

Nonmetric traits of permanent posterior teeth in Kerala population: A forensic overview

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Abstract

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

Aims and Objectives: To determine the frequency and variability of possible nonmetric tooth traits using extracted permanent posterior teeth from Kerala population for discerning racial ethnicity.

Materials and Methods: This qualitative, cross-sectional study was carried out using 1743 extracted intact permanent posterior teeth collected from different dental clinics situated all over Kerala.

Results: The more common features on premolars were multiple lingual cusps (31.21%), distal accessory ridges (16.28%) and Tom's root (17.9%). In upper first molars, Carabelli trait expression was 17.78% and other common features included metaconulo, cusp 5 and enamel extensions.

Conclusion: Posterior tooth traits had variable expression in the study population. Low prevalence rate of Carabelli trait in this study is characteristic of Asian population. This research explored new elements of invaluable tooth traits values to understand racial ethnicity of Kerala population.

Keywords: Cusp of Carabelli, dental anthropology, forensic racial ethnicity, nonmetric tooth traits, protostylid, Tom's root

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INTRODUCTION

The morphology subfield of dental anthropology deals with the evaluating, recording and interpreting metric and nonmetric morphological crown and root traits.^[1] The dental nonmetric traits are used primarily to determine a person's identity, gender and origin. The significance of a dental morphological trait depends on its frequency of occurrence and distinctiveness in a given population.^[2] The nonmetric tooth traits also have crucial role in the

forensic racial identification. Dental morphology is a highly heritable characteristic which is stable with time and has a fairly high state of preservation compared to the bone material.^[3] Another advantage is that teeth do not undergo morphological changes such as bones. However, dental traits can disappear due to dental wear and certain oral pathologies such as caries.^[1] The observation of dental traits is done through different methods reported in the literature, excelling Arizona State University Dental Anthropology System (ASUDAS) method is a successfully as well as

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commonly used standard for scoring dental variation on contemporary human teeth.^[4] Out of 135 dental traits that have been recognized in the human dentition, only few traits are used in most worldwide research.^[4]

Many bioarcheological studies have demonstrated the differences in the expression and frequency of dental traits between various ethnic groups in ancestry determination in the context of forensic dental anthropology.^[5] Indian population investigations have provided information on local-scale nonmetric dental variation by Lukacs and Walimbe in 1984 and Lukacs and Hemphill in 1991.^[4,5] Few studies have been undertaken regarding ethnic and gender difference of tooth morphology in living population like metric dental traits and nonmetric traits such as groove pattern, Carabelli trait, shoveling and protostylid. These studies were done on plaster models, direct clinical assessment, radiographs or digital photographs.^[6-12]

This study focused on recording and analyzing the frequency and variability of possible nonmetric tooth crown and root traits using extracted permanent posterior teeth in Kerala population for discerning racial ethnicity. This finds to be the very first tooth trait study done on extracted posterior teeth after extensive literature search. This study is also the very first one on premolar crown and root traits.

MATERIALS AND METHODS

This qualitative, cross-sectional study for the frequency and variability of nonmetric tooth traits was done using 1743 extracted permanent posterior teeth with unknown history. The sample size included 1259 premolars and 484 molars of both the jaws, collected from different dental clinics situated all over Kerala. Extracted teeth having intact morphology only were included in this study. Teeth with caries, restoration, root canal treatment, crown placement, root/crown fracture, attrition, erosion, abrasion, etc., were excluded from the present study.

All the teeth were identified by Federation Dentaire Internationale system except upper third molars and lower third molars and visual observation made macroscopically in a room with natural light using the dental explorer. All the teeth were checked by two same observers together to avoid inter observer bias and was performed over approximately 3 months. To avoid potential eye strain of the viewer that would compromise the following observations, short breaks (5 min) were taken between each assessment during the data collection. Eighteen different nonmetric tooth traits were observed for all permanent premolars and

molars [Tables 1 and 2, Figures 1-4].^[3,13,14] All teeth crown traits were observed as per modified ASUDAS method.^[13] Variability was recorded as Grade 0–3 where 0 = absence, 1 = evident and 3 = prominent. Root traits were recorded according to ASUDAS method.^[13]

RESULTS

The results of this observational tooth traits analysis are presented in Tables 3-6. Frequencies were obtained for each of the tooth trait on each tooth type. Most of the expressed traits were having Grade = 2. The more common feature was distal accessory ridges (16.28%) on all types of premolars with less expression of mesial accessory ridges (6.27%) [Figure 1]. Lingual cusps were more than one in 31.21% of premolars, exclusively seen on lower ones with a frequency of 11.73% and 52.92% in first and

Table 1: Teeth traits observed in permanent premolars

Names of nonmetric teeth traits	Description of nonmetric teeth traits
Mesial accessory ridge	Small ridge located toward mesial of accessory sagittal grooves
Distal accessory ridge	Homologous mesial accessory crest, but is located toward distal of the buccal cusp of the maxillary premolars
Tuber apex	Blunt cusp mesial region between the buccal and palatal cusps of the premolars
Terra	Cusp or tubercle apex blunt cusp between the distal buccal and palatal cusps of the premolars
Tricuspid upper premolars	Developed distolingual cusp is smaller and closer to the palatal cusp
Hypostyle	Small cusp with vertex set which usually appears between the buccal cusp and distolingual cusp
Paracone	Mesiobuccal cusp
Vestibular sulcus	Odontoglyphic feature that is the distal groove projecting from the distal pit to buccal
Central ridge	Ridge of enamel bridge that connects the buccal cusp with mesiolingual cusp
Distolingual groove	Odontoglyphic trait that corresponds to groove originate from the distal marginal ridge and crosses the same side of the distal-lingual direction
Lingual cusp number >1	Number of cusps that can occur in the region lingual
Groove pattern	Configuration of the grooves and the contact pattern of the cusps of the occlusal surface of the lower premolars
Double shovel	Relative development the mesial and distal marginal ridges on the labial surface of upper first premolars
Odontome	Conical projection/circular light brown dentin exposure centrally located in the sagittal groove of premolars, U/L, often dentin component seen
Uto-Aztec upper premolar	Buccal cusp may bulge out to the buccal with a marked fossa in its distal shoulder
Root number	Number of roots
Tome's root	Deep groove on mesial root surface of lower first premolars
Radicals	Radicular developmental grooves with no root division in cross-sectional view

second premolars, respectively [Table 3 and Figure 1]. Tom's root frequency was 17.9% in lower first premolars, a root trait specific for it [Table 4 and Figure 2]. In upper

first molars, Carabelli trait expression was 17.78%, total frequency of occurrence in all upper molars was 11.26%. Other features more expressed were metaconulo, cusp 5 and enamel extensions [Figure 3]. Dryopithecus groove expression on lower first molars was 100% Y pattern and 96.39% of lower second molars showed + pattern and rest expressed X pattern [Table 5].

Table 2: Teeth traits observed in permanent molars

Names of nonmetric teeth traits	Description of nonmetric teeth traits
Carabelli trait	Pit or cusp in the mesiolingual cusp of the upper molars
Parastyle	Cusp on buccal surface of upper molars
Metaconulo	Small cusp between distobuccal cusp and distopalatal maxillary molars
Hypoconid reduction	Downsizing distolingual cusp of the upper molars
Metacone	Reduced/absent distobuccal cusp in upper molars
Hypocone	Lack of distolingual cusp in upper molars
Dryopithecus groove pattern	Contact configuration of the cusps of the lower molars-X/+ /Y
Elbow crease	Mesiolingual cusp is directed toward the central fossa in lower molars
Protostylid	Buccal cusp on the buccal developmental groove of the mandibular molars
Cusp 5/hypoconulid	Small cusp at distal fovea between distolingual and distobuccal cusps lower molars
Cusp 6/tuberculum sextum	Cusp between the distobuccal cusp and distolingual surfaces of lower molars
Cusp 7/tuberculum intermedium	Cusp between the mesiolingual cusp and distolingual surfaces of lower molars
Taurodontism	Tall root trunk encloses a high pulp chamber and short roots
Deflecting wrinkle	Variation of medial ridge on mesiolingual cusp of lower first molars
Distal trigonid crest	A ridge/loph that bridges mesiobuccal and distobuccal cusps of lower molars
Enamel extensions	Projection of enamel border in apical direction
Root number	Number of roots
Radical	Number of radicular developmental grooves with no root division in cross-sectional view

DISCUSSION

The initial description on nonmetric tooth traits was done by A. Hrdlicka in 1920 after observing the characteristic shovel-shaped incisors. Dental crown and root traits are morphological features which constitute the enamel

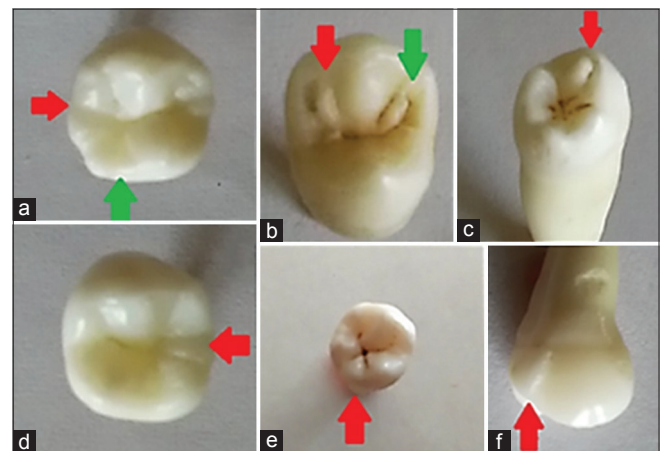


Figure 1: Original photograph of premolars show, (a) terra (red arrow), multiple lingual cusps (green arrow), (b) mesial accessory ridge (green arrow), distal accessory ridge (red arrow), (c) odontome in mandibular first premolars (red arrow), (d) tuber apex, (e) mandibular second premolar with three lingual cusps and "X" occlusal groove pattern, (f) double shovel in maxillary first premolars

Table 3: Prevalence of expressed crown traits in permanent premolars

Crown traits	Tooth in FDI notation, sample size in brackets and number of expressed crown traits (total sample - 1259)								Total of number expressed crown traits	Total percentage of expressed crown traits	
	14 (285)	15 (54)	24 (223)	25 (82)	34 (134)	35 (161)	44 (190)	45 (130)			
Mesial accessory ridge	20	1	11	12	20	7	11	9	79	6.27	
Distal accessory ridge	29	11	38	12	25	25	20	35	205	16.28	
Tuber apex	19	2	18	1	2	8	2	9	61	4.84	
Terra	8	5	13	5	11	15	9	12	78	6.19	
Tricuspid upper premolars	3	1	1	0	-	-	-	-	5	0.77	
Hypostyle	0	0	0	0	0	3	0	2	5	0.39	
Paracone	1	1	0	0	1	1	0	1	5	0.39	
Vestibular sulcus	2	0	1	1	2	2	0	1	9	0.71	
Central ridge	1	1	0	0	1	12	0	17	32	2.54	
Distolingual groove	0	0	0	0	8	4	7	2	21	1.66	
Lingual cusp number >1	0	0	0	0	2-16	2-58	2-15	2-81	192 (2-170, 3-22)	31.21	
Double shovel	41	-	23	-	3-2	3-5	3-5	3-10	64	12.59	
Odontome	4	0	1	0	4	7	3	3	22	1.74	
Uto-Aztec upper premolar	0	0	0	0	-	-	-	-	0	0	
Groove pattern on lower premolars	-	-	-	-	W - 117 Y - 16 C - 1	C - 98 Y - 58 X - 5	W - 167 Y - 19 C - 1	Y - 81 C - 39 X - 10	4 s 5 s	W - 284 Y - 35 C - 137 Y - 139	W - 87.65 Y - 10.8 C - 47.07 Y - 47.76

FDI: Federation Dentaire Internationale

Table 4: Prevalence of expressed root traits in permanent premolar

Root traits	Tooth in FDI notation, sample size in brackets and number of expressed root traits (total sample - 1259)							
	14 (285)	15 (54)	24 (223)	25 (82)	34 (134)	35 (161)	44 (190)	45 (130)
Tom's root	-	-	-	-	20	-	38	-
Supernumerary root	2	6	2	7	9	4	8	5
Number of roots:number of radicals								
1:1	26	10	18	35	34	91	45	83
1:2	126	37	112	40	50	57	82	29
1:3	3	1	0	0	36	6	46	7
1:4	0	0	0	0	4	3	8	6
1:5	0	0	0	0	1	0	1	0
2:2	123	6	84	7	8	4	7	4
2:3	5	0	7	0	1	0	1	1
3:3	2	0	2	0	0	0	0	0

FDI: Federation Dentaire Internationale

Table 5: Prevalence of expressed crown traits in permanent molars

Crown traits	Molar teeth FDI notation, sample size in brackets and number of expressed traits (total sample - 484)										Total number of expressed traits	Total percentage of expressed traits
	16 (72)	17 (12)	26 (63)	27 (17)	UM3 (67)	36 (24)	37 (40)	46 (28)	47 (71)	LM3 (93)		
Carabelli trait	13	0	11	0	2	-	-	-	-	-	26	11.26
Parastyle	0	0	0	0	2	-	-	-	-	-	2	0.87
Metaconulo	1	2	0	1	13	-	-	-	-	-	17	7.35
Hypocone	0	0	4	2	12	0	0	0	0	4	18	3.72
Hypoconid reduction	0	1	0	1	11	-	-	-	-	-	13	5.63
Metacone	0	0	0	0	0	-	-	-	-	-	0	0
Dryopithecus groove pattern	-	-	-	-	-	Y - 24	+38X - 2	Y - 28	+69X - 2	Y - 23 X - 4+66	+173Y - 79 X - 8	+68.38Y - 31.22 X - 3.16
Elbow crease	-	-	-	-	-	0	0	0	0	0	0	0
Protostylid	-	-	-	-	-	1	0	0	0	1	2	0.79
Cusp 5	-	-	-	-	-	0	0	0	0	20	20	7.91
Cusp 6	-	-	-	-	-	1	0	0	0	2	3	1.19
Cusp 7	-	-	-	-	-	0	0	0	0	0	0	0
Taurodontism	0	0	0	0	0	0	0	0	0	0	0	0
Deflecting wrinkle	-	-	-	-	-	1	-	1	-	-	2	3.84
Distal trigonid crest	-	-	-	-	-	0	0	0	0	0	0	0
Enamel extensions	7	2	4	3	9	1	5	3	6	1	41	8.47

FDI: Federation Dentaire Internationale, LM3: Lower third molars, UM3: Upper third molars

Table 6: Prevalence of expressed root traits in permanent molar

Root traits	Permanent molar teeth in FDI notation and sample size (total sample - 484)										
	16 (72)	17 (12)	26 (63)	27 (17)	UM3 (67)	36 (24)	37 (40)	46 (28)	47 (71)	LM3 (93)	
Supernumerary root	0	0	2	0	5	1	0	3	2	6	
Number of roots:number of radicals											
1:1	0	0	0	0	3	0	0	0	0	8	
1:2	0	0	0	0	4	0	0	0	4	13	
1:3	0	0	0	1	18	0	0	0	0	2	
1:4	0	0	0	0	3	0	0	0	1	2	
2:2	0	0	0	0	2	15	20	14	33	52	
2:3	0	0	0	0	7	5	0	9	5	4	
2:4	0	0	0	0	2	3	20	1	26	6	
3:3		41	9	43	10	20	1	0	3	2	
3:4		31	3	20	5	2	0	0	0	0	
3:5		0	0	0	0	0	0	0	0	0	
4:4		0	0	0	0	5	0	0	0	1	

FDI: Federation Dentaire Internationale, UM3: Upper third molars, LM3: Lower third molars

phenotypic forms expressed and regulated by the genome of an individual and a population during odontogenesis.^[3] It can be positive structures (tubercular and radicular) and negative (pit form and intertubercular) which present or not in a specific location (frequency) in different

ways (variability) in one or more members of a population group. Studies showed that dental traits have a strong genetic component in their expression or gradation and occurrence or frequency.^[3,6] The dentition helps in identification of individuals whose death makes it difficult to distinguish

by visual recognition, fingerprints and documents.^[3] One or few dental traits analysis have limited use; all degrees of expression and complex analysis are advised.^[1]

Various theories explain the differences in trait expression among different races. Field theory suggests that the trait is induced, affected by environmental stresses such as vitamins, nutrients, intake of fluorides and the size of the jaws. While clonal model theory suggests that the trait is intrinsic, it does not respond to environmental factors. Thus, traits are the result of interaction between genetic and environmental factors.^[15]

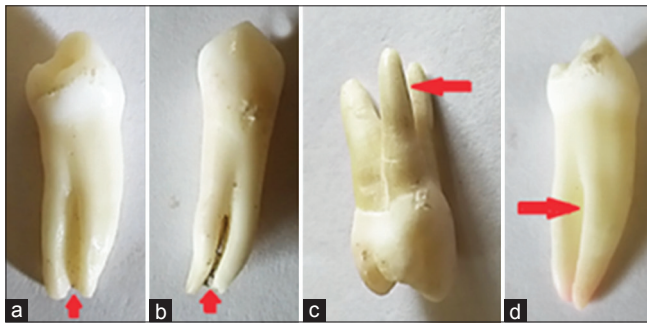


Figure 2: (a and b) Supernumerary roots with mandibular premolars, (c) supernumerary root with maxillary first premolar, (d) Tome's root (red arrows)

In the case of the premolars, only a very few archeological studies were conducted. Butler P. in 1939 suggested that the size and morphology of premolars are controlled by the canines (“caninization” of the first premolars) and molars (“molarization” of the second premolars) during odontogenesis, but A. A. Dahlberg in 1945 suggested that the premolars have a morphogenetic field independent and exclusive to them.^[3] The frequencies reported by G. Giron *et al.* showed the trend of the first premolar to have moderate expression of distal accessory ridge, a low frequency of mesial accessory crest, two cusps with constant presence, absence of buccal grooves and lower frequencies of interstitial tubercle while the second premolars show high expression of the mesial and distal accessory ridges, and the interstitial tubercles. In lower premolars, the first is characterized by only one lingual cusp present, have a high central peak expression, mesiolingual groove and a U-groove pattern while second had the absence of central ridge and high frequency of a single lingual cusp and groove U pattern.^[3] Our premolar study had more frequency for distal accessory ridge and multiple lingual cusps [Table 3 and Figure 1].

The Carabelli trait was first observed in 1827 by Rousseau; however, it is known as Carabelli's trait or cusp, due to the

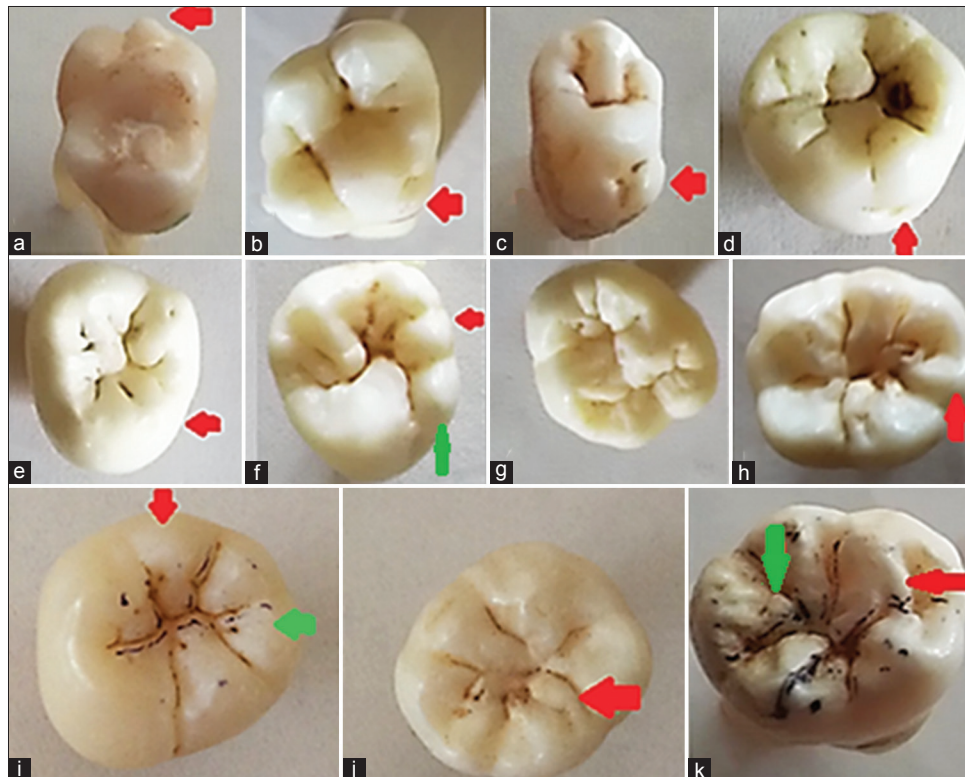


Figure 3: Original photograph of molars show, (a) parastyle, (b and c) carabelli trait in maxillary first and third molar, (d) protostylid, (e) hypocone, (f) metaconulo (red arrow), hypoconid reduction (green arrow), (g) supernumerary cusps in maxillary third molars, (h) tuberculum sextum (red arrow), (i) tuberculum intermedium (red arrow), hypoconulid (green arrow) in mandibular third molar, (j) distal trigonid crest (red arrow), (k) elbow crease (red arrow), hypoconulid (green arrow)

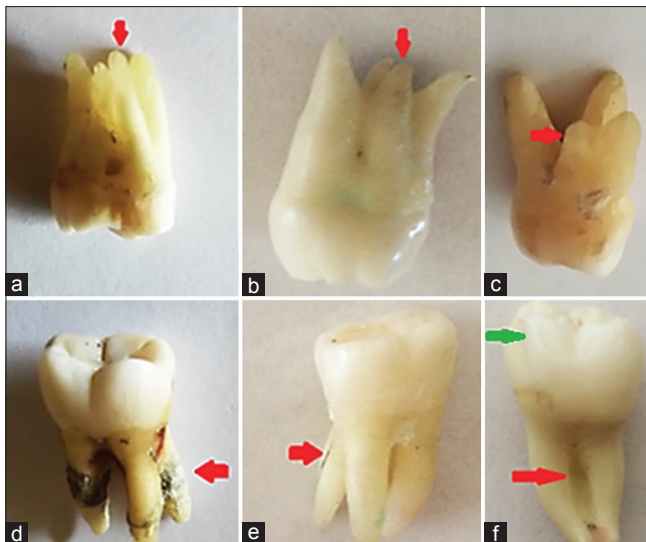


Figure 4: (a-c) Supernumerary roots in maxillary molars, (d and e) supernumerary roots in mandibular molars, (f) protostylid (green arrow), radical (red arrow)

observations of Georg Carabelli, the dentist of Austrian Emperor Franz in 1842.^[1] The function of Carabelli's trait is still uncertain. The authors hypothesize that (1) the trait evolved recently to make up for dental size reduction, a secular trend, (2) it is primitive and molar reduction is indeed causing its disappearance and (3) Carabelli's trait can supply the first upper molar with greater resistance to biomechanical stress. Low Carabelli trait frequency and high presence of shoveling was found to be characteristic of Asian populations, distinguishing them from European ones.^[1]

A Saudi Arabian Carabelli trait prevalence study showed 41.7% of the population and more predilections to permanent maxillary first molar. Other studies from same country had a prevalence of 57.6% in Riyadh and 58.7% in Jeddah for Carabelli trait.^[15] However, our study has much less expression for Carabelli trait in permanent maxillary first molars (17.78%) which is characteristic of Asian population [Table 5 and Figure 3].

A South Indian study found 89.8% of primary second molars, 63.7% of permanent first molars, and 8% of permanent second molars with the expression of Carabelli trait in the target population.^[16] Another South Indian (Chennai) study had a prevalence of 52.77% for cusp of Carabelli.^[16] A study by Kirthiga *et al.* in pediatric Bangalore population showed 39.7% of subjects had Carabelli trait on first upper molars using direct clinical assessment. They also found 17.8% occurrence of 5 cusps in upper first molar, 6 cusps and 7 cusps first lower molar with a frequency of 6.1% and 0.2%, respectively.^[8]

Uthaman *et al.* found in their study (2015) that there was no statistically significant difference with respect to Carabelli trait among the three ethnic groups of Coorg, Tibetans, Malayalees (native people of Kerala) and Kodavas (native of Coorg) where plaster casts were analyzed.^[9] They suggested that it could be due to the similar genetic composition for the phenotypic expression of Carabelli trait among the three ethnic groups. Literature also supports the Carabelli trait as a Caucasoid trait. Frequency of expression was 49% in Malayalees (sample size = 30) which is much higher than our result.^[9] A latest study (2016) of Carabelli trait in Bangalore population found 40.5% prevalence rate on permanent maxillary first molars.^[17] This varied expression of Carabelli trait could be due to environmental factors and also could be due to difference in sample type, size or observer bias.

Bolk adopted the term "paramolar cusps" for supernumerary cusps occurring on the buccal surfaces of molars.^[18] He thought that the paramolar cusps were derived from supernumerary teeth fused with the permanent molars during their development. In 1945, Dahlberg proposed the term "protostylid or parastyle" and he did point out that the presence of a protostylid should not be considered to be an example of atavism.^[18] However, at present, the method to observe it in permanent molars is by ASUDAS where protostylid and parastyle are considered as two entities.^[13,18]

Suzuki and Sakai reported that 18.5% of their 108 Japanese subjects had protostylid and 65% had the Carabelli's cusp on their permanent maxillary molars. In the primary dentition, the protostylid trait expression was more than 40% in Mongoloid children, while in non-Mongoloid populations, it was <20%. Thus, the protostylid trait has been regarded as a characteristic feature of the Mongoloid dentition. By contrast, Dahlberg suggested that in mandibular first permanent molars, this trait had a tendency to occur more commonly in Caucasians than Mongoloids and was rarely seen in Negroids.^[18]

A. Zoubov defines americanoide protostylid as a feature due to the low frequency of expression in the populations of Europe, Africa and Asia, the peculiarity of the high prevalence of American populations. However, K. Hanihara suggested that the expression of protostylid cusp is rarely present in different populations, occurring rarely in modern human groups except Asians, allow differentiating the dental complex of Caucasoid from Mongoloid or Negroid.^[3] Our study had two protostylid and two parastyle trait expressions [Figures 3 and 4].

Chinese study on pediatric study models revealed prevalence of Carabelli's trait and protostylid in permanent

were 50.5% and 37.5%, respectively, which is much higher than any other population studied. While primary dentition showed 93.7% expression for Carabelli trait.^[18]

Lukacs found in his North Indian anthropological study that upper first molars have full-sized hypocones than second and third molars and accessory cusps were infrequent and small. Lower molar accessory cusps were infrequent, though cusp 6 attains moderate grades in third molars.^[19] However, our study group had more expression of accessory cusps in third molars.

In a Colombian study (2014) from 60 dental casts for 14 tooth traits, the result showed a great affinity with ethnic groups belonging to the Mongoloid Dental Complex due to the frequency (expression) and variability (gradation) of the tooth crown traits. The most frequent dental crown features were of Carabelli's cusp (38.5%), the metaconules (30%), Y6 cusp pattern, protostylid (5.4%) and cusp 6 (35.6%).^[6]

The groove pattern of the first lower permanent molars describes the configuration of contact of the cusps and their number. The classic "Y" pattern or "Driopitecino" originated from past Asian populations, along with "X" configurations and the "+" or "cruciform" which are all considered as reductions that are frequently observed in Caucasian populations.^[6] In a study of African descents, J. Rocha *et al.* found a reduction in Driopitecino pattern characteristic of non-Mongoloid populations. Cusp 6 is supposed to be characteristic of Asian populations, while cusp 7 of Negro populations.^[6]

The accurate observation and grading of nonmetric tooth traits on plaster casts can only be done using polymeric impression materials having high dimensional stability, with the aid of a stereomicroscope, thus the study becomes costly.^[3] Most of plaster casts studies were done on retrieved samples which have limitations. The main disadvantages of plaster models are artifacts which confuses the presence of real traits and impossible root trait analysis.^[7]

Although root number trait analysis was done using periapical radiographs, it is restricted because of overlapping of buccal roots and radical number or other root traits are impossible with radiological images.^[12] Crown traits are not at all feasible with radiographs. Direct clinical observation is also limited as the reflection of light is exacerbated by the presence of saliva and limited observation perspectives.^[5] The accuracy and reliability of intact extracted teeth for assessing nonmetric dental traits to explore the forensic racial ethnicity of a population is excellent and promising.

The present study suggested that Kerala population who formed the sample for this study has low frequencies of cusp of Carabelli trait compared to other Indian studies. Distal accessory ridge in premolars showed better expression than mesial accessory ridges. Tom's root trait on lower first premolars showed increased expression in this study population. These traits expression pattern in the given population can be valuable in the determination of ethnic origin of an individual.

CONCLUSIONS

This nonmetric tooth traits analysis showed distal accessory ridge, multiple lingual cusps and Tom's root in premolars and Carabelli trait, metaconulo, cusp 5 and enamel extensions in molars to be the most frequent tooth posterior trait observed in this Kerala population. Low prevalence rate of Carabelli trait is characteristic of Asian population. Dental trait expression is varied between populations and also among the population. This research found new elements of invaluable ethnographic value from the analysis of dental morphology to understand racial ethnicity of this population. Further extensive tooth traits analysis is recommended on extracted teeth for discerning complete racial ethnicity in this population.

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Conflicts of interest

There are no conflicts of interest.

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