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Expression of Carabelli trait in children from Southern India – A cross sectional study

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Abstract

Background: The distribution of the Carabelli trait is highly variable in different regions and races of the world. **Objective:** To determine the prevalence of Carabelli trait in a group of children from Nellore. **Materials and Methods:** Children who attended the department between October 2011 to March 2012 were selected and examined for the expression of Carabelli trait in the maxillary primary second molar, permanent first and permanent second molars on the basis of the classification developed by Kraus and standards developed by Dahlberg. **Statistical Methods:** Descriptive statistics was performed and the relative frequency of expression in each category, according to Kraus's and Dahlberg's classification was calculated. Sexual dimorphism was statistically analyzed using Mann-Whitney U-test. **Results:** A total of 89.8% of primary second molars, 63.7% of permanent first molars, and 8% of permanent second molars showed some form of expression of Carabelli trait in the target population. **Conclusion:** Though there was a high frequency of intermediate expressions of this trait, occurrence of a definite cusp of Carabelli on the primary maxillary second molar and permanent maxillary first molar was relatively infrequent. A high percentage of the permanent maxillary second molars showed complete absence of Carabelli trait and there was no sexual dimorphism. Bilateralism with varying degrees of asymmetry was noted and there was tendency for concordance between the two sides but not within individual sides.

Key words: Carabelli trait, Dahlberg's classification, Kraus classification

Introduction

Human dentition is constantly changing in its form, size, and number. Morphological simplification is a general trend in the evolution of Hominoid dentition. Tooth size reductions, increased frequency of agenesis, and morphological generalizations are a part of it. Carabelli trait of maxillary molars is one such structure that is frequently considered in anthropological studies.[1-8]

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Analyzing this trait is a good diagnostic tool, as some argue that Carabelli's trait is increasing in size and frequency to compensate for the overall loss of tooth material,[9,10] while others opine that this trait is in the process of reduction and simplification.[11,12] This debate and the wide morphological variations make it an important study subject and this trait has got its role in anthropological studies and those related to Forensic dentistry.

To determine the distribution of this trait, various investigations have been carried out. As the investigators did not use the same criteria, it is not possible to compare all the studies, but, we attempted a generalized correlation of the existing literature[13-41] [Table 1].

Most of these studies were confined to maxillary permanent molars[16-22,24-34,36-38,40,41] and very few studies have considered primary molars.[23,35,39] In India, the research in this area is very limited[20,35] and confined to few geographic areas;

