Bioarchaeology International
Volume 5, Numbers 1–2: 47–67
DOI: 10.5744/bi.2021.1001

Classic Maya Dental Interventions: Evidence for Tooth Extractions at Piedras Negras, Guatemala

Joshua T. Schnell[a*] and Andrew K. Scherer[a]

[a]Department of Anthropology, Brown University, Providence, RI 02912, USA
*Correspondence to: Joshua T. Schnell, Department of Anthropology, Brown University, Box 1921, Providence, RI 02912, USA
e-mail: joshua_schnell@brown.edu

ABSTRACT: Tooth extractions are among the most common dental procedures performed globally today; however, archaeological evidence for such procedures in the past is relatively scant and largely limited to the Classical world. We present a case of therapeutic dental extractions of pathological teeth at the ancient Maya site of Piedras Negras, Guatemala, during the Late Classic period (A.D. 600–800). The evidence comes from an assemblage of fractured, pathological teeth (n = 127) recovered from the marketplace at Piedras Negras during excavations in 2016 and 2017. We compare the Piedras Negras marketplace teeth to the broader Late Classic period mortuary population at the site along three lines of analysis: (1) distribution of teeth by type (incisors, canines, premolars, and molars), (2) pathologies, including dental caries and calculus, and (3) dental wear. We also explore in detail the fracture patterns apparent in the marketplace assemblage. Our results indicate that the marketplace teeth display a significantly greater caries rate than the broader mortuary population and that posterior teeth (premolars and molars) are overrepresented in the marketplace sample. These findings point toward therapeutic extractions intended to ameliorate pain associated with oral pathologies. This article presents one of the few case studies of ancient health care in the Americas and situates these practices within the market, an important, urban space across much of precolonial Mesoamerica.

Keywords: Maya; dentistry; tooth extraction; paleopathology

Las extracciones dentales se encuentran entre los procedimientos dentales más comunes realizados a nivel mundial en la actualidad. Sin embargo, la evidencia arqueológica para tales procedimientos es relativamente escasa en el pasado y se limita en gran medida al mundo Clásico. En este artículo, se presenta un caso de extracciones dentales terapéuticas de dientes patológicos en el antiguo sitio maya de Piedras Negras, Guatemala, durante el periodo Clásico Tardío (600-800 d.C.). La evidencia de este caso proviene de una colección de dientes patológicos y fracturados (n = 127) recolectados en el mercado de Piedras Negras durante las excavaciones realizadas en los años de 2016 y 2017. Estos dientes fueron comparados con otros dientes recolectados alrededor del sitio en contextos mortuorios del periodo Clásico Tardío a lo largo de tres líneas de análisis: (1) la distribución de los dientes por tipo (incisivos, caninos, premolares y molares), (2) las patologías, incluyendo caries dentales y cálculo y (3) el desgaste dental. Asimismo, se exploró en detalle los patrones de fractura aparentes en la colección del mercado. Los resultados de este análisis indican que los dientes del mercado muestran una tasa de caries significativamente mayor que los dientes recolectados en contextos mortuorios y que los dientes posteriores (premolares y molares) se encuentran sobrerrepresentados en la muestra proveniente del mercado. Estos hallazgos demuestran el uso de extracciones terapéuticas designadas a aliviar el dolor asociado a las patologías bucales. Este artículo presenta uno de los pocos estudios de caso de atención médica en el pasado en las Américas y sitúa estas prácticas dentro del mercado, un importante espacio urbano que se encuentra a través de la Mesoamérica precolombina.

Received 27 July 2020
Revised 16 December 2020
Accepted 28 December 2020

Excavations in the Maya area (and elsewhere in the world) frequently produce isolated human teeth. Conventional wisdom is that these teeth come from disturbed burials and little further thought is given to their occurrence. In other instances, loose teeth have been found in Classic Maya ritual deposits and one interpretation holds that these were extracted from mourners as part of a royal mortuary rite (Scherer 2015a:154, 2015b). When we consider the loss of permanent teeth across human societies, both traumatic injury and extraction of carious and abscessed teeth are common occurrences (Cahen et al. 1985; Morita et al. 1994; Reich and Hiller 1993; Richards et al. 2005). And yet, archaeologically recovered isolated teeth are rarely understood within this framework, owing to the difficulty of reconstructing both the methods and contexts of ancient tooth extraction.

In this article, we provide evidence for tooth extractions at the Classic period (A.D. 350–900) Maya site of Piedras Negras, Guatemala (Fig. 1). Evidence for tooth extraction comes from a sample of 127 fractured and pathological teeth recovered in approximately 74 m^3 of excavated stratigraphy within the marketplace of Piedras Negras (see below), dating largely to the Late Classic period (A.D. 600–800). We compare the Piedras Negras marketplace tooth sample to that of the broader Piedras Negras mortuary sample along three lines of evidence: (1) distribution of tooth type, (2) pathology (caries and calculus), and (3) wear to determine whether the marketplace teeth, as a group, were markedly different from the general mortuary population. If the marketplace sample represents the remains of extraction, we expect a different composition in terms of tooth type (incisor, canine, premolar, molar) than that derived from the mortuary population where teeth should be represented in close to the same proportions as they are in living individuals. This is because oral pathologies that require extraction disproportionately affect the posterior teeth: premolars and molars (Demirci et al. 2010; Whittington 1999). Further, a greater incidence of pathology should be present in the marketplace sample if they were extracted for palliative reasons. Finally, less wear may be present in a sample of extracted teeth relative to the overall mortuary population, given that they were used for a shorter period of time than those teeth that followed their owners to the grave. In addition to these comparisons, we also consider the ante- and perimortem fracture patterns in the marketplace sample.

We hope our results inspire scholars working elsewhere in the Maya area, especially those excavating public quotidian spaces such as marketplaces, to look for similar patterns in their assemblage of human remains from non-mortuary contexts. Moreover, these data provide an important window into ancient health care practices in the Americas. Finally, the approaches taken here may prove useful for scholars interested in the study of ancient dentistry elsewhere in the world.

Figure 1. Regional map depicting location of Piedras Negras in relation to other archaeological sites mentioned in the text (map by J. Schnell).

Teeth in the Archaeological Record of the Maya Region

In the Maya area, aside from mortuary contexts, human teeth are found as part of isolated skulls in cases of decapitation (Barrett and Scherer 2005; Duncan 2011; Massey and Steele 1997; Whittington 2003) or pectorals and other objects manufactured from skulls (Scherer 2015a:100–102; Wrobel et al. 2019). Teeth also are found isolated from skulls, most often as a single tooth encountered in construction fill. There are examples, however, of intentional deposits of teeth that warrant further consideration. In Belize as well as the central and eastern Petén of Guatemala, loose human teeth have been found within lip-to-lip cache vessels and have been variously interpreted as offerings, sacrificial victims, and companion burials (Chase and Chase 1998; Pitcavage and Braswell 2010;

Scherer 2015b). Often, these caches are located within or associated with tombs and burials, usually of elite or royal individuals as at El Zotz, Guatemala (Scherer 2015b, 2018), or Pusilha and Cahal Pech, Belize (Awe et al. 2009; Cheetham 2004; Pitcavage and Braswell 2010).

In these contexts, teeth usually occur in small numbers, generally no more than four or five, although a few large deposits of teeth are known (Pendergast et al. 1968; Saul and Hammond 1974). In the case of cache vessels, human teeth are occasionally accompanied by human phalanges (e.g., Ricketson and Ricketson 1937:55–56). Vessels have also been found containing phalanges alone. Collectively, these are often referred to as tooth caches and finger bowls (Chase 1994; Chase and Chase 1994, 1998, 2011; Cheetham 2004; Norton 2016; Song et al. 1994). In other contexts, such deposits exist independent of any sort of vessel. In the cave of Actun Kabul, Belize, for example, several cultural scatters were found within the antechambers that contained isolated human skeletal elements. These were areas of intentional deposition and comprised primarily of human teeth and bones of the hands and feet (Shelton et al. 2015:24).

There are two prevailing explanations concerning the origins of the teeth, phalanges, and other bones in these cache deposits. Considering the small, portable nature of teeth and phalanges, it may be that these elements were collected from extant burials and kept on hand, and later deposited as part of ritual practice, perhaps at stations in established ritual circuits (Wrobel et al. 2013:132–133). The second concerns the removability of these elements from living persons. The teeth in these deposits are most often incisors, the teeth that are most easily avulsed from living persons *and* whose absence will have the least impact on masticatory function (Scherer 2015a:154). Similarly, the bones present are most often the distal and intermediate phalanges of the hand, both easier and more dramatic to remove than the comparable bones of the foot.

Archaeologists have recovered a few deposits consisting solely of teeth. At Lubaantun, Belize, for example, 59 loose teeth were found against the wall of a small structure at the far north end of the site core, dating to the Late Classic (ca. A.D. 700–800). They appear to have been buried as a single deposit (Saul and Hammond 1974:124). The Lubaantun deposit is unique in that it seems to be the intentional deposition of the complete dentitions of two individuals. The authors argue, based on the completeness of the dentitions and the preservation of the teeth, that they were recovered from a burial long after decomposition had occurred (Saul and Hammond 1974:124–126).

The largest deposit of loose teeth was excavated at the site of Yakalche, located just 16 miles northeast of Altun Ha, Belize. During the 1967 season of the Royal Ontario Museum's project at Altun Ha (Pendergast 1979), preliminary excavations at Yakalche yielded a total of 379 human teeth scattered in a single layer dated to the Postclassic period along the western face of a platform in the central area of the site (Pendergast et al. 1968). Unlike the Lubaantun cache, the Yakalche teeth come from a minimum of 43 individuals. Additionally, the majority (60.9%) of these teeth come from individuals aged 6 to 9 based on dental development (Pendergast et al. 1968:641). Unlike the restricted radius of the Lubaantun cache, the Yakalche teeth were encountered scattered along the face of a platform, often one at a time or in small groups of no more than five, within fill that overlaid the plaza floor (Pendergast et al. 1968:637–638). While the Yakalche deposit remains poorly understood, it highlights the range of contexts, quantities, and ages of the individuals represented in individuals represented in deposits of loose teeth in the Maya region.

Piedras Negras, Guatemala

The major Maya polity capital of Piedras Negras is located on the eastern shore of the Usumacinta River in the western region of what is now Guatemala's Parque Nacional Sierra del Lacandón. Piedras Negras was the seat of a royal dynasty that governed the community and greater kingdom throughout the Classic period (Proskouriakoff 1960). Its occupational history began ca. 250 B.C. in the Late to Terminal Preclassic period (Houston et al. 2000) and ended around A.D. 930 in the Terminal Classic period by which point most of the region was largely depopulated (Golden et al. 2008:252; Golden et al. 2016).

The site has been the focus of a number of archaeological projects since it was reported to the international community by Teobert Maler who visited the site in 1894 (Maler 1901). Subsequent visits by Sylvanus Morley in the early twentieth century eventually led to an expedition sponsored by the University of Pennsylvania from 1931 to 1939, directed by Linton Satterthwaite (Weeks et al. 2005:1–2). From 1997 to 2000, and again in 2004, the site was revisited by the Proyecto Arqueológico Piedras Negras (PAPN), directed by Stephen Houston and Héctor Escobedo (Escobedo and Houston 1997, 1998, 1999, 2001, 2005) and, from 2016 to 2017, the Proyecto Paisaje Piedras Negras–Yaxchilan (PPPNY) conducted excavations at the site under the direction of Andrew Scherer, Charles Golden, Griselda Pérez Robles, and Mónica Urquizú (Pérez Robles et al. 2016; Urquizú et al. 2017).

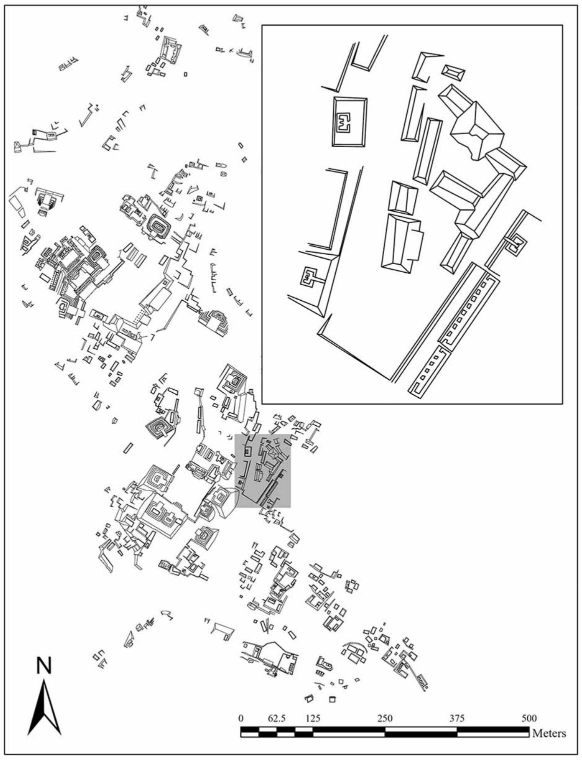

Figure 2. Map of the marketplace (inset) and its location within the Piedras Negras site core (digital map by Z. Nelson, N. Curritt, and T. Murtha with additions by J. Schnell based on original map by F. Parris and T. Proskouriakoff).

This paper deals directly with materials recovered during those two most recent field seasons of the PPPNY and with comparative data from the PAPN. Specifically, it focuses on excavations conducted within a series of three patio groups located in the S quadrant of the site, hereafter referred to as the Southeast Marketplace (Fig. 2).

Based on a density of materials recovered during early test excavations in the northernmost of these three patios (Escobedo 1997; Jackson and Hruby 2001; Urquizú 1998), Zachary Hruby, Richard Terry, and Mark Child of the PAPN proposed that this area may have functioned as Piedras Negras's market. When the PPPNY returned to the site, they sought to confirm this hypothesis and excavated a total of 29 units across these three patio groups, focusing largely on the open plaza spaces (Fig. 3). For detailed information on these excavations, see the original research reports (Pérez Robles et al 2016; Urquizú et al. 2017). These excavations yielded a larger than normal quantity of ceramic sherds, worked and unworked shell, lithic debitage and artifacts, unworked and worked skeletal material from both humans and animals, bone debitage, human teeth, and small quantities of greenstone, quartz, pyrite, and other stones (Roche Recinos and Matsumoto 2016; Roche Recinos et al. 2017).

As a result of these excavations, these three patio groups have been confirmed as a marketplace, now referred to as the Southeast Marketplace, with the supposition that the area covered by Operation 15I represents the focal point of marketing activities (Fig. 3; Golden 2017; Golden et al. 2020; Pérez Robles et al. 2017; Roche Recinos 2016; Roche Recinos and Matsumoto 2016; Roche Recinos et al. 2017; Scherer et al. 2017; Schnell 2017). The identification of Piedras Negras's marketplace builds off of prior observations that Classic period Maya markets are bounded by long-range structures (similar to S-17 and S-18) and may have a pyramidal structure similar to the small S-11 pyramid, as at Buenavista del Cayo, Calakmul, and Chunchucmil (Cap 2015a; Carrasco Vargas et al. 2009; Dahlin et al. 2007; Doyle 2012; Roche Recinos 2016:42–45; Tokovinine and Beliaev 2013). Pre-Columbian Mesoamerican markets are known to have been both places of production and healing (Cap 2015b; Hirth 2009, 2013, 2016; Nichols 2013; Shaw 2012). These three patio groups, which produced large quantities of lithic and bone debitage indicative of production, are also bounded by three

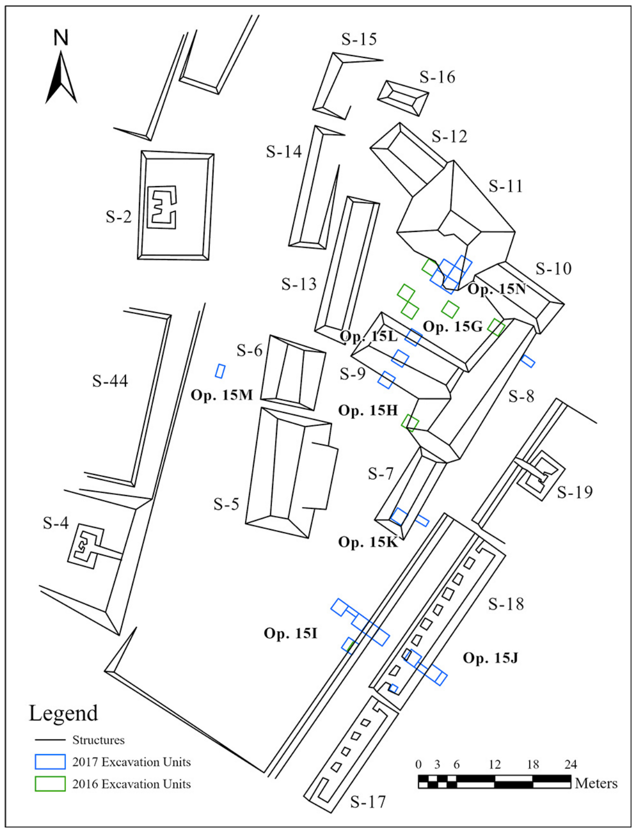

Figure 3. Excavations within the marketplace during the 2016–2017 field seasons (digital map by Z. Nelson, N. Curritt, and T. Murtha with additions by J. Schnell based on original map by F. Parris and T. Proskouriakoff).

sweatbaths, used across Mesoamerica for birthing and a range of curing activities.

The distinctive stratigraphy of the patio floors of the marketplace further distinguishes it from both residential contexts and the civic-ceremonial center of Piedras Negras. Most of the marketplace's stratigraphy is comprised of a sequence of thin floors laid over the course of the Classic period that then give way to a sequence of platforms in the final episodes of construction and occupation (Golden 2017:57). Missing from the stratigraphic layers of the marketplace excavations is evidence for stucco-finished floors typical of the acropolis of Piedras Negras and the adjacent ceremonial zone. In contrast, the patio floors of the marketplace vary between packed sediment and sand, suggestive of the regular resurfacing of a heavily trafficked space. The density and distribution of artifacts are interpreted as a mix of debris swept into the floors during relatively frequent resurfacings as well as objects that fell or were dropped during quotidian activities and subsequently trampled into the floor surface.

Chronology of the marketplace excavations has been derived from a series of radiocarbon dates provided by the University of Arizona AMS laboratory, combined with analysis of associated ceramic materials, under the direction of Mónica Urquizú and Ana Lucia Arroyave (Urquizú and Menéndez 2016; Arroyave et al. 2017). Both analyses indicate that this area of the site saw initial use and construction during the Early Classic period with most of the layers dating to either the Yaxche (A.D. 620–750) or Chacalhaaz phase (A.D. 750–850) of the Late Classic period (Holley 1983; Muñoz 2004).

No burials have been found within the marketplace despite their ubiquity in other areas of Piedras Negras where a total of 127 burials have been excavated to date (Coe 1959; Houston et al. 2003; Schnell and Scherer 2017; Schnell et al. 2017). The lack of burials not only highlights the unlikelihood that this area served a domestic function but also indicates that the teeth were not eroded or exhumed from nearby mortuary deposits, as has been suggested for miscellaneous human remains found at other sites, such as Tikal, Guatemala (Weiss-Krejci 2011). Classic period mortuary practices at Piedras Negras generally consisted of the placement of extended supine bodies in primary interments below household or plaza floors. Residences elsewhere in the site are so crowded with subfloor burials that some were dug through earlier ones (Scherer 2015a:102). Isolated elements of human bone were found in the marketplace excavations, including a partial cranial vault, an os coxa, a distal humerus, numerous long bone fragments, and a smaller number of cranial fragments (Jackson and Hruby 2001:29; Schnell et al. 2017). Many of these elements bear cutmarks related to the manufacture of bone tools and other objects. From the PPPNY excavations, bone that could be securely identified as human (including teeth) represents a small portion (n = 290; 6.1%) of a much larger assemblage of bone recovered from the marketplace (n = 4,741). Additionally, 1,429 (30.14%) elements could be securely identified as animal, leaving a sizable number as potentially human or animal (n = 3,022; 63.74%). Of the unidentified elements, 19.6% (n = 593) were worked, which hindered taxa identification. The worked bone included both production debris and finished products consistent with sites of bone working found elsewhere in the Maya area, such as the Group L4-3 workshop at Dos Pilas, identified by Kitty Emery (2008, 2009, 2010). Notably, no children's bones were found in the Southeast Marketplace assemblage despite subadults representing roughly one-third of the remains recovered in the mortuary sample at the site (Scherer 2015a:41).

The Dental Assemblage

Among the human remains and other objects recovered from the marketplace of Piedras Negras were 127 isolated teeth, many of which were fractured and pathological (Fig. 4). In no instance were the teeth found clustered together nor were they found within a ceramic vessel. There is little evidence to suggest they were part of a ritual deposit and, in fact, no example of a tooth cache or finger bowl as described earlier in this paper has ever been found at Piedras Negras. Rather, these teeth (and teeth fragments) appear to have been treated similar to the other materials recovered in the marketplace excavations and likely represent debris that was either lost accidentally or intentionally discarded. Of the 127 total

Figure 4. Selected teeth and tooth fragments demonstrating the pathological, fragmentary nature of the marketplace assemblage (photo by J. Schnell).

Table 1. Distribution of teeth in the Piedras Negras marketplace Late Classic sample by ceramic phase

Ceramic Phase	Dates (CE)	n
Yaxche	620–750	20
Yaxche-Chacalhaaz	620–850	23
Chacalhaaz	750–850	35
Total		78

dental elements, 9.5% (n = 12) were deciduous and 28% (n = 35) were very small enamel or root fragments that could not be further identified and were excluded from this study. Only two teeth, both molars, were definitively associated with Early Classic (A.D. 350–600) strata and were also excluded due to the small sample size from this period. The rest of the identified teeth (n = 78) were recovered from Late Classic strata and comprise the marketplace sample for this study (Table 1).

It was not possible to identify discrete individuals in the marketplace assemblage, and thus we could only estimate a Minimum Number of Individuals (MNI) based on the most frequently encountered tooth, in this case the right third maxillary premolar (MNI = 6). However, if we assume that the dental remains do not represent complete dentitions and that each individual may be represented by only one or a few teeth, the actual number of individuals represented by the dental assemblage is likely much higher. Outside of the marketplace, isolated teeth are rare in the Piedras Negras archaeological record. In the combined 7 years of work by the PAPN and PPPNY, only 15 human teeth have been found scattered across 73 operations (not including burials or the marketplace). This is in stark contrast to the 127 human teeth produced in the marketplace alone.

Observing the unlikelihood that such a large number of teeth in a part of the site void of burials was a product of postdepositional taphonomic processes, we hypothesized that the teeth entered the archaeological record following extractions for palliative care based on the fragmentary and pathological nature of the sample. To test this hypothesis, we completed a series of basic statistical comparisons between the marketplace sample and an aggregated mortuary population. This mortuary population is comprised of all individuals excavated from the burials at Piedras Negras, previously studied by Scherer (Houston et al. 2003; Scherer et al. 1999, 2001; Scherer et al. 2007). Since we excluded the two Early Classic marketplace teeth from the study due to low sample size, all comparisons are made to only the Late Classic period mortuary sample. We also limited the mortuary population to permanent teeth, as the subsample of deciduous teeth (n = 12) from the marketplace was too small for statistical comparisons. Because discrete individuals could not be identified in the marketplace assemblage, we treated the Late Classic mortuary population as an aggregate collection of teeth, to facilitate comparison. The Piedras Negras mortuary sample, then, consists of 853 permanent teeth dating to the Late Classic period. The Late Classic marketplace sample, on the other hand, consists of 78 permanent teeth and tooth fragments.

Methods

Each human tooth from the Southeast Marketplace was inventoried and scored for dental caries, dental wear, enamel hypoplasia, dental modification, damage, and any other notable features (Buikstra and Ubelaker 1994; Romero 1951; Scott 1979; Smith 1984). Dental modifications were scored but are not considered in this paper. These are the same methods employed by Scherer in his analysis of the teeth from the 127 burials that comprise the Piedras Negras mortuary population, with some minor differences as noted below. The marketplace teeth were compared to those of the broader Piedras Negras mortuary population along three lines of analysis: (1) the distribution of teeth by type in each sample, (2) pathologies, including caries and calculus, and (3) dental wear. Each tooth from the marketplace was scored twice, once by Schnell and a second time by Scherer. Discrepancies between the two scores favored Scherer's interpretation in order to maintain compatibility with his earlier analyses. Additionally, the marketplace teeth were examined carefully for damage and fractures.

Raw counts of tooth types (incisors, canines, premolars, molars) were tabulated for both the marketplace and the Piedras Negras mortuary samples and used to calculate relative proportions for molars, premolars, canines, and incisors. If the teeth entered the archaeological record randomly, whether taken from graves elsewhere in the site or perhaps from skulls that were worked, carried, or retained at the marketplace, the relative proportion of tooth type (incisor, canine, premolar, molar) should be similar to the proportions of the Piedras Negras burial assemblage. Of course, not all burials will produce teeth in the ratio expected for a typical adult owing to antemortem tooth loss and incomplete recovery by archaeologists. Nevertheless, we expect the deviation should be small unless a particular practice targeted the removal of certain teeth across the entire population of Piedras Negras. Moreover, proportions in both should mirror that of a typical adult mouth. Third molar agenesis is rare among the Maya and so a complete dentition consists of 32 teeth, with eight incisors (25%), four canines (12.5%), eight premolars (25%), and 12 molars (37.5%). If the marketplace dental assemblage was produced from patterned behavior that targeted certain teeth, then we should expect deviations in those anticipated frequencies. For example, as noted earlier, Maya tooth caches are significantly comprised of incisors. In regard to pathologies like dental caries and abscesses, the posterior teeth are disproportionately affected, a pattern with significant temporal depth and global scale that still holds true today (Cucina et al. 2011; Demirci et al. 2010; Lanfranco and Eggers 2012; Moore and Corbett 1973; Whittington 1999). Thus, we should expect their overrepresentation in a sample of extracted teeth where the practice was intended to ameliorate pain associated with oral pathology.

Within the marketplace sample, caries were only recorded when they could be observed as discrete lesions on whole teeth or large fragments of tooth crowns. Frequencies of carious versus non-carious teeth were compared between the marketplace and the mortuary sample. Dental calculus was scored for both location and severity (Buikstra and Ubelaker 1994). Because of the limits of sample size within the marketplace, dental calculus was compared between the marketplace and the mortuary sample by calculating a general combined average calculus score for all teeth from each sample. Dental wear was recorded on all teeth and tooth fragments that had more than half of their occlusal or incisal surfaces present following Smith (1984). Molar wear was also scored following Scott's (1979) quadrant scoring method. The Smith method utilizes an eight-point scale and differentiates scoring guidelines according to tooth type. The Scott method records each quadrant of a molar on a 10-point scale, giving each tooth a score ranging between four and 40. Wear was compared across the two samples by tooth type (incisors, canines, premolars, molars). With regard to dental wear, the Scott (1979) method was not utilized in Scherer's study of the mortuary sample. Thus, all comparisons of dental wear focus on scores derived using Smith's (1984) method. All descriptive and univariate statistics were conducted using R statistical software.

In the case of damaged teeth from the marketplace, fractures were qualitatively described to distinguish between antemortem, perimortem, and postmortem trauma on the basis of location and quality of the defect. Unfortunately, anthropological research on tooth fractures (as opposed to bone fractures) is quite limited in terms of distinguishing between antemortem trauma, perimortem fractures, and postmortem damage. Here, we use perimortem to refer to the death of the tooth, whether caused by the death of the person or from its extraction from a living person. By postmortem we mean damage to the tooth long after death, whether caused by taphonomic processes in the archaeological record, excavation, or damage in subsequent handling by researchers (Hughes and White 2009; Viciano et al. 2012). Antemortem fractures are readily distinguished from perimortem fractures or postmortem damage in that the margins of fractures will become rounded and blunted due to continued occlusion (Milner and Larsen 1991; Scott and Winn 2011). Perimortem tooth fractures are difficult to distinguish from postmortem damage because both are characterized by sharp, angular margins. However, right angles are common in postmortem damage as are fractures that traverse the dentinoenamel junction (DEJ) (Fig. 5A). In vivo, the DEJ acts as a stabilizing biomechanical structure and plays an important role in arresting crack propagation before it reaches the dentin. Without this important structure, postmortem cracks require much less force to bridge enamel and dentin (Dong and Ruse 2003). When postmortem damage does involve separation of enamel from the dentin, as during excavation or handling of the teeth in the laboratory, a color contrast may result on the newly exposed surfaces (Fig. 5B; Milner and Larsen 1991; Scott and Winn 2011:724).

Results

The marketplace sample included 78 permanent teeth that could be identified by tooth type (Table 2). The

Figure 5. Teeth demonstrating postmortem damage from the Brown University Osteology Teaching Laboratory collection: (a) fracture of buccal crown of a mandibular premolar showing a right-angle fracture that bisects the enamel and dentin and exposes the pulp chamber; (b) enamel fragmentation from the buccal aspect of a mandibular molar exposing the underlying dentin (arrow; photos by J. Schnell).

Table 2. Distribution of teeth by type in the Late Classic period marketplace and the Late Classic period Piedras Negras mortuary population as compared to the distribution of teeth within a "typical" Late Classic period Maya adult individual

Tooth	Marketplace n (%)	Piedras Negras Mortuary Population n (%)	Distribution of Teeth in a "typical" adult n (%)
Incisor	8 (10)	218 (25.6)	8 (25)
Canine	8 (10)	141 (16.5)	4 (12.5)
Premolar	29 (37)	237 (27.8)	8 (25)
Molar	31 (40)	257 (30.1)	12 (37.5)
Supernumerary	2 (3)	0 (0)	0 (0)
Total	78 (100)	853 (100)	32 (100)

Table 3. Overall Late Classic period caries rates of the marketplace assemblage versus the adult mortuary population of Piedras Negras

	Marketplace n (%)	Piedras Negras Mortuary Population n (%)
Total teeth	41 (100)	832 (100)
Total carious teeth	24 (59)	143 (17.2)
Total non-carious teeth	17 (41)	689 (82.8)

posterior teeth (77%; premolars and molars) notably outnumber the anterior teeth (23%; incisors, canines, and two supernumerary teeth), deviating from what we would expect if the distribution followed that of a typical Maya adult (37.5% anterior; 62.5% posterior). In contrast, the Piedras Negras mortuary sample more closely matches the expected ratio: 42.1% anterior, 57.9% posterior. The distinctions are even more stark when individual tooth classes are considered. Only 10% of the marketplace teeth were identified as incisors, versus 25.6% in the mortuary sample, the latter closely mirroring the expected 25% of incisors in a typical complete adult dentition. Premolars are the most overrepresented tooth in the marketplace sample, comprising 37% of the sample, as compared to their 27.8% representation in the mortuary population. Again, that latter figure more closely mirrors the 25% we would expect based on premolar distribution in a complete dentition. Molar teeth are also more represented in the marketplace sample (40%) than in the mortuary sample (30.1%). The fact that the relative frequency of molars in the mortuary population is below what is expected for a normal dentition points to posterior tooth loss in the Piedras Negras population, some of which may have been due to extractions. It is noteworthy that premolars are not underrepresented in the mortuary sample as molars are, but it is difficult to point to a specific etiology that may explain this pattern. Tooth loss can result from a number of different causes, of which extraction is just one. It may simply be that, all factors considered, molars were more susceptible to tooth loss than premolars in the Piedras Negras population. Overall, though, the distribution of tooth type within the marketplace not only highlights that it is an atypical sample but accords with expectations that premolars and molars should be overrepresented in a sample of tooth extractions aimed at alleviating oral pathologies that disproportionately affect the posterior teeth.

The second line of analysis used to evaluate evidence for dental extraction is the pattern of pathologies present in the marketplace sample relative to Piedras Negras's mortuary sample. Since we eliminated small tooth fragments from the pathological analysis, we were able to score only 53% of the marketplace sample (n = 41) for caries. The calculated caries rate for the marketplace was 59% (n = 24). In contrast, of the 832 teeth (97.5% of total) in the Late Classic period Piedras Negras mortuary population sample that were scored for caries, 17.2% (n = 143) demonstrated caries. The marketplace dental sample demonstrated a caries rate more than three times that of the Piedras Negras burial sample (Table 3), a difference that is statistically significant based on chi-square analysis $\chi^2 = 40.6$, df = 1, $P < .001$). Nevertheless, the number of carious teeth is likely underestimated within the marketplace since small tooth fragments were not counted despite the fact that some of the fragments from the marketplace are clearly carious (Fig. 6). Dental calculus was compared between the total marketplace sample and that of a combined sample of teeth from the mortuary population. The combined average calculus score for the marketplace ($\mu = 0.9$) was slightly lower than that of the broader mortuary population ($\mu = 1.09$), but a t-test indicates that this is not a statistically significant difference ($t = 1.4$, df = 31.58, $P = 0.18$).

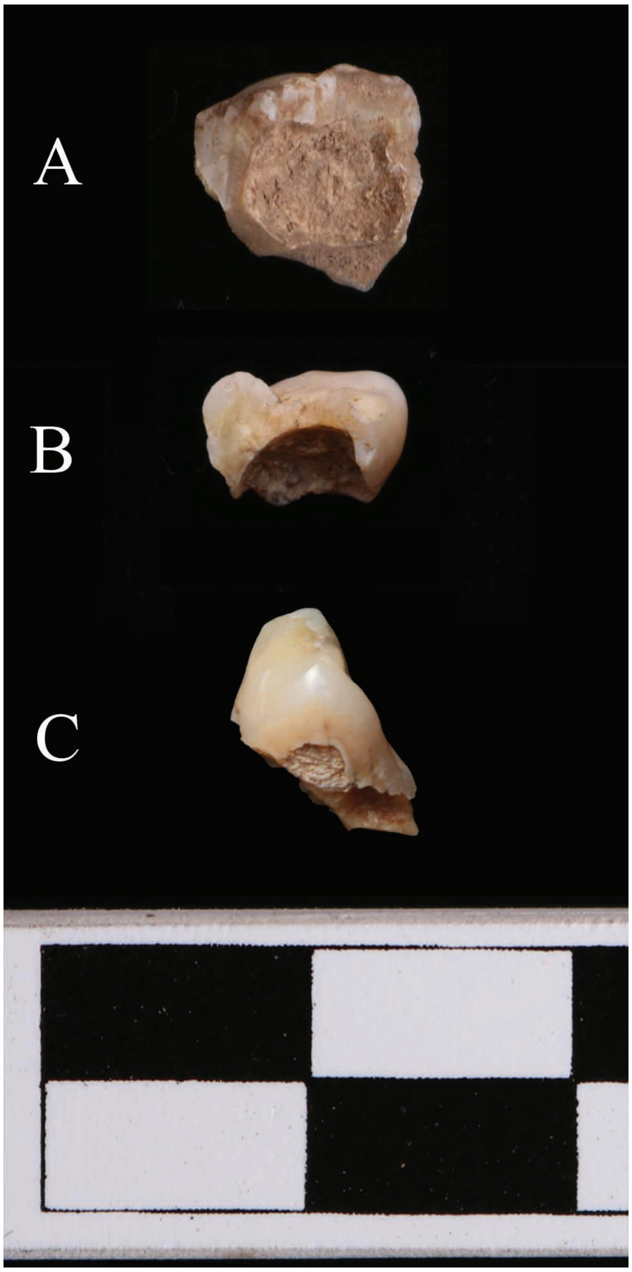

Figure 6. Small dental fragments from the marketplace sample exhibiting carious destruction: (a) unknown crown fragment with destruction of the dentin within the pulp chamber (PN-15H-1-3), (b) maxillary premolar fragment with destruction of the dentin within the pulp chamber (PN-15I-11-8), and (c) left mandibular canine with caries on the distal aspect of the enamel (PN-15I-1-9; photos by A. Scherer).

Comparison of the incidence of dental wear focused on the posterior teeth due to the low number of incisors and canines in the marketplace sample that could be scored for wear (n = 1 and n = 4, respectively). Of the 29 identified premolars and premolar fragments, 35% (n = 10) could be scored for wear and of the 31 molars, 39% (n = 12) could be scored. In the Late Classic Piedras Negras mortuary population, 95.8% (n = 227) of the 237 premolars had been scored for wear, as had 97.3% (n = 250) of the 257 available molars (Table 4). The mean premolar wear score for the Southeast Marketplace sample ($\mu = 2.0$) is roughly equivalent to that of the mortuary sample ($\mu = 2.044$) and a two-sided t-test shows the difference is not statistically significant ($t = 0.1$, $df = 9.43$, $P = 0.93$). On the other hand, the mean wear score of the molars in the Southeast Marketplace sample was lower ($\mu = 1.58$) than that of the mortuary sample ($\mu = 2.50$). A two-sided test on the molar values did indicate a statistically significant difference ($t = 4.4$, $df = 14.63$, $P < .001$). The molar wear analyses do support our hypothesis that the marketplace teeth would exhibit less wear than those in the mortuary sample. However, dental wear is multifaceted and although a younger age-at-death profile is a plausible explanation for the discrepancy in mean molar wear between the two samples, we cannot rule out other explanatory factors such as occupational differences and dietary differences. We suggest, though, in light of our other findings, that being extractions, these teeth were in use (and thus subject to attrition) for a shorter period of time than those teeth that followed their owners into the grave.

Of the 78 teeth in the marketplace sample, 77% (n = 60) are fractured (e.g., missing part of a crown or root) or are themselves fragments of a root or crown. Only one of the fractured teeth is consistent with a traumatic blow to the mouth of a living person. However, this tooth is afflicted by extensive caries, which presumably facilitated its fracturing. Overall, the fracture patterns observed in the teeth from the marketplace at Piedras Negras are consistent with either (1) damage from extraction or (2) fragmentation of dental crowns already partially destroyed by dental caries. In one example, a right maxillary molar (PN-15I-1-4) exhibits a perimortem fracture and appears to have fractured due to a twisting motion (Fig. 7A). The same tooth also shows apical root resorption that is consistent with root behavior at the site of a pulpal infection (Fig. 7A; Fuss et al. 2003:176). Observations of modern exodontia indicate that rotation is one of the most common forces applied (Ahel et al. 2015:984). This combined presence of root resorption and fracture by axial rotation is consistent with extraction in response to oral pathology. In quite a few other cases, enamel chipping and even crown fractures were observed on or near the cementoenamel junction (CEJ), particularly on the labial or buccal aspects of teeth (Fig. 7B). None of this chipping is consistent with antemortem damage where subsequent use of the tooth would polish the fractured edges. While postmortem damage may also cause separation of the enamel, the focus on the CEJ and the small

Table 4. Late Classic period premolars and molars distributed by Smith dental wear score for the marketplace and Piedras Negras adult mortuary population with percentages by column

	Marketplace		Piedras Negras Mortuary Population	
Smith Score	Premolars n (%)	Molars n (%)	Premolars n (%)	Molars n (%)
1	4 (40)	6 (50)	60 (26)	41 (16)
2	4 (40)	5 (42)	112 (49)	109 (44)
3	0	1 (8)	40 (18)	62 (25)
4	2 (20)	0	15 (7)	19 (8)
5	0	0	0	13 (5)
6	0	0	0	3 (1)
7	0	0	0	3 (1)
8	0	0	0	0
Total	**10 (100)**	**12 (100)**	**227 (100)**	**250 (100)**

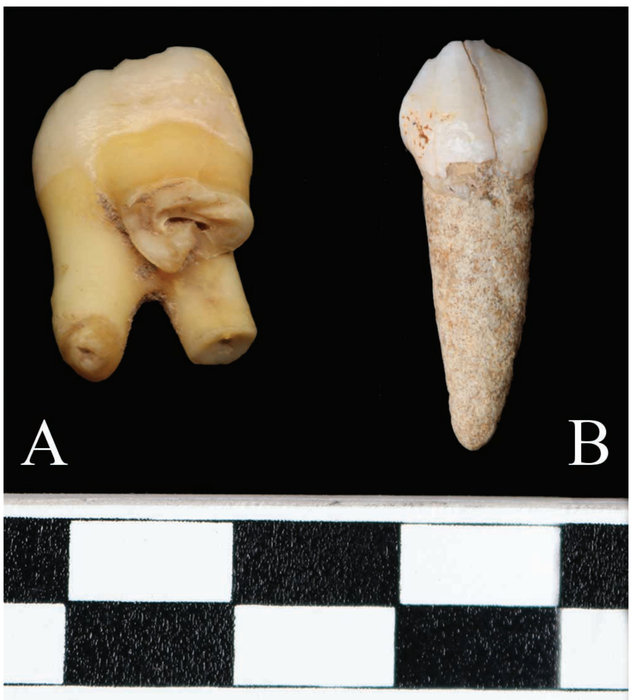

Figure 7. Fractured teeth from the marketplace sample: (a) right maxillary molar exhibiting external apical root resorption and fractured roots (PN-15I-1-4); (b) left mandibular canine with labial enamel chipping at the cementoenamel junction (PN-15I-1-21; photos by A. Scherer).

surface area affected is more suggestive of damage caused during extraction (compare the slight chipping in Fig. 7B with exfoliation of the enamel of the buccal surface of the tooth in Fig. 5B).

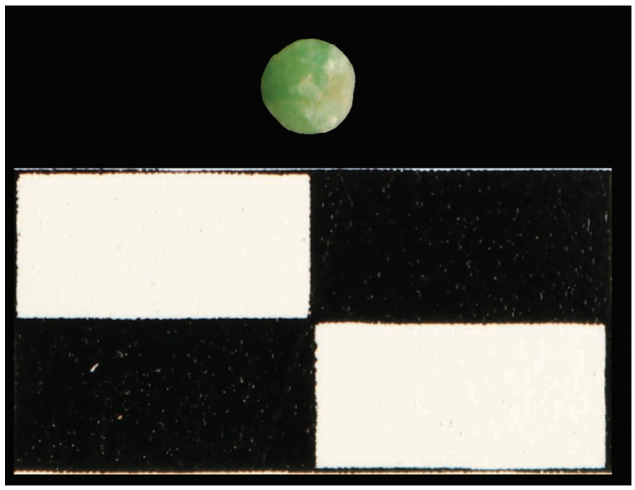

Figure 8. Prepared jade tooth inlay (PN-15I-1-4; photo by A. Roche Recinos).

Figure 9 Micro-quartz fragments including a prismatic fragment that may have served as a drill bit (white circle) from Piedras Negras's marketplace (PN-15I-1-4; photo by A. Roche Recinos).

Discussion

The combination of an atypical distribution of teeth and pathology in the marketplace sample relative to the mortuary sample, coupled with the evidence for fracturing within the marketplace sample, supports our hypothesis that this anomalous assemblage of isolated teeth might be explained by therapeutic tooth extractions. While one could argue that the elevated frequency of caries in the marketplace sample indicates these teeth were drawn from a more caries-prone population than that of their contemporaries in the greater mortuary sample, the more parsimonious explanation is that the higher prevalence of dental caries reflects the extraction of pathological teeth from living individuals. It is also probable that teeth were extracted as a result of abscesses and other infections of both teeth and the associated alveolar region, including nonspecific disorders, such as nonodontogenic tooth pain (Mattscheck et al. 2016) or persistent dentoalveolar pain (Nixdorf and Moana-Filho 2011). Without the aid of radiography, the source of oral pain is often difficult to isolate and tooth extraction—even when not needed—provides one of the few options available to alleviate suffering.

Interpretation of the calculus data is less straightforward, in part because the presence of calculus reflects a broader range of factors, including diet, hygiene, and other individual differences (Hanihara et al. 1994; Kinaston et al. 2019; Lieverse 1999; White 1997). Calculus, like all dental pathologies, is also age related—the longer a person lives, the more time is available for calculus to build up. The slightly lower levels of calculus in the marketplace sample may reflect loss of calculus postmortem, with the teeth not protected in a sealed mortuary context. Calculus may also have been lost when teeth were extracted. Finally, the lower incidence of calculus may be due to the fact that as dental extractions, the teeth have a potentially younger age-at-death profile than the mortuary sample, assuming that at least some of the individuals who had their teeth extracted at the marketplace then went on to continue to live and eventually die at Piedras Negras. Ultimately, it is impossible to explain why the incidence of calculus is lower in the marketplace sample, though a number of potential explanations accord with the hypothesis that these teeth represent the remains of tooth extractions.

Ancient Maya dentistry

Earlier work on Maya dentistry has focused almost exclusively on cosmetic dental modifications at the expense of other dental interventions. Much of the earliest work involved classification efforts and the creation of typologies describing the breadth of modifications present in Mesoamerica (Rubín de la Borbolla 1940; Dembo and Imbelloni 1938; Engerrand 1917; Hamy 1882; Romero 1951, 1970; Stewart 1941). Since the mid-twentieth century, focus has shifted toward understanding the social significance of these modifications and the technical aspects of their preparation (Fastlicht 1951, 1976; Fastlicht and Romero 1951; Gwinnet and Gorelick 1979; Havill et al. 1997; Ramírez-Salomón 2016; Ramírez-Salomón et al. 2003; Tiesler 2001; Tiesler et al. 1999; Tiesler et al. 2002; Tiesler et al. 2017). Even archaeological studies that position dentistry as an occupation have historically focused exclusively on cosmetic modification procedures (Becker 1973:400–401; Romero 1958). Only very recently have scholars begun to pay attention to oral care practices (Cucina and Tiesler 2011; Tiesler et al. 2017), despite acknowledgment of these practices in the literature for quite some time. In 1971, Samuel Fastlicht wrote that Maya dentistry "had two aspects; one referred to the diseases of the mouth and their treatments, the other to dental mutilations involving filing and incrustations" (Fastlicht 1971:36; authors' translation from Spanish original).

At Piedras Negras, there is circumstantial evidence to indicate that both therapeutic interventions, such as tooth extractions, and cosmetic modifications, such as inlaying, were conducted in the marketplace. At least one finished, prepared jade dental inlay was encountered during excavations in a stratigraphic deposit within which a number of teeth were also found (Fig. 8). While it is impossible to know whether inlays were kept on hand or commissioned as bespoke productions, it is probable that the actual drilling of the enamel openings into which the inlays were set did take place in the marketplace. Fastlicht was the first to draw a connection between jewelry making and lapidary drilling and drilling dental inlay cavities. He suggested that holes were drilled into the enamel with a tube of hard stone, such as quartz, aided by abrasives, such as sand (Fastlicht and Romero 1951:70–71). Similar methods are proposed for the drilling and polishing of jade by Maya lapidarists (Kidder et al. 1946; Kovacevich 2007, 2011). A number of prismatic quartz pieces and chert drill bits (Fig. 9) were found during the marketplace excavations that could have been used to drill both teeth and precious stones (Roche Recinos, personal communication, 2020).

While ethnohistoric sources shed light on precolonial therapeutic dental interventions, the subject has not been a central focus for scholars interested in indigenous medicine in Mesoamerica (Andrews Heath de Zapata 1979; Bricker and Miram 2002; Gates 2000; Gubler and Bolles 2000; Hernández 1959; Roys 1965, 1976; Sahagún 2012). Much of what we know comes from early colonial-era documents, such as Sahagún's *Florentine Codex*, an expansive chronicle of Mexica life at the time of the conquest. In addition to providing instructions for cleaning and extracting teeth, the *Florentine Codex* also presents 27 images of patients and doctors, one of which shows an individual suffering from toothache alongside a glyph representing teeth affixed with the sign for water (Fig. 10). The central Mexican *Badianus Manuscript,* as well as several Maya texts such as the *Chilam Balam* books and the *Libro del Judío,* describe a number of remedies for cleaning the teeth, dealing with dental pain, and even extracting teeth. Additionally, Alonso de Molina's (1571) Nahuatl dictionary defines a number of terms related to dental specialists, oral diseases, and dental anatomy that suggests a robust, complex dental tradition in Mesoamerica.

Our identification of isolated teeth with fractured roots aligns well with a hypothesis posed by Fastlicht who, speaking of Mesoamerican sites, observed that "[it is] with great curiosity we hope to find fractured roots, since one would imagine primitive dentists would have left roots in the alveolus during unpleasant extractions, as is encountered in modern ones" (Fastlicht 1947:12; authors' translation from Spanish original). The fracturing of roots remains a problem in contemporary clinical extractions. For example, a recent report suggests that anywhere from 15% to 37% of edentulous dental patients have at least one retained root fragment (Nayyar et al. 2015:Table 1). This was clearly a problem for Maya extractions as well as evident in a recently reported case of an embedded root fragment in a mandible at Xcambó, Yucatán (Cucina and Tiesler 2011). Similar instances may be overlooked in other Maya skeletal samples since radiography is often necessary to identify retained rood tips. While the maxillae and mandibles of the Piedras Negras mortuary sample have not been subject to radiography, 81 cases of antemortem tooth loss were observed out of a total sample of 301 observable alveolar canals, providing at least circumstantial evidence for tooth extraction at the site. Even more dramatic are two edentulous mandibles, one of which belongs to the occupant of an Early Classic period royal tomb (Fig. 11).

Figure 10. Folio 160 from Book 10 of the *Florentine Codex*, depicting an individual suffering from a toothache; the symbol at left is a Nahuatl glyph that includes a water sign and may somehow relate to toothache (drawing by J. Schnell after the original, Sahagún 2012).

Figure 11. Superior view of an edentulous mandible from Piedras Negras Burial 110, an old adult probable male, from an Early Classic royal tomb (photo by A. Scherer).

Contemporary clinical data indicate that anywhere from 9% to 20% of simple extractions result in fracture to the tooth (Baniwal et al. 2007; MacGregor 1969; Venkateshwar et al. 2011), making it the "most common intraoperative complication during tooth extraction" (Ahel et al. 2015:984). The risk of complication is due to a variety of factors, including the skill and expertise of the practitioner, the technique and instrument used, and the integrity of both the tooth and surrounding alveolar bone. Clinical studies show that during in vivo tooth interventions (e.g., caries drilling or extraction) teeth are more likely to fracture if the structural integrity of the enamel or dentin has already been weakened by caries or some other pathology and fracture lines may run along those points of weakness (Kishen 2015). In contrast, teeth that are fractured in vivo as a result of violent injury (e.g., a heavy blow to the mouth) tend to result in root fractures, or fracturing along horizontal planes, usually at the alveolar margin, typically involving complete separation of the crown from the roots (Fig. 12; Andreasen et al. 2018:377; Lukacs 2007:150). Only one such case was observed in the marketplace sample,

Figure 12. Left mandible from Plaza 1, Oztoyahualco, Teotihuacán, showing horizontal perimortem fracturing of the canine and molars consistent with a traumatic blow (photo by A. Scherer). The lateral aspect of the ascending ramus shows extensive cutmarks (not visible in the photo) consistent with defleshing and extraction from a fleshed body.

Figure 13. Complicated dental fractures in the marketplace sample: (a) left third mandibular molar with fractured root and enamel (PN-15G-25-2); (b) maxillary premolar buccal cusp (PN-15I-12-4; photos by A. Scherer).

with fractures to individual root radicals more common, as described in the results.

While studies concerning antemortem and perimortem dental fractures and trauma in archaeological populations are scant (Alvrus 1997; Gibbon and Grimoud 2014; Lukacs 2007; Lukacs and Hemphill 1990; Merbs 1968; Viciano et al. 2012), clinical literature in modern populations suggests that dental fractures primarily affect the anterior dentition (Bastone et al. 2000; Brunner et al. 2009). Severe fractures such as crown-root fractures that involve the enamel, dentin, and cementum are quite rare (Andreasen et al. 2018:355). In the posterior teeth, these fractures are typically caused by indirect trauma (usually the result of the lower jaw coming into forceful contact with the upper through a fall or collision; Andreasen et al. 2018:274). Further, these fractures are almost always "uncomplicated," that is, they do not involve the pulp (Andreasen et al. 2018:355). In the marketplace sample, however, complicated crown-root fractures of the posterior teeth are quite common, many of which display fracture planes indicative of the forces typically involved in exodontia. A left mandibular third molar from PN-15G-25-2 exhibits this pattern, with half of the root complex fractured from the tooth, as well as a significant portion of the coronal dentin and surrounding enamel, exposing the pulp chamber (Fig. 13A). This particular tooth also exhibits a large cervical caries on the aspect of the tooth opposite the fracture. Although traumatic fractures of the posterior teeth are exceptionally rare (Bastone et al. 2000:6), fractures affecting these teeth, especially the molars, are common during extraction (MacGregor 1969:Table III). Here, the presence of a large caries as well as the tooth's position in the dental arcade relative to the fracture planes both point toward a therapeutic extraction. Some of the enamel chipping around the CEJ observed in the marketplace sample (Fig. 7B) may be explained by extraction methods. For example, if a gripping instrument or percussive force was used, damage to the enamel and/or fractures to the tooth at the gum line would be expected. In other cases, such as a buccal cusp fragment of a maxillary premolar from PN-15I-12-4, similar fracture patterns to those described in the molar above are directly associated with carious dentin (Fig. 13B). Moreover, many of the dental fragments recovered within the marketplace exhibit carious dentin (Fig. 6) and are thus consistent with the pattern of expected fragmentation during exodontia of crowns weakened by caries. Importantly, there were no obvious refits in the assemblage, indicating that crown fragmentation was not due to postmortem taphonomic damage once the teeth had entered the stratigraphy.

Health care in the marketplace

These findings suggest that the marketplace at Piedras Negras was not only a destination for economic exchange but was also an important center for healing along the Usumacinta River. Skilled tooth extractors in antiquity were likely sought out by individuals with oral pathologies who were suffering immense pain. It was, however, not a procedure without risk and the process itself could also be a source of pain. As an analogy from contemporary times, one K'iche' woman from Guatemala with no fewer than 22 tooth extractions observed: "It hurts and sometimes it bleeds a lot. Sometimes the *dentista* does not have much experience and leaves the root. That really hurts!" (Lee 2007:186).

We do not know precisely how the ancient Maya extracted teeth. In some cases, it may have been done with simple manipulation by hand. In other instances, it may have involved cutting the surrounding gingival tissue or the use of tools made of bone, wood, or stone to leverage the tooth within and ultimately out of the alveolus. Tweezers like those found at Tikal (Moholy-Nagy and Coe 2008:Fig. 209) were perhaps used, though no such implements have been found at Piedras Negras. Ethnographic and ethnohistoric evidence suggests that plants may also have been used to aid in tooth extraction (Atran et al. 2004; Balick and Arvigo 2015; Breedlove and Laughlin 2000; Hunter and Arbona 1995; Mendieta and del Amo 1981; Roys 1976). Ongoing paleoethnobotanical analyses in the marketplace have confirmed the presence of a variety of plants with known medicinal uses, including some associated with the management of dental pain (Watson et al. 2019).

The identification of dental extractions at Piedras Negras presents one of the few case studies of ancient health care in the Americas and emphasizes the close relationship between medicine and markets across much of Mesoamerica (Kashanipour 2012:132; Sahagún 2012). The market has long played a central role in indigenous medical systems in the region, particularly due to its tendency to draw visitors from relatively large catchment areas into a single, often urban setting. Early colonial writers noted the presence of apothecaries and physicians in these markets as well (Cortés 1962:87–88; Sahagún 1961:30, 53). The provision of medical services as an economic exchange is also prevalent in the Maya region. In the eighteenth century *Popol Vuh*, a quasi–mythical-historical account of creation and the history of the K'iche' nation, the pair of primordial grandparents describe how they provide for their family by offering a variety of medical services, such as curing the eyes, setting broken bones, and removing worms from teeth (Christenson 2003:99). This last service is a metaphor for tooth extractions, as belief in the "tooth worm" as a cause of toothache and dental disease is widespread in the Maya region (Augusto Ávila 1977:26–27; Breedlove and Laughlin 2000:234, 243; Casagrande 2002:77; Lee 2007:187; Roys 1965:55–57).

In recent times in Mesoamerica, itinerant healers, including dental specialists, travel to regional markets in order to offer their services on major market days. Gordon Schendel (1968:51) reports on an indigenous dental practitioner who visited Querétaro, a city in central Mexico, on market days. He would set up an old kitchen chair in a street behind the market and pull teeth using ancestral medicine. In the Guatemalan town of Nahualá, patients line up outside of dental offices on market days, many "clutching their cheek, sometimes with a towel draped over the shoulder to catch the blood when they get their turn" (Lee 2007:186). At Antigua Santa Catarina Ixtahuacán, another town in Guatemala, an itinerant *dentista* comes to town on market days, rents out a small adobe room, and charges just 10 quetzales (~ US$1.30) for dental extractions (Lee 2007:188).

Archaeologically, sweatbaths provide the most salient evidence for loci of ancient Maya healing due to their association with midwifery, ritual, and healing as commonly noted by colonial writers (Coto 1983:61; Durán 1971) and ethnographers (Berlin and Berlin 1966; Cosminsky 1972; Katz 1993; Maffi 1994; Moedano 1977; Virkki 1962; Wagley 1949; Wauchope 1938). Ethnohistoric evidence also associates sweatbaths with marketplaces. For example, in the mid-sixteenth century, Francisco López de Gómara noted the presence of a public bath in the marketplace at Ocotelulco (1966:120). The traditional Maya sweatbath is a vapor bath in which steam is produced through water applied to a bed of heated rocks in a central chamber (Groark 2005:786). Ancient monumental sweatbaths have a distinct architectural signature, including a firebox in the central chamber. Eight sweatbaths have been identified at Piedras Negras: seven monumental baths and one associated with a rural house group, the largest number in the Maya area (Child 2006; Houston 1996). Three of Piedras Negras's eight sweatbaths are found at the Southeast Marketplace (Fig. 3): S-2 and S-4 are located along the western edge of the market and S-19 is located on the opposite end of the market, adjacent to the two principal range structures (S-17 and S-18). These three sweatbaths are in the most accessible part of the site and were the ones presumably available to the general populace as well as visitors to the site, many of whom would have arrived from the south, either by the pathway that enters the site or via canoe at Piedras Negras's nearby beach.

Conclusions

In this article, we provide bioarchaeological evidence for tooth extractions conducted at the Maya site of Piedras Negras, Guatemala, during the Late Classic period. We suggest that these extractions were conducted to alleviate pain and other ill consequences associated with dental caries. This research presents one of the few case studies of ancient health care in the Americas and provides a complement to prior scholarship on ancient Maya dentistry. Similar therapeutic dental extractions were presumably practiced across much of the Maya region and may explain some of the loose, isolated teeth found archaeologically. This study also supplements an emerging body of literature concerning indigenous therapeutic dentistry in the Americas (Goguitchaichvili et al. 2017; Ortiz et al. 2016; Schwartz et al. 1995; Seidel et al. 2005; Turner 2004) and ancient dental traditions elsewhere in the world (Becker 2014; Bennike 1985; Bernardini et al. 2012; Coppa et al. 2006; Forrai 2009; Oxilia et al. 2015; Oxilia et al. 2017). We hope that this study broadens the scope of scholarship on ancient Maya dentistry, beyond cosmetic modifications. It is clear that the indigenous peoples of Mesoamerica, the Maya included, had a deep understanding of human anatomy and a complex medical tradition that surprised the Spanish upon their arrival and that most certainly existed long before then as well. Although we cannot draw a direct historical connection between the Piedras Negras marketplace assemblage and the dental treatments prescribed in the colonial and ethnomedical literature, this evidence for dental extractions during the Classic period does provide significant temporal depth for therapeutic dentistry in the region more generally.

Acknowledgments

The authors would like to thank the entire Proyecto Paisaje Piedras Negras–Yaxchilan research team and all of its collaborators, as well as the Proyecto Arqueológico Piedras Negras, without whom this work would not have been possible. 2016 and 2017 excavations in the marketplace were conducted by Charles Golden, Andrew Scherer, Shanti Morell-Hart, Alejandra Roche Recinos, Mallory Matsumoto, and Joshua Schnell. We offer a special thanks to our colleagues for all of their efforts. Funding for the PPPNY was generously provided by the National Science Foundation (BCS-1505483/1505399) as well as the Alphawood Foundation. Funding for this particular research, which was part of Schnell's master's thesis, was provided by the Brown University Graduate School, Department of Anthropology, and Center for Latin American and Caribbean Studies, as well as the Tinker Foundation. We also thank Stephen Houston and Charles Golden for comments and suggestions on a previous version of this paper. Finally, we would like to thank the four anonymous reviewers for their helpful comments on this work.

References Cited

Ahel, V., T. Ćabov, S. Špalj, B. Perić, D. Jelušić, and M. Dmitrašinović. 2015. Forces that fracture teeth during extraction with mandibular premolar and maxillary incisor forceps. *British Journal of Oral and Maxillofacial Surgery* 53(10): 982–987. DOI: 10.1016/j.bjoms.2015.08.007.

Alvrus, A. 1997. Trauma to the teeth and jaws: Three Nubian examples. *Journal of Paleopathology* 9:5–14.

Andreasen, Jens O., Frances M. Andreasen, and Lars Andersson, eds. 2018. *Textbook and Color Atlas of Traumatic Injuries to the Teeth*. 5th ed. Wiley-Blackwell, Hoboken, NJ.

Andrews Heath de Zapata, Dorothy. 1979. *El Libro del Judío, o Medicina Doméstica*. Dorothy Andrews Heath de Zapata, Mérida.

Arroyave, Ana Lucia, Ricardo Rodas, and Mónica Urquizú. 2017. Análisis de la cerámica y figurillas de Piedras Negras. In *Proyecto Paisaje Piedras Negras–Yaxchilan, Informe de la Segunda Temporada de Investigación*, edited by Mónica Urquizú, Andrew K. Scherer, and Charles W. Golden. Instituto de Antropología e Historia, Guatemala City, pp. 168–193.

Atran, Scott, Ximena Lois, and Edilberto Ucan Ek'. 2004. *Plants of the Petén Itza' Maya*. Memoirs of the Museum of Anthropology No. 38. University of Michigan, Ann Arbor.

Augusto Ávila, César. 1977. El Xul-E': Creencias populares sobre la etiología de la caries y del dolor dental en grupos de indígenas Kekchies. *Guatemala Indígena* 12(1–2):4–51.

Awe, Jaime, Nikolai Grube, and David Cheetham. 2009. Cahal Pech Stela 9: A Preclassic monument from the Belize Valley. *Research Reports in Belizean Archaeology* 6:179–189.

Balick, Michael J., and Rosita Arvigo. 2015. *Messages from the Gods: A Guide to the Useful Plants of Belize*. Oxford University Press, Oxford.

Baniwal, S., K. R. Paudel, U. Pyakurel, M. Bajracharya, and S. R. Niraula. 2007. Prevalence of complications of simple tooth extractions and its comparison between a tertiary center and peripheral centers: A study conducted over 8,455 tooth extractions. *Journal of the Nepal Medical Association* 46(165):20–24. DOI: 10.31729/jnma.420.

Barrett, Jason W., and Andrew K. Scherer. 2005. Stones, bones, and crowded plazas: Evidence for Terminal Classic Maya warfare at Colha, Belize. *Ancient Mesoamerica* 16(1):101–118. DOI: 10.1017/S0956536105050091.

Bastone, Elisa B., Terry J. Freer, and John R. McNamara. 2000. Epidemiology of dental trauma: A review of the literature. *Australian Dental Journal* 45(1):2–9. DOI: 10.1111/j.1834-7819.2000.tb00234.x.

Becker, Marshall Joseph. 1973. Archaeological evidence for occupational specialization among the Classic Period Maya at Tikal, Guatemala. *American Antiquity* 38(4):396–406. DOI: 10.2307/279144.

Becker, Marshall Joseph. 2014. Dentistry in ancient Rome: Direct evidence for extractions based on the teeth from excavations at the Temple of Castor and Pollux in the Roman Forum. *International Journal of Anthropology* 29(4):209–226.

Bennike, Pia. 1985. *Paleopathology of Danish Skeletons: A Comparative Study of Demography, Disease and Injury*. Akademisk Forlag, Copenhagen.

Berlin, Elois Ann, and Brent Berlin. 1966. *Medical Ethnobiology of the Highland Maya of Chiapas, Mexico: The Gastrointestinal Diseases*. Princeton University Press, Princeton, NJ.

Bernardini, Federico, Claudio Tuniz, Alfredo Coppa, Lucia Mancini, Diego Dreossi, Diane Eichert, Gianluca Turco, Matteo Biasotto, Filippo Terrasi, Nicola de Cesare, Quan Hua, and Vladimir Levchenko. 2012. Beeswax as dental filling on a

Neolithic human tooth. *PLoS ONE* 7(9):e44904. DOI: 10.1371/journal.pone.0044904.

Breedlove, Dennis E., and Robert M. Laughlin. 2000. *Flowering of Man: A Tzotzil Botany of Zinacantán, Abridged Edition*. Smithsonian Institution Press, Washington, D.C.

Bricker, Victoria R., and Helga-Maria Miram. 2002. *An Encounter of Two Worlds: The Book of Chilam Balam of Kaua*. Tulane University Middle American Research Institute, New Orleans.

Brunner, Flavio, Gabriel Krastl, and Andreas Filippi. 2009. Dental trauma in adults in Switzerland. *Dental Traumatology* 25(2):181–184. DOI: 10.1111/j.1600-9657.2008.00752.x.

Buikstra, Jane E., and Douglas H. Ubelaker. 1994. *Standards for Data Collection from Human Skeletal Remains*. Arkansas Archeological Survey Research Series No. 44, Fayetteville.

Cahen, P. M., R. M. Frank, and J. C. Turlot. 1985. A survey of the reasons for dental extractions in France. *Journal of Dental Research* 64(8):1087–1093. DOI: 10.1177/00220345850640081401.

Cap, Bernadette. 2015a. *Classic Maya Economies: Identification of a Marketplace at Buenavista del Cayo, Belize*. Ph.D. dissertation, University of Wisconsin, Madison.

Cap, Bernadette. 2015b. How to know it when we see it: Marketplace identification at the Classic Maya site of Buenavista del Cayo, Belize. In *The Ancient Maya Marketplace: The Archaeology of Transient Space*, edited by Eleanor M. King. The University of Arizona Press, Tucson, pp. 111–137.

Carrasco Vargas, Ramón, Verónica A. Vázquez López, and Simon Martin. 2009. Daily life of the ancient Maya recorded on murals at Calakmul, Mexico. *Proceedings of the National Academy of Sciences* 106(46):19245–19249. DOI: 10.1073/pnas.0904374106.

Casagrande, David Gregory. 2002. *Ecology, Cognition, and Cultural Transmission of Tzeltal Maya Medicinal Plant Knowledge*. Ph.D. dissertation, University of Georgia, Athens.

Chase, Arlen F., and Diane Z. Chase. 1994. Maya veneration of the dead at Caracol, Belize. In *Seventh Palenque Round Table, 1989*, edited by Merle Greene Robertson and Virginia M. Fields. Pre-Columbian Art Research Institute, San Francisco, pp. 55–62.

Chase, Diane Z. 1994. Human osteology, pathology, and demography as represented in the burials of Caracol, Belize. In *Studies in the Archaeology of Caracol, Belize*, edited by Diane Z. Chase and Arlen F. Chase. Pre-Columbian Art Research Institute Monograph 7, San Francisco, pp. 123–138.

Chase, Diane Z., and Arlen F. Chase. 1998. The architectural context of caches, burials, and other ritual activities for the Classic Period Maya (as reflected at Caracol, Belize). In *Function and Meaning in Classic Maya Architecture*, edited by Stephen D. Houston. Dumbarton Oaks Research Library and Collection, Washington, D.C., pp. 239–332.

Chase, Diane Z., and Arlen F. Chase. 2011. Ghosts amid the ruins: Analyzing Relationships between the Living and the Dead among the Ancient Maya at Caracol, Belize. In *Living with the Dead: Mortuary Ritual in Mesoamerica*, edited by James L. Fitzsimmons and Izumi Shimada. University of Arizona Press, Tucson, pp. 78–101.

Cheetham, David. 2004. The role of "terminus groups" in lowland Maya site planning: An example from Cahal Pech. In *The Ancient Maya of the Belize Valley: Half a Century of Archaeological Research*, edited by James F. Garber. University Press of Florida, Gainesville, pp. 125–148.

Child, Mark B. 2006. *The Archaeology of Religious Movements: The Maya Sweatbath Cult of Piedras Negras*. Ph.D. dissertation, Yale University, New Haven, CT.

Christenson, Allen J. 2003. *Popol Vuh: The Sacred Book of the Maya*. University of Oklahoma Press, Norman.

Coe, William R. 1959. *Piedras Negras Archaeology: Artifacts, Caches, and Burials*. University Museum Monograph, 18. The University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia.

Coppa, A., L. Bondioli, A. Cucina, D. W. Frayers, C. Jarrige, J.-F. Jarrige, G. Quivron, M. Rossi, M. Vidale, and R. Macchiarelli. 2006. Early Neolithic tradition of dentistry: Flint tips were surprisingly effective for drilling tooth enamel in a prehistoric population. *Nature* 440:755–756. DOI: 10.1038/440775a.

Cortés, Hernando. 1962. *Five Letters of Cortés to the Emperor: 1519–1526*. W. W. Norton, New York.

Cosminsky, Sheila. 1972. *Decision Making and Medical Care in a Guatemalan Indian Community*. Ph.D. dissertation, Brandeis University, Waltham, MA.

Coto, Thomás de. 1983. Thesaurus verborum. In *Vocabulario de la Lengua Cakchiquel v[el] Guatemalteca, Nuevamente Hecho y Recopilado con Summo Estudio, Trabajo y Erudición*, edited by R. Acuña. Universidad Nacional Autónoma de México, Mexico City.

Cucina, Andrea, Cristina Perera Cantillo, Thelma Sierra Sosa, and Vera Tiesler. 2011. Carious lesions and maize consumption among the Prehispanic Maya: An analysis of a coastal community in northern Yucatan. *American Journal of Physical Anthropology* 145(4):560–567. DOI: 10.1002/ajpa.21534.

Cucina, Andrea, and Vera Tiesler. 2011. Salud oral y caries entre los mayas del período clásico. In *Vida Cotidiana de los Antiguos Mayas del Norte de la Península de Yucatán*, edited by Rafael Cobos and Lilia Fernández Souza. Ediciones de la Universidad Autónoma de Yucatán, Mérida, pp. 23–44.

Dahlin, Bruce H., Christopher T. Jensen, Richard E. Terry, David R. Wright, and Timothy Beach. 2007. In search of an ancient Maya market. *Latin American Antiquity* 18(4):363–384. DOI: 10.2307/25478193.

Dembo, Adolfo, and José Imbelloni. 1938. *Deformaciones Intencionales del Cuerpo Humano de Carácter Étnico. Sec. A, Tomo 3*. Humanior Biblioteca del Americanista Moderno. José Anesi, Buenos Aires.

Demirci, Mustafa, Safa Tuncer, and Ahmet Ayhan Yuceokur. 2010. Prevalence of caries on individual tooth surfaces and its distribution by age and gender in university clinic patients. *European Journal of Dentistry* 4(3):270–279.

Dong, X. D., and N. D. Ruse. 2003. Fatigue crack propagation path across the dentinoenamel junction complex in human teeth. *Journal of Biomedical Materials Research* 66A(1):103–109. DOI: 10.1002/jbm.a.10541.

Doyle, James A. 2012. Regroup on "E-groups": Monumentality and early centers in the Middle Preclassic Maya lowlands. *Latin American Antiquity* 23(4):355–379. DOI: 10.7183/1045-6635.23.4.355.

Duncan, William N. 2011. Bioarchaeological analysis of sacrificial victims from a Postclassic Maya temple from Ixlu, El Peten, Guatemala. *Latin American Antiquity* 22(4):549–572. DOI: 10.7183/1045-6635.22.4.549.

Durán, Fray Diego. 1971. *Book of the Gods and Rites and the Ancient Calendar*. Translated by Fernando Horcasitas and Doris Heyden. University of Oklahoma Press, Norman.

Emery, Kitty F. 2008. Techniques of ancient Maya bone working: Evidence from a Classic Maya deposit. *Latin American Antiquity* 19(2):204–221. DOI: 10.1017/S104566350000780X.

Emery, Kitty F. 2009. Perspectives on ancient Maya bone crafting from a Classic period bone-artifact manufacturing assemblage. *Journal of Anthropological Archaeology* 28(4):458–470. DOI: 10.1016/j.jaa.2009.07.003.

Emery, Kitty F. 2010. *Dietary, Environmental, and Societal Implications of Ancient Maya Animal Use in the Petexbatun: A Zooarchaeological Perspective on the Collapse*. Vanderbilt Institute of Mesoamerican Archaeology Series Volume 5. Vanderbilt University Press, Nashville.

Engerrand, G. 1917. Les mutilations dentaires chez les anciens Mayas. *Revue Anthropologique* 27:488–493.

Escobedo, Héctor L. 1997. PN 15: Excavaciones en las estructuras S-11, S-12 y S-10. In *Proyecto Arqueológico Piedras Negras Informe Preliminar No. 1, Primera Temporada, 1997*, edited by Héctor L. Escobedo and Stephen Houston. Instituto de Antropología e Historia, Guatemala City, pp. 121–132.

Escobedo, Héctor L., and Stephen D. Houston. 1997. *Proyecto Arqueológico Piedras Negras Informe Preliminar No. 1, Primera Temporada, 1997*. Instituto de Antropología e Historia, Guatemala City.

Escobedo, Héctor L., and Stephen D. Houston. 1998. *Proyecto Arqueológico Piedras Negras Informe Preliminar No. 2, Segunda Temporada, 1998*. Instituto de Antropología e Historia, Guatemala City.

Escobedo, Héctor L., and Stephen D. Houston. 1999. *Proyecto Arqueológico Piedras Negras Informe Preliminar No. 3, Tercera Temporada, 1999*. Instituto de Antropología e Historia, Guatemala City.

Escobedo, Héctor L., and Stephen D. Houston. 2001. *Proyecto Arqueológico Piedras Negras Informe Preliminar No. 4, Cuarta Temporada, 2000*. Instituto de Antropología e Historia, Guatemala City.

Escobedo, Héctor L., and Stephen D. Houston. 2005. *Informe de las Intervenciones en la Estructura K-5 de Piedras Negras*. Instituto de Antropología e Historia, Guatemala City.

Fastlicht, Samuel. 1947. Estudio dental y radiográfico de las mutilaciones dentarias. *Anales del Instituto Nacional de Antropología e Historia* 2:7–13.

Fastlicht, Samuel. 1951. Contribución al estudio del pegamento de las incrustaciones. In *Homenaje al Doctor Alfonso Caso*, edited by Alfonso Caso. Imprenta Nuevo Mundo, Mexico City, pp. 153–165.

Fastlicht, Samuel. 1971. *La odontología en México Prehispánico*. Ediciones Mexicanas, Mexico City.

Fastlicht, Samuel. 1976. *Tooth Mutilations and Dentistry in Pre-Columbian Mexico*. Quintessence Books, Berlin.

Fastlicht, Samuel, and Javier Romero. 1951. *El Arte de las Mutilaciones Dentarias*. Enciclopedia Mexicana de Arte, 14. Ediciones Mexicanas, Mexico City.

Forrai, Judit. 2009. The beginning of dental caries and its treatments. *Revista de Clínica e Pesquisa Odontológica* 5(2):187–192.

Fuss, Zvi, Igor Tsesis, and Shaul Lin. 2003. Root resorption—diagnosis, classification and treatment choices based on stimulation factors. *Dental Traumatology* 19(4):175–182. DOI: 10.1034/j.1600-9657.2003.00192.x.

Gates, William. 2000. *An Aztec Herbal: The Classical Codex of 1552*. Dover Publications, Mineola, NY.

Gibbon, Victoria, and Anne Marie Grimoud. 2014. Dental pathology, trauma and attrition in a Zambian Iron Age sample: A macroscopic and radiographic investigation. *International Journal of Osteoarchaeology* 24(4):439–458. DOI: 10.1002/oa.2228.

Goguitchaichvili, Avto, Juan Morales, Ramiro Aguayo Haro, Humberto Quiroz Castañon, and Jasinto Robles Camacho. 2017. First evidence of complex dental practice about 1300 BP in Mesoamerica revealed by absolute geomagnetic intensity. *Studia Geophysica et Geodaetica* 61(2):310–317. DOI: 10.1007/s11200-016-0851-3.

Golden, Charles W. 2017. Operación 15K: Excavaciones en la Estructura S-7. In *Proyecto Paisaje Piedras Negras–Yaxchilan, Informe de la Segunda Temporada de Investigación*, edited by Mónica Urquizú, Andrew K. Scherer, and Charles W. Golden. Instituto de Antropología e Historia, Guatemala City, pp. 49–61.

Golden, Charles, Andrew K. Scherer, Melanie Kingsley, Stephen D. Houston, and Héctor Escobedo. 2016. The life and afterlife of the Classic Period Piedras Negras kingdom. In *Ritual, Violence, and the Fall of the Classic Maya Kings*, edited by Gyles Iannone, Brett A. Houk, and Sonja A. Schwake. University Press of Florida, Gainesville, pp. 108–133.

Golden, Charles, Andrew K. Scherer, and René Muñoz. 2008. Piedras Negras and Yaxchilan: Divergent political trajectories in adjacent Maya polities. *Latin American Antiquity* 19(3):249–274. DOI: 10.2307/25478230.

Golden, Charles, Andrew K. Scherer, Whittaker Schroder, Clive Vella, and Alejandra Roche Recinos. 2020. Decentralizing the economies of the Maya west. In *The Real Business of Ancient Maya Economies: From Farmers' Fields to Rulers' Realms*, edited by Marilyn A. Masson, David A. Freidel, and Arthur A. Demarest. University Press of Florida, Gainesville, pp. 403–417.

Groark, Kevin P. 2005. Vital warmth and well-being: Steambathing as household therapy among the Tzeltal and Tzotzil Maya of highland Chiapas, Mexico. *Social Science & Medicine* 61(4):785–795. DOI: 10.1016/j.socscimed.2004.08.044.

Gubler, Ruth, and David Bolles. 2000. *The Book of Chilam Balam of Na: Facsimile, Translation, and Edited Text*. Labyrinthos, Lancaster.

Gwinnett, A. J., and L. Gorelick. 1979. Inlayed teeth of ancient Mayans: A tribological study using the SEM. *Scanning Electron Microscopy* 3(3):575–580.

Hamy, E. T. 1882. Les mutilations dentaires au Mexique et dans le Yucatan. *Bulletins et Mémoires de la Société d'Anthropologie de Paris* 5:879–882.

Hanihara, Tsunehiko, Hajime Ishida, Naoyuki Ohshima, Osamu Kondo, and Tetsuo Masuda. 1994. Dental calculus and other dental disease in a human skeleton of the Okhotsk culture unearthed at Hamanaka-2 site, Rebun-Island, Hokkaido, Japan. *International Journal of Osteoarchaeology* 4(4):343–351. DOI: 10.1002/oa.1390040408.

Havill, Lorena M., Diane M. Warren, Keith P. Jacobi, Karen D. Gettelman, Della Collins Cook, and K. Anne Pyburn. 1997. Late Postclassic tooth filing at Chau Hiix and Tipu, Belize. In *Bones of the Maya: Studies of Ancient Skeletons*, edited by Stephen L. Whittington and David M. Reed. Smithsonian Institution Press, Washington, D.C., pp. 89–104.

Hernández, Francisco. 1959. *Historia Natural de Nueva España, Volumen II*. Universidad Nacional Autónoma de México, Mexico City.

Hirth, Kenneth G. 2009. Craft production in a central Mexican marketplace. *Ancient Mesoamerica* 20(1):89–102. DOI: 10.1017/S0956536109990034.

Hirth, Kenneth G. 2013. The merchant's world: Commercial diversity and the economics of interregional exchange in highland Mesoamerica. In *Merchants, Markets, and Exchange in the Pre-Columbian World*, edited by Kenneth G. Hirth and Joanne Pillsbury. Dumbarton Oaks Research Library and Collection, Washington, D.C., pp. 85–112.

Hirth, Kenneth G. 2016. *The Aztec Economic World: Merchants and Markets in Ancient Mesoamerica*. Cambridge University Press, Cambridge.

Holley, George R. 1983. *Ceramic Change at Piedras Negras, Guatemala*. Ph.D. dissertation, Southern Illinois University, Carbondale.

Houston, Stephen D. 1996. Symbolic sweatbaths of the Maya: Architectural meaning in the Cross Group at Palenque, Mexico. *Latin American Antiquity* 7(2):132–151. DOI: 10.2307/971614.
Houston, Stephen D., Héctor L. Escobedo, Mark Child, Charles Golden, and A. René Muñoz. 2000. El inicio de una ciudad Maya: Una perspectiva desde Piedras Negras, Guatemala. In *Los Investigadores de la Cultura Maya, Vol. 8, Tomo I*. Universidad Autónoma de Campeche, Campeche, pp. 9–27.
Houston, Stephen D., Héctor Escobedo, Andrew K. Scherer, Mark Child, and James Fitzsimmons. 2003. Classic Maya death at Piedras Negras. In *Antropología de la Eternidad: La Muerte en la Cultura Maya*, edited by Andrés Ciudad Ruíz, Mario H. Ruz, and María Josefa Iglesias Ponce de León. Sociedad Española de Estudios Mayas, Mexico City, pp. 113–143.
Hughes, Cris E., and Crystal A. White. 2009. Crack propagation in teeth: A comparison of perimortem and postmortem behavior of dental materials and cracks. *Journal of Forensic Sciences* 54(2):263–266. DOI: 10.1111/j.1556-4029.2008.00976.x.
Hunter, John M., and Sonia I. Arbona. 1995. The tooth as a marker of developing world quality of life: A field study in Guatemala. *Social Science & Medicine* 41(9):1217–1240. DOI: 10.1016/0277-9536(95)00011-U.
Jackson, Sarah E., and Zachary X. Hruby. 2001. PN 15: Excavaciones en la Estructura S-11 y plaza asociada. In *Proyecto Arqueológico Piedras Negras Informe Preliminar No. 4, Cuarta Temporada, 2000*, edited by Héctor L. Escobedo and Stephen D. Houston. Instituto de Antropología e Historia, Guatemala City, pp. 27–36.
Kashanipour, Ryan Amir. 2012. *A World of Cures: Magic and Medicine in Colonial Yucatán*. Ph.D. dissertation, The University of Arizona, Tucson.
Katz, Esther. 1993. El temazcal: entre religión y medicina. In *III Coloquio de Historia de la Religión en Mesoamérica y Áreas Afines*, edited by Barbro Dahlgren Jordan. Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México, Mexico City, pp. 175–185.
Kidder, Alfred V., Justin Jennings, and Edwin M. Shook. 1946. *Excavations at Kaminaljuyu, Guatemala*. Carnegie Institution of Washington, Washington, D.C.
Kinaston, Rebecca, Anna Willis, Justyna J. Miszkiewicz, Monica Tromp, and Marc F. Oxenham. 2019. The dentition: Development, disturbances, disease, diet, and chemistry. In *Ortner's Identification of Pathological Conditions in Human Skeletal Remains*, edited by Jane E. Buikstra. 3rd ed. Academic Press, New York, pp. 749–798.
Kishen, Anil. 2015. Biomechanics of fractures in endodontically treated teeth. *Endodontic Topics* 33(1):3–13. DOI: 10.1111/etp.12089.
Kovacevich, Brigitte. 2007. Ritual, crafting, and agency at the Classic Maya kingdom of Cancuen. In *Mesoamerican Ritual Economy: Archaeological and Ethnological Perspectives*, edited by E. Christian Wells and Karla L. Davis-Salazar. University Press of Colorado, Boulder, pp. 67–114.
Kovacevich, Brigitte. 2011. The organization of jade production at Cancuen, Guatemala. In *The Technology of Maya Civilization: Political Economy And Beyond in Lithic Studies*, edited by Zachary X. Hruby, Geoffrey E. Braswell, and Oswaldo Chinchilla Mazariegos. Routledge, London, pp. 151–166.
Lanfranco, Luis Pezo, and Sabine Eggers. 2012. Caries through time: An anthropological overview. In *Contemporary Approach to Dental Caries*, edited by Ming-Yu Li. IntechOpen, Rijeka, HR, pp. 3–34.
Lee, Jared T. 2007. "If My Tooth Hurts, I Pull It Out": Oral health in Antigua Santa Catarina Ixtahuacán. In *Health Care in Maya Guatemala: Confronting Medical Pluralism in a Developing Country*, edited by Walter Randolph Adams and John P. Hawkins. University of Oklahoma Press, Norman, pp. 179–193.
Lieverse, Angela R. 1999. Diet and the aetiology of dental calculus. *International Journal of Osteoarchaeology* 9(4):219–232. DOI: 10.1002/(SICI)1099-1212(199907/08)9:4219::AID-OA4753.0.CO;2-V.
López de Gómara, Francisco. 1966. *Cortés: The Life of the Conqueror by his Secretary*. University of California Press, Berkeley.
Lukacs, J. R. 2007. Dental trauma and antemortem tooth loss in prehistoric Canary Islanders: Prevalence and contributing factors. *International Journal of Osteoarchaeology* 17(2):157–173. DOI: 10.1002/oa.864.
Lukacs, J. R., and B. E. Hemphill. 1990. Traumatic injuries of prehistoric teeth: New evidence from Baluchistan and Punjab provinces, Pakistan. *Anthropologischer Anzeiger* 48(4):351–363.
MacGregor, A. J. 1969. Factors affecting fracture of teeth during extraction. *British Journal of Oral Surgery* 7(1):55–62. DOI: 10.1016/S0007-117X(69)80061-2.
Maffi, Luisa. 1994. *A Linguistic Analysis of Tzeltal Maya Ethnosymptomatology*. Ph.D. dissertation, University of California, Berkeley.
Maler, Teobert. 1901. *Researches in the Central Portion of the Usumatsintla Valley: Report of Explorations for the Museum, 1898–1900*. Memoirs of the Peabody Museum of American Archaeology and Ethnology Vol. 2, No. 1. Peabody Museum of Archaeology and Ethnology, Cambridge.
Massey, Virginia K., and D. Gentry Steele. 1997. A Maya skull pit from the Terminal Classic period, Colha, Belize. In *Bones of the Maya: Studies of Ancient Skeletons*, edited by Stephen L. Whittington and David M. Reed. Smithsonian Institution Press, Washington, D.C., pp. 62–77.
Mattscheck, Donna, Alan S. Law, and Donald R. Nixdorf. 2016. Diagnosis of the non-odontogenic toothache. In *Cohen's Pathways of the Pulp*, edited by Kenneth M. Hargreaves and Louis H. Berman. 11th ed. Elsevier, St. Louis, pp. 684–705.
Mendieta, Rosa M., and Silvia del Amo R. 1981. *Plantas Medicinales del Estado de Yucatán*. Instituto Nacional de Investigaciones Sobre Recursos Bióticos, Xalapa.
Merbs, Charles F. 1968. Anterior tooth loss in Arctic populations. *Southwestern Journal of Anthropology* 24(1):20–32.
Milner, George R., and Clark Spencer Larsen. 1991. Teeth as artifacts of human behavior: Intentional mutilation and accidental modification. In *Advances in Dental Anthropology*, edited by Mark A. Kelley and Clark Spencer Larsen. Wiley-Liss, New York, pp. 357–378.
Moedano, Gabriel. 1977. El temazcal y su deidad protectora en la tradición oral. *Boletín del Departamento de Investigación de las Tradiciones Populares* 4:5–32.
Moholy-Nagy, Hattula, and William R. Coe. 2008. *The Artifacts of Tikal: Ornamental and Ceremonial Artifacts and Unworked Material. Tikal Report 27A*. University Museum Monograph, 127. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia.
Molina, Alonso de. 1571. *Vocabulario en Lengua Castellana y Mexicana*. Editorial Antonio Espinosa, Mexico City.
Moore, W. J., and Elisabeth Corbett. 1973. The distribution of dental caries in ancient British populations: II. Iron Age, Romano-British and mediaeval periods. *Caries Research* 7(2):139–153. DOI: 10.1159/000259838.
Morita, Manabu, Toshihide Kimura, Masaru Kanegae, Akira Ishikawa, and Tatsuo Watanabe. 1994. Reasons for extraction

of permanent teeth in Japan. *Community Dentistry and Oral Epidemiology* 22(5PT1):303–306. DOI: 10.1111/j.1600-0528.1994.tb02056.x.

Muñoz, Arturo René. 2004. *The Ceramic Sequence of Piedras Negras, Guatemala: Type and Varieties*. FAMSI Report #2055. http://www.famsi.org/reports/02055/02055Munoz01.pdf.

Nayyar, J., M. Clarke, M. O'Sullivan, and L. F. A. Stassen. 2015. Fractured root tips during dental extractions and retained root fragments: A clinical dilemma? *British Dental Journal* 218(5):285–290. DOI: 10.1038/sj.bdj.2015.147.

Nichols, Deborah L. 2013. Merchants and merchandise: The archaeology of Aztec commerce at Otumba, Mexico. In *Merchants, Markets, and Exchange in the Pre-Columbian World*, edited by Kenneth G. Hirth and Joanne Pillsbury. Dumbarton Oaks Research Library and Collection, Washington, D.C., pp. 49–84.

Nixdorf, Donald, and Estephan Moana-Filho. 2011. Persistent dento-alveolar pain disorder (PDAP): Working towards a better understanding. *Reviews in Pain* 5(4):18–27. DOI: 10.1177/204946371100500404.

Norton, Brandy N. 2016. *A Categorization and Comparative Analysis of Maya Body Part Caches*. Master's thesis, University of Chicago, Chicago.

Ortiz, A., E. C. Torres Pino, and E. Orellana González. 2016. First evidence of pre-Hispanic dentistry in South America—Insights from Cusco, Peru. *HOMO-Journal of Comparative Human Biology* 67(2):100–109. DOI: 10.1016/j.jchb.2015.09.006.

Oxilia, Gregorio, Flavia Fiorillo, Francesco Boschin, Elisabetta Boaretto, Salvatore A. Apicella, Chiara Matteucci, Daniele Panetta, Rossella Pistocchi, Franca Guerrini, Cristiana Margherita, Massimo Andretta, Rita Sorrentino, Giovanni Boschian, Simona Arrighi, Irene Dori, Giuseppe Mancuso, Jacopo Crezzini, Alessandro Riga, Maria C. Serrangeli, Antonino Vazzana, Piero A. Salvadori, Mariangela Vandini, Carlo Tozzi, Adriana Moroni, Robin N. M. Feeney, John C. Willman, Jacopo Moggi-Cecchi, and Stefano Benazzi. 2017. The dawn of dentistry in the Late Upper Paleolithic: An early case of pathological intervention at Riparo Fredian. *American Journal of Physical Anthropology* 163(3):446–461. DOI: 10.1002/ajpa.23216.

Oxilia, Gregorio, Marco Peresani, Matteo Romandini, Chiara Matteucci, Cynthianne Debono Spiteri, Amanda G. Henry, Dieter Schulz, Will Archer, Jacopo Crezzini, Francesco Boschin, Paolo Boscato, Klervia Jaouen, Tamara Dogandzic, Alberto Broglio, Jacopo Moggi-Cecchi, Luca Fiorenza, Jean-Jacques Hublin, Ottmar Kullmer, and Stefano Benazzi. 2015. Earliest evidence of dental caries manipulation in the Late Upper Palaeolithic. *Scientific Reports* 5:1–10. DOI: 10.1038/srep12150.

Pendergast, David M. 1979. *Excavations at Altun Ha, Belize, 1964–1970*. 3 vols. Royal Ontario Museum, Toronto.

Pendergast, David M., Murray H. Bartley, and George J. Armelagos. 1968. A Maya tooth offering from Yakalche, British Honduras. *Man* 3(4):635–643. DOI: 10.2307/2798584.

Pérez Robles, Griselda, Andrew K. Scherer, and Charles Golden. 2016. *Proyecto Paisaje Piedras Negras–Yaxchilan: Informe de la Primera Temporada de Investigación*. Instituto de Antropología e Historia, Guatemala City.

Pérez Robles, Griselda, Andrew Scherer, Charles Golden, Shanti Morell-Hart, Juan Carlos Pérez, Omar Alcover, Alejandra Roche, Mallory Matsumoto, Joshua Schnell, Max Seidita, and Edwin Pérez Robles. 2017. Resultados de la segunda temporada de investigaciones del Proyecto Paisaje Piedras Negras–Yaxchilan. Paper presented at the 31st Simposio de Investigaciones Arqueológicas en Guatemala, Guatemala City.

Pitcavage, Megan R., and Geoffrey E. Braswell. 2010. Diet, health, and death at Pusilhá, Belize. *Research Reports in Belizean Archaeology* 7:65–72.

Proskouriakoff, Tatiana. 1960. Historical implications of a pattern of dates at Piedras Negras, Guatemala. *American Antiquity* 25(4):454–475. DOI: 10.2307/276633.

Ramírez-Salomón, Marco. 2016. *Composición Química, Propiedades Antisépticas y Selladoras del Cemento Utilizado en las Antiguas Incrustaciones Dentales Mayas y su Potencial Aplicabilidad en la Odontología Contemporánea*. Ph.D. dissertation, Universidad Autónoma de Yucatán, Mérida.

Ramírez-Salomón, Marco, Vera Tiesler, Iván Oliva Arias, and Guillermo Mata Amado. 2003. Posibles técnicas empleadas en la decoración dental en la Mesoamérica Prehispánica. Un estudio experimental de instrumentos y superficies. In *Estudios de Antropología Biológica XI*, edited by Carlos Serrano Sánchez, Sergio López Alonso, and Francisco Ortiz Pedraza. Universidad Nacional Autónoma de México, Mexico City, pp. 983–998.

Reich, Elmar, and Karl-Anton Hiller. 1993. Reasons for tooth extraction in the western states of Germany. *Community Dentistry and Oral Epidemiology* 21(6):379–383. DOI: 10.1111/j.1600-0528.1993.tb01103.x.

Richards, W., J. Ameen, A. M. Coll, and G. Higgs. 2005. Reasons for tooth extraction in four general dental practices in South Wales. *British Dental Journal* 198(5):275–278. DOI: 10.1038/sj.bdj.4812119.

Ricketson, Oliver G., and Edith B. Ricketson. 1937. Human remains. In *Uaxactun, Guatemala: Group E—1926–1931*, edited by Oliver G. Ricketson and Edith B. Ricketson. Carnegie Institution of Washington, Washington, D.C., pp. 139–149.

Roche Recinos, Alejandra. 2016. *Maya Lithic Economies at Piedras Negras, Guatemala: Production and Exchange in an Elite Architectural Complex*. Master's thesis, Brown University, Providence, RI.

Roche Recinos, Alejandra, Jesús Alejandro González Córdova, Shanti Morell-Hart, and Charles Golden. 2017. Operación 15I: Excavaciones en la plaza de la Estructura S-18. In *Proyecto Paisaje Piedras Negras–Yaxchilan, Informe de la Segunda Temporada de Investigación*, edited by Mónica Urquizú, Andrew K. Scherer, and Charles Golden. Instituto de Antropología e Historia, Guatemala City, pp. 8–32.

Roche Recinos, Alejandra, and Mallory Matsumoto. 2016. Operación 15: Excavaciones en el Grupo S. In *Proyecto Paisaje Piedras Negras–Yaxchilan, Informe de la Primera Temporada de Investigación*, edited by Griselda Pérez Robles, Andrew K. Scherer, and Charles W. Golden. Instituto de Antropología e Historia, Guatemala City, pp. 7–34.

Romero, Javier. 1951. Las mutilaciones dentarias prehispánicas de América. In *El Arte de las Mutilaciones Dentarias*, edited by Samuel Fastlicht and Javier Romero. Ediciones Mexicanas, Mexico City, pp. 9–58.

Romero, Javier. 1958. *Mutilaciones dentarias prehispánicas de México y América en general*. Serie Investigaciones 3. Instituto Nacional de Antropología e Historia, Mexico City.

Romero, Javier. 1970. Dental mutilation, trephination, and cranial deformation. In *Handbook of Middle American Indians, Volume 9: Physical Anthropology*, edited by T. Dale Stewart. University of Texas Press, Austin, pp. 50–67.

Roys, Ralph L., ed. 1965. *Ritual of the Bacabs*. University of Oklahoma Press, Norman.

Roys, Ralph L. 1976. *The Ethno-Botany of the Maya*. Reprint ed. Institute for the Study of Human Issues, Philadelphia.

Rubín de la Borbolla, D. F. 1940. Types of tooth mutilation found in Mexico. *American Journal of Physical Anthropology* 26(1):349–365. DOI: 10.1002/ajpa.1330260136.

Sahagún, Fray Bernardino de. 1961. *Florentine Codex: General History of the Things of New Spain, Book 10: The People*. Translated by Charles E. Dibble and Arthur J. O. Anderson. University of Utah Press, Salt Lake City.

Sahagún, Fray Bernardino de. 2012. *Florentine Codex: General History of the Things of New Spain, Book 10: The People*. 2nd ed. Translated by Charles E. Dibble and Arthur J. O. Anderson. University of Utah Press, Salt Lake City.

Saul, Frank P., and Norman Hammond. 1974. A Classic Maya tooth cache from Lubaantun, Belize. *Man* 9(1):123–127. DOI: 10.2307/2800040.

Schendel, Gordon. 1968. *Medicine in Mexico: From Aztec Herbs to Betatrons*. University of Texas Press, Austin.

Scherer, Andrew K. 2015a. *Mortuary Landscapes of the Classic Maya: Rituals of Body and Soul*. University of Texas Press, Austin.

Scherer, Andrew K. 2015b. Osteology of the El Diablo Complex: Burial 9 and associated caches. In *Temple of the Night Sun: A Royal Tomb at El Diablo, Guatemala*, edited by Stephen Houston, Sarah Newman, Edwin Román, and Thomas Garrison. Precolumbia Mesoweb Press, San Francisco, pp. 180–209.

Scherer, Andrew K. 2018. Grave matters: Bioarchaeology and mortuary archaeology at El Zotz, Bejucal, and El Palmar. In *An Inconstant Landscape: The Maya Kingdom of El Zotz, Guatemala*, edited by Thomas G. Garrison and Stephen Houston. University Press of Colorado, Louisville, pp. 303–360.

Scherer, Andrew K., Griselda Pérez Robles, Charles W. Golden, Shanti Morell-Hart, Omar Alcover, Alejandra Roche Recinos, Mallory Matsumoto, Juan Carlos Pérez Calderón, Laura Lucía Gámez Díaz, Edwin Pérez Robles, and Rony Piedrasanta Castellanos. 2017. Resultados de la primera temporada de investigaciones del Proyecto Paisaje Piedras Negras–Yaxchilan. In *XXX Simposio de Investigaciones Arqueológicos en Guatemala, 2016*, edited by B. Arroyo, L. Méndez Salinas, and G. Ajú Álvarez. Museo Nacional de Arqueología y Etnología, Guatemala, Guatemala City, pp. 287–295.

Scherer, Andrew K., Lori E. Wright, and Cassady J. Yoder. 2007. Bioarchaeological evidence for social and temporal differences in diet at Piedras Negras, Guatemala. *Latin American Antiquity* 18(1):85–104. DOI: 10.2307/25063087.

Scherer, Andrew K., Cassady J. Yoder, and Lori E. Wright. 1999. Los esqueletos de Piedras Negras: Reporte preliminar #3. In *Proyecto Arqueológico Piedras Negras: Informe Preliminar No. 3, Tercera Temporada, 1999*, edited by Héctor L. Escobedo and Stephen Houston. Instituto de Antropología e Historia, Guatemala City, pp. 387–400.

Scherer, Andrew K., Cassady J. Yoder, and Lori E. Wright. 2001. Los esqueletos de Piedras Negras: Reporte preliminar #4. In *Proyecto Arqueológico Piedras Negras: Informe Preliminar No. 4, Cuarta Temporada, 2000*, edited by Héctor L. Escobedo and Stephen Houston. Instituto de Antropología e Historia, Guatemala City, pp. 553–557.

Schnell, Joshua T. 2017. *Medicine, Dental Practice, and the Production of Bone Objects among the Classic Maya as seen from the S-Sector of Piedras Negras Guatemala*. Master's thesis, Brown University, Providence, RI.

Schnell, Joshua T., Sarah E. Newman, and Andrew K. Scherer. 2017. Análisis óseos de Operación 15 de Piedras Negras. In *Proyecto Paisaje Piedras Negras–Yaxchilan, Informe de la Segunda Temporada de Investigación*, edited by Mónica Urquizú, Andrew K. Scherer, and Charles Golden. Instituto de Antropología e Historia, Guatemala City, pp. 200–228.

Schnell, Joshua T., and Andrew K. Scherer. 2017. Análisis de huesos humanos de Operación 74 de Piedras Negras. In *Proyecto Paisaje Piedras Negras–Yaxchilan, Informe de la Segunda Temporada de Investigación*, edited by Mónica Urquizú, Andrew K. Scherer, and Charles Golden. Instituto de Antropología e Historia, Guatemala City, pp. 229–234.

Schwartz, Jeffrey H., Jaymie Brauer, and Penny Gordon-Larsen. 1995. Brief communication: Tigaran (Point Hope, Alaska) tooth drilling. *American Journal of Physical Anthropology* 97(1):77–82. DOI: 10.1002/ajpa.1330970106.

Scott, E. C. 1979. Dental wear scoring technique. *American Journal of Physical Anthropology* 51(2): 213–217. DOI: 10.1002/ajpa.1330510208.

Scott, G. Richard, and J. R. Winn. 2011. Dental chipping: Contrasting patterns of microtrauma in Inuit and European populations. *International Journal of Osteoarchaeology* 21(6):723–731. DOI: 10.1002/oa.1184.

Seidel, John C., Roger H. Colten, Edward A. Thibodeau, and John G. Aghajanian. 2005. Iatrogenic molar borings in 18th and early 19th century Native American dentitions. *American Journal of Physical Anthropology* 127(1):7–12. DOI: 10.1002/ajpa.20177.

Shaw, Leslie C. 2012. The elusive Maya marketplace: An archaeological consideration of the evidence. *Journal of Archaeological Research* 20(2):117–155. DOI: 10.1007/s10814-011-9055-0.

Shelton, Rebecca, Amy Michael, Maxwell Forton, and Joshua Burbank. 2015. Cultural Assemblages in the front and middle chambers of Actun Kabul. In *The Central Belize Archaeological Survey Project: A Report of the 2013 Field Season*, edited by Gabriel D. Wrobel, Shawn G. Morton, and Christopher R. Andres. Belize Archaeological Research and Education Foundation, East Lansing, MI, pp. 14–33.

Smith, B. Holly. 1984. Patterns of molar wear in hunter-gatherers and agriculturalists. *American Journal of Physical Anthropology* 63(1):39–56. DOI: 10.1002/ajpa.1330630107.

Song, Rhan-ju, Bobbi Hohmann, Denise Mardiros, and David Glassman. 1994. All in the family circle: A second interim report of the human skeletal remains from Tolok, Cahal Pech, Belize. In *Belize Valley Archaeological Reconnaissance Project: Progress Report of the Sixth (1993) Field Season*, edited by Jaime J. Awe. Institute of Archaeology, University of London, London, pp. 147–163.

Stewart, T. Dale. 1941. New examples of tooth mutilation from Middle America. *American Journal of Physical Anthropology* 28(1):117–124. DOI: 10.1002/ajpa.1330280107.

Tiesler, Vera. 2001. *Decoraciones Dentales entre los Antiguos Mayas*. Ediciones Euroamericanas, Mexico City.

Tiesler, Vera, Andrea Cucina, and Marco Ramírez-Salomón. 2017. Permanent dental modifications among the ancient Maya: Procedures, health risks, and social identities. In *A World View of Bioculturally Modified Teeth*, edited by Scott Burnett and Joel Irish. University Press of Florida, Gainesville, pp. 270–284.

Tiesler, Vera, Marco Ramírez-Salomón, and Iván Oliva Árias. 1999. Técnicas de decoración dental en México: Un acercamiento experimental. *Actualidades Arqueológicas: Pasado en Presente* 2:18–24.

Tiesler, Vera, Marco Ramírez-Salomón, and Iván Oliva Árias. 2002. Decoration techniques in ancient Mexico—a study of dental surfaces using radiography and S.E.M. *Oral Health* 92(9):33–36.

Tokovinine, Alexandre, and Dmitri Beliaev. 2013. People of the road: Traders and travelers in ancient Maya words and images. In *Merchants, Markets, and Exchange in the Pre-Columbian World*, edited by Kenneth G. Hirth and Joanne Pillsbury. Dumbarton Oaks Research Library and Collection, Washington, D.C., pp. 169–200.

Turner, Christy G., II. 2004. A second drilled tooth from prehistoric western North America. *American Antiquity* 69(2):356–360. DOI: 10.2307/4128425.

Urquizú, Mónica. 1998. PN 15: Excavaciones en Estructura S-8, del Grupo S-11. In *Proyecto Arqueológico Piedras Negras Informe Preliminar No. 2, Segunda Temporada, 1998*, edited by Héctor L. Escobedo and Stephen D. Houston. Instituto de Antropología e Historia, Guatemala City, pp. 83–102.

Urquizú, Mónica, and Damaris Menéndez. 2016. Análisis cerámico temporada 2016 Proyecto Paisaje Piedras Negras–Yaxchilan. In *Proyecto Paisaje Piedras Negras–Yaxchilan, Informe de la Primera Temporada de Investigación*, edited by Griselda Pérez Robles, Andrew K. Scherer, and Charles W. Golden. Instituto de Antropología e Historia, Guatemala City, pp. 216–242.

Urquizú, Mónica, Andrew K. Scherer, and Charles Golden, eds. 2017. *Proyecto Paisaje Piedras Negras–Yaxchilan: Informe de la Segunda Temporada de Investigación*. Instituto de Antropología e Historia, Guatemala City.

Venkateshwar, Gokul Parameswar, Mukul Nandkumar Padhye, Aman Rajiv Khosla, and Shruti Tejprakash Kakkar. 2011. Complications of exodontia: A retrospective study. *Indian Journal of Dental Research* 22(5):633–638. DOI: 10.4103/0970-9290.93447.

Viciano, Joan, Sandra López-Lázaro, Deneb Teresa Cesana, Ruggero D'Anastasio, and Luigi Capasso. 2012. Multiple traumatic dental injuries: A case report in a young individual from the Samnitic Necropolis of Opi Val Fondillo (VI–V century BC; Central Italy). *Journal of Archaeological Science* 39(2):566–572. DOI: 10.1016/j.jas.2011.10.030.

Virkki, N. 1962. Comentarios sobre el baño de vapor entre los indígenas de Guatemala. *Guatemala Indígena* 2(2):71–85.

Wagley, Charles. 1949. The social and religious life of a Guatemalan village. *American Anthropologist* 51(4, Part 2):1–150.

Watson, Sarah, Joshua T. Schnell, Shanti Morell-Hart, and Andrew K. Scherer. 2019. Health Care in the Marketplace: Exploring Medicinal Plants and Practices at Piedras Negras. Paper presented at the 84th Annual Society for American Archaeology Meetings, Albuquerque, NM.

Wauchope, Robert. 1938. *Modern Maya Houses: A Study of Their Archaeological Significance*. Carnegie Institution of Washington publication, 502. Carnegie Institution of Washington, Washington, D.C.

Weeks, John M., Jane Hill, and Charles W. Golden, eds. 2005. *Piedras Negras Archaeology, 1931–1939*. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia.

Weiss-Krejci, Estella. 2011. The formation of mortuary deposits: Implications for understanding mortuary behavior of past populations. In *Social Bioarchaeology*, edited by Sabrina C. Agarwal and Bonnie A. Glencross. Blackwell Publishing, Hoboken, NJ, pp. 68–106.

White, Donald J. 1997. Dental calculus: Recent insights into occurrence, formation, prevention, removal and oral health effects of supragingival and subgingival deposits. *European Journal of Oral Sciences* 105(5):508–522. DOI: 10.1111/j.1600-0722.1997.tb00238.x.

Whittington, Stephen L. 1999. Caries and antemortem tooth loss at Copán: Implications for commoner diet. In *Reconstructing Ancient Maya Diet*, edited by Christine D. White. University of Utah Press, Salt Lake City, pp. 151–167.

Whittington, Stephen L. 2003. Analysis of human skeletal material excavated by Guillemin. In *Archaeology and Ethnohistory of Iximché*, edited by C. Roger Nance, Stephen L. Whittington, and Barbara E. Borg. University Press of Florida, Gainesville, pp. 241–304.

Wrobel, Gabriel, Christophe Helmke, Sherry Gibbs, George Micheletti, Norbert Stanchly, and Terry Powis. 2019. Two trophy skulls from Pacbitun, Belize. *Latin American Antiquity* 30(1):218–223. DOI: 10.1017/laq.2019.1.

Wrobel, Gabriel D., Rebecca Shelton, Shawn Morton, Joshua Lynch, and Christopher Andres. 2013. The view of Maya cave ritual from the Overlook Rockshelter, Caves Branch River Valley, central Belize. *Journal of Cave and Karst Studies* 75(2):126–135. DOI: 10.4311/2011AN0233.