Frequency and variability of five non metric dental crown traits in the permanent maxillary dentitions of a racially mixed population from Bengaluru, Karnataka

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Abstract

Introduction: Evaluation of Tooth Crown non metric traits benefits to assess the biological distance between populations. It is well known that these traits are characterised by a high inter-population differentiation, low sexual dimorphism, and their recording is loaded by relatively small intra and inter observer error. The dental morphological traits are successfully used in the description and explanation of the microevolutionary and ethnogenetic processes. This paper presents the results of the permanent maxillary dentition tooth crown traits differentiation of human populations from Bengaluru.

Materials and Methods: The comparative analysis was carried out on the basis of 4 groups for 5 Tooth Crown non metric traits in maxillary permanent dentition using Arizona State University Dental Anthropology System for morphological scoring system of each trait and each score was charted on Osteoware Dental Morphology software.

Results: Study analysed 400 dental casts from 4 different ethnic groups. Traits Winging, shovelling, lingual tubercle showed highest expression in Iranians while Cusp of Carabelli's trait expression showed 87% of prevalence in the surveyed group but the Hypocone trait showed the highest expression in Muslims.

Conclusion: Traits of the human dentition can be a valuable diagnostic tool for anthropological studies in classifying and characterizing different ethnic groups. According to the results obtained from this study, it can be said that the groups Hindus, Muslims and Christians (Indians) belong to Sundonts, while Iranians fall under sinodonts population group.

Keywords: Dental anthropology, forensic odontology, maxillary permanent dentition, nonmetric traits

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INTRODUCTION

Bioarchaeology is the contextual study of the biology, culture and evolution of human populations using skeletal remains interpreted within archaeological, historical, and contemporary problem orientations.[1,2] Bioarchaeology has close connections with skeletal biology and forensic science and emerged as a popular field during the 1970s in the light of the New Archaeology.[3,4] One of the disciplines within

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bioarchaeology is dental anthropology. Although the term "dental anthropology" was first introduced by Klatsky and Fisher,[5-9] some of the earliest pioneers working on human dental morphology were Hrdlicka (1920) and Krogman (1927).

It was in the 19th to early 20th century that interests in descriptive morphology flourished, leading to the discovery and description of many nonmetric traits. The use of dental characteristics in studies of population relationships developed from then on. Some of the early contributions to understanding population variability came from Dahlberg (1945), Pedersen (1949) and Moorrees (1957).[10] The observation that morphological dental traits exhibit significant differences in frequency among major geographic areas was made from the early 20th century (Dahlberg 1945; Dahlberg 1951; Hrdlicka 1920; Hrdlička 1921). For some traits, the differences between groups were so pronounced that researchers defined Mongoloid, Caucasoid and African dental 12 complexes in the second half of the 20th century (Haeussler 1989; Hanihara 1968; Irish 1994; Mayhall *et al*. 1982).

Until the 1950s, biological anthropology consisted mainly of collecting, categorizing and comparing data to fit into fixed typological classifications. It was Washburn in 1953 who stressed that researchers needed to focus on hypothesis testing rather than classification. Although it has been the focus of dental anthropology for many decades, classification and interregional research on a global scale neglect the genetic and nonmetric variation within those populations. The general characteristics of dental nonmetric traits are still used in the forensic sciences to estimate ethnic affiliation. For example, an individual with or trace incisor shoveling, a Carabelli's cusp and a 4-cusped lower second molar would most likely be of a European or Western Eurasian decent because those traits tend to occur in those populations.[10] However, this is only a small part of what human dental morphology can accomplish. When testing hypotheses about population affinity by the use of dental morphology, distance statistics are often used to estimate relative degrees of similarity or dissimilarity. In 1971, Turner used a single root trait to distinguish three primary subgroupings within the Americas; Eskimo-Aleut, Na-Dene and all other Indians of North and South America (Turner 1971). The information derived from this dental research formed the framework for the three-migration model. This model assumed that the Americas were colonized by three different migration waves.[11] This research shows the impact of dental anthropology on archaeology and other neighboring disciplines.

The term "trait" has been defined as a distinguishing feature or characteristic of an individual. The frequency of occurrence of a trait may be low in a specific population because that trait is becoming progressively more or less well developed in that population. Hence, it is not inconceivable that a trait could inadvertently be considered to be an anomaly, even though it may be a characteristic feature of that population. Thus, what may be considered to be an anomaly in one population may be a trait in another population.

Hence, the analysis of dental morphology in the context of dental anthropology seeks to understand the manner in which the frequency, sexual dimorphism and bilateral symmetry of tooth crown morphological traits (TCMT) present in permanent teeth.[3]

The tissues that make up the human dentition are the most mineralized and most durable tissues in the human body. Teeth can maintain their form for long periods and makeup about 90% of the fossil record. Therefore, the morphology of the human mouth is very important to anthropologists. The Arizona State University Dental Anthropology System (ASUDAS) is a morphological scoring system used by anthropologists to collect data on the human dentition. The traits observed by the ASUDAS are reliable and easily observed. They can be identified if the dentition has become degraded, and they have no sexual dimorphism. Furthermore, these traits powerfully characterize populations for affinity studies. Because dental nonmetric studies have yet to be applied to the Indian populations, it is unknown which traits are most suited for analysis within this area. Therefore, the individuals under this study were investigated for five dental nonmetric traits. Furthermore, it is important to score all possible traits to notice differences and identify possible influences from other geographic areas.

MATERIALS AND METHODS

This is a quantitative, cross-sectional, descriptive study of the frequency, variability and bilateral symmetry of 5 TCMT's in maxillary permanent dentition. A total number of 400 age- and sex-matched individuals from four different ethnic groups belonging to Hinduism, Islam, Christianity and Persians were considered in this study. Participants for the study were selected from a survey and interview examination who met the inclusion criteria (with clinically healthy teeth where the TCMT were taken into account) and who were asked to sign an informed consent. Participants were examined clinically, and study casts were made. Individual teeth on casts, examined using an illuminated magnifying glass (×2) to diagnose the presence or absence of a trait. The dental nonmetric traits were

Table 1: The different nonmetric traits scored on the according teeth

Feature	Tooth	Gradation	Degree of expression	
			Rank	Presence
Winging Winging is characterized by the (bi) lateral mesiolingual rotation of the distal margins of the central upper incisors (I1), so that from an incisal view, the incisors have a v-shape Breakpoint*: Grade 1; (bi) lateral winging	Upper central incisors	0 - Absent 1 - Unilateral 2 - Bilateral	0-2	2
Shovelling The distinguishing feature of this trait is the presence of mesial and distal marginal ridges on the lingual surface of the upper incisors (I1 and I2) and canines. In a shovel shaped tooth, the marginal ridges extend from the incisal edge to the basal eminence Breakpoint*: Grade three on UI1; strong ridging is present and there is a tendency for ridge convergence at the cingulum	Upper central incisors, lateral incisors and canine	0 - Absent 1 - Smooth 2 - Well-marked 3 - Semi-shovel shape 4 - Marked semi-shovel shaped 5 - Shovel-shaped 6 - Marked shovel-shape 7- Barrel form	0-7	2-7
Dental tubercle These cingular derivatives are expressed on the lingual surfaces of the upper anterior teeth, the incisors (I1 and I2) and the canines, as ridges and/or tubercles Breakpoint: Grade one on UI1: Faint ridging	Upper central incisors, lateral incisors and canine	0 - No expression: Cingular region of the lingual surface is smooth. Ignore any shoveling presence 1 - Faint ridging. 2 - Trace ridging. 3 - Strong ridging. 4 - Pronounced ridging. 5 - A weakly developed cuspule is attached to either the mesio - or distolingual marginal ridge. Cuspule apex is not free. Not shown in plaque 6. Interpolate between Grade 4 in plaque 5 and the tuberculum dentale found in Grade 4 of plaque 7 6 - Weakly developed cuspule with a free apex. Size corresponds approximately with the tuberculum dentale found in Grade 4 of plaque 7 7 - Strong cusp with a free apex. Size is equal to or greater than the tuberculum dentale found in Grade 5 of plaque 7	0-7	1-7
Carabelli trait Carabelli's trait is one of the most studied nonmetric traits. It is characterized by a cingular derivative expressed on the mesiolingual or lingual aspect of the protocone of the upper molars. The eight grade scale indicates the wide range in degrees of trait presence varying from small grooves to large tubercles Breakpoint*: Grade five on UM1; a small cusp without a free apex occurs	Upper molars	0 - The mesiolingual aspect of cusp 1 is smooth 1 - A groove is present 2 - A pit is present 3 - A small Y-shaped depression is present 4 - A large Y-shaped depression is present 5 - A small cusp without a free apex occurs. The distal border of the cusp does not contact the lingual groove separating cusps 1 and 4 6 - A medium-sized cusp with an attached apex making contact with the medial lingual groove is present 7 - A large free cusp is present	0-7	1-7
Hypoconid The hypocone, distolingual cusp or cusp four of the upper molars is the cusp most often reduced in size and even lost in the later stages of hominid evolution Breakpoint*: Grade one (and lower) on UM2; faint ridging present at the site	Upper molars	0 - No hypocone. Site is smooth 1 - Faint ridging present at the site 2 - Faint cuspule present 3 - Small cusp present 3.5 - Moderate-sized cusp present 4 - Large cusp present 5 - Very large cusp present	0-5	1-5

*This the rule to ascertain the score

identified and scored in accordance with the odontoscopic system developed from ASUDAS. The ASUDAS uses standard recording forms and 3D reference plaques.

Illustrated versions of the various classifications of the following traits – winging, shoveling, dental tubercle, cusp of Carabelli and hypocone [Table 1] and a list of the teeth on which they could be expected to occur, were prepared to enhance the accuracy of the diagnoses and to maintain the level of examiner reliability.

The scores were recorded on Osteoware Software Version 1.80, Smithsonian Museum of Natural History, USA [Figure 1]. The cast was examined by two observers independently to eliminate intra-observer variation in interpretation and mean of 2 was taken for the analysis.

The data obtained from TCMT observation were entered into a template on Excel® and processed with the Statistical Package for the Social Sciences (SPSS) version 22, IBM Corporation software through the Chi-square test for each

Table 2: Prevalence (%) of tooth crown non metric traits in permanent maxillary dentitionc, in 4 ethnic groups

Score	Hindu	Muslim	Christian	Iranian	P (χ^2)
TRAIT - WINGING - UPPER CENTRAL INCISORS					
0	89	84	80	18	0.004
1	11	16	20	82	
TRAIT - SHOVELING - UPPER CENTRAL INCISORS - RIGHT					
0	94	56	66	20	<0.001
1	6	44	34	80	
TRAIT - SHOVELING - UPPER CENTRAL INCISORS - LEFT					
0	91	63	69	16	<0.001
1	9	37	31	84	
TRAIT - DENTAL TUBERCLE - UPPER ANTERIOR TEETH - RIGHT					
0	85	65	88	55	<0.001
1	11	35	12	45	
TRAIT - DENTAL TUBERCLE - UPPER ANTERIOR TEETH - LEFT					
0	94	71	85	58	<0.001
1	6	29	15	42	
TRAIT - CUSP OF CARABELLI - UPPER PERMANENT FIRST MOLAR - RIGHT					
1	31	5	0	9	<0.001
2	48	14	42	8	
3	10	54	46	11	
4	5	17	6	16	
5	3	0	0	6	
6	3	10	6	0	
TRAIT - CUSP OF CARABELLI - UPPER PERMANENT FIRST MOLAR - LEFT					
1	31	5	0	9	<0.001
2	48	14	22	8	
3	10	54	46	11	
4	5	17	26	16	
5	3	0	0	6	
6	3	10	6	0	
TRAIT - HYPOCONE - UPPER SECOND MOLAR - RIGHT					
0	100	11	80	50	<0.001
1	0	89	20	50	
TRAIT - HYPOCONE - UPPER SECOND MOLAR - LEFT					
0	100	12	100	50	<0.001
1	0	88	0	50	

of the morphological features. A $P < 0.05$ was considered statistically significant.

RESULTS

The five traits, their frequencies and the number of individuals observed for each trait for the Hindu, Islam, Christian and Persian samples are provided in Table 2.

The differentiation which can be traced in the Bengaluru populations is demonstrated as in Table 2. Winging showed 82% expression in Iranians and this trait was not expressed in any other group. While shoveling trait expression was significantly high in Iranians (80%–84%) group followed by Christian with least expression in Hindu group. There was a high prevalence of lingual tubercle on the permanent anterior teeth in Iranians, followed by Muslims. In this study, the single lingual tubercle affected

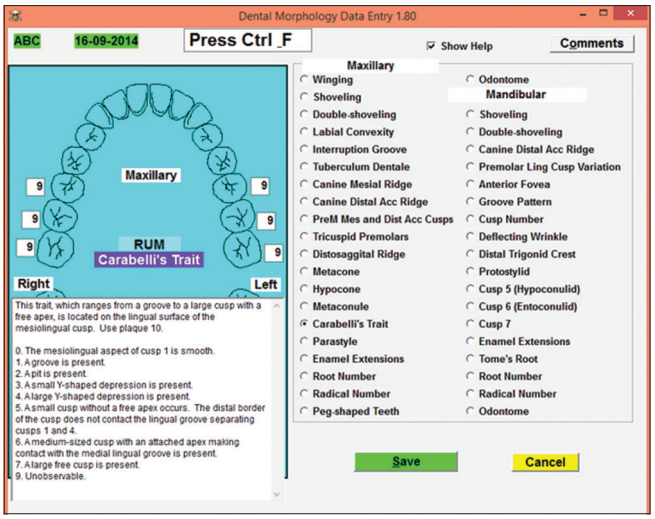

Figure 1: Dental morphology data entry – Osteoware software Version 1.80

the teeth more than the double tubercle variation. Cusp of Carabelli's trait expression showed 87% of prevalence in the surveyed group. Type 3 was most frequently expressed and type 6 was least frequently expressed and both types being expressed in Islamic groups. The expression of trait was bilateral in 90% of surveyed groups. Hypocone traits showed the highest expression in Muslims, between 88% and 89%.

DISCUSSION

Teeth have a large variation in morphological features and their form may not be easily altered; thus, a trait of the human dentition can be a valuable diagnostic tool for anthropological studies in classifying and characterizing different ethnic groups.

The studying of traits on dental casts is comparable to using fossilized material to diagnose characteristics of the dentition of prehistoric man. Detailed information can usually be successfully obtained from these sources. This may indeed be more reliable than direct clinical examinations for which instant clinical decisions have to be made, and visual access is restricted in the oral cavity. The use of an oral examination may result in information being inadvertently not collected. For example, the line form of Carabelli's trait cannot be easily detected in the clinical environment because the quality and direction of the light can be critical factors. Thus, the studying of dental casts was considered to be superior to the clinical method of examination. However, it is essential that the dental casts are a true and accurate reproduction of the original teeth and that they have not been damaged during preparation or storage.

Diagnostic criteria for the seven dental traits were difficult to develop even with the aid of previously published literature because there is a lack of universally accepted classifications for each trait. Hence, the diagnostic criteria used in this study has been described by ASUDAS . This system enables the researcher to get familiar with the different nonmetric traits and reliably compare them for assessing different grades of presence. Furthermore, caution and repeat observations serve to minimalize intraobserver error.

The five major traits of maxillary permanent dentition will be discussed respectively by first considering the physical characteristic, followed by the prevalence of that trait in the permanent dentition. The objective is to demonstrate any similarities or differences between the previously published literature and where data are available to identify any distinctive features in the data for the permanent dentition of the Bengaluru population.

Winging

Scott and Turner[6] relate this feature with the absence of space in the dental arch that prevents the proper alignment of the incisors. According to Rodríguez,[12] the mesolingual rotation of both incisors is considered the product of genetic factors characteristic of Native American populations while the rotation of a single tooth or both in a distolingual direction is caused by crowding. In a population of Amazonian Indians, this feature was observed with high frequency.[13] In this study, a relative frequency of the trait was observed, represented in Grade 1 expression (distobuccal rotation of both incisors) with the high frequency of this expression in the Iranian population [Figure 2].

Shoveling

Hrdlicka's report of this anomaly in 1920, and he proposed shoveling has been accepted as a trait of the mongoloid dentition. High prevalence has been reported in Eskimos,[14] Pima Indians,[15,16] North American Indians,[16] and Aleuts.[17] The reverse has been found for Europeans and Negroids.[18] It is quite accurate to describe shoveling as a characteristic for populations of Mongoloids, irrespective of the geographic region. As expected, most of the maxillary incisors examined in this study were found to demonstrate shoveling, giving this trait a prevalence in Iranians [Figure 3], mainly in the middle grades (semi-shovel and marked semi-shovel). Furthermore, bilateral symmetry was evident.

The degree of shoveling has been used to differentiate ethnically between the Pueblo Indians and the Plains Indians, and some Asian and African populations.[19,20]

Dental tubercle

Berry[21] showed a significant correlation of lingual tubercle with Carabelli's trait. Similarly, lingual tubercle was found in this study to be closely related to Carabelli's trait and in addition to the shoveling trait. There was a prevalence of lingual tubercle on the permanent anterior teeth in Iranians at 42%–45% followed by Muslims at 29%–35% [Figure 4]. In this study, the double lingual tubercle affected the teeth more than the single tubercle variation. Nevertheless, the prevalence figures of different types of lingual tubercles were not reported for the majority of other studies.

Carabelli's trait

Carabelli's trait name has been credited to von Carabelli, who first described this feature in 1842 in a paper by Korenhof. It has also been referred to as the tuberculum anomalies, tuberculum Carabelli and tuberculum imparon. Although some specimens of Paleolithic man have been found to exhibit Carabelli's trait on the maxillary molars,[22] this has not been a consistence finding, and it is a generally held opinion that the cusp form of the Carabelli trait is a recent acquisition of man. Conversely, the pit form of the Carabelli trait has been observed in numerous specimens of Neanderthal man and has been considered to be a

Figure 2: Incisors exhibiting bilateral Winging in study sample of Iranian

Figure 3: Incisors exhibiting various grades of shovelling in study sample of Iranian

consistent characteristic of the maxillary molars. Thus, it is reasonable to conclude that the Carabelli trait is significant in the evolution of man and possibly in different racial groups.

The Carabelli trait is said to be an inherited characteristic.[23] Data from studies of twins support this etiological hypothesis. However, although an autosomal dominant mode of inheritance has been proposed, the degree of expression of the trait in twins has varied from fully concordant to fully discordant. Thus, because of the varying manifestations and prevalence of Carabelli's trait, the mode of inheritance is probably not a simple Mendelian pattern. A high degree of equivalence of Carabelli trait expression between primary and permanent molars was demonstrated by Kieser.[24] It was then hypothesized that the high degree of within individual equivalence suggests a low epigenetic and high genetic influence on Carabelli trait expression and that the findings support the clonal rather than the field theory of tooth morphogenesis.[24]

For the permanent dentition, Carabelli's trait appears to be generally most common among the European populations, followed by the African populations and American Indians, with the lowest prevalence occurring in the other Mongoloid races. However, the present study showed an overall prevalence of 87.6% in the surveyed group, which is higher than that in previous reports. Among Indians, 52.77% of maxillary first permanent molars displayed a Carabelli tubercle Iranians, the prevalence of the trait was 58.7%.

Dahlberg's classification is the most commonly applied method for determining the degree and expression of Carabelli cusps. In this study, Class 3 was the most frequent Carabelli cusp configuration (54%) and Class 6 was the least frequent (10%) both types being expressed in Islam. Few researchers stated that Carabelli's tubercle is invariably bilateral; but, the majority describes it as usually bilateral. In the present study, most cases (90%) had the bilaterally same configuration, and only 20 cases (10%) did not have Carabelli cusp, bilaterally. Therefore, expression of Carabelli's tubercle is invariably bilateral [Figure 5].

Figure 4: Maxillary anterior teeth exhibiting various grades ofdental tubercle in study sample of Iranian

Hypocone

Severe reduction and the absence of the distolingual cusp (hypocone) is a valued trend from the first upper molar to the second upper molar[9] and is associated with a simplification of the dental morphology and reduced size. In this study, the reduction of the hypocone resulted in the absence of the bilateral form in both sexes. Hypocone is most prevalent in Grades 0 and 1. In Muslims, it is between 88% and 89% [Figure 6]. The global variation is between 13% and 95%, with a minimum found among Australian aborigines and a maximum among Mongoloids, which was true in regard to this study.[7]

Dental nonmetric traits can aid in the reconstruction of biological relationships demonstrating differences or similarities between groups. This might reveal information concerning a population history regarding different aspects such as migration, trade and other aspects which might have created the potential for the exchange of genes between groups.

Because of the frequency and variability of TCMTs, human populations can be associated with geographical distributions, and different researchers have ethnographically classified human beings in complex populations from dental morphology.[25,26]

The first of these complexes was defined by Hanihara in 1966[27] as the mongoloid dental complex, which brings together different populations from East Asia that are

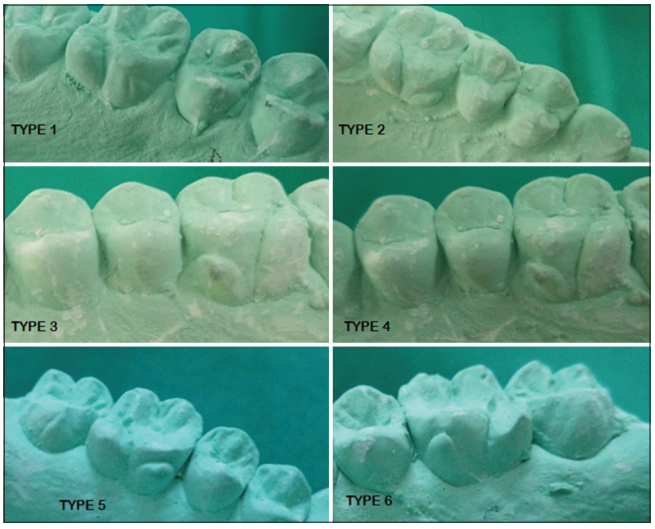

Figure 5: Maxillary first molar exhibiting various grades of Carabelli's trait in study sample of Indian

Figure 6: Maxillary molar exhibiting various grades of hypocone in study sample of Iranian

characterized by having a complex dental morphology represented in a high frequency of shovel-shaped, layered fold and cusp pattern 6 incisors.

Later, Turner in 1984[13] divided the mongoloid dental complex into two groups. The first subdivision, or Sinodont, composed of Northeast Asian populations, is characterized by the addition and enhancement of some TCMTs, such as the shovel-shaped and layered fold incisors, along with winging. The second subdivision or sundadont covers Southeast Asian populations that have retained an ancestral condition and have simplified the expression of some morphological traits.

On the other hand, Zoubov[20] proposed a dental delimitation of global populations into two complexes: the eastern dental complex, the equivalent of the mongoloid dental complex proposed by Hanihara; and the western dental complex, consisting of Northern Caucasoid and Negroid populations (Southern Caucasoid populations) characterized by the high frequency of the Carabelli cusp (cusp forms), of the cusp pattern X, the groove pattern + and the cusp 7 more prevalent in Negroid populations.

Irish[18] subdivided the Negroid populations of Southern Africa (Western Dental Complex) into the Sub-Saharan Dental Complex and North African Dental Complex.

Edgar[28] grouped humans into five clusters: the mongoloid dental complex formed by sinodont and sundadont groups; the Caucasoid Dental Complex formed by Western Eurasian groups (Europe, North Africa, Middle East and India); the Saharan African Dental Complex (composed of West African and South African subgroups closer to sundadont populations of the South Pacific), several Pacific groups of Sahul or Oceania and American Paleo-Indians who present frequencies and morphological variations that take them out of the complexes described.

The term "dental complex" refers to the characterization of large population groups, according to a specific combination of TCMTs, and since modern human groups have the same number of these features in both dentitions, the only detectable difference is in the frequencies of these traits. That is why it is necessary to cover a wider range of population groups with significant samples.

According to the results obtained from this study, it can be said that the indigenous group of the sample who formed the sample for this study have high frequencies of TCMT characteristic of the Sundonts– Hindus, Muslims and Christians (Indians). While Iranians fall under sinodonts, and similarly with other Colombian and American indigenous groups, the findings are consistent with those reported by Turner, Hanihara, Zoubov and Rodríguez, which also coincide with the theory of the Mongoloid origin of the indigenous tribes of South America.[13,18,29]

CONCLUSION

It is important to recognize that population identification/differentiation is undertaken based on the presence/absence of multiple nonmetric traits, and not through the use of a single feature. The large variation in morphological features and their form may not be easily altered; thus, a trait of the human dentition can be a valuable diagnostic tool for anthropological studies in classifying and characterizing different ethnic groups. It similarly constitutes an accurate means of recognizing individuals whose death makes it difficult to distinguish them by other processes which are part of the individual reconstruction of osteobiography (odontography) or for that of the general population. In all, this research makes a valuable contribution to the field of dental anthropology. This research found new elements of invaluable ethnographic value from the analysis of dental morphology that eventually will allow us to understand the human diversity of this region of, the establishment of regional linkages associated with macroevolutionary events that occurred since the settlement.

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Conflicts of interest
There are no conflicts of interest.

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