Original Article

Multivariate Analysis of Nonmetric Traits in Permanent Anterior Teeth: A Forensic Overview

Tibin K Baby, S Sunil

Department of Oral Maxillofacial Pathology, Pushpagiri College of Dental Sciences, Tiruvalla, Pathanamthitta, Kerala, India

Abstract

Introduction: Dental morphology is a highly heritable characteristic, also stable with time and has a fairly high state of preservation. Nonmetric dental traits have a crucial role in ethnic classifications of a population which helps in forensic racial identification purposes.

Aims and Objectives: The objective of the study is to determine the frequency and variability of possible nonmetric tooth traits using extracted permanent anterior teeth from Kerala population for discerning racial ethnicity.

Materials and Methods: This qualitative, cross-sectional study was carried out using 1761 extracted intact permanent anterior teeth collected from different dental clinics situated all over Kerala.

Results: The most common trait noted was shoveling in both incisors and canines with maximum expression in 11 (69.12%) followed by 21 (62.94%). Double shoveling and lingual tubercle prevalence in canines (12.64% and 10.18%) were more than incisors (6.09% and 7.55%). In canines, the expression percentage of palatal fossae, lingual fossae, and distal accessory ridge was 31.13, 18.49, and 10.56, respectively.

Conclusion: The results showed a higher degree of shoveling trait in this population. This research suggested new elements of invaluable ethnographic tooth traits value to understand racial ethnicity of Kerala population.

Key Words: *Dental anthropology, forensic racial ethnicity, nonmetric tooth traits, shoveling*

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Introduction

The study of dental morphology (odontoscopy) from the dental anthropology concept aims to observe, record, analyze, and understand the behavior of the expression (frequency and variability) of coronal and root morphology of human teeth.[1,2] These dental morphological or nonmetric traits clarify the historical, cultural, and biological macro- and micro-evolution which help to understand displacement, migration paths, and ethnic variation of humanity.[2,3] These nonmetric tooth traits also have a crucial role in the forensic racial identification purposes. It has potential to establish racial classifications. Dental morphology is a highly heritable characteristic, also stable with time and has a fairly high state of preservation compared to the bone material.[2] Although up to 135 dental traits that have been recognized in the human dentition, only 17 traits are used in most worldwide research. The observation of these features is done through different methods reported in the literature, excelling Arizona State University Dental Anthropology System (ASUDAS) method is a commonly and successfully used standard for scoring dental variation on contemporary human teeth.[4] This was developed by A. Dahlberg since 1940 from standard dental plates and transferred to C. G. Turner II in 1981 at the Department of Anthropology of the Arizona State University, hence its name.[2,5] Bailey has shown several additional traits of interest in fossil hominid teeth which may have phylogenetic value.[4] These observational methods provide a scoring system to classify the degree of expression of tooth trait variants allowing to evaluate them beyond the dichotomy presence or absence.[2,5,6]

Many bioarchaeological studies have demonstrated the differences in the expression and frequency of dental traits among various ethnic groups in the determination of ancestry in the context of forensic dental anthropology.[7] Investigations have provided information on local-scale nonmetric dental variation in Indian population by Lukacs and Walimbe in 1984 followed by Lukacs and Hemphill in 1991.[4,7] All these studies were done on skulls retrieved from cemetery graves. Few studies have been undertaken regarding ethnic and gender difference of tooth morphology in the present population on plaster models, direct clinical assessment, or digital photographs.[3,6,8-12] The main disadvantages of plaster models are artefacts which confuses the presence of real traits and the restricted morphological observation as root trait

Address for correspondence:
Dr. Tibin K Baby, E-mail: tibinkbaby@gmail.com

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analysis is impossible.[6] Although root number trait was done using periapical radiographs, it has limitations.[13] The direct clinical observation is also not apt as the reflection of light is exacerbated by the presence of saliva and limited observation perspectives.[6]

The main objective of this study was to observe record and analyze the frequency and variability of possible nonmetric tooth traits using extracted permanent anterior teeth from Kerala population for discerning racial ethnicity. After extensive literature search, we could find our study to be the very first tooth traits study done on extracted anterior teeth and also the first extensive anterior tooth traits exploration in Kerala population.

Materials and Methods

This study was conducted after the ethical clearance from our institutional ethical board. This was a qualitative, cross-sectional study of the frequency and variability of nonmetric tooth traits using 1761 extracted permanent anterior teeth with unknown history for discerning ethnicity. The sample size included 1231 incisors (central and lateral) and 530 canines of both maxillary as well as mandibular jaw, collected from different dental clinics situated all over Kerala. Extracted teeth with intact morphology only were included in this study. Teeth with root/crown fracture, restoration, root canal treatment, crown placement, attrition, erosion, and abrasion were excluded from the present study.

All the teeth were identified by Federation Dentaire Internationale system and visual observation made macroscopically in a room with natural light using the dental explorer. To avoid interobserver bias, all the teeth were checked by two same observers together and were performed over approximately 2 months. In order to minimize potential eyestrain of the viewer that would compromise the following observations, short breaks (5 min) were taken between each assessment during the data collection. Nine and thirteen nonmetric tooth traits were observed for the all permanent incisors and canines, respectively[2,5,14] [Table 1].

Additional permanent canine tooth traits observed were

1. Canine mesial ridge/bushman canine – mesial crest variation
2. Distal accessory ridge – small accessory crest that appears on the distal-incisal region
3. Palatal fossae – two graves, mesial and distal, which appear in the palatal surface of the upper canines
4. Lingual fossae – two graves, mesial and distal, which appear on the lingual surface of the lower canines.

Peg lateral trait assessment was done on maxillary lateral incisors only. Teeth crown traits were observed as per modified ASUDAS method.[2] Variability was recorded as Grade 0–3 where 0 = absence, 1 = evident, 2 = prominent. Root traits were observed according to ASUDAS method.[2]

Results

The results of this observational tooth traits analysis are presented in Tables 2 and 3. Frequencies were obtained for each of the tooth trait on each tooth type. The most common feature was shoveling with maximum expression in 11 (69.12%) followed by 21 (62.94%) [Figure 1]. The better expression of shoveling was also noted in 12, 22, 13, and 23 at a frequency of 61.11%, 55.79%, 59.85%, and 59.19%, respectively. Mandibular incisors showed the least expression of <17% [Tables 2 and 3].

Table 1: Teeth traits observed in permanent incisors and canines

Names of nonmetric teeth traits	Description of nonmetric teeth traits
Shoveling	Development of the mesial and distal marginal ridges
Double shoveling	Relative development of the buccal marginal ridge
Lingual tubercle	Crest or tubercle which appears in the region of the cingulum on the lingual surface
Interruption groove	A groove across the cingulum to reach cementoenamel junction, often continues into the root
Labial convexity	Curvature of the labial surface , convex in the middle third of the labial surface of the crown surface viewed from the incisal view
Vestibular contour	Contour shape of the incisors in relation to the mesial and distal marginal ridges, the incisal and cervical margins
Radical number	Radicular developmental grooves with no root division in cross-sectional view
Root number	Number of roots
Hypotrophic root	Root length is ≤crown length

Double shoveling trait prevalence in canines (12.64%) was more than incisors (6.09%) and lingual tubercle trait prevalence in incisors (7.55%) was lesser than canines (10.18%). In incisors, interruption groove and radical number 1 trait expression were 7.71% and 96.1%, respectively [Table 2]. In canines, the most commonly expressed traits were palatal fossae (31.13%), lingual fossae (18.49%), and distal accessory ridge (10.56%) [Table 3].

Discussion

The morphology subfield of dental anthropology has the objective of recording, evaluating and interpreting metric and nonmetric morphological crown and root traits.[15] The initial description about the tooth morphological traits was done by A. Hrdlicka in 1920 after observing the characteristic shovel-shaped incisors. The teeth morphological features are known as dental crown and root traits, which constitute the enamel phenotypic forms expressed and regulated by the genome of an individual and a population during odontogenesis.[2] Tooth traits can be positive (tubercular and radicular) or negative structures (pit form and intertubercular) which have potential to be present or not in a specific location (frequency) in different ways (variability) in one or more

Table 2: Percentage of expressed teeth traits in permanent incisors

Tooth traits	Tooth in FDI notation, sample size in brackets and percentage of expressed tooth traits								Total percentage of expressed tooth traits in incisors
	12 (154)	11 (149)	21 (170)	22 (138)	42 (134)	41 (159)	31 (175)	32 (152)	
Shoveling	61.11	69.12	62.94	55.79	9.70	7.54	16	13.81	36.96
Double shoveling	13.63	4.69	6.47	7.97	1.49	3.77	3.42	3.28	6.09
Lingual tubercle	18.18	8.72	11.17	23.91	0	0	0	0	7.55
Interruption groove	22.72	8.05	7.64	23.91	1.49	0	0	0	7.71
Peg lateral	1.29	-	-	2.17	-	-	-	-	1.71
Curvature of the labial surface	1.94	6.71	5.29	2.89	0	0	0	0	2.11
Root number >1	0	0	0	0	0	0	0	0	0
Radical number 1	98.05	100	100	100	95.52	92.45	92.57	90.78	96.1
Radical number 2	1.94	0	0	0	4.47	7.54	7.42	9.21	3.89
Hypotrophic root	1.94	4.69	3.52	0	2.98	0.62	0.57	0.65	1.86

FDI: Federation Dentaire Internationale

Table 3: Percentage of expressed teeth traits in permanent canine

Toothtraits	Tooth FDI notation, sample size in brackets, and percentage of expressed tooth traits				Total percentage of expressed tooth traits
	13 (174)	23 (142)	33 (107)	43 (107)	
Shoveling	59.19	59.85	46.72	32.71	51.51
Double shovel	18.39	16.19	6.54	4.67	12.64
Labial convexity	6.89	0	0	0	2.64
Slot interrupt	12.06	15.49	0	0	8.11
Lingual tubercle	17.81	16.19	0	0	10.18
Canine mesial ridge	9.77	7.04	0.93	0.93	5.47
Distal accessory ridge	16.66	17.61	0.93	0.93	10.56
Palatal fossae	47.7	87.74	0	0	31.13
Lingual fossae	0	0	49.53	42.05	18.49
Radical number 1	83.90	76.76	85.04	85.98	82.64
Radical number 2	16.09	23.23	14.95	14.02	17.35
2 roots	0	0	0.93	0.93	0.37
Hypotrophic roots	0	0	0	0	0

FDI: Federation Dentaire Internationale

members of a population group. The existing studies showed that dental traits have a strong genetic component in their expression or gradation and occurrence or frequency.[2,3]

Dental morphology enables the taxonomical classification of different populations and species. The dentition helps to identify individuals whose death makes it difficult to distinguish by visual recognition, fingerprints, and documents.[2] The use of one or few dental traits is limited; all degrees of expression and complex analysis are recommended.[15]

Shoveling is seen mainly in the upper central incisors, although it can be expressed in the upper lateral, canines and less frequently in both lower incisors and canines. The central incisor alone is used as intergroup marker in population analysis, according to the statement of the theory of morphogenetic fields.[2] The worldwide variation of shoveling in the central incisors ranges from 100% in Mongoloid to 5% in Europe origin populations. Since the early hominids this trait is clearly expressed in Asia.[2] This trait in incisors has been regarded as a strong ethnic indicator for the Mongoloid populations and less in Caucasoid. K. Hanihara developed the Mongoloid dental complex from five dental morphological traits including shovel-shaped upper central incisors. T. Hanihara found a shoveling prevalence of 9.2% in Japanese, 33.3% in African Americans, and 27.7% in European Americans. Leon and Riaño 20 analyzed plaster dental casts of several current Colombian indigenous populations which showed a high frequency of shovel-shaped incisors.[3] High frequencies of shoveling in Amazonian indigenous groups were also observed 1.[3]

Archaeological dental traits study in Indian population showed 27.3% shoveling in upper central incisors.[4] The present study had 65.83% shoveling expression in upper central incisors. Uthaman *et al*. found in their recent study that statistically significant difference in shoveling trait in central incisors among the three ethnic groups of Coorg where plaster casts were analyzed.[10] Majority of the Tibetans showed shoveling trait while Malayalees (native people of Kerala) had trace shovel to no expression. Kodavas, the native of Coorg had semi-shovel trait followed by trace shovel and no shovel traits.[10] The immigrant population from Kerala was included in their study where the sample size was less (30). Environmental factors have an important role for shoveling

trait expression (field theory) could be suggested in difference in expression compared to the present study. Only few cases of shovel trait have been found in Punjabi population (combined frequency being 3.4%), a study done Malik *et al*., using incisors and canines from plaster models.[12] A study conducted by Kirthiga *et al*., in Bengaluru population found 68.2% shoveling trait on upper central incisors using retrieved plaster casts.[8] Another study by Kirthiga *et al*., in pediatric Bengaluru population showed double shoveling (66.6%) followed by shoveling (65.7%) on the direct clinical assessment.[9]

In an Indian population study which included North, South, East, and West Indians, shoveling was more pronounced in the West Indians than East and North Indians and was very minimal in the South Indians (9/100) which included all four states. They used a digital photograph of trait positive maxillary central Incisors.[11] In the Chinese population, shovel trait study showed 66.1% of total prevalence with majority with semi-shovel-shaped incisors (42.6%–48.6%).[16] The prevalence of lingual tubercle trait was 18.02% and canines were more commonly affected than incisors. They assessed all the maxillary permanent anterior teeth with side separately similar to our study, but they used using plaster casts.[16] Various theories have been put forward to explain the differences in shoveling expression among different races. Field theory suggests that the trait is induced and subjected to environmental stress such as vitamins, nutrients, intake of fluorides, and the size of jaws. The clonal model theory suggests that the trait is intrinsic and does not respond to environmental factors. Thus, it is a result of interaction between genetic and environmental factors.[10,17]

As the lingual tubercle is more frequently observed and better developed in fossil than in modern man, it is believed to be a derivative of cingulum and a feature of the evolution of the primate.[2] The present study showed 15.22% lingual tubercle in upper incisors in which lateral incisors showed maximum (23%) [Figure 2]. Even upper canines showed 17% prevalence of lingual tubercles and lower canines had none. Archaeological study in Indian population reported 36.4% of lingual tubercles in upper lateral incisors.[4] High prevalence of lingual tubercle on the permanent anterior teeth was reported in southern Chinese (38.9%).[16] Lingual tubercle occurred more on the canines and to a lesser on the maxillary incisors in southern Chinese; similar results have also been reported for Caucasians which is inverse to our results. A surprising incidence of both lingual tubercle [Figure 2] and interruption grooves [Figure 3] was significantly noted on the same teeth in our study; thus, the same prevalence rate was seen in the upper lateral incisors for both traits (23%).

Cunha *et al*. (2012) described a newly defined nonmetric trait in the human dentition, hypotrophic roots of the upper central incisors.[14] Their criterion was defined by a root: crown ratio of <1.5:1. This trait was observed in 20% samples from collective funerary sites in the Iberian Peninsula dated from the Late Neolithic to the Chalcolithic period. The previous study also showed a prevalence rate of 10% in Mongoloid and 2.4% in Caucasian ethnic groups.[14] As our study was an observational one, we considered hypotrophic root only if the

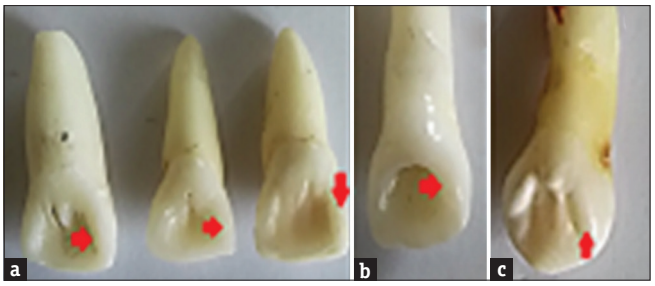

Figure 1: Clinical original image shows prominent shoveling in maxillary (a) central incisors, (b) lateral incisors, (c) canine (red arrows)

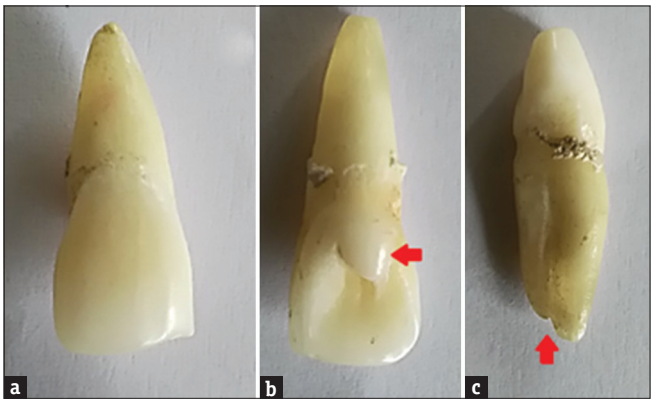

Figure 2: Clinical original image shows (a) Hypotrophic root in maxillary central incisors, (b) Lingual tubercle (red arrow), (c) Two-rooted mandibular canine (red arrow)

Figure 3: Clinical original image shows interruption grooves in maxillary (a) lateral incisors, (b) canine (red arrows)

root length was less/equal to the crown length to avoid visual bias [Figure 2]. This study showed 4% hypotrophic roots with upper central incisors.

"Bushman canine" or canine mesial ridge was described by Morris initially in a population of Bushmen in South Africa. Distal accessory ridge has been one of the most worldwide studied morphological crown dental traits of canines.[2] Our study showed 8% mesial canine ridge trait and 17% distal accessory ridge trait in upper canines and least in lower canines. Indian studies are very rare on canines, archaeological Indian canine studies showed 25% prevalence in distal

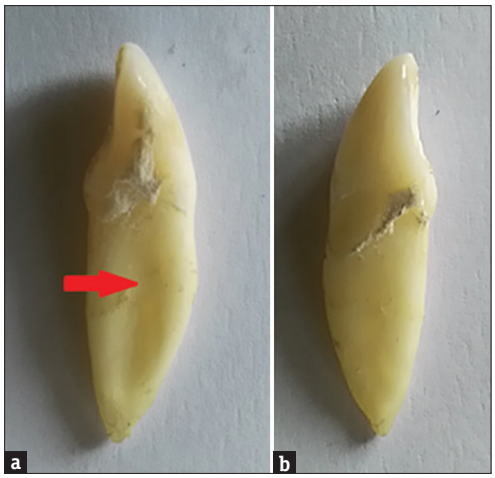

Figure 4: Clinical original image shows mandibular central incisors (a) with radicals (red arrows), (b) without radicals

accessory ridges.[4] Two mandibular canines showed accessory roots in the present study [Figure 2]. Radicals number trait was also noted in the present study which showed 96% of incisors and 82.64% canines had single radicals, i.e., two root developmental groove were least expressed in permanent anterior teeth [Figure 4].

The accurate observation and grading of nonmetric tooth traits on plaster casts can only be done from dental impressions in polymeric materials with high dimensional stability with the aid of a stereomicroscope and a fine tip dental explorer, thus the study becomes expensive.[2] Most of the plaster casts studies were done on retrieved samples from different dental department which have limitations. The study of dental morphological characteristics in skeletonized remains has the great advantage to include the study of root morphology in the research protocol, even in the absence of dental structures. However, 100 human skeletons do not provide a sample of 100 morphological features to be observed.[6] The accuracy and reliability of extracted intact teeth for assessing nonmetric dental traits to explore the forensic racial ethnicity of a population is satisfactory and promising. A recent nonmetric traits study supported the same which was conducted using extracted posterior teeth.[18]

According to the results obtained from this study, it can be said that Kerala population who formed the sample for this study have high frequencies of shoveling in maxillary central incisors which can be valuable in the determination of the ethnic origin of an individual.

Conclusion

This nonmetric tooth traits analysis showed shoveling to be the most frequent tooth trait observed in Kerala population. This research found new elements of invaluable ethnographic value from the analysis of dental morphology that eventually will allow us to understand racial ethnicity of this population. Further tooth traits analysis is recommended using extracted permanent teeth for discerning complete racial ethnicity in this population.

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Conflicts of interest

There are no conflicts of interest.

References

1. Scott GC, Turner CG 2nd. The Anthropology of Modern Human Teeth: Dental Morphology and its Variation in Recent Human Populations. London: Cambridge University Press; 1997.
2. Moreno-Gómez F. Sexual dimorphism in human teeth from dental morphology and dimensions: A dental anthropology viewpoint. In: Moriyama H, editor. Sexual Dimorphism. Croatia: Intech Open Science Open Minds; 2013. p. 97-124.
3. Díaz E, García L, Hernández M, Palacio L, Ruiz D, Velandia N, *et al.* Frequency and variability of dental morphology in deciduous and permanent dentition of a Nasa Indigenous Group in the Municipality of Morales, Cauca, Colombia. Colomb Med (Cali) 2014;45:15-24.
4. Irish JD, Nelson GC. Technique and Application in Dental Anthropology. London: Cambridge University Press; 2008. p. 302.
5. Turner CG 2nd, Nichol CR, Scott GR. Scoring procedures for key morphological traits of the permanent dentition: The Arizona State University dental anthropology system. In: Nelly MA, Larsen CS, editors. Advances in Dental Anthropology. New York: Wiley-Liss Inc.; 1991. p. 13-31.
6. Abrantes C, Santos R, Pestana D, Pereira CP. Application of Dental Morphological Characteristics for Medical-Legal Identification: Sexual Diagnosis in a Portuguese Population. J Forensic Leg Investig Sci 2015;1:001.
7. Khudaverdyan AY. Non-metric dental traits in human skeletal remains from Transcaucasian populations: Phylogenetic and diachronic evidence. Anthropol Rev 2014;77:151-74.
8. Kirthiga M, Manju M, Praveen R, Umesh W. Ethnic association of cusp of carabelli trait and shoveling trait in an Indian population. J Clin Diagn Res 2016;10:ZC78-81.
9. Kirthiga M, Manju M, Praveen R, Umesh W. Prevalence of aberrant dental morphological details in 6-10 year old school children in an Indian population. Contemp Clin Dent 2015;6:S175-80.
10. Uthaman C, Sequeira PS, Jain J. Ethnic variation of selected dental traits in Coorg. J Forensic Dent Sci 2015;7:180-3.
11. Nagaraj T, Sherashiya PA, Hemavathy S, Yogesh TL, Goswami RD, Sreelakshmi N. Regional variation in incisor shoveling in Indian population. J Adv Clin Res Insights 2015;2:193-6.
12. Malik P, Singh G, Gorea R, Jasuja OP. Prevalence of developmental dental anomalies: A study of Punjabi population. Anil Aggrawals Internet J Forensic Med Toxicol 2012;13:21.
13. Yeli MM, Acharya AB. Is the frequency of non-metric dental Traits distinct in Indians? A preliminary analysis based on tooth Root number. J Forensic Odontostomatol 2013;31:34.
14. Cunha C, Silva AM, Irish J, Richard Scott G, Tomé T, Marquez J. Hypotrophic roots of the upper central incisors – A

proposed new discrete dental trait. Dent Anthropol 2012;25:8-14.
15. Marado LM, Campanacho V. Carabelli's trait: Definition and review of a commonly used dental nonmetric variable. Cadernos GEEvH 2013;2:24-39.
16. King NM, Tsai JS, Wong HM. Morphological and numerical characteristics of the Southern Chinese dentitions. Part II: Traits in the permanent dentition. Open Anthropol J 2010;3:71-84.
17. Sadatullah S, Odusanya SA, Mustafa A, Abdul Razak P, Abdul Wahab M, Meer Z. The prevalence of fifth cusp (Cusp of Carabelli) in the upper molars in Saudi Arabian school students. Int J Morphol 2012;30:757-60.
18. Baby TK, Sunil S, Babu SS. Nonmetric traits of permanent posterior teeth in Kerala population: A forensic overview. J Oral Maxillofac Pathol 2017;21:301-8.