Table 1: Percentage distribution of Carabelli trait in different studies

Year	Investigator	Study population	Race	Percentage distribution of tooth investigated		
				PM2	M1	M2
1896	Batujeff W[13]	Russian	Mongoloids		50	
1905	De Terra M[13]	Europeans	Caucasians		18	
1915	Bolk L[13]	Europeans	Caucasians		61.6	
1931	Shaw JCM[13]	Bantu Race of South Africa	Negroids		3.5 (skulls) 6 (living)	
1938	Hirakawa W[13]	Japanese	Mongoloids		10.7	
1944	Dietz VH[13]	American Army men	Caucasians		72.3	
1949	Pederson PO[13]	East Greenland Eskimos	Mongoloids		0	0
1949	Oshima S[13]	Modern Chinese	Mongoloids		2.1	
1952	Diamond M(13)	Mixed Europeans	Caucasians		50	
1954	Meredith HV and Hixon EH[14]	American children of Northwestern Europe	Caucasians		84	
1957	Kallay J[13]	Yugoslavian children	Caucasians		52.13	
1957	Moorrees CF[13]	Aleut	Mongoloids		13.3	
1958	Tsuji[15]	Japanese	Mongoloids		31.9	
1960	Carbonell VM[13]	Kish (on 3000BC skulls; only right molars)	Caucasians		23.7	2.4
1963	Dahlberg AA[13]	American Whites	Caucasians		85.7	
1963	Dahlberg AA[13]	Pima Indians	Mongoloids		83.5	
1966	Goaz PW[2]	Peruvian Indians	Mongoloids		67	11.4
1967	Rosenzweig[16]	Jews from Yemen	Caucasians		93	
1967	Rosenzweig[16]	Jews from Cochin	Caucasians		62	
1967	Turner CG[15]	Koniag Eskimos	Mongoloids		34.1	
1968	Keene HJ[17]	American whites	Caucasians		60	
1970	Jien SS[18]	Taiwanese	Mongoloids		35.5	
1971	Goose GH and Lee GTR[19]	Chinese in Liverpool	Mongoloids		29	
1971	Goose GH and Lee GTR[19]	British	Caucasians		78.8	
1972	Joshi MR[20]	Western India (Gujarat)	Caucasians		64.6	
1974	Kirveskari P[3]	Skolt Lapps	Caucasians		77.5	
1975	Alvesalo L[21]	Finnish rural population	Caucasians		79	
1976	Berry AC[4]	Southeastern British	Caucasians		42.3	
1976	Berry AC[4]	Northwestern British	Caucasians		56.7	
1976	Berry AC[4]	Orkney Islanders	Caucasians		45.9	
1976	Berry AC[4]	Shetland Islanders	Caucasians		47.7	
1976	Berry AC[4]	Bonn Germans	Caucasians		60.6	
1976	Berry AC[4]	Heidelberg Germans	Caucasians		57.4	
1977	Escobar V[5]	Queckchi Indians	Negroids		54.4	
1977	Liu KL[22]	Taiwan aborigines (Ami)	Negroids		57	
1977	Liu KL[22]	Taiwan aborigines (Atayal)	Negroids		72.9	
1981	Townsend GC[23]	Australian aborginal	Negroids	80	70	
1981	Kieser JA, Preston CB[9]	Lengua Indians in Paraguay	Mongoloids		70.1	
1981	Kaul V, Prakash S[9]	Jats Indians	Caucasians		61.6	
1982	Saunders SR and Mayhall JT[6]	Canadian whites	Caucasians		83.9	
1982	Hassanali J[25]	Kenyan Africans and Asians	Negroids		26-27	
1983	Sharma JC[26]	Tibetan in India	Mongoloids		5.9	
1983	Scott GR[27]	Pima Indians	Mongoloids		72.9	
1986	Thomas CJ[28]	South African whites	Caucasians		82.5	
1986	Thomas CJ[28]	South African blacks	Negroids		79.2	
1992	Rusmah M[29]	Malaysian	Mongoloids		52.2	
1992	Ling YJK[30]	Southern Chinese	Mongoloids		41.9	
1992	Townsend GC and Martin NG[15]	Asian Indians	Caucasians		86	
1995	Guo L[31]	Chinese	Mongoloids		20.6	
1996	Tsai PL *et al*[32]	Mongoloid	Mongoloids		48.07	

Contd....

Table 1:Contd....

Year	Investigator	Study population	Race	Percentage distribution of tooth investigated		
				PM2	M1	M2
1996	Tsai PL *et al*[32]	Taiwan aborigines (Bunun)	Negroids		48.1	
1996	Ooshima *et al*[7]	Japanese	Mongoloids		8.3 (Considered only cusps)	
1997	Hsu JW *et al*[33]	Chinese	Mongoloids		36.89	
1997	Hsu JW *et al*[33]	Bunun aboriginal (Mongoloid)	Mongoloids		47.6	
1997	Hsu JW *et al*[12]	American whites	Caucasians		77.1	
1997	Irish JD[8]	Sub-Saharan African	Negroids		51.2	
1999	Njemirovskij V[34]	Croatian population (European) Considered only Grade 5,6,7 of Dahlberg	Caucasians		43.4	
2001	Kanappan JG[35]	Southern Indians (Chennai)	Caucasians	67.5	52.77	
2002	Falomo OO[36]	Nigerians	Negroids		17.43	
2007	Mavrodisz K[37]	Hungary	Caucasians		65.34	
2007	Edgar HJ and Lease LR[38]	Northern American	Caucasians		60	
2010	King NM[15]	Southern Chinese	Mongoloids		50.5	
2010	Ferreira MA[39]	Brazil	Mongoloids	69.5	52.1	
2011	Khan DB[40]	Pakistan	Caucasians		29.7	
2011	Khraisat Ameen[41]	Jordanians	Caucasians		65	3.8

PM2: Maxillary primary second molar; M1: Maxillary permanent first molar; M2: Maxillary permanent second molar

hence, the present study provides an initial odontologic description of a hitherto unreported population so as to assess its applicability to dental morphologic studies in ethnic groups, and it is an attempt made to determine the prevalence of Carabelli trait in the group of children from Nellore.

Materials and Methods

Native children of Nellore district, who attended the department of pedodontics and preventive dentistry, were chosen for this study. After obtaining the permission from the institutional ethical committee, the study was carried out over a period of 6 months from October 1st 2011 to March 31st 2012. Healthy primary second molars and/or permanent first molars and/or permanent second molars have been included in the study, and those with carious lesions or restorations or any developmental anomaly were excluded from the study. The required consent and assent from the parents and children were obtained after explaining them about the examination method and those willing to participate were included in the study. During the study period, a total number of 254 children were recruited into the study and the minimum age was 4 years and maximum age was 16 years (Median age: 10 years). Intraoral examination (Type III examination- in good illumination using mouth mirror and probe[42]) of children was done, to determine the presence and degree of expression of Carabelli's trait of maxillary primary second molar and permanent first molar and if possible the observation of the same in second permanent molars according to the age of the assessed child. To avoid inter-examiner bias, only one examiner recorded the degree of expression of this trait and was evaluated on the basis of the classification developed by Kraus and standards developed by Dahlberg. Kraus's classification of Carabelli's trait, used in the present study, is as follows: pronounced tubercle, slight tubercle, groove, pit, and absence.[43] Dahlberg's classification was used with the following gradations: 0- smooth mesiobuccal crown surface; 1- small vertical ridge and groove; 2- small pit with minor grooves diverging from depression; 3- double vertical ridges or slight and incomplete cusp outline; 4- Y-form (i.e., moderate grooves curving occlusally in opposite directions); 5- small tubercle; 6- broad cusp outline with a moderate tubercle, and 7- large tubercle with a free apex.[44] In Dahlberg's classification, four grades [1 through 4] can be termed negative and three grades [5 through 7] positive trait forms.

Results

Trait expression

Descriptive statistics was performed and the relative frequency showing the percentage of children in each category, according to Kraus's and Dahlberg's classification are presented in Tables 2 and 3, respectively. To determine the significance between the distribution of the trait based on gender, dentition, and hemi-arch, Mann-Whitney U-test was applied with the level of significance set at 5% level. No statistically significant difference was observed between boys and girls and between right and left sides for primary second molars ($P = 0.78$), permanent first ($P = 0.49$), and second molars ($P = 0.22$). Only significance noted was between the expressions of primary second molars and permanent first molars ($P = 0.0001$).

When the Carabelli trait was divided into absent, negative, and positive expressions (negative being a pit or groove

form and positive being a definite cusp form), a positive expression was observed in 27.6% of primary second molars, 30.7% of permanent first molars, but only in 1.2% of permanent second molars. Negative expression was noted in 62.2% of primary second molars, 33.1% permanent first molars and 6.9% permanent second molars and the absence of the trait in 10.2% of primary second molars, 36.2% permanent first molars, and 91.9% permanent second molars.

Trait symmetry

The bilateral presence of the trait was noted in 84% of primary second molars, 54.5% of permanent first molars, and 2.3% of permanent second molars. Bilateral absence was noted in 7.1% of primary second molars, 26.4% permanent first molar, and 86% of permanent second molars [Table 4].

Discussion

Carabelli's cusp or trait or tubercle or even tuberculum impar, whichever term we might designate for this primitive structure, it has an evolutionary and functional perspective. In the evolutionary perceptive, it is considered as a primitive structure that tends to disappear with molar size reduction in all hominoid evolutionary lines[11] and another controversy in the evolutionary perspective is that it is an adaptation that enlarged the occlusal surface of the first molars in the buccolingual dimension as a compensation for evolutionary reduction in the length of maxillary molar row.[1] According to the functional perceptive, it is a structure that resists excessive biomechanical stresses on the molar.[45]

Being a distinguishing feature or characteristic of an individual it is frequently considered in the evolutionary studies. Understanding or knowing this trait is of clinical, anthropological, and forensic significance. Apart from these routine clinical issues like, placement of sealants and band adaptation, it has definite anthropological significance and knowledge on the distribution of Carabelli trait can be very useful for a forensic dentist in the identification of deceased individuals as it is one of the factors that help in comparative identification of postmortem and antemortem dental records. It also plays part in postmortem dental profiling, where antemortem records are not available or to narrow down the search for the antemortem materials.[46]

Irrespective of the clinical, anthropological, or forsenic point of view, several studies have been carried out in different parts of the world and racial differences in the representation of this trait had been reported in the literature.[15,18,22,25,28,29,40] Racial classification of Caucasoid, Negroid, and Mongoloid, though an outdated system is still followed by the forensic odontologists based on skull shape, cusps of Carabelli, shovel-shaped incisors, and multi-cusped premolars to determine the ancestry.[46] So, the factors responsible for the representation

Table 2: Relative frequency table showing the percentage of children in each category of Kraus's classification of Carabelli trait

Kraus's criteria	Absence	Pit	Groove	Slight tubercle	Pronounced tubercle	Total
Primary right second molar						
Male (%F)	7(7.2)	10(10.3)	49(50.5)	26(26.8)	5(5.1)	97
Female (%F)	10(13.1)	7(9.2)	37(48.7)	19(25)	3(3.9)	76
Total (%F)	17(9.8)	17(9.8)	86(49.7)	45(26)	8(4.6)	173
Primary left second molar						
Male (%F)	9(9.5)	10(10.5)	50(52.6)	20(21)	6(6.3)	95
Female (%F)	9(11.8)	7(9.2)	41(53.9)	16(21)	3(3.9)	76
Total (%F)	18(10.5)	17(9.9)	91(53.2)	36(21)	9(5.8)	171
Permanent right first molar						
Male (%F)	47(35)	1(0.7)	37(27.6)	48(35.8)	1(0.7)	134
Female (%F)	45(44.1)	3(2.9)	26(25.5)	26(25.5)	2(2)	102
Total (%F)	92(39)	4(1.7)	63(26.7)	74(31.3)	3(1.3)	236
Permanent left first molar						
Male (%F)	41(30.6)	1(0.8)	44(32.8)	46(34.3)	2(1.5)	134
Female (%F)	38(37.2)	6(5.9)	33(32.4)	25(24.5)	0(0)	102
Total (%F)	79(33.5)	7(3)	77(32.6)	71(30)	2(0.9)	236
Permanent right second molar						
Male (%F)	18(94.7)	0(0)	1(5.3)	0(0)	0(0)	19
Female (%F)	24(96)	0(0)	1(4)	0(0)	0(0)	25
Total (%F)	42(95.5)	0(0)	2(4.5)	0(0)	0(0)	44
Permanent left second molar						
Male (%F)	16(88.9)	0(0)	2(11.1)	0(0)	0(0)	18
Female (%F)	22(88)	0(0)	2(4.5)	0(0)	0(0)	25
Total (%F)	38(88.4)	0(0)	4(9.3)	1(2.3)	0(0)	43

%F: Relative frequency

Table 3: Relative frequency table showing the percentage of children in each category of Dahlberg's classification of Carabelli trait

Dahlberg's criteria	0	1	2	3	4	5	6	7	Total
Primary right second molar									
Male (%F)	7(7.2)	45(46.4)	10(10.3)	1(1)	4(4.1)	16(16.5)	10(10.3)	4(4.1)	97
Female (%F)	10(13.2)	26(34.2)	7(9.2)	1(1.3)	10(13.2)	11(14.5)	8(10.4)	3(4)	76
Total (%F)	17(9.8)	71(41)	17(9.8)	2(1.2)	14(8)	27(15.6)	18(10.4)	7(4)	173
Primary left second molar									
Male (%F)	9(9.5)	44(46.3)	10(10.5)	1(1)	6(6.3)	13(13.7)	7(7.4)	5(5.3)	95
Female (%F)	9(11.8)	24(31.6)	7(9.2)	1(1.3)	17(22.4)	9(11.8)	6(7.9)	3(3.9)	76
Total (%F)	18(10.5)	68(39.8)	17(9.9)	2(1.2)	23(13.5)	22(12.9)	13(7.6)	8(4.7)	171
Permanent right first molar									
Male (%F)	47(35)	30(22.4)	1(0.7)	3(2.2)	7(5.2)	27(20.1)	18(13.4)	1(0.7)	134
Female (%F)	45(44.1)	20(19.6)	3(2.9)	0(0)	6(5.9)	16(15.7)	10(9.8)	2(2)	102
Total (%F)	92(39)	50(21.2)	4(1.7)	3(1.3)	13(5.5)	43(18.2)	28(11.9)	3(1.3)	236
Permanent left first molar									
Male (%F)	41(30.6)	34(25.4)	1(0.7)	2(1.5)	9(6.7)	30(22.4)	16(11.9)	1(0.7)	134
Female (%F)	38(37.3)	23(22.5)	6(5.9)	1(1)	10(9.8)	11(10.8)	13(12.7)	0(0)	102
Total (%F)	79(33.5)	57(24.2)	7(3)	3(1.3)	19(8)	41(17.4)	29(12.3)	1(0.4)	236
Permanent right second molar									
Male (%F)	18(94.7)	1(5.3)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	19
Female (%F)	24(96)	1(4)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	25
Total (%F)	42(95.5)	2(4.5)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	44
Permanent left second molar									
Male (%F)	16(88.9)	2(11.1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	18
Female (%F)	22(88)	2(8)	0(0)	0(0)	0(0)	1(4)	0(0)	0(0)	25
Total (%F)	38(88.4)	4(9.3)	0(0)	0(0)	0(0)	1(2.3)	0(0)	0(0)	43

%F: Relative frequency

Table 4: Relative frequency table showing the bilateral symmetry of the Carabelli trait

