although these protocols have not been yet successfully applied to living subjects because of technical limitations (Correia *et al.*, 2021). Instead, the analysis of macrowear has revealed more success in informing about functional aspects of the masticatory cycle, also in living subjects. A recent anthropological work by Silvester *et al.* (2021) showed how changes in food preparation between England's medieval and post-industrial times resulted in different occlusal patterns reflecting a functionally distinct power stroke during the chewing cycle. In particular, the medieval sample managed to produce flatter occlusal surfaces by exerting higher shearing forces, which, as known from experimental studies, are required to comminute harder and tougher food items (Laird *et al.*, 2020). Conversely, the consumption of softer, more refined foods resulted in a punctiform power stroke in the more recent sample, as the lateral component of masticatory movements was reduced. This study represents an excellent demonstration of how anthropology can inform dentists, and suggests a high potential of these methods for further research with clinical applications.

Besides focusing on the effects of modern food, the combined effort of anthropologists and clinicians should extend to the investigation of other aspects of industrialization and technological advancements that are known to negatively impact the development of the face and the function of the masticatory system. For example, pollution has to be considered in relation to the increase of airway obstructions (Lin *et al.*, 2022), reduced levels of wear and malocclusions have been associated with micro trauma causing failure of the dental crown (Benazzi *et al.*, 2013) or degenerative conditions of the temporomandibular joint (Sagl *et al.*, 2022).

Common methods and tools for the study of the stomatognathic system

In respect to data collection, working with living subjects poses different challenges than skeletal remains. In both cases, non-invasive approaches should be preferred to minimize the health risks in the living subjects and preserve the integrity of the human remains. Metric and non-metric data and landmark coordinates can be sampled directly from the individual. Alternatively, the anatomical area of interest can be imaged through photos, x-ray-based techniques or magnetic resonance, and can be replicated *via* surface scans or casts, as is customary for teeth. This section was not meant to be exhaustive of all possible methods and tools in use for the investigation of the craniomandibular system, but aimed to provide some examples of suitable approaches that both anthropologists and dentists have traditionally applied. As aforementioned, these include tools for the morphometric evaluation of the face, jaws and teeth, like cephalometry and other landmark-based methods such as geometric morphometrics on 2D (Katsadouris & Halaizonetis, 2016) or 3D images (Huanca Ghislanzoni *et al.*, 2017).

Geometric morphometrics is a set of statistical tools for the study of shape covariation based on the analysis of landmark coordinates (Mitteroecker & Schaefer, 2022). It differs fundamentally from traditional cephalometric analysis, which is based on linear distances between landmarks and derived angles. The (biological) objects are represent-

ed by a configuration of landmarks that need to be normalized (superimposed) before the square root of the sum of squared differences between homologous landmarks, are computed. Landmark collection should respect the principle of homology to guarantee the consistent representation of the same points or structures across the sample. This quantity, called Procrustes difference, is a measure of the differences in the shape of the analyzed objects as represented by the chosen landmarks and can be further analysed to assess within- and between-group shape variation. Unlike conventional cephalometric analysis, geometric morphometric methods present the advantage of preserving the spatial relationships between points, thus representing a more suitable tool for the analysis of shape.

Besides morphometrics methods, which can be used for the evaluation of dental and skeletal deviations, malocclusions have been assessed in dentistry as in anthropology through grading systems developed for the analysis of the type and severity of malocclusions and their impact on the individual. One of the most known and used approaches is the 1899 classification system by Edward Angle, based on the anteroposterior relationship between the mesiobuccal cusp of the maxillary first molar and the buccal groove of the mandibular first molar. Other systems in use are more focused on aesthetics, such as the Dental Aesthetic Index (DAI) (Cons *et al.*, 1986), which is recommended by the WHO, or are suitable to assess dental crowding (Pilloud, 2018) or the need for orthodontic treatment (Index of Orthodontic Treatment Need, IOTN) based on dental health and aesthetics (Brook & Shaw, 1989).

Dental surfaces can be investigated in more detail to score the degree of dental wear (Molnar, 1971). However, as mentioned above, methods exist for the analysis of morphometric characteristics of macrowear (Occlusal Fingerprint Analysis, OFA) including the number, extension, dip and inclination of the occlusal facets (Kullmer *et al.*, 2009). The variables can be interpreted functionally also through a dedicated software called Occlusal Fingerprint Analyzer (<https://www.paleontology.uni-bonn.de/de/forschung/ehemalige-forschergruppen/for-771-ofa/occlusal-fingerprint-analyser-ofa>). This methodology requires the use of high-end equipment, including high-resolution dental casts, digital models of the casts and CAD software, but has shown great potential in the anthropological and paleoanthropological field, and is open for applications in clinical settings. Alternatively, various, more simple techniques are in use to assess dental occlusion in the living, such as the occlusogram (White, 1982), consisting of a wax sheet placed between the upper and lower teeth. Recordings are performed in maximum intercuspatation and during basic movements such as protrusion and mediotrusion, thus allowing a comparative assessment of the marks left by the teeth on the wax. These marks can be clinically interpreted by evaluating the presence of undesired contacts (or interferences) or missing areas of contact. Instead, bruxing activities can be monitored through the BruxChecker®, a thin foil adhering to the patient's teeth that can be used during the day or while sleeping and that wears down through the tooth-to-foil contact (Onodera *et al.*, 2006). This method is informative and affordable compared to polysomnography, which is considered the gold standard for the assessment of sleep quality and sleep bruxism when used in combination with electromyography, but is of difficult application. Polysomnography is expensive, and sleep laboratories are available at a few locations, while portable devices do not offer a comparable level of accuracy (Yanez-Regonesi *et al.*, 2023).

Other functional aspects of the stomatognathic system, such as masticatory forces and efficiency, that, for obvious reasons, can be recorded in living subjects only, can be obtained using relatively simple tools such as strain-gauge, piezoelectric and pressure

transducers in the laboratory as in the field. However, the recording of bite forces remains challenging since the reproducibility of results using different devices has not been tested (Verma *et al.*, 2017). Various methods have been used also for assessing chewing performance, some of which are relatively simple and inexpensive, such as colorimetric tools like two-color chewing gums which assess mixing ability, or food-based tests where the size of the comminuted particles is measured. Data stemming from some of the approaches mentioned here could be combined to explore clinical, morphometric and functional variables thereby deepening our understanding of the stomatognathic system.

DISCUSSION

The account provided above about the relevant biological and cultural factors influencing oral health yielded evidence that anthropology and dentistry can operate based on a common understanding of the stomatognathic system and its functions. This fact is corroborated by the report on the methods and tools suitable for the study of the masticatory system that have been shared by biological anthropologists and dentists throughout the history of these disciplines. Because of the overlap in their aims to understand the biological, clinical and social implications of oral pathologies and craniomandibular dysfunctions, it is evident that anthropologists and dentists are likely to share several or numerous research interests. These include fundamental knowledge on the craniomandibular and its functions, prevalence and etiology of its ailments including the contribution of economic, cultural and social factors, as well as the exploration of the effects of oral pathologies and dysfunctions on the individual quality of life. Thus, successful collaboration could stem from the combination of the complementary competencies and set of skills that these two professional figures possess.

Having established this background information, I will discuss the principles of good clinical practice and work ethics for interdisciplinary work supporting oral health. Compliance with these principles is necessary to reduce the risk of inequalities and inequities in oral health as well as in research collaborations, especially when working with disadvantaged groups. I will also elaborate on why research, education and clinical practice should be considered three inseparable elements of the same mechanism promoting the progress of oral health care. Finally, I will conclude by presenting ideas for possible research projects specifically suggested to support Central American oral health care, but eventually applicable also in other countries.

Ethical considerations

Research on human subjects imposes the observations of ethical guidelines that are in place to safeguard the health and the rights of the participants. Thus, researchers have to familiarize themselves with the ethical guidelines of the country where the study is conducted and comply with its research rules (Varkey, 2020). One of the cornerstones of ethical research is informed consent, which implies that participants should give their assent to a specific research project after being well informed. The requirement for informed consent is crucial to guarantee the other fundamental principle of autonomy which is in place to ensure that participants in research involving human beings choose to take part in it based on their own free will, and confidentially. It follows that conforming to the rule

of informed consent carries with it a series of inherent difficulties, worthy of further consideration. In particular, it is important that the informed consent conveys all the relevant information about benefits and risks related to the experimental work carried out and that the participants are well aware of their rights. These include the freedom to leave the program at any time without any negative consequence, with assurance of continuous medical care if that is the purpose of the study. To be informative, the form should be formulated in a simple language accessible to non-professionals and additional care should be used to make sure that the main points of the research protocol are clear to the participants. This task becomes even more critical when cultural or linguistic barriers come into place. For example, in the case of research involving indigenous populations, it is of the essence that local representatives participate in the formulation of the informed consent and in the design of the research project itself. In so doing, the important principle of distributive justice is respected. This principle is meant to guarantee that the participants will be treated fairly, equitably and appropriately, specifically in the distribution of health care resources. The principle of justice, in turn, supports the principles of beneficence and non-maleficence which ensure that the research involving human beings is conceived to benefit the target group and not bring harm to the participants involved, being their individual rights considered superior to the right to do research or contribute to scientific or clinical knowledge.

In bioethics, exceptional care is taken for groups of people that for medical, psychological, cognitive, social, political or economic reasons are considered vulnerable or disadvantaged. Examples of such groups include marginalized individuals, who might be economically or socially weaker, or indigenous populations, for their geographical isolation, for instance, prisoners, whose freedom is reduced, or even students, whose academic success might be subjected to the evaluation of the investigators. In such cases, the direct benefit of the participants in the research project has to be proven, while researchers are asked to put in place measures to eliminate any possible coercion in the decision to participate in the study. The stricter ethical requirements necessary for working with disadvantaged groups pose additional challenges in conducting research projects, which might discourage researchers and investors. In turn, this results in an unfavorable situation where fundamental clinical or scientific knowledge about a certain group is lacking, exposing them to health risks (as in the case of insufficient testing of a certain drug or of a diagnostic approach) and in any case, it raises the problem of unjust distribution of health care resources. Coleman (2009) discussed these problems, suggesting that vulnerability should be considered as three possible distinct phenomena, which can be consent-, risk-, or justice-based. Accordingly, once the consent-based vulnerability is solved by making sure that the participants are well informed and can decide to participate in full autonomy (without coercion) and in confidentiality, risk- and justice-based vulnerabilities should be considered resolved. Otherwise, preventing them from taking part in the study should be considered a paternalistic decision resulting in the stigmatization of that individual or group of individuals. In this perspective, in the case of research work with indigenous people, marginalized groups or individuals living in remote areas, it should be made sure that effective communication is established thanks to facilitators such as the representatives of the communities. They speak the original language of the group, possess profound awareness of their needs, beliefs and traditions and act in their interest. The consent of the population should be sought by making sure that the main

aspects of the research are clear and the benefits are considered superior to the potential risks involved in the study, contributing directly to the health of the group. More recently, awareness has been raised on key elements for equitable research in the Global South (Ávila-Arcos *et al.*, 2022), which should entail active involvement of the local researchers and local communities for the establishment of long-term collaboration.

A Global Code of Conduct for Research in Resource-Poor Settings (GCC) was developed (Schroeder *et al.*, 2019) to promote equitable research by conforming to main values such as fairness, respect, care and honesty, which are at risk especially when research in low- and middle-income countries is carried out. In recent years, concerns have been raised regarding research led by foreign organizations in the Global South for the risk that the work performed and the acquired data could be exploited without an adequate return to the country of origin. Worse, the disregard for the ethical rules in place (ethics dumping) could result in the exploitation of individuals, communities, animals or the environment. For this reason, while designing a research project, it is important to identify all possible sources of vulnerabilities as recommended by Schroeder *et al.* (2019, p. 37-50). These considerations should extend to the research team in case of international collaborations involving investigators from both economically disadvantaged and high-income countries. Research is considered fair if the investigators from low- or middle-income countries are involved in a meaningful way and are adequately represented in publications, if the chosen topic is locally relevant, and proper transfer of knowledge is guaranteed (see also, Yáñez *et al.*, 2023). Respectful research projects are designed in collaboration with all partners and with joint ethical application. Care is ensured by the presence in the host country of a well-trained research ethics committee, adequately supported by national authorities. An independent ethics committee is necessary for honest research, which has to be conveyed by the investigators clearly and exhaustively.

The virtuous mechanism of research, education and clinical practice

A comprehensive assessment of a population's orofacial condition, including craniofacial variation, dental wear, the prevalence of malocclusion and oral pathologies in rural and urbanized settings would represent a step forward in the effort to advance oral health care. The appreciation of biometric variation of the stomatognathic system and related structures is fundamental in supporting disciplines such as biological anthropology, dentistry and orofacial medicine. Such advancement would be particularly important for Latin American countries, as well as other low- and middle-income regions of the world, and for all disadvantaged and marginalized human groups that are known to suffer the most from oral pathologies and their consequences. A similar endeavor should be carried out via collaborative efforts of professionals, including anthropologists, medical doctors, statisticians, and representatives of national institutions, among others. These professionals should collaborate for the identification of the most pressing clinical and social matters to address, and for the realization of scientific and clinical studies or missions with humanitarian, scientific and educational purposes directed at underprivileged, disadvantaged groups. Following on the example in the introduction of this article on the case of the Lenca people, the Mixcure community mission in the Intibucá Forest represented one of the several, but unfortunately still too rare, virtuous initiatives address-

ing the problem of caries (Valle Galo *et al.*, 2018). Differently from other humanitarian missions, it is possible for me to talk about it because its outcomes were published. This mission aimed to provide dental treatment to the Lenca people living in a remote area, the Intibucá Forest, who do not have regular access to oral care. At the same time, a preliminary screening of the prevalence of dental caries and missing teeth was conducted. Information about diet and some biometric parameters such as height, weight and facial proportions were collected. According to the ethical requirements of Honduras, treatment was provided to all individuals in need, regardless of whether they consented to data collection. The mission was carried out thanks to a team of volunteering dentists, medical doctors and assistants. It was partially self-financed and partially supported by benefactors contributing materials or means of transportation. Missions such as these present multiple advantages, including the acquisition of fundamental knowledge, immediate and direct help to the target group, sharing of relevant information to increase consciousness on oral health, and, eventually, awareness promotion among the public about the population's specific needs.

Besides the obvious positive outcomes for the studied group, such a synergic approach would be advantageous also to local academic institutions by contributing to the advancement of education through the interdisciplinary and possibly international character of the research. Numerous benefits would be observed, including students training, generation of new knowledge, publications of the obtained results and, possibly, the implementation of new methods and techniques in the local institutions.

CONCLUSIONS

Relevant research projects for Central and South America

In this conclusive section, I will illustrate some ideas for interdisciplinary projects that were discussed on the occasion of the "AnthropologyCA workshop: Anthropology meets Dentistry in Central America: Education and Research in Oral Biology" from which the homonymous, special Dossier hosting this article originated. After discussion, a consensus was reached on the projects briefly described below that were considered of common interest to the participating anthropologists and clinicians, and most of all, were deemed relevant in addressing some of the oral health needs of Central American populations. These projects should be developed thanks to the effort of an interdisciplinary team including anthropologists and dentists among other professionals and, hopefully, these research ideas could inspire other researchers too, in Latin America or elsewhere.

Oral health epidemiological profile of Central American indigenous people

Both local authorities and clinicians agreed on the impellent need to collect epidemiological data in Costa Rica as in other Central American countries as such reports are partial and outdated. For example, the only published report for the Lenca population of Honduras is a preliminary account of the prevalence of caries and facial biotypes based on a sample of 76 individuals (Valle Galo *et al.*, 2018). Because of a carbohydrate- and sugar-rich diet combined with the lack of regular oral hygiene, indigenous populations in Central America show a very high prevalence of caries (up to 100%) which inevitably leads to loss of teeth and eventually to diminished masticatory function and other orofa-

cial conditions such as muscle pain and temporomandibular joint degeneration. An epidemiological profile represents the basis for any well-planned and effective oral health campaign. The main goals of such an endeavor are:

- to assess the prevalence of caries and other oral diseases;
- to evaluate the functional and psychosocial consequences of such conditions;
- to eventually take action through prevention campaigns and new policies for treatment.

The health and function of the oral system in Central American populations are associated with diet, social and ethnic background, and various stages of maturation of teeth (i.e., deciduous, mixed and permanent dentition). Of utmost importance is to operate according to the will of the indigenous populations, respecting their cultures, traditions and beliefs. In this regard, we found ourselves in a fortunate position as our task force included clinicians and anthropologists with previous experience with the communities (such as the Lenca and Maya Ch'ortí, in Honduras, and the Ngäbe Buglé indigenous people of Coto Brusand, Costa Rica) and their representatives, that have already established a relationship of mutual trust and can instruct further missions. To optimize the benefits for the indigenous communities, we have discussed in detail short-, medium- and long-term interventions, including immediate dental treatment, education on nutritional and oral hygiene using local products, and additional medical training for the doctors operating within the communities for the assessment and treatment of functional disturbances with easy-to-apply approaches.

Assessment of elevated levels of stress on the masticatory system in university students

The Central American clinicians reported a tremendous amount of stress that Dentistry students undergo during their training. As students are a vulnerable group, we have discussed a program to be introduced in postgraduate courses monitoring their stress level through dedicated questionnaires (Schiffman *et al.*, 2014), bruxing activity through the use of a BruxChecker®, and the effect that this produced on their masticatory system through clinical investigation. While collecting data, once a year during the study program, the forming dental doctors should be instructed on the use of the questionnaires and BruxChecker®. Based on the study outcomes, interventions such as counselling or splints shall be provided to the students.

Secular trends in dentognathic morphological changes in relation to diet

Advancements in food technology have had a profound impact on the growth and development of the masticatory system. Changes have been noted starting from the transition from hunter-gatherers to early agriculturalists. For Europe, the most dramatic reduction of the masticatory structures associated with malocclusion was recorded with the occurrence of the Industrial Revolution and the concomitant introduction of a much softer and refined diet. Such dentognathic secular trends, informing oral medicine based on the principles of evolutionary medicine, have not yet been explored for Central American populations, thus, in collaboration with archeologists, we discussed performing such an investigation. These studies should build upon the information currently available for South American human groups (Eyquem *et al.*, 2019; Toro-Ibacache *et al.*, 2019).

In conclusion, based on their shared interest in the various aspects of the stomato-

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gnathic system, including its morphology and function, the evolutionary origin of its pathologies and dysfunctions, and the influence of biological, cultural, and social aspects on oral health, anthropologists and dentists should collaborate for their common intent to improve the understanding of the craniomandibular system as well as support the advancement of oral health care. Low- and middle-income countries and disadvantaged human groups who are most likely to suffer from the consequences of compromised oral health, would mostly benefit from such endeavors. The synergic work of anthropologists and dentists would allow addressing at best the suggested research and many other projects, thus this interdisciplinary collaboration should be sought and fostered for the benefit of people's oral health.

CONFLICT OF INTEREST STATEMENT

The author has no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

Cinzia Fornai: Conceptualization, financial acquisition, methodology, manuscript writing and editing (principal and only author).

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