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Original Article

The frequency and degree of expression of Carabelli's trait on the permanent maxillary molars in a sample of Turkish individuals

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Abstract

Aim: Carabelli's trait, a morphological feature on the mesiopalatal surface of the maxillary molars, has importance in anthropology, forensic sciences, and clinical dentistry. The aim of this study was to find the frequency and degree of expression of Carabelli's trait and to assess the asymmetry of the trait, on three permanent maxillary molars in a sample of Turkish individuals.
Methodology: Carabelli's trait was evaluated using Dahlberg's eight-grade scale on 462 subjects. Data were analyzed using a chi-square test.
Results: The frequencies in the total, positive and negative expressions of the trait were, respectively, 64.5%, 37.7% and 26.8% on the first molars, 27.1%, 19.6% and 7.6% on the second molars and 10.3%, 8.7% and 1.6% on the third molars. The occurrence of the trait on the first and second molars was more prevalent in males than in females. The trait was most frequently bilateral and symmetrical without significant sex differences, with varying degrees of asymmetry that increased from the first to the third molars. The frequencies of presence-absence asymmetry and any degree of asymmetry on the first molars were 5.3% and 15.7%, respectively.
Conclusion: This study revealed a comparatively high frequency of Carabelli's trait with a relatively low asymmetry in a contemporary Turkish sample. This data has the potential to be used for anthropological, forensic, and clinical purposes.

Keywords: Tooth abnormalities, carabelli anomaly, asymmetry, biological variation, population, permanent dentition

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Introduction

Carabelli's trait is a morphological feature on the mesiopalatal surface of the maxillary molars and may occur in the form of a pit, groove, tubercle or cusp. The protuberant- and cusp-formed structures are referred to as positive or tubercular forms, and the groove- and pit-formed structures are negative or non-tubercular forms (1). Synonyms for Carabelli's trait are Carabelli's tubercle, Carabelli's cusp, Carabelli's anomaly, a fifth lobe, a fifth cusp, a supplemental cusp, and an accessory cusp (2, 3). The trait is seen most frequently in the first permanent molars and the second deciduous molars and also in the second and third permanent molars, although this is rare. It is usually observed bilaterally, with no significant differences in the sexes (1). The lowest incidence of Carabelli's trait is in Asian populations, and the highest is in Whites; indeed, it is commonly considered to be a distinctive feature of these groups (4-6).

Genetic and environmental factors have both been reported as being associated with the occurrence of Carabelli's trait. Most authors agree that the trait is genetically determined (7); however, some authors have reported that its heritability is low (1).

Evolutionary and functional arguments have both been proposed to explain the existence of the trait. One argument is that Carabelli's trait is an adaptation to compensate for the overall loss of tooth material due to the evolutionary reduction in tooth sizes (negative association). The other argument is that Carabelli's trait is a primitive structure that has tended to reduce and disappear with evolutionary reduction in tooth sizes (positive association) (8).

Carabelli's trait has been studied from several perspectives such as descriptive morphology and classification (1, 9), morphogenesis (10), modes of inheritance and heritability (1,7), sexual differences (11), inter-trait association and population variation (3-5,12-18). Because its frequency and the degree of expression differ among species as well as among present and past human populations, Carabelli's trait has become an important tool for the assessment of evolutionary history and relationships and of population history (18-20). It has importance not only in anthropology, but also in forensic odontology and clinical dentistry. This trait can be used for comparative identification and post-mortem dental profiling to identify and categorize populations to which an individual belongs when forensic data are not available (12, 20, 21). Tinoco et al. have stated that the frequencies of dental traits must be updated from contemporary populations for their potential contributions to forensic identification (20). Its clinical importance is that this trait can lead to difficulties in endodontic, surgical and orthodontic procedures and increased caries due to the presence of deep pits and fissures (22-24). In the studies performed on both primary (25) and permanent dentition (26), the occurrence of caries has been found to be higher in the positive forms of the trait compared with the negative forms. Bhavyaa et al. reported that the different expressions of Carabelli's trait, as a potential plaque retentive area, should be recognized for appropriate management (25).

The aim of the present study was to figure out the frequency and degree of expression of Carabelli's trait and to evaluate its asymmetry among maxillary permanent molars in a sample of Turkish individuals.

Materials and Methods

The investigational protocol described herein was approved by the local ethics committee at Aydın Adnan Menderes University (ADUDHF2017/006). The study was conducted in full accordance with Helsinki Declaration. Informed consent was obtained from all patients. The study group consisted of patients who had applied to the Department of Dentomaxillofacial Radiology, in the university's Faculty of Dentistry, located in the western Turkey, for routine dental examinations between May 2017 and November 2017. The ages and sexes of the patients were recorded. Patients were selected according to the following criteria: they had at least one maxillary first permanent molar but no developmental anomalies, previous dental restoration, dentinal caries, abrasions, erosion or attrition that could impede the evaluation of Carabelli's trait. The study sample consisted of 462 subjects (266 females and 196 males) whose ages ranged from 15 to 75 years.

Dahlberg's eight-grade classification system (4, 27), which has been found to be the method associated with the greatest degree of confidence (9), was used to evaluate the degree of expