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A Histological Study of Enamel Developmental Defects in a Chacma Baboon (*Papio ursinus*) Incisor

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ABSTRACT Physiological stress disrupts normal tooth growth creating grooves on the enamel surface (i.e., linear enamel hypoplasia or LEH). Hypoplastic defects often, but not always, co-occur with internal accentuated lines (AL). Monkeys reportedly exhibit fewer enamel defects than hominoids as their presumably faster-growing teeth produce shallower LEH defects that are harder to macroscopically identify. In this case study of a chacma baboon (*Papio ursinus*) incisor, we assessed whether AL are matched by LEH defects; how enamel extension rates (EER) and striae angles relate to the surface distribution of LEH defects; and whether striae angles are acute and EERs fast compared to hominoid anterior teeth. Normal wear to this specimen resulted in enamel loss (first two deciles) and surface abrasion, mainly near the cusp. We found a higher occurrence of AL (N = 48) compared to LEH defects (N = 10), which co-occurred in all instances of LEH. The spatial distribution of AL is more consistent, ranging from 3-10/decile, while LEH defects occur mainly in the midcrown and cervical regions. This incisor exhibits faster EERs (mean = 23.6 μm/day) and acuter striae angles (11-16°) compared to hominoids, likely creating shallower LEH defects and contributing to the discrepancy between AL and LEH defects.

Some chacma baboons inhabiting South Africa's Cape Peninsula live in close proximity to human dwellings and tourist attractions (Hoffman and O'Riain, 2011). Human-modified environments have been shown to offer baboons the opportunity to find high-calorie foods in the form of crops or food waste, which is linked to more rest time and improved body condition (Strum, 2010). Each square kilometer of human-modified habitat on the Cape Peninsula can support almost five times the baboon population compared to a square kilometer of natural habitat (Hoffman and O'Riain, 2012). However, human-modified environments can expose baboons to more frequent, and often-aggressive, interactions with humans (Kansky and Gaynor, 2000) (Figure 1). Baboons that persistently exhibit behavior that threatens the safety and welfare of residents in the Cape Peninsula may be euthanized (Beamish and O'Riain, 2014), sometimes leading to the extirpation of entire baboon troops (Skead, 1980).

Both physiological and behavioral responses to stress have been observed in chacma baboons residing in Table Mountain National Park; adult baboons that spend more time in anthropogenic habitats have higher levels of glucocorticoid hormones, exhibit more aggressive behavior, and spend less time socializing (Chowdhury et al., 2020). Physiological stress during early development, such as bodily trauma, febrile illness, or malnutrition, is associated with disruptions in the normal enamel

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Figure 1. Left: female chacma baboon attempting to access food in a locked waste disposal bin (courtesy of Larissa Swedell). Right: male showing teeth in an act of intimidation (courtesy of Human Wildlife Solutions).

secretion activity (amelogenesis) of ameloblasts (Goodman and Rose, 1990; Guatelli-Steinberg et al., 2012; Hillson and Bond, 1997; Nanci, 2018). The present study focuses on two types of disruptions in enamel secretion: linear enamel hypoplasia and accentuated lines.

Linear enamel hypoplasia (LEH) manifests as horizontal grooves or lines that appears on the enamel surface (Goodman and Rose, 1990; Guatelli -Steinberg et al., 2012) (Figure 2). LEH defects often, but not always, co-occur with accentuated lines (AL) visible in the enamel cross-section (Condon and Rose, 1992; Witzel et al., 2008). The co -occurrence of the two defect types is expected, as it is thought that LEH and AL are external and internal manifestations of the same disruption in normal tooth growth (Goodman and Rose, 1990). However, a three threshold model for interpreting disturbances in enamel secretion at the cellular level has been set forth (Kierdorf et al., 2000; Kierdorf et al., 2004; Witzel et al., 2006; Witzel et al., 2008) and proposes an explanation for the variable co-occurrence of the two defect types: when the lowest threshold is surpassed, the minor disruption in growth can result in an LEH defect without the formation of a co-occurring accentuated line. They also considered the timing of the disruption, arguing that accentuated lines are formed when all the involved ameloblasts are impaired, while LEH defects manifest when ameloblasts are disrupted during the late stage of secretion.

Accentuated lines manifest in enamel cross-sections as dark, pronounced lines that either fall between, or are coincident with, normal striae of Retzius (Guatelli-Steinberg, 2016). The latter structures form due to regular alterations in mineralization, mineral composition, or changes in the prism or crystalline structure of the enamel (Risnes, 1990), and represent a regular enamel growth rhythm, ranging from 2 to 12 days in primates (Dumont, 1995; Mahoney et al., 2017; McGrath et al., 2019).

It has been suggested that monkeys are less likely to exhibit LEH defects than great apes as the angles that their striae of Retzius make with the enamel surface are acute, leading to defects that are shallow and difficult to detect (Guatelli-Steinberg et al., 2012; McGrath et al., 2019). The acute striae angles in monkey teeth may represent fast rates of enamel extension, or the rate at which ameloblasts differentiate along the enamel-dentine junction (Shellis, 1998). Previous analyses in great

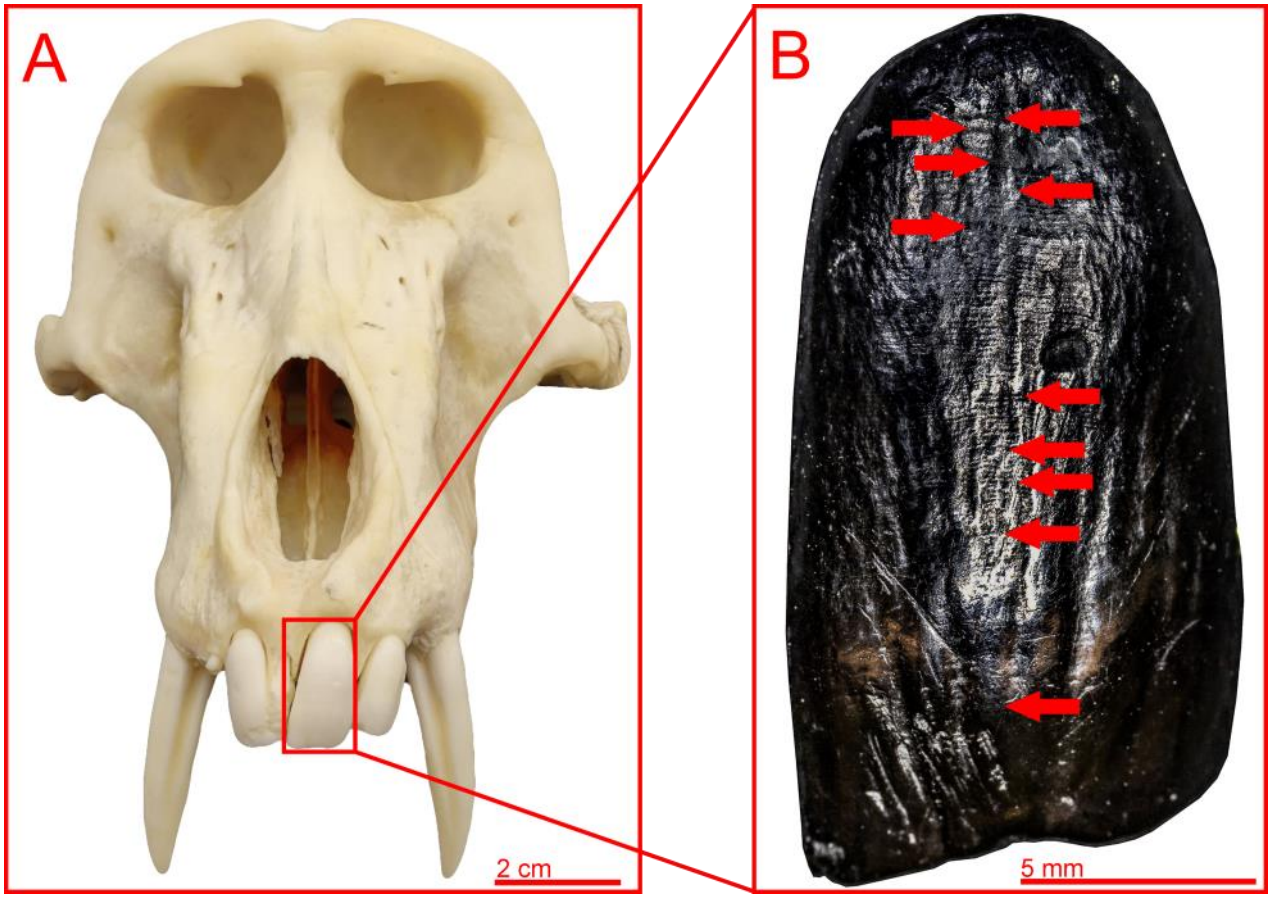

Figure 2. A: Cranium of male chacma baboon B4-03 with the sectioned incisor (ULI1) highlighted. B: Macrophotograph of the incisor epoxy replica; red arrows mark the approximate locations of LEH defects (N = 10). Nine LEH defects were classified as minor; one defect (fifth LEH defect from the top of the image) was classified as moderate.

apes have documented strong relationships between faster enamel extension rates, acute striae angles just below the outer enamel surface (OES), and shallow LEH defects (McGrath et al., 2019). Enamel extension rates and associated striae angles change as enamel formation proceeds from cusp to cervix (Guatelli-Steinberg et al., 2012; McGrath et al., 2019; Shellis, 1998). Both human and nonhuman primate anterior teeth exhibit the highest enamel extension rates in the cuspal part of the crown, with reductions by the midcrown region. In humans, extension rates continue to decrease from the midcrown to the cervix. In nonhuman ape canines, extension rates remain constant, or in some cases, and particularly in males, increase toward the cervix (McGrath et al., 2019), with an associated decrease in the number of identified LEH defects in the last deciles (Guatelli-Steinberg et al., 2012). Less is known about the details of how enamel extension rates and striae angles change along the crowns of incisors, and currently no LEH defect depths exist for any monkey species. However, it might be expected that monkeys with their faster life histories and relatively smaller body sizes should exhibit even faster enamel extension rates and acuter striae angles compared to hominoids.

Intrinsic growth variation influences LEH defect expression among species, sexes, and tooth types, while extrinsic variables like dental wear and abrasion add additional complications when interpreting imperfectly preserved teeth. Primate enamel is generally subject to considerable abrasion pressure that is attributed to the composition of their diet (Lucas et al., 2008) and the nature of their masticatory and extra-masticatory (e.g., using anterior teeth to grasp non-food items) tooth use behaviors (Molnar, 2011; Stojanowski et al., 2016). Incisor enamel is more susceptible to polishing and chipping compared to other tooth types (Stojanowski et al., 2016). This abrasion pattern is observed due to the anterior position of incisors in the skull, which provides the animal greater control when manipulating or processing dietary and non-dietary items using teeth (Stojanowski et al., 2016; Ungar, 1994).

This abrasion is exacerbated by the fact that many food items in baboon diets (especially hypogeous foods) are often contaminated with soil, sand, or other particulate matter, accelerating the wear rate of teeth by introducing exogenous grit to the oral cavity (Daegling and Grine, 1999; Galbany et al., 2014). Since normal tooth wear occurs mostly near the cusp, cuspal LEH defects may erode off the surface and become imperceptible, making them more challenging to identify compared to cervical LEH defects.

In the present study, a male chacma baboon (*Papio ursinus*) upper left incisor was thin sectioned and analyzed. The correspondence between LEH and AL defects is evaluated by comparing the association between these defect types on the enamel surface (LEH) and in the enamel cross-section (AL). Here we ask: (1) To what extent do LEH and AL defects co-occur on this baboon incisor? (2) Are rates of enamel extension, and associated striae angles, related to the distribution of LEH on the surface of this incisor? (3) Are this baboon's incisor striae angles acute and rates of enamel extension fast in comparison with those of great apes? Answers to these questions add to our understanding of the correspondence between AL and LEH defects, how much of a baboon's anterior tooth crown is likely to exhibit LEH in relation to AL, how fast baboon incisors grow, and how striae angles affect the manifestation of LEH defects.

Materials and Methods

The individual chosen for this analysis (identifier: B4-03) was a large (29.2 kg) male that lived in Table Mountain National Park near Cape Town and was euthanized for exhibiting aggressive behavior towards locals. This tooth was chosen for this histological study during the data collection phase of a larger study examining the difference in LEH prevalence between baboons living inside versus outside national parks. A second tooth (ULI1) from a different male chacma baboon (identifier: B2-03) was included in this study to measure midcrown striae of Retzius angles at the outer enamel surface.

An impression of the first upper left incisor (ULI1) (see Figure 2) was created using Coltene President Jet Light Body silicone impression material. The incisor's impression allowed for the creation of a high-resolution replica using Loctite EA E -60NC epoxy. Macrophotographs of the replica were acquired using a digital microscope (Leica DMS1000) and stitched using Adobe Photoshop CS6.

The replica was examined with the naked eye to identify LEH defects on the surface. Individual LEH defects were assessed both with the naked eye and with the aid of macrophotographs. In this study, even minor perturbations involving the disruption of one or two perikymata growth increments were included in the LEH sample, which some authors might instead call "accentuated perikymata" (Thylstrup and Fejerskov, 1978; Kierdorf et al., 2000; Temple, 2014; O'Hara et al., 2023). A tripartite scheme was used to classify LEH defects as minor, moderate, or severe. The qualitative classification of LEH was made relative to other defects within the same tooth; comparing a given defect relative to other defects in the same tooth corrects for inter-tooth differences in growth and wear patterns. The position of an LEH defect along the length of the enamel was also considered, as seemingly shallow defects near the cusp of a heavily worn tooth are likely to be more severe (i.e., associated with a larger disruption in enamel formation) than their current state suggests.

The incisor was extracted by first securing the cranium to a laboratory bench and covering the tooth with padding material to prevent surface damage. The incisor was then pulled away from the cranium using locking flat pincers. After extraction, the incisor was embedded in Buehler EpoxiCure 2 epoxy. Using a Buehler Isomet low-speed saw, an initial cut was performed along the sagittal plane of the incisor at a speed of 90 revolutions per minute. One side of the halved tooth was then attached to a microscope slide using the same epoxy material.

The second cut was performed at the same angular speed and at a distance of 800 μm into the sectioned incisor relative to the surface of the microscope slide. The second cut yielded a thin section of the incisor 800 μm in thickness. After the sectioning process was complete, the specimen was attached to a target holder and ground to a thickness of 150 μm (thickness measurement includes thin section and epoxy adhesive) using progressively finer silicon carbide grinding paper. To minimize fine scratches, 0.3 μm alumina polishing compound was used to polish the slide in preparation for microscopy and imaging.

Using a brightfield microscope, images of the enamel were acquired at 4x magnification (1 pixel = 1.62 μm). FIJI (Preibisch et al., 2009) and Adobe Photoshop CS6 were used to stitch the images, producing a single image of the entire tooth section. The cuspal region is not preserved in this section due to normal wear (Figure 3). Therefore, the approximate location of the dentine horn was estimated by extending the trajectories of the labial and lingual enamel-dentine junctions until they

met. The reconstructed enamel-dentine junction length was measured and divided into deciles 1 through 10 (numbered from cusp to cervix) for analysis. Decile 1 and approximately half of the length of decile 2 constitute enamel lost to normal wear.

Enamel extension rates for the preserved deciles (3-10) were calculated by dividing the length of each decile (1/10 of the total length) by the number of days each decile took to form (Table 1). Days were calculated by counting the number of regular striae of Retzius in each decile and multiplying by the periodicity. Figure 4 shows the microscopic images of the enamel cross section obtained at 10x and 40x magnification to assess enamel periodicity, which was determined to be 7 days. This periodicity matches the previously reported value for the genus *Papio* (Dirks et al., 2002). The number of days it took for deciles 3-10 to form was also calculated by multiplying the number of striae in each decile by the periodicity (see Table 1). Striae angle measurements were taken within the middle of each decile directly below the outer enamel surface. Using Adobe Photoshop, one arm of the angle tool was placed on the outer enamel surface while the other arm was extended along a single stria of Retzius approximately one third into the enamel thickness. Midcrown striae angles of another incisor (ULI1) from a different male chacma baboon (identifier: B2-03) were also measured at the outer enamel surface (the mean of the two specimens is reported in Table 3).

Accentuated lines (AL) appear as relatively dark and pronounced lines that do not follow the normal enamel formation rhythm (Guatelli-Steinberg, 2016). We attempted to score AL with the same level of sensitivity as we scored LEH defects; this meant that even minor AL were included in this sample. Lines were considered accentuated when they appeared out of the normal rhythm (i.e., there was an extra line between normal striae of Retzius) and/or when lines, whether falling with the normal rhythm or not, appear darker, thicker, and course more deeply into the enamel thickness compared to nearby striae of Retzius. Examples of AL defects are shown in Figure 5.

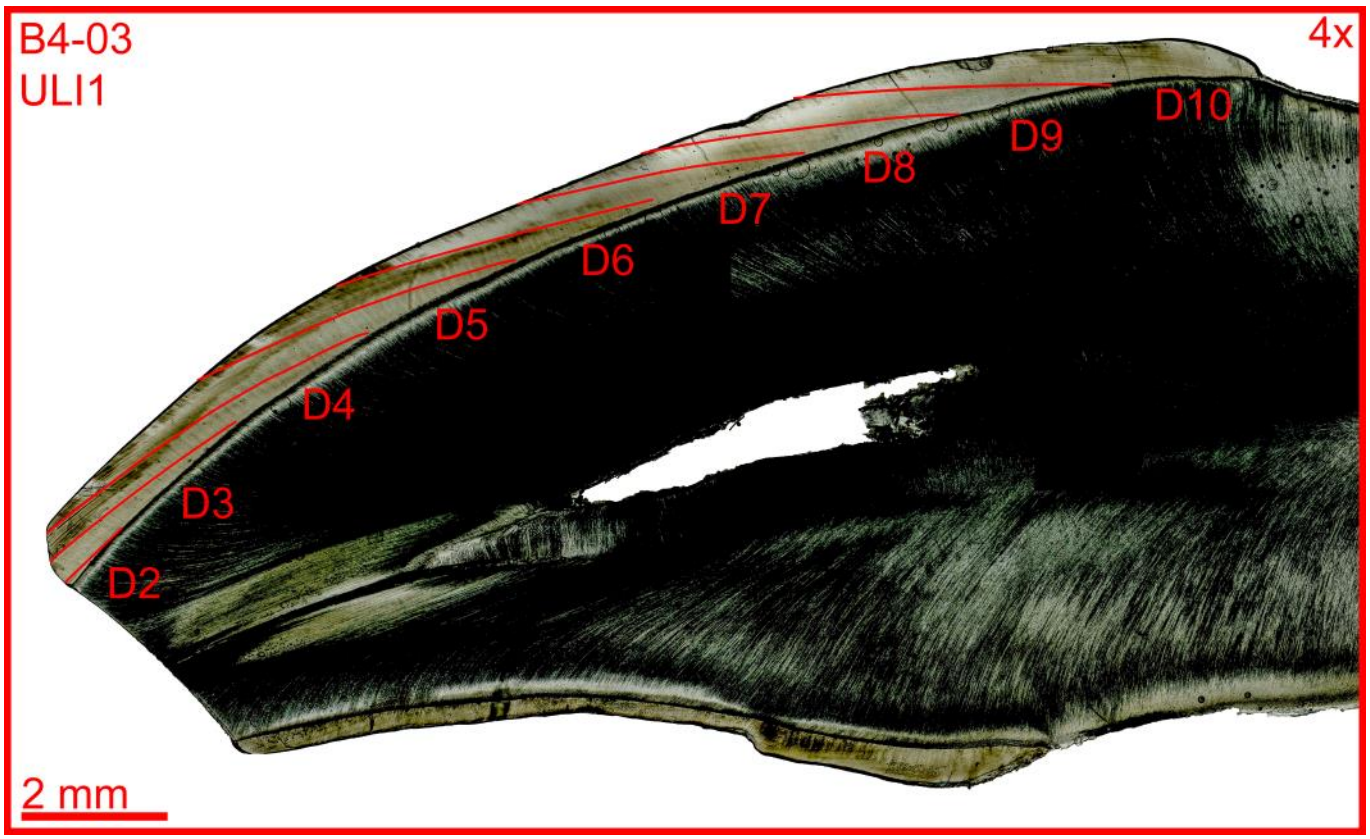

Figure 3. Overview montage of male chacma baboon B4-03 ULI1 thin section (4x magnification). Red lines mark the starting locations of deciles on the enamel-dentine junction and continue across the enamel to the points at which the striae of Retzius terminate on the outer enamel surface.

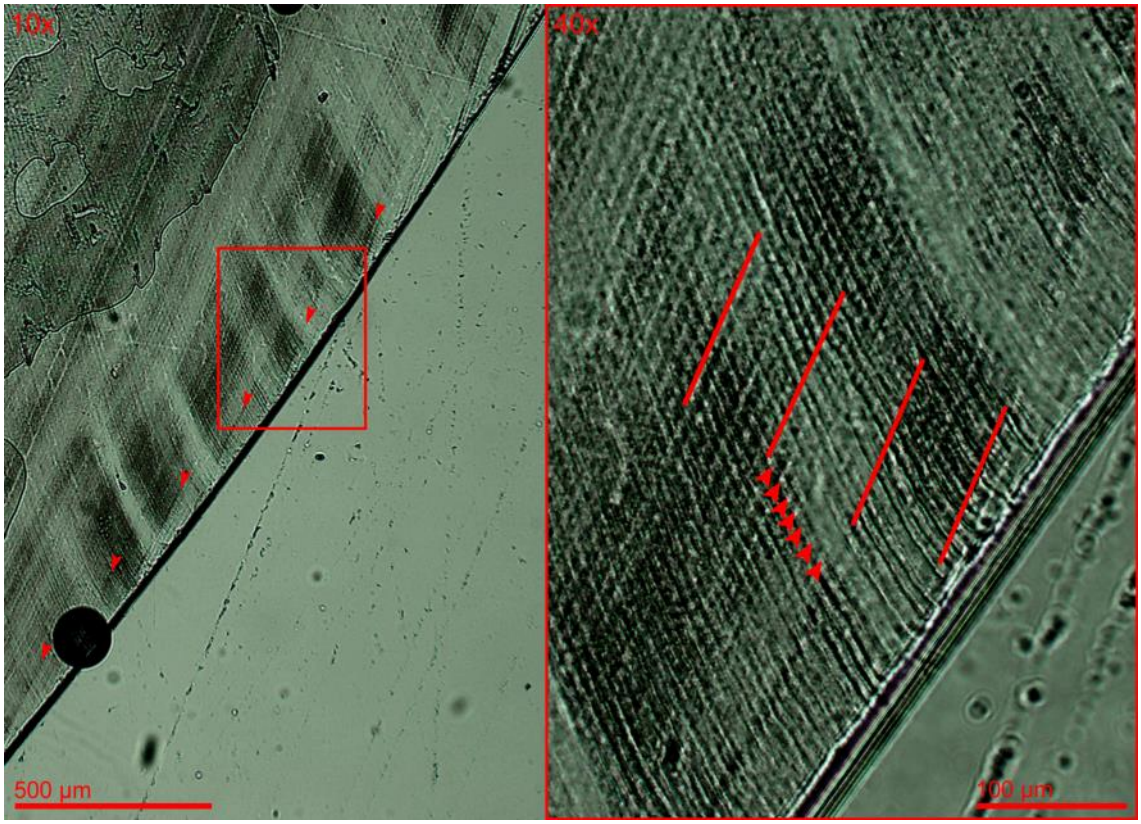

Figure 4. Left: 10x magnified image of B4-03 ULI1 with arrows showing the locations of striae of Retzius and rectangle denoting the region imaged at 40x magnification for periodicity assessment. Right: 40x magnified image with lines marking striae of Retzius and arrows marking daily cross striations. Daily cross striations were counted and measured to determine the periodicity of seven days.

Table 1. Mean striae of Retzius angles, enamel extension rates (µm/day), cumulative days of enamel formation, LEH defects, and AL defects per decile for B4-03 ULI1.

Decile	Mean striae of Retzius angles	EER (µm/day)	Cumulative days (years)	LEH defects	AL defects
3	N/A	43.9	49 (0.134)	0	6
4	N/A	43.9	98 (0.268)	0	5
5	10.7°	17.1	224 (0.614)	0	10
6	13.7°	15.4	364 (0.997)	1	7
7	14.0°	16.2	497 (1.362)	1	4
8	13.7°	25.6	581 (1.592)	2	5
9	15.3°	18.1	700 (1.918)	1	3
10	11.0°	9.0	938 (2.570)	5	8

In order to assess LEH and AL defect co-occurrence, the distance from the cementum-enamel junction to each LEH defect was recorded from the macrophotographs. The straight-line tool (Adobe Photoshop) was then dragged the same distance from the cementum-enamel junction visible in the thin section to the outer enamel surface where a surface groove was identified.

Results

There is a higher occurrence of accentuated lines (N = 48) compared to LEH defects (N = 10) in this chacma baboon first upper incisor. LEH defects were found to always co-occur with AL defects. Accentuated line defects are more evenly distributed throughout the enamel, while all LEH defects originated only within deciles 6-10 as defined at the enamel-dentine junction. However, due to the nature of crown development and curvature of striae, LEH defects are visible across much of the crown surface (see Figure 2). The frequency of LEH defects increases from cusp to cervix, with no defects originating in deciles 3-5, one defect per decile originating in deciles 6, 7, and 9, two defects originating in decile 8, and five defects originating in decile 10.

Table 1 (above) lists mean striae of Retzius angles for deciles 5 through 10. The most acute mean striae of Retzius angles are found in decile 5 (10.7°), while the most obtuse mean angles are found in decile 9 (15.3°). Table 1 also lists enamel extension rates (EER) and cumulative enamel formation days. Deciles 3 and 4 exhibited the highest EER in this tooth (43.9 µm/day), while decile 10 exhibited the lowest EER (9.0 µm/day). The mean EER across all deciles for B4-03 ULI1 is 23.6 µm/day, and is listed in Table 2 in comparison to mean EERs of anterior teeth of six other primate taxa derived from other studies. Midcrown striae of Retzius angles for the main subject of this study, individual B4-03, are 13.7°, while individual B2-03 had more acute midcrown angles at 13.3°. Mean midcrown striae angles are listed in Table 3 along with comparisons to the mean angles of anterior teeth of five other primate taxa derived from other studies.

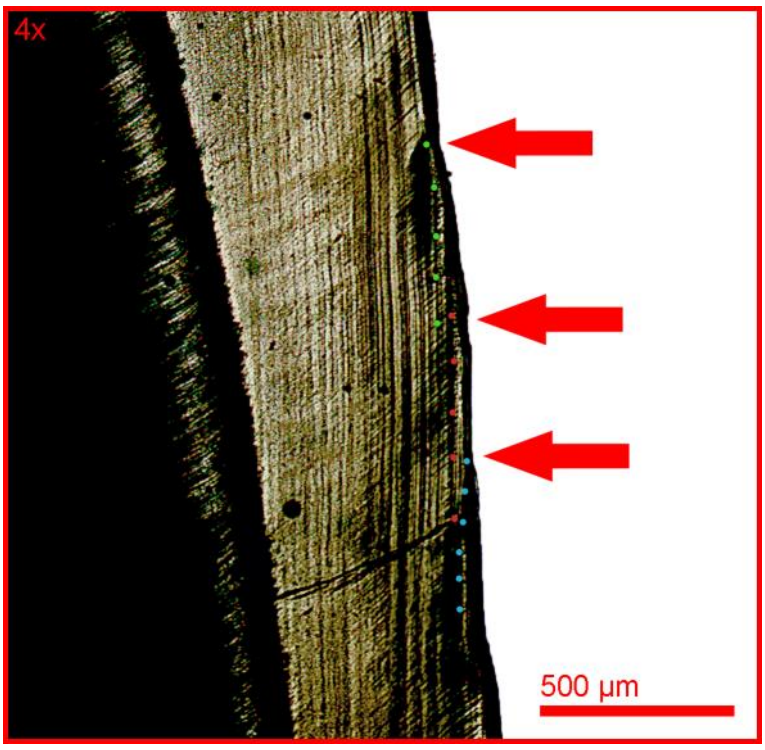

Figure 5. 4x magnified image of B4-03 ULI1. Red arrows mark the approximate locations of LEH defects on the outer enamel surface. Dotted red, green, and blue lines mark the approximate locations of AL defects in the enamel cross-section.

Table 2. Mean enamel extension rates (EER) in µm/day for individual anterior teeth of six primate taxa.

Taxon	Tooth type	Mean EER (µm/day)
Papio ursinus	ULI1	23.6
Mandrillus sphinx[1]	LI1	15.5
	LI2	14.9
G. b. beringei[2]	LC	12.7
G. g. gorilla[2]	LC	9.4
P. troglodytes[2]	LC	8.6
Pongo sp.[2]	LC	8.0

ULI1: upper left first incisor. LI1: lower first incisor. LI2: lower second incisor. LC: lower canine.

[1]Dirks, Lemmers, Ngoubangoye, Herbert, and Setchell, 2020.

[2]McGrath et al., 2019

Table 3. Mean midcrown striae of Retzius angles in the anterior teeth of five primate taxa.

Taxon	Tooth type	Number of specimens	Sex	Mean angle
Papio ursinus	Central incisor	2	M	13.5°
G. b. beringei[1]	Canine	2	M	18.5°
Gorilla gorilla[2]	Central incisor	4	M, F	18.0°
Pan troglodytes[2]	Central incisor	5	M, F	32.0°
Pongo pygmaeus[2]	Central incisor	4	M, F	45.0°

[1]McGrath et al. 2019.
[2]Guatelli-Steinberg et al., 2012.

Discussion

Specimen selection

This specific incisor (B4-03 ULI1) was chosen for this study for three reasons. First, the incisor contained a considerable number of LEH defects that are not confined to a small area of the outer enamel. This indicated that the enamel histology was likely to contain a number of AL defects that are also distributed throughout the enamel. These defects also varied in severity, allowing for the opportunity to find accentuated lines of varying severity. Second, incisors have relatively low EER compared to canines. Slow EERs (associated with relatively obtuse striae angles) may create LEH defects that are deeper and more defined (Guatelli-Steinberg et al., 2012; McGrath et al., 2019). In male primates, canines tend to have longer crown formation times compared to incisors (Ash and Nelson, 2003; Reed, 1973), allowing for the accrual of more LEH defects (Guatelli-Steinberg and Lukacs, 1998). However, this individual's canines contained a very large number of extremely shallow defects that often merged into indistinct grooves, preventing accurate discrimination of the boundaries of each defect. The third reason we chose an incisor (vs. a canine) for this study was a practical one; our low-speed saw was able to effectively cut the incisor, whereas the great length of the male chacma baboon canines prevented reliable sectioning using the available equipment.

Tooth wear: important considerations

In this study's main tooth of focus, normal tooth wear resulted in the loss of the first two enamel deciles and abrasion of the outer enamel surface, particularly near the cusp. This loss of enamel necessitates that the LEH and AL counts, as well as the average enamel extension rate, are considered minimum values. Cuspal enamel usually has the fastest extension rate in primate teeth (Guatelli-Steinberg et al., 2012; McGrath et al., 2019; Shellis, 1998), meaning that the average EER reported in this study is likely lower than the actual rate due to the exclusion of the two lost cuspal deciles. The number of AL and LEH defects are also considered minimum counts in this study; since LEH, and particularly AL, defects are not confined to a limited section of the enamel, there are likely AL and LEH defects in the first two deciles that are not reported in this study.

EERs and LEH defect perceptibility

Large-bodied monkeys, such as baboons and mandrills, usually have higher average anterior teeth EERs than humans and extant great apes (Dirks et al., 2002; McGrath et al., 2019). Table 2 shows mean EERs for the anterior teeth of six primate taxa. The *Papio ursinus* upper incisor belonging to individual B4-03 exhibited the highest mean EER (23.6 µm/day) of all the primate taxa listed in Table 2, despite the fact that the first two deciles (i.e., those with the highest EER) had to be excluded due to wear. *Mandrillus sphinx*, the most closely-related species to *Papio ursinus* in Table 2, exhibits the second fastest mean EER (15.5 µm/day). Male *G. b. beringei* (mountain gorillas) canines have the highest EERs among the apes in Table 2 at 12.7 µm/day, but this is still lower than both of the aforementioned large-bodied monkey species. An examination of mountain gorilla incisors is needed in order to make direct comparisons with the data derived from the current study.

High EER is typically associated with relatively acute striae of Retzius angles, especially near the

cusp. Table 3 shows the mean midcrown OES striae of Retzius angles in the anterior teeth of five primate taxa. The mean striae of Retzius angles of the two *Papio ursinus* central incisors measured in this study exhibit the most acute mean midcrown OES angles of all the taxa listed in Table 3 (13.3°). Male *G. b. beringei* canines exhibit the second most acute striae angles in Table 3 (18.5°), and are the acutest angles among the ape species listed. The very acute striae angles observed in these two incisors may produce very shallow LEH defects on the surface (Guatelli-Steinberg et al., 2012; McGrath et al., 2018, 2019), which are inherently less perceptible than deeper defects, particularly when using qualitative scoring methods. Since the main tooth in this study exhibits much faster EERs compared to apes, along with its acute striae angles, the difficulty in identifying LEH defects on the surface of this tooth can be attributed to, at least in part, the high EERs and acute striae angles found in this specimen.

The low perceptibility of shallow LEH in this tooth is further exacerbated by the intense feeding-induced teeth wear commonly seen in baboons. Since LEH defects are presumably very shallow in chacma baboons (though their depth is yet to be measured via profilometry), even relatively small amounts of tooth wear can obscure LEH defects. This is evident towards the cusp, as the cusp is naturally subject to more wear pressure compared to the cervical and middle sections of the incisor.

EERs and striae angles

The enamel extension rate gradient observed in this tooth likely contributed to more defined and deeper LEH defects in regions with low EER (midcrown and cervix) compared to regions with high EER (cusp). This is potentially another factor contributing to the difficulty in locating cuspal LEH defects. Interestingly, a disconnection is observed between striae of Retzius angles and EER, where, for example, the striae angles in deciles 7 and 8 are 14.0° and 13.7°, while the EERs are 16.2 and 25.6 µm/day, both respectively.

Striae of Retzius angles measured along the EDJ have been shown to serve as reliable proxies for EER estimations in human teeth (Boyde, 1964; Shellis, 1984), and at the OES, angles are strongly correlated with extension rates in ape canines (McGrath et al., 2019). However, individual-level variation in ameloblast cellular activity (i.e., variable rates of enamel matrix secretion) might influence EERs while not directly translating to a change in striae of Retzius angles. Other enamel structure parameters also influence EER, such as the angle between the forming prisms and the EDJ or the length of enamel prism formed per day (Shellis, 1984), and may play a role in producing this unexpected decoupling between striae of Retzius angles and EER in this specimen. Future studies of multiple individuals will be able to assess whether this pattern occurs more broadly, and could incorporate measurements of daily secretion rates and geometric variables throughout the enamel thickness rather than just the OES.

Spatial distribution of AL and LEH defects

In this analysis, accentuated lines were evenly distributed throughout the enamel. Conversely, nine of the ten total LEH defects were observed in the middle and cervical sections of the outer enamel, while only one defect was observed in the cuspal third. This confinement of LEH distribution (which is not observed with accentuated line defects) can be attributed to a number of factors that serve to disconnect the two defect types, including the aforementioned dental wear. All but one of the LEH defects were classed as minor in severity, meaning that they represent short-lived growth disruptions only affecting a very small number of similar perikymata growth increments. This study did not attempt to classify AL based on their severity, though we did include even minor internal defects in the sample. Future studies could incorporate severity scoring into AL analyses to assess whether LEH occur in the absence of more marked AL, as has been proposed by Kierdorf et al. (2000, 2004) and Witzel et al. (2006, 2008), or if moderate to severe AL usually underlie LEH, as demonstrated by Smith and Boesch (2015).

In permanent upper central incisors, enamel at the cusp is composed mostly of appositional enamel, while the remainder of the crown is composed mainly of imbricational enamel (Hillson and Bond, 1997). During the formation of appositional enamel, stress-associated enamel formation impairment may never manifest as LEH on the surface, as the striae of Retzius do not terminate at the outer enamel surface as is the case with imbricational enamel (Witzel et al., 2008). This key difference suggests that histological examination of accentuated lines (as opposed to surface examination of LEH) in teeth regions composed of appositional enamel is necessary to identify stress markers that do not extend to the OES. In this study, the cuspal enamel could not be analyzed due to wear, so the remaining eight deciles are comprised of entirely imbricational enamel where LEH defects could

manifest on the surface.

Future directions

Future work will focus on expanding the sample size to include more individuals and several other tooth types. Incorporating life records of tracked individual baboons in both anthropogenic and rural environments can help in drawing connections between documented stress episodes (e.g., malnutrition, illness, or physical injury) and specific LEH or AL defects.

It is important to note that accentuated lines and LEH defects are disruptions in the normal enamel growth rate, meaning they can only manifest as the enamel is actively growing. Consequently, the physiological stress episodes that resulted in LEH and AL defects happened within the developmental window of the examined tooth. Different tooth types have different, and sometimes non-overlapping, windows of development (Reed, 1973). Examination of a set of teeth from one individual can help with identifying stress episodes occurring over a larger span of an animal's life compared to the examination of only a single tooth.

Profilometric analysis of the enamel surface can aid in the process of identifying LEH defects in general (e.g., McGrath et al., 2018), and especially toward the cusp where they tend to be either very shallow due to cuspal enamel geometry or obscured by normal tooth wear. Profilometry can also be helpful in providing quantitative measurements of the various topographical characteristics of the enamel (defect depth, width, regularity, etc.), allowing for better definition of criteria for minor, moderate, and severe defects.

Conclusions

We found a higher occurrence of internal AL (N = 48) compared to external LEH defects (N = 10), which co-occurred in all instances of LEH. Despite the loss of the first two deciles to normal wear, this incisor exhibited a fast mean EER of 23.6 μm/day, which is faster than several large-bodied monkey species reported in other studies (see Table 2). With the inclusion of a second specimen for mid-crown OES striae angle measurements, the mean angle measured was more acute than several primate taxa reported in other studies (see Table 3). LEH and AL counts and mean EER reported in this study are considered minimum values, as enamel loss and surface abrasion prevented the analysis of the first two deciles, which likely exhibited the fastest EERs and contained additional enamel defects. We offer the findings of this study as an initial exploration of the questions set out in the introduction, as our sample size is small. Future work will expand sample size, utilize profilometric analysis of the enamel surface, and incorporate detailed life records of individual baboons to investigate links between documented stress episodes and LEH or AL defects.

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Dental Anthropology Research Conducted at the School of Dentistry of the Universidad del Valle (Cali, Colombia) between 2002 and 2021: A Literature Review

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Keywords: dental morphology, dental complexes, ethnic pattern, biological distances, literature review

ABSTRACT In the last 20 years, the Dental Anthropology and Forensic Dentistry Research Group at the Universidad del Valle (Cali, Colombia) has integrated knowledge from anthropology, dentistry, biology, paleontology and paleopathology to characterize the dental morphology of living populations in southwestern Colombia. This has been done by studying the frequency and variability of dental morphological features in populations with different ancestries, including Euro-descendants, Afro-descendants and Native Americans. The group has employed strategies such as formative research and the creation of cooperative research networks to publish and disseminate their findings on dental morphology mainly within the Colombian dental clinical context. However, these studies have been limited in their impact on the international anthropological academic community due to a lack of publication in English and refusals from some specialized journals to publish research on contemporary Colombian populations. To address this issue, this article aims to provide a literature review of the research on dental anthropology carried out at the School of Dentistry of the Universidad del Valle (Cali, Colombia) between 2002 and 2021. Despite the high amount of available information, the results of this scientific research have been difficult to make visible, search, access, and recover.

At the School of Dentistry of Universidad del Valle (Cali, Colombia), dental anthropology is considered an interdisciplinary area of knowledge that integrates anthropology, dentistry, biology, paleontology, and paleopathology. The objective is to study all the information provided by human dentition, including anatomical, evolutionary, pathological, cultural and therapeutic variations. This is done by taking into consideration the living conditions, culture, nutrition and adaptation processes of present and past human populations, through the morphology, measurements, diseases, and modifications of the teeth (Hillson, 1996; Scott & Turner, 1997, 1998).

In particular, a group of researchers from the aforementioned university has focused their interest on dental metric and nonmetric variations. Their approach has allowed for the documentation, analysis, explanation, and understanding of a range of dental phenotypes that can provide insight into the biological relationships among human populations. These dental variations also serve as intergroup markers that facilitate comparative analysis to clarify the history, origin, formation, contact, isolation, and displacement of past and present human groups (Alt et al., 1998; Rodríguez, 2003, 2004).

In Colombia, dental anthropology began relatively late compared to other Latin American countries, such as Mexico and Peru. Some anthropological and paleontological studies on living populations and archaeological samples had been carried out earlier by researchers such as Paul Rivet, Gonzalo Correal, Miguel Méndez, Martin Nweeia, Edward Harris, Héctor Polanco, and Benjamin Hera-

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zo, among others. However, the field gained more attention in 1989 with the publication of the "Cuaderno de Antropología No. 19" of the Universidad Nacional (Bogotá, Colombia) entitled "Introducción a la antropología dental" by the anthropologist José Vicente Rodríguez. This work compiled all available information on the metric and morphological variations of teeth in human populations, drawing mainly from previous research by the Institute of Ethnology and Anthropology of the Russian Academy of Science (Moscow, Russia) and studies on the origin and diversity of Americans carried out by Arizona State University.

Since then, dental anthropology research in Colombia has focused on forensic sciences, specifically within the context of forensic anthropology and the study of oral morbidity in pre-Hispanic communities. In 1997, Alexander Zoubov gave a lecture on "La antropología dental y la práctica forense" at the symposium "De lo prehispánico a lo forense: avances de la antropología biológica en Colombia," which shifted the research focus towards forensic applications. Notable contributions to this field include the work carried out by the Expedición Humana of the Pontificia Universidad Javeriana (Bogotá, Colombia), the studies conducted by the Laboratorio de Antropología Física of the Universidad Nacional by José Vicente Rodríguez, the work of the groups Antropacífico and Antropos under the supervision of anthropologists Carlos David Rodríguez and Miguel Eduardo Delgado Burbano at the Departamento de Antropología of the Universidad del Cauca (Popayán, Colombia), and the studies conducted by the Julio César Cubillos Museum of the Universidad del Valle under the historian Carlos Armando Rodríguez (Rodríguez, 2003; Moreno and Moreno, 2007).

At the end of the 20th century, research groups focused on dental anthropology were formed in the Schools of Anthropology of the Universidad Nacional and the Universidad del Cauca. However, it wasn't until 2004 that a study group from a School of Dentistry, led the Dental Anthropology and Forensic Dentistry Research Group, as was the case with the Oral and Maxillofacial Surgery Research Group of the School of Dentistry of the Universidad del Valle, whose researchers joined forces to disseminate knowledge from other disciplines that have studied teeth and to apply this information in the dental, anthropological, and forensic contexts. Although the study group was inactivated by 2014, the research has continued independently through the work of dentists Sandra Moreno and Freddy Moreno (Moreno-Gómez et al., 2019).

To keep research in dental anthropology active, two fundamental strategies were implemented. The first strategy was to establish scientific cooperation alliances with the "Laboratorio de Antropología Física" of the Universidad Nacional, with the "Instituto Nacional de Medicina Legal y Ciencias Forenses de Colombia." and with the "Laboratorio de Identificación de la Fiscalía General de la Nación de Colombia." The second strategy was to use formative research so that dentistry students from different universities in Colombia could develop their theses on topics related to dental anthropology, mainly dental measurements and dental morphology. Thus, during the last 20 years, a series of studies have been carried out in contemporary populations of southwestern Colombia to generate new knowledge on the frequency and variability of non-metric dental traits from research studies, to update the current understanding through literature reviews, to describe the unusual presence of some dental morphological characteristics through case reports, and to encourage critical reading through systematic analysis of the literature (Moreno-Gómez et al., 2019).

The aim of this study is to perform a literature review of the research in dental anthropology conducted at the School of Dentistry of the Universidad del Valle (Cali, Colombia). Due to the lack of available scientific information and the difficulties in searching, accessing, and retrieving scientific research results, it is not possible to objectively quantify the scientific knowledge generated. The literature review is a type of research synthesis that aims to map the literature on a particular topic or research area and identify key concepts and types of evidence generated in the research practice, produced by individuals (researchers), groups (research groups, centers, and institutes), and educational institutions (departments, faculties, and universities) (Daudt et al., 2013).

Materials and Methods

This study reviewed publications on dental anthropology conducted at the School of Dentistry of the Universidad del Valle (Cali, Colombia) with the participation of dentistry students from different universities. Their theses were advised by researchers affiliated with the Dental Anthropology and Forensic Dentistry Research Group through formative research processes. All populations stud-

ied gave their consent to participate and received feedback from the researchers, allowing them to recognize their ethnic origin from the historical processes of colonization in Colombia over the last 500 years. Specifically, these results have been used in the ethnographic processes of identity construction for community councils of Afro-descendant populations and governorates of indigenous communities.

The categories used to classify articles and perform the comprehensive review were: article name, year of publication, study type, population studied, sample, journal of publication, country of the journal, language of publication, publisher, thematic context, and number of citations (Table 1).

Results

Between 2002 and 2021, 44 articles were identified that met the inclusion criteria. Therefore, the Dental Anthropology and Forensic Dentistry Research Group published an average of 2.09 articles per year.

Of these articles, 29 (65.9%) were published in dental journals, including 13 (33.3%) in the *Revista Estomatología*, which allowed for the scientific dissemination of the School of Dentistry of the Universidad del Valle. The remaining articles were published in biomedical journals (10.3%), anthropological journals (13.6%), morphological science journals (5.1%), and forensic journals (5.1%).

Twenty-eight of the journals in which articles were published were edited by public universities (63.6%); five by private universities (11.3%); four by scientific societies (10.3%) and four by private publishers (10.3%).

Thirty-six articles were published in Spanish (81.8%), five in English (11.3%), and three in both languages (7.69%).

All 44 articles implemented the keyword dental anthropology (100%), 38 implemented dental morphology (86.3%), four implemented dental measurements (9.09%), 13 implemented forensic anthropology (30.2%), 12 implemented dental identification (27.2%), and three implemented radiology (7.7%).

Twelve of the journals in which the articles were published are indexed in MedLine (30.8%), 17 in DOAJ (38.6%), 23 in Latindex (52.2%), 11 in SciELO (28.2%), and 31 in national (Colombia) and regional (Latin America) indexes (79.5%). Thirty-four of these articles have been cited from Google Scholar (87.1%), six articles from Publons (2.34%), and five from Scopus (1.95%).

The articles were derived from 23 undergraduate degree works, one undergraduate degree work in pediatric dentistry, and one master's degree work in criminalistics. Fourteen articles were derived from research processes carried out by professors as part of their scientific activities. The 39 articles included a total of 90 dentistry students (2.6 students per study) and six graduate students. Likewise, 78 participations of professors were observed with an average of 2.2 professors per article.

According to the methodological design of the study, 30 articles corresponded to descriptive observational studies (68.1%), 11 articles to literature reviews (25%), and four articles to case reports (9.09%).

Regarding the thematic area, 36 articles corresponded to dental morphology (81.8%), four articles to dental measurements (9.09%), three articles to dental eruption (7.7%), one article to dental morphology and dimensions (2.6%), and one article to general dental anthropology (2.6%). Likewise, and according to the observational method of the sample, 28 articles used plaster models obtained from dental impressions taken of the individuals that made up the sample (63.6%), three used panoramic radiographs (7.7%), five were mainly case reports that used direct observation of the patients (12.8%), and eight did not conduct any type of observational study because they were literature reviews with a purely theoretical approach (18.1%).

According to the type of dentition, permanent dentition was studied in 25 articles (56.8%), deciduous and permanent dentition in 16 articles (41.0%), deciduous dentition in two articles (4.5%), and no type of dentition was specified in two articles (5.1%). The most frequently observed teeth were incisors in 22 articles (50%), canines in 10 articles (22.7%), premolars in 19 articles (43.1%), and molars in 31 articles (79.5%).

The dental morphological features most frequently observed in the studies were winging in seven articles (17.9%), crowding in six articles (15.4%), shovel-shaped incisors in 13 articles (30.2%), Carabelli's trait in 20 articles (45.4%), hypocone reduction in eight articles (20.5%), protostylid in 20 articles (45.4%), deflecting wrinkle in 13 articles (29.5%), cuspid pattern in 15 articles (34.09%), number of cusps in 10 articles (25.6%), cusp 6 in 12 articles (30.8%), and cusp 7 in 12 articles (30.8%). Similarly, other morphological features were observed in canines, premolars, and molars in 17 articles (38.6%).

Regarding the methods of observation of dental morphological features, ASUDAS (Arizona State University Dental Anthropology System) was used for permanent dentition in 25 articles (56.8%), ASUDAS, Hanihara (1961), Grine (1986), and Sciul-

Table 1. Scientific articles organized by year of publication

Article	Year	Type of study	Population studied	Sample	Journal	Country	Language	Publisher	Thematic context	Google citations	Publons Citations	Scopus citations
Moreno & Moreno	2002	Literature review	None	0	Revista Estomatología	Colombia	Spanish	Universidad publica	Forensic	21	0	0
Moreno et al.	2004	Descriptive observational	Mixed group	100 individuals (50 females and 50 males)	Colombia Médica	Colombia	Spanish	Universidad publica	Anthropological	55	0	7
Moreno & Moreno	2005	Descriptive observational	Mixed group and indigenous	100 individuals (50 females and 50 males)	International Journal of Dental Anthropology	Colombia	English	Editorial privada	Anthropological	34	0	0
Rodríguez & Moreno	2006	Case Report	Mixed group	1 individual (1 female)	Dental Anthropology	United States	English	Sociedad científica	Odontological and Anthropological	23	0	0
Aguirre et al.	2006	Descriptive observational	Mixed group and indigenous	100 individuals (50 females and 50 males)	Dental Anthropology	United States	English	Sociedad científica	Anthropological	53	0	0
Rocha et al.	2007	Descriptive observational	Indigenous	84 individuals (42 females and 42 males)	Colombia Médica	Colombia	Spanish	Universidad publica	Anthropological	36	2	3
Aguirre et al.	2007	Descriptive observational	Mixed group	100 individuals (50 females and 50 males)	International Journal of Dental Anthropology	Colombia	English	Editorial privada	Anthropological	4	0	0
Moreno & Moreno	2007	Literature review	None	0	Revista Estomatología	Colombia	Spanish	Universidad publica	Odontological and Anthropological	12	0	0
Aguirre et al.	2007	Descriptive observational	Mixed group and indigenous	100 individuals (50 females and 50 males)	Revista Estomatología	Colombia	Spanish	Universidad publica	Anthropological	5	0	0
Hernández et al.	2007	Case Report	Indigenous	1 individual (1 male)	Revista Facultad de Odontología Universidad de Antioquia	Colombia	Spanish	Universidad publica	Odontological and Anthropological	2	0	0
Aragón et al.	2008	Descriptive observational	Indigenous	96 individuals (48 females and 48 males)	Revista Odontológica Mexicana	Mexico	Spanish	Universidad publica	Anthropological and Forensic	29	0	0
Girón et al.	2009	Descriptive observational	Mixed group, Afro-Colombians and indigenous	110 individuals (46 females and 66 males)	International Journal of Morphology	Chile	Spanish	Universidad privada	Odontological, Anthropological and Forensic	27	0	4
Ocampo et al.	2009	Descriptive observational	Mixed group, Afro-Colombians and indigenous	285 individuals (97 females and 104 males)	Revista Estomatología	Colombia	Spanish	Universidad publica	Anthropological	14	0	0
Soto et al.	2010	Literature review	None	0	Acta Odontológica Venezolana	Venezuela	Spanish	Universidad publica	Odontological and Anthropological	0	0	0
Corral et al.	2010	Descriptive observational	Mixed group	196 individuals (109 females and 87 males)	Colombia Médica	Colombia	Spanish	Universidad publica	Odontological and Forensic	38	14	15

Table 1. Scientific articles organized by year of publication, cont'd

Article	Year	Type of study	Population studied	Sample	Journal	Country	Language	Publisher	Thematic context	Google citations	Publons Citations	Scopus citations
Moreno & Moreno	2010	Case Report	Mixed group	1 individual (1 male)	Revista Estomatología	Colombia	Spanish	Universidad publica	Odontological and Anthropological	9	0	0
Hernández et al.	2010	Literature review	Indigenous	5 individuals (5 males)	Revista Facultad de Odontología Universidad de Antioquia	Colombia	Spanish	Universidad publica	Odontological and Anthropological	22	3	0
Goyes et al.	2011	Descriptive observational	Mixed group and indigenous	122 individuals (59 females and 63 males)	Revista Colombiana de Investigación en Odontología	Colombia	Spanish	Sociedad científica	Anthropological	8	0	0
Castillo et al.	2011	Descriptive observational	Mixed group, Afro-Colombians and indigenous	66 individuals (27 females and 39 males)	Revista Estomatología	Colombia	Spanish	Universidad publica	Odontological, Anthropological and Forensic	9	0	0
Acosta et al.	2011	Descriptive observational	Mixed group, Afro-Colombians and indigenous	48 individuals (24 females and 24 males)	Revista Estomatología	Colombia	Spanish	Universidad publica	Odontological, Anthropological and Forensic	12	0	0
Marcovich et al.	2012	Descriptive observational	Afro-Colombians	116 individuals (59 females and 57 males)	Revista Facultad de Odontología Universidad de Antioquia	Colombia	Spanish and English	Universidad publica	Anthropological	26	3	0
Padilla et al.	2013	Descriptive observational	Mixed group, Afro-Colombians and indigenous	126 individuals	International Journal of Morphology	Chile	Spanish	Universidad publica	Odontological, Anthropological and Forensic	9	1	0
Díaz et al.	2014	Descriptive observational	Afro-Colombians and indigenous	60 individuals (35 females and 25 males)	Colombia Médica	Colombia	Spanish	Universidad publica	Anthropological	40	6	7
García et al.	2015	Descriptive observational	Indigenous	60 individuals (37 females and 23 males)	Revista Colombiana de Investigación en Odontología	Colombia	Spanish	Sociedad científica	Anthropological	1	0	0
García et al.	2015	Descriptive observational	Mixed group and indigenous	60 individuals (34 females and 26 males)	Revista Estomatología	Colombia	Spanish	Universidad publica	Anthropological	10	0	0
Hernández et al.	2015	Literature review	Mixed group and indigenous	0	Revista Facultad de Odontología Universidad de Antioquia	Colombia	Spanish and English	Universidad publica	Odontological, Anthropological and Forensic	6	0	0
Pérez et al.	2016	Descriptive observational	Mixed group and Afro-Colombians	195 individuals (101 females and 94 males)	Cuadernos de Medicina Forense	Spain	Spanish	Editorial privada	Odontological and Forensic	4	0	0

Table 1. Scientific articles organized by year of publication, cont,'d

Article	Year	Type of study	Population studied	Sample	Journal	Country	Language	Publisher	Thematic context	Google citations	Publons Citations	Scopus citations
Moreno et al.	2016	Case Report	Mixed group, Afro-Colombians and indigenous	1 individuals (1 male)	Journal of Forensic Dental Sciences	India	Spanish	Editorial privada	Odontological, Anthropological and Forensic	3	0	0
Moreno & Moreno	2016	Descriptive observational	Mixed group, Afro-Colombians and indigenous	380 individuals (206 females and 174 males)	Revista Científica Sociedad de Ortodoncia	Colombia	Spanish	Sociedad científica	Odontological and Anthropological	0	0	0
Moreno & Moreno	2016	Literature review	None	0	Revista Estomatología	Colombia	Spanish	Universidad publica	Odontological and Anthropological	0	0	0
Moreno & Moreno	2016	Literature review	Mixed group, Afro-Colombians and indigenous	0	Revista Estomatología	Colombia	Spanish	Universidad publica	Anthropological and Forensic	2	0	0
Zúñiga et al.	2016	Descriptive observational	Mixed group, Afro-Colombians and indigenous	24 embera (13 females and 11 males), 27 afrodescendientes (16 females and 11 males) and 32 Caucasoid mixed etiology (18 female and 14 males)	Revista Nacional de Odontología	Colombia	Spanish	Universidad privada	Anthropological	5	0	0
Carreño et al.	2017	Descriptive observational	Mixed group	355 individuals (181 females and 174 males)	Revista Estomatología	Colombia	Spanish	Universidad publica	Odontological and Forensic	4	0	0
Pérez et al.	2017	Descriptive observational	Indigenous	101 individuals (59 females and 42 males)	Revista Estomatología	Colombia	Spanish	Universidad publica	Anthropological	3	0	0
Asprilla et al.	2017	Descriptive observational	Mixed group, Afro-Colombians and indigenous	100 individuals (50 females and 50 males)	Revista Estomatología	Colombia	Spanish	Universidad publica	Anthropological	1	0	0
Moreno & Moreno	2017	Descriptive observational	Mixed group, Afro-Colombians and indigenous	30 individuals (15 females and 15 males)	Revista Nacional de Odontología	Colombia	Spanish	Universidad privada	Odontological and Anthropological	2	0	0
Moreno & Moreno	2017	Literature review	None	0	Revista Odontológica Mexicana	Mexico	Spanish	Universidad publica	Odontological and Anthropological	0	0	0

Table 1. Scientific articles organized by year of publication, cont'd

Article	Year	Type of study	Population studied	Sample	Journal	Country	Language	Publisher	Thematic context	Google citations	Publons Citations	Scopus citations
Parra et al.	2018	Descriptive observational	Mixed group, Afro-Colombians and indige-nous	480 individuals (257 females and 223 males)	Revista Facultad de Odontología Universidad de Antioquia	Colombia	Spanish and English	Universida d publica	Anthropological and Forensic	0	0	0
García et al.	2018	Descriptive observational	Mixed group, Afro-Colombians and indige-nous	60 individuals (37 females and 23 males)	Revista Nacional de Odontología	Colombia	Spanish	Universida d privada	Anthropological	0	0	0
Marin et al.	2020	Systematic literature review and Case Report	Mixed group	1 individual male	Dental Anthropology	United States	English	Sociedad científica	Anthropological	0	0	0
Amado et al.	2019	Descriptive observational	Mixed group, Afro-Colombians and indige-nous	613 individuals (344 females and 269 males)	Journal Odontológico Colegial	Colombia	Spanish	Universida d privada	Odontological	0	0	0
García et al.	2020	Descriptive observational	Afro-Colombians	60 individuals (37 females and 23 males)	Journal Odontológico Colegial	Colombia	Spanish	Universida d privada	Odontological	0	0	0
Moreno & Moreno	2021	Literature review	None	0	Revista Facultad de Odontología Universidad de Antioquia	Colombia	Spanish and English	Universida d publica	Anthropological and Forensic	0	0	0
Hurtado et al.	2021	Descriptive observational	Indigenous	30 individuals (16 females and 14 males)	Jangwa Pana	Colombia	Spanish	Universida d pública	Anthropological	0	0	0

li (1998) were used for permanent and deciduous dentition in 11 articles (25%), and ASUDAS, Hillson (1996), van Reenen et al. (1998), and Higa et al. (2003) were used for premolars in three articles (6.8%). One article used Powell and Humphreys (1984) for dental arch form (2.6%), and three articles used the methods of Massler, Moorrees et al. (1963), Demirjian et al., (1973), and Smith (2005) to estimate eruption pattern (7.7%). Four articles did not employ any observational method as they were literature reviews (10.3%). Finally, one article used manual intercuspal dimensions to determine the area of the occlusal polygon (2.2%). Only one article considered dental metric features, meso-distal and buccolingual dimensions, specifically for premolars) (2.6%), using the method of Moorrees et al. (1963).

The samples included in the studies were defined as mixed populations in 28 articles (63.6%), Afro-Colombians in 19 articles (43.1%), and indigenous people in 29 articles (65.9%) (Figure 1). It is important to mention, according to the discussion by Pilloud et al. (2021), that in all the studies carried out, the traditional anthropological nomenclature has prevailed, classifying the studied populations according to their Caucasoid, Negroid, and Mongoloid origin. However, because biological anthropologists are now avoiding these terms, this article uses the terms "Asian," "African," and "European" under the category of continental descent.

The results of the studies were directed towards dental contexts in 21 articles (47.7%), with 16 of them oriented towards the study of dental anthropology with dental clinical correlation, anthropological in 38 articles (86.3%), and forensic in 14 articles (31.8%).

Figure 1. Location of contemporary Colombian human populations that have been studied by the Research Group of Dental Anthropology and Forensic Odontology of the Universidad del Valle. A. Choco region (groups of Afro-descendants, Native Americans –embera– and mixed groups); B. Valle del Cauca region (mixed groups and Afro -descendants); C. Cauca region (groups of Afro-descendants –Puerto Tejada and Villarrica–, Native Americans –Nasa and Misak– and Caucasoid mixed origin); D. Amazon region (groups of indigenous –Ticuna, Huitoto and Cocama–).

Discussion

The results obtained will be discussed under four thematic categories: bibliometrics, formative research, methodology implemented, and obtained results. It should be noted that the discussion is not exhaustive due to space limitations and will focus mainly on dental morphology since it has the greatest impact and is the most studied by the Dental Anthropology and Forensic Dentistry Research Group.

The review of the categories considered in this study helped to determine that the Dental Anthropology and Forensic Dentistry Research Group has been active since 2002. Two research professors initiated the group's activities within a university that lacks a School of Anthropology and a School of Dentistry that does not offer a specialization in forensic dentistry. Their aim was to investigate dental anthropology to broaden and deepen knowledge among dentistry students on dental morphology and its application in other contexts, such as anthropology and forensic dentistry. It is worth highlighting the editorial effort of the Colombian anthropologist Carlos David Rodríguez, who edited and published the International Journal of Dental Anthropology to promote the dissemination of Colombian research on topics related to bioarchaeology, paleontology, anthropology, dentistry, and forensic dentistry with an international perspective (Rodríguez-Flórez, 2005). This is similar to Debbie Guatelli-Steinberg's (2018) description of the Dental Anthropology Newsletter (today *Dental Anthropology*) and research in dental anthropology in the context of North American biological anthropology.

López-Lázaro et al. (2016) conducted a systematic review of the literature on non-metric dental traits in current South American populations. They found that remarkable scientific production has

been generated around the study of non-metric dental traits in the last few decades. This study aimed to define the geographical patterns of contemporary South American human groups and to propose the possibility of using the frequency of differential expression traits in the forensic context. The authors identified the *Revista Estomatología* (Colombia), *Dental Anthropology* (United States), and *American Journal of Biological Anthropology* (United States) as the journals with the most publications (four each), followed by the *International Journal of Morphology* (Chile) and *Colombia Médica* (Colombia) with three each. The *HOMO Journal of Comparative Human Biology* (Germany), *Journal of Dental Research* (United States), *Human Biology* (United States), *Revista de la Facultad de Odontología de la Universidad de Antioquía* (Colombia), and *Universitas Odontologica* (Colombia) had two publications each. Out of the 18 journals identified, six were from Colombia, four from the United States, two from Germany, and one each from Argentina, Canada, Chile, Ireland, Mexico, and Uruguay. It is noteworthy that seven journals are dedicated to general dentistry, three to general anthropology, two to biology, two to dental anthropology, two to forensic sciences (one of them to forensic dentistry), one to morphology, and one to medicine. However, most articles have been published in dental journals, specifically in the *Revista Estomatología*, which is edited by the same academic unit to which the authors belong. This is mainly due to the difficulty that still exists in the Colombian environment to publish in English (Moreno et al., 2012). Despite this, some results were disseminated in anthropological, morphological, and forensic journals, adjusting the focus of the objectives and methodological designs of the studies to include specialized journals whose publication language is English. This includes *Dental Anthropology*, edited by the Dental Anthropology Association in the United States, since the scientific genre's standard norm is writing in English, and the international community has limited access to articles written in Spanish (Ferguson et al., 2011).

Although the information obtained from the research has been relevant and had some local and regional impact, the results have not gained much visibility in the international community. Publishing in English in journals indexed in international directories and using different strategic thematic descriptors, such as dental anthropology, dental morphology, and non-metric dental traits, has contributed to an increase in the number of citations (as measured by the h index of Google Scholar). The articles published in journals indexed in MedLine and DOAJ, which are considered of high impact as they are included in Publons and Scopus, have achieved the highest number of citations due to their greater visibility (Madsen, 2019). This finding is consistent with the results of our analysis, which show that articles published in *Dental Anthropology*, *Colombia Médica*, and *International Journal of Morphology* have received the highest number of citations among articles in English published in international journals.

Formative research

The Dental Anthropology and Forensic Dentistry Research Group, formerly included in the Oral and Maxillofacial Surgery Research Group of the School of Dentistry at Universidad del Valle, has been operating independently since the group was inactivated in 2014. Two research professors have continued the group's work and have found an opportunity to make an academic and scientific impact on the dental field through formative research. The group's focus is mainly on dental morphology and dimensions from the perspective of dental anthropology.

A bibliometric analysis of research conducted at the School of Dentistry at Universidad del Valle revealed that topics such as forensic dentistry and dental anthropology, which are not very common in the national dental academic context, have gained relevance in undergraduate dentistry. Approximately 100 dentistry students from different universities in southwestern Colombia, including Universidad del Valle, Universidad Santiago de Cali, Institución Universitaria Colegios de Colombia, and Universidad Antonio Nariño, have developed 23 undergraduate degree projects resulting in 39 publications (Pizarro et al., 2018).

In this regard, López-Lázaro et al. (2016) analyzed the impact of the Dental Anthropology and Forensic Dentistry Research Group. Since 2000, the number of publications on dental morphology in different South American countries has been increasing, thanks to the impact of the Dental Anthropology Association and the publication of *Dental Anthropology*, as well as the systematization of the observation, registration, and analysis of dental morphological features through ASUDAS.

In the specific case of Colombia, the work of Rodríguez since 1989 and the development of research groups in different Colombian schools of anthropology since 2000 marked the beginning of the systematic study of dental anthropology. However, the vast majority of publications have been developed in dental schools, all of them being the product of formative research processes conducted

by odontologist Freddy Moreno, in an attempt to raise awareness of the importance of dental anthropology from an anthropological point of view. The expression and variability of dental morphological features can predispose or favor the development of a pathological process, and a correct diagnosis based on the knowledge of the behavior of the feature as an etiological factor is fundamental in dental clinical practice based on preventive, diagnostic, and therapeutic evidence (Moreno and Moreno, 2007).

All this confirms the important presence of publications in journals with a dental profile. However, it is essential to strengthen interdisciplinary work between anthropologists and dentists to solve potentially conflicting methodological competencies when studying dental morphology in individuals in a clinical context (López-Lázaro et al., 2016).

Lastly, it is worth highlighting the support provided by professors with diverse specialties who acted as thematic advisors and methodological tutors within the Research Group of Dental Anthropology and Forensic Dentistry. These professors integrated collaborative work in formative research, thus creating a community of interest and a culture of sustainable research over time. This has resulted in the creation of an important network of academic and scientific cooperation, which is composed of dentists, anthropologists, epidemiologists, and statisticians. In this regard, López-Lázaro et al. (2016) stated that the authors of publications on dental morphology in South America mainly have an academic profile in dentistry (57 from Colombia, 10 from Brazil, eight from Chile, six from Argentina, three from Paraguay and Uruguay, two from Canada and South Africa, and one from Venezuela). This is followed by eight geneticists (five of them from Chile), three anthropologists (all from Colombia), three statisticians, two speech therapists (Chile), one archaeologist (United States), and one epidemiologist (Colombia).

Methodology implemented in the studies on dental morphology

The impetus created by anthropologist José Vicente Rodriguez to the Research Group of Dental Anthropology at the Universidad del Valle since 2000 was not only based on the theoretical deepening of the study of dental morphology in the anthropological and forensic context but also on the methodological foundation of observing and recording the expression and variability of dental morphological traits. The ASUDAS method, proposed by Christy G. Turner, Christian R. Nichol, and G. Richard Scott, and complemented by different authors during the development of new morphological traits, such as van Reenen et al. (1998) and Higa et al. (2003) or for its application in the deciduous dentition such as Hanihara (1961), Grine (1986), and Sciulli (1998), has been used as an instrument of analysis. However, Fonseca et al. (2016) stated that although ASUDAS has globalized the study of dental morphology, its use still does not transcend the boundaries of anthropology, making the system practically unknown in the dental context.

López-Lázaro et al. (2016) also indicated that not all studies carried out by dentists used ASUDAS as a methodological framework, which could eventually make it difficult to compare results globally. According to the same authors, the low usage of ASUDAS could be due to a lack of knowledge of its existence or to the difficulty of use. As of 2006, only 242 sets of plaques had been distributed in 36 countries (more than half distributed in the United States). In South America, the plates were only distributed in physical form in Argentina, Chile, and Brazil. Hence, their use has only been possible through internships and collaborations between researchers.

On the other hand, there have been reports on morphological features that are considered "unusual" in the dental clinical context (López-Lázaro et al., 2016). Since the morphogenetic development of these features is unknown, they are often misdiagnosed as sites prone to the accumulation of bacterial plaque and the development of dental caries or periodontal disease (Moreno and Moreno, 2007). Therefore, beyond anthropological interest and forensic utility, the majority of the studies developed by the Research Group of Dental Anthropology and Forensic Dentistry have had the purpose of expanding the knowledge of dentists about dental morphology through descriptive observational designs, literature reviews, and case reports. For example, there have been efforts to expand the information on different ontological aspects of the dental cingulum, a morphological structure misunderstood by many dentists, and its implications in periodontal disease (Moreno and Moreno, 2016). There have also been studies to divulge the expression and variability of the protostylid and its controversial point expression in the fossa (P point) during caries diagnosis, as well as the expression of a fossa of Carabelli's trait (Hernández et al., 2014; Moreno & Moreno, 2017).

López-Lázaro et al. (2016) discussed that 19 studies from the Research Group of Dental Anthropology and Forensic Dentistry led by dentist Fred-

dy Moreno made specific mention of the potential use of dental morphological features as forensic identification tools. However, the limitations of using these features for forensic identification have been described by Edgar (2009). Despite this potential forensic application, the studies on dental anthropology conducted by the Research Group have primarily had a clinical orientation (López-Lázaro et al., 2016).

Obtained results

According to Scott and Turner (1997), just over 100 morphological traits have been identified and described in the crowns and roots of teeth, of which no more than 30 have been widely used for the study of populations due to their high frequency. The majority of observational studies carried out by the Research Group in Dental Anthropology and Forensic Odontology, which described the dental morphology of different populations of southwestern Colombia, used ten of these traits.

Regarding winging and crowding position traits, Rodriguez (2003) stated that despite the lack of knowledge of their global variation, these traits have been used to discriminate the Sinodonts from the Sundadonts within Asian populations, which has given them an important value in intragroup comparisons.

Moreno and Moreno (2016) found that, after studying five southwestern Colombian populations, the frequency of winging was low, and its variability was characterized by expressions in grade 2 unilateral in Afro-descendants from Cali and Villa Rica, and in grade 1 bilateral in Afro-descendants from Puerto Tejada, Indigenous Nasa, and Misak. The frequency of crowding in Afro-descendants from Cali and Villa Rica, and in Indigenous Misak from Silvia was observed in a greater expression of grade 1, and in Afro-descendants from Puerto Tejada and the Nasa de Morales indigenous people, the highest expression was grade 2.

Another morphological feature that can be observed in anterior teeth is the shovel-shaped incisors, which Hanihara (1992) used, along with four other traits, to develop the Asian dental complex due to its high frequency in North Asian populations. This trait has been useful in differentiating these populations from European and African populations. After Turner (1984) studies, it was demonstrated that Sinodont groups, which originated in Asia, crossed the Bering Strait and began to populate the American continent, so all pre-Hispanic and contemporary American Indians have conserved the ancestral Asian condition of shovel-shaped incisors, with expressions of over 80%. Rodriguez (2003) has used this trait to discriminate between European populations and Asian populations, including Amerindians. Different studies on Colombian indigenous populations have identified high frequencies of the shovel-shaped incisor trait in groups that have remained relatively isolated, while the decrease in their expression (grades 1 to 3) could be associated with mixed origin with European and Afro-descendant mixed origin groups (Rodríguez, 2003; Aragón et al., 2008; Díaz et al., 2014).

One of the most interesting traits to study in contemporary Colombian populations is Carabelli's trait, which is considered a European trait with great discriminating power between mixed, Afro-Colombian, and indigenous Colombian groups. However, through different studies, it has been possible to understand that the dichotomous expression (absence/presence) of the ASUDAS reference plaque should not be associated with ethnically mixed origin (Aragón et al., 2008; Díaz et al., 2014, Zúñiga et al., 2016), due to the fact that indigenous Colombian populations have been characterized by presenting fossa expressions in intermediate degrees, which are considered present in the gradation, so they have been recognized as a characteristic pattern of all Amerindians (Rodríguez, 2003). In a study that grouped different contemporary populations of southwestern Colombia, it was found that mixed groups presented fossa expressions, Y depressions, and small cusps. Afro-descendant groups had the expression of medium and large cusps with free vertex. Indigenous groups had pit expressions. Nevertheless, the authors observed that the ethnic groups mentioned were not grouped according to the three established dental complexes because Carabelli's trait did not constitute itself as an ethnic discriminator. This conclusion was associated with the mixed origin of the populations of southwestern Colombia given the tendency of the mixed population of Cali, the Afro-descendants of Puerto Tejada and the Nasa indigenous people to group with Asian populations (pit shape expressions), while the Afro -descendants of Villarica, Guapi, and Tumaco did so with European populations (cuspid expression) (Moreno and Moreno, 2017).

The behavior of Carabelli's trait contrasts with the hypocone reduction because the worldwide expression of this trait varies from 13% in European to 95% in Asian populations, according to Rodriguez (2003). In Colombian populations, regardless of the ethnic component, the tendency has

been to maintain the size of the distolingual cusp from the first upper molar towards the second, without significantly impacting the dichotomous expression of the ASUDAS, except for some reports in mestizo populations, where reduction has been observed in grades 3 and 4 (Pérez et al., 2017).

Another dental morphological trait that deserves attention in Colombian populations is the protostylid. This trait is defined as an indigenous trait with low frequencies in European, African, and Asian populations. The high expression of the P-point is particular to American populations (Zoubov, 1998). In their study, Hernández et al. (2014) concluded that the frequency of the protostylid of the first lower permanent molars allowed the grouping of the categories mentioned, according to the three established world dental complexes. In this way, the processes of mixed origin influenced its expression by decreasing the groove expression, weak or small cusp and free cusp tip in the indigenous groups and increasing the pit expression or P-point in the Euro-descendant and Afro-descendant mixed populations. However, the protostylid was not, by itself, a morphological feature that discriminated the population groups of southwestern Colombia.

Regarding the cuspid pattern and the deflecting wrinkle, two traits considered to belong to the Asian populations, Parra et al. (2017) correlated their expression in different contemporary populations. They concluded that, due to the mixed origin of the population of southwestern Colombia (south of Valle del Cauca and north of the department of Cauca) from Euro-descendant mixed populations, indigenous and Afro-descendant ethnic groups, the expressions of both traits showed great variability. This made it possible to differentiate the groups of Euro-descendant mixed populations and Afro-descendants (with a tendency towards the European populations) from the indigenous groups (with a tendency towards the Asian populations). This was represented in the configuration of deciduous lower first molars with significant frequencies of cuspid pattern (Y expression) and deflecting wrinkle (grades 2 and 3), permanent lower first molars with relative frequencies of cuspid pattern (Y and + expressions) and deflecting wrinkle (grades 1 and 2), and permanent lower second molars with significant frequencies of cuspid pattern (+ and X expressions) and deflecting wrinkle (grades 1 and 2). The classic Y groove pattern (Dryopithecus Pattern) predominates in Asian populations, while the X and + configurations considered reductions predominate in African and European populations. Therefore, the variability in the configuration of the way the cusps contact each other and the number of cusps tends to conserve the classic pattern and reduce to the other patterns as mixed origin with European and African populations becomes evident.

Finally, the expression of cusps 6 and 7 has been considered ethnically distinctive. Hanihara (1992) identified cusp 6 as being more prevalent in Asian populations, while Turner (1984) demonstrated high frequencies of this cusp in groups of Paleo-Indians and pre-Hispanic Amerindians due to its origin. On the other hand, cusp 7 has been observed with greater frequency in Afro-descendant populations. In contemporary Colombian populations, the expression of both cusps has varied depending on the Asian, European, and African ethnic components and the extent of historically mixed populations associated with the geographic distribution of a specific population (Rodríguez, 2003).

Dental complexes

Since the 1991 political constitution, Colombia has identified itself as a multicultural and multiethnic country, acknowledging the presence of five ethnic groups: Native Americans, Afro-Colombians (differentiated into negros, raizales and palenqueros according to the 2015 National Population and Housing Census), romani populations (Rom or Gypsy group that is part of the ethnic and cultural diversity of Colombia), and mixed populations without ethnic recognition (called mestizos) dispersed throughout various geographical regions shaped by ethnohistorical processes during the conquest, colony, struggles for independence, formation of the republic, and the current armed conflict.

Dental morphology studies have provided valuable contributions to the ability to compare past and present populations based on the frequency (expression) and variability (gradation) of dental morphological traits. Various statistical methods, such as similarity or dissimilarity matrices, have been employed to determine the proximity or distance between populations. These matrices can be plotted using dendrograms, which show the biological distances between human groups. In the anthropological context, Smith's Mean Measure of Divergence (MMD) has been predominantly used, which is based on the degree of dissimilarity between samples. However, in the Colombian dental context, the squared Euclidean distance has been commonly used to obtain a distance matrix for hierarchical cluster analysis. Both statistical methods rely on the frequencies of dental morphological

traits that can be grouped into clusters to represent the way in which human populations are associated, either by similarity or dissimilarity, regarding their geographic distribution. These studies have made it possible to ethnically classify human beings into complex populations based on dental morphology. Due to the complexity of the concept of race, the Research Group of Dental Anthropology and Forensic Dentistry has adjusted the use of the notions of ethnicity and ancestry to avoid biological determinism and incorporate concepts from social anthropology, sociology, and historiography. This approach has enabled the group to focus the research discussion on genotype, phenotype, dental complexes, and geographic distribution. The homogenizing narrative of mixed origin has been challenged, and the notion of interculturality is being explored to integrate the ethnocultural diversity of the entire Colombian population.

The term "dental complex" or "population dental complex" refers to the way in which past and present human populations can be grouped based on the frequency and variability of dental morphological traits. This allows for grouping populations based on their Asian, European, and African origins, as well as the way in which they behave intragroup and intergroup (Turner, 1984, 1990; Hanihara, 1992; Irish, 1997; Zoubov, 1998; Edgar, 2007). In Colombia, the study of dental morphology and its association with the revised dental complexes has been challenging due to the complex ethnohistoric processes that have occurred in the region. Rodríguez (2003) proposed that past indigenous populations were characterized by high frequencies of winging, crowding, hypocone reduction, deflecting wrinkle, and the P-point of the protostylid, which placed them closer to the Paleoindians derived from the Sinodonts. However, for contemporary indigenous populations, the study of dental morphology and its association with the described dental complexes has been complicated due to 500 years of mixed origin resulting from the arrival of western European groups, represented by the Spanish conquistadors, and African groups represented by African slaves who populated the American territory in three historical processes recognized as the discovery, conquest, and colony.

This process of mixed origin was particularly pronounced in the southwestern region of Colombia, especially in the south of the department of Valle del Cauca and the north of the departamento del Cauca. This justifies why the largest number of studies on contemporary populations described as mixed populations, Afro-descendants, and indigenous Colombians have been conducted in that region by the Research Group of Dental Anthropology and Forensic Odontology at the Universidad del Valle. The results of these studies concluded that the frequency of morphological traits is a consequence of mixed origin and the dominance of certain phenotypic expressions of morphological traits. Thus, mixed populations were characterized by the simplification of dental morphology, with low frequencies of Carabelli's trait, which was ambiguously expressed in its fossa forms (Asiatic characteristic) and medium-sized cusps (European characteristic) the reduction of the hypocone, which is typical of Western European populations, and the high frequency of the protostylid P-point, a trait exclusive to American Indian populations (Moreno et al., 2004; Pérez et al., 2017).

Contemporary indigenous populations have preserved the Asian populations with significant frequencies of winging, crowding, shovel-shaped incisors, the deflecting wrinkle, the protostylid P-point and the cuspid Y groove pattern; however, they have incorporated morphological features of the European populations such as Carabelli's trait (fossa expressions and small cusps) and the cuspid X and + pattern (Diaz et al., 2014) and Afro-descendant populations have been characterized by presenting high frequencies of medium-sized Carabelli trait, cuspid + pattern, X pattern and high frequency of cusp 7, suggesting a notable influence of the European populations (Marcovich et al., 2012; Rocha et al., 2007; García et al., 2015).

Delgado-Burbano (2007) indicated that Afro-Colombians derive from Africans who arrived in the American continent as slaves from West Africa, Central West Africa (sub-Saharan Africa), Southeast Africa, and the North, all of them classified in the African-western dental complex. The dental morphological traits that have been most widely used to estimate the ethnic pattern in the Colombian anthropological and forensic contexts are the Carabelli's trait, protostylid, cusp 6, and cusp 7, which have high taxonomic value and intragroup discriminating power. The statistical information accumulated from different world populations has allowed grouping the populations through the frequency and variability of these traits, represented in distance matrices and plotted through dendrograms (Rodriguez, 2003). The dendrogram generated by Pérez et al. (2017), which grouped the largest number of Colombian populations studied based on these morphological traits and according to the influence of the three world dental complexes, is included in this article (Figure 2).