	Number of children	Bilateral absence	Bilateral presence	Unilateral presence
Primary second molar				
Male (%F)	91	6(6.6)	81(89)	4(4.4)
Female (%F)	78	6(7.7)	61(78.3)	7(9)
Total (%F)	169	12(7.1)	142(84)	11(6.5)
Permanent first molar				
Male (%F)	134	30(22.4)	76(56.7)	28(20.9)
Female (%F)	101	32(31.7)	52(51.5)	17(16.8)
Total (%F)	235	62(26.4)	128(54.5)	45(19.1)
Permanent second molar				
Male (%F)	18	15(83.3)	0(0)	3(16.7)
Female (%F)	25	22(88)	1(4)	2(8)
Total (%F)	43	37(86)	1(2.3)	5(11.7)

%F: Relative frequency

of this trait and its distribution in various populations are very important. There are controversies about the extent of ontogenetic and environmental factors that are responsible for the expression of the Carabelli trait. Studies to estimate the heritability of the Carabelli trait have given conflicting results, with high estimates found in some studies,[23,47,48] where as low estimates in others.[21,49,50] As many studies have concluded the interaction of both, one cannot assume this trait to be purely genetic, hence, there is a need to study the detailed distribution of the Carabelli trait geographically.

Based on the previous studies of Carabelli trait on racial basis, it is proved that, the Mongoloids had a low prevalence of Carabelli trait whereas Caucasians had a high prevalence.[32,33] Among the Caucasians, it is assumed that the Asiatic and Asiatic derived population show low trait frequencies, whereas, European population show high trait frequencies.[27,35] Racial type of India seems to a complicated mixture of all major types. The southern Indians usually referred to as Dravidians are classified as Caucasoid, due to their Caucasoid skull structure and other physical traits such as nose, eyes and hair. Even all Indians are classified as being genetically Caucasians.[51] Contrary to this widely accepted assumption that the Asiatic Caucasians have low

trait frequency,[52] in the present study done on hitherto unreported population contradicting results were observed. When the overall frequency of all possible Carabelli traits is taken into consideration, high expression of Carabelli trait (89.8% in primary second molars and 63.7% in permanent first molars) was noted in the sample population. When well expressed traits only are considered, the representation of this trait in the selected population is low.

When the type of expression of this trait is considered in the target population, we found that 40.4% of the representation in primary second molars was in groove form, where as in permanent first molars, there was no trait representation in 36.2% and it was represented as groove form in 22.7%. In permanent second molars, almost 91.9% had absent trait. Hence, it is possible that the Carabelli trait in this particular part of the country might disappear in future generation.

When the Carabelli trait expression of boys and girls were considered, sexual dimorphism was not statistically significant. Sexual dimorphism in the expression of Carabelli's trait has been reported previously,[9,19,23,33,40,53] but some authors found no significant difference in representation as observed in the present study.[21,45,54,55] Though there was no statistically significant difference, we observed that the expression of positive trait is more among males [28.6%] when compared to females [20.3%], in primary second molars. Permanent first molars too showed greater representation of positive trait in males [34.6%] than females [25.5%]. The reason for this might be due to greater crown reduction observed in females, during the evolutionary process. It has been proved by a study that the degree of expressivity of a trait seems to be associated with molar size, with crown base sizes larger in trait positive than in trait negative molars.[11]

Though there was no statistical difference between the right and left sides of primary and permanent dentition, we observed that there are variations in the type of representation of the trait. Some studies have proved similar correspondence between right and left sides,[28,29,39] whereas another study reported discordance.[14] When primary and permanent dentitions were compared, statistically significant variations were observed in the type of representation of the trait. These variations in the phenotypic trait expression between dentitions and sides probably reflect the interplay between environmental influences and timing of developmental processes.

When the trait symmetry is considered, and the bilateralism of this trait is observed as either absent or present in whichever form it was, we found that in most of the cases there was bilateral development and in a few unilateral instances with 6.5% of primary second molars, 9.1% of permanent first molars, and 11.7% of permanent second molars. Though there was bilateral symmetry, when only the presence or absence of the trait was considered, the type of the representation varied in many children and there were few unilateral cases. These findings signify the polygenic nature and environmental role in representation of this trait.

Conclusion

A small population from South India considered in the present study was found to possess high degree of trait expression, mostly in groove form. The trait was bilateral with varying degrees of asymmetry and there was no sexual dimorphism. There was tendency for concordance between the sides but not within sides, as there was variation between the expression of primary second molar and permanent molars on the same side. As this is a trait with high variability, to know the anthropological significance of Carabelli trait and to make it a useful part of forensic odontology, similar studies in different regions of our country and the world are needed. To reduce the bias, we need standardization of the methodological approach and the classification system, so as to simplify the comparisons.

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