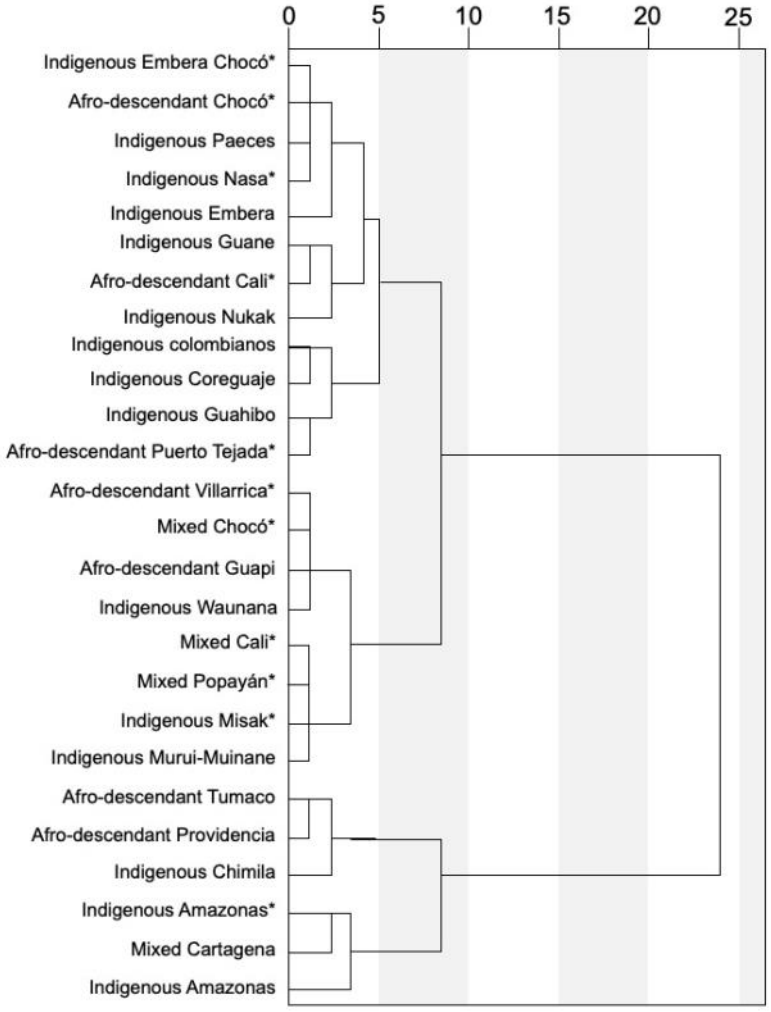

Figure 2. Dendrogram showing the biological distance between different Colombian populations and Colombian populations of mixed groups, Native Americans, and Afro-descendants, based on the frequency and variability of the Carabelli trait, protostylid, cusp 6 and cusp 7. *Contemporary Colombian human populations studied by the Research Group of Dental Anthropology and Forensic Odontology of the Universidad del Valle.

The dendrogram shows that mixed groups, Afro-descendants, and indigenous people are distributed in clusters according to the dichotomous expression and variability of the four traits included in the analysis. The expressions of Carabelli's trait in fossa (grade 1 to grade 3 ASUDAS), protostylid in grooves and small cusps (grade 2 and 3 ASUDAS), cusp 6 in small cusps (grade 1 and 2 ASUDAS), and the absence of cusp 7, grouped populations with a tendency to the Asian dental complex, as in the case of groups of Emberá, Paeces, Nasa, Guane, and Nukak Indigenous groups distributed in specific geographic regions where contact with other groups of mixed groups and Afro-descendants has been reduced.

In contrast, indigenous groups such as Coreguaje, Guahibo, Waunana, Misak, and Murui-Muinane, who share territory with mixed groups from Cali and Popayán, as well as Afro-descendant groups from Puerto Tejada, Villarica, and Guapi, presented a higher frequency of Carabelli's trait in small cusp expression (grade 4 ASUDAS). On the other hand, these same mixed and Afro-descendant groups were characterized by cuspid expressions of the Carabelli trait and the expression of cusp 7 (grades 2 and 3 ASUDAS), even though they exhibited pit expressions of Carabelli's trait and the P-point of the protostylid associated with the intense process of mixed origin that has historically occurred in the southwest of Colombia

with Nasa and Misak indigenous groups. It is worth noting that the P-point expression can be found in the same tooth as other grades of the protostylid; however, in contemporary populations of southwestern Colombia (mixed groups, Afro-descendant, and indigenous groups), the prevalence of the cuspid expression of this trait is practically absent, according to the dichotomous expression defined by ASUDAS, while the prevalence of the P-point is between 80% and 100% (Hernández et al., 2014).

Interest in the forensic context

During the process of forensic identification and medical-legal documentation, whether dealing with living or deceased individuals, it is crucial to establish their identity. The search for identity is conducted through the general biographical reconstruction, also known as the biological profile. This includes the estimation of age, sex, ethnic pattern, and stature through the application of validated bioanthropological methods (Rodriguez et al., 1995). Teeth provide significant information for estimating age (chronology of dental development and eruption, as well as dental wear), sex (dental measurements), and population pattern (dental morphology), and in many cases, are the only element capable of providing biological and cultural information on an individual or human population (Rodríguez, 2003; Rodríguez-Flórez, 2003, 2005).

Most population studies on dental morphological traits have demonstrated their great value in classifying human groups according to their ethnic origin and geographic distribution, and the absence of sexual dimorphism and bilateral asymmetry in the expression of dental morphological traits. Additionally, particular expressions of tubercular features, such as paramolar cusps (Carabelli's trait, parastyle, and protostylid), can individualize a human being (Rodriguez, 2003, 2004, 2011).

In Colombia, the Instituto Nacional de Medicina Legal y Ciencias Forenses reported in 1993 that 72% of all cases in which bone and dental remains were analyzed with bioanthropological techniques and methods corresponded to mixed origin populations with Caucasoid characteristics, while 28%, 7%, and 1% corresponded to mixed origin populations with Asian, Indigenous, and Afro-descendant characteristics, respectively (Rodriguez, 2004). Despite ongoing controversy over the use of dental morphological traits and their limitations, their observation and recording can be considered as an attempt to test their validity as a method of ancestry estimation in a forensic context (Edgar, 2005; 2013). Therefore, it is necessary for research areas to keep constant work and to carry out studies on statistical prediction models to test whether dental Fmorphological traits are valid as a method of ancestry estimation in a forensic context, or if they can be used as a complementary method to others (López-Lázaro et al., 2016).

Based on the information presented in this article, studies on morphological characterization carried out in contemporary populations of southwestern Colombia have shown that the frequency and variability of dental morphological traits differ among mixed populations, Afro-Colombian populations, and contemporary indigenous populations (Moreno-Gómez, 2019):

Mixed populations are characterized by low expressions of shovel-shaped incisors (grades 2 and 3 ASUDAS), fossa and cuspid expressions of Carabelli's trait (grades 3 and 4 ASUDAS), hypocone reduction (grades 2 and 3 ASUDAS), absence of deflecting wrinkle, variations of the cuspid pattern between Y and + with five cusps; absence of protostylid combined with mean P-point expressions, and absence of cusps 6 and 7.

Afro-Colombian populations are characterized by absence of shovel-shaped incisors, cuspid expressions of Carabelli's trait (grades 4 and 5 ASUDAS), hypocone reduction (grades 2 and 3 ASUDAS), absence of deflecting wrinkle, cuspid x or + pattern with five or six cusps, absence of protostylid combined with middle expressions of P-point, and relative expressions of cusp 7 (grades 2 and 3 ASUDAS).

Contemporary Indigenous populations are characterized by high frequencies of shovel-shaped incisors (grades 3 to 6 ASUDAS), reduced Carabelli's trait (grades 2 and 3 ASUDAS), absence of hypocone reduction, deflecting wrinkle (grade 3 ASUDAS), cuspid Y groove pattern with five and six cusps, groove expressions and small protostylid cusps (grades 2 and 3 ASUDAS) combined with P-point, and relative expressions of cusp 6 (grades 2 and 3 ASUDAS).

However, according to the territory occupied by the human groups and the historical processes of mixed origin, the behavior (frequency and variability) of some of the traits may change.

Conclusions

This literature review has enabled the continuous work of the Dental Anthropology and Forensic Dentistry Research Group at the School of Dentis-

try of the Universidad del Valle (Cali, Colombia) to be followed up. For nearly 20 years, this group has characterized the dental morphology of southwestern Colombia through the study of the frequency and variability of dental morphological traits in different populations of mixed groups, Afrodescendants, and Native Americans. However, it is necessary to expand the research on other topics of dental anthropology that have been barely addressed by the Dental Anthropology and Forensic Dentistry Research Group, such as the study of dental measurements, dental eruption patterns, and dental pathologies applied to anthropological and forensic contexts.

The strategies employed by the Dental Anthropology and Forensic Dentistry Research Group, including formative research and the formation of cooperative research networks, have contributed to the publication and dissemination of the results of studies on dental morphology, mainly in the Colombian dental clinical context. The thematic direction of the studies and the journals in which the articles were published demonstrated the impact on the knowledge that dentists have about dental morphology from an anthropological point of view, and how this knowledge can be applied to their clinical interest as etiological factors associated with the accumulation of bacterial plaque and the subsequent development of caries and periodontal disease. However, the publication of research in international anthropological contexts is limited by the lack of publications in English and resistance from some specialized journals to research in contemporary Colombian populations. Nevertheless, it is important to understand that, given the current conditions for research and publication in dental anthropology, researchers from universities in the United States, Great Britain, and Australia have been able to create a broader vision of the study of dental morphology by comparing and contrasting anthropological knowledge from Latin American countries, such as Colombia, based on information published in English and high-impact specialized journals.

From an anthropological perspective, one of the most significant accomplishments of the Research Group has been the systematic study of contemporary Colombian populations of European, Native American, and African origin, historically settled in southwestern Colombia. This has enabled the construction of a population dendrogram based on the frequency and variability of four non-metric dental traits (Carabelli's trait, protostylid, cusp 6, and cusp 7), which have been observed, registered, and analyzed using the ASUDAS methodology. These findings are comparable to other population studies that have used this methodology worldwide. Additionally, it has been identified that the expression of dental morphological traits is bilaterally symmetrical and does not present sexual dimorphism.

Considering that forensic dental identification processes rely on comparative and reconstructive methods, it is crucial to urge clinical odontologists to include in clinical records the description of the presence and variation of morphological characteristics with marked expressions in the four classes of teeth and in both dentitions. This would allow dental experts and forensic anthropologists to use dental morphology in estimating the ethnic pattern during the biographical reconstruction of an individual or their human remains. Hence, dental morphological features can become reliable markers for comparative use in antemortem-postmortem comparisons when carrying out the biological profile.

In conclusion, the efforts of the Dental Anthropology and Forensic Dentistry Research Group are currently focused on finding ways to make the international dental anthropological and dentistry community aware of the research on Colombian dental anthropology. The researchers, comprising anthropologists and odontologists, have appropriated various theories and methods to create their own discourse on the behavior of dental morphological traits. This article precisely presents an account of this "discurso propio del otro (nosotros)" and is presented in tension with the anxiety produced by encountering the "discurso universal del hegemónico (ustedes)" with whom we share the ambition of generating applicable knowledge in the anthropological, dentistry and forensic contexts. The aim is to make the knowledge generated during these 20 years of work visible and to believe that it is possible to think outside the hegemonic discourses.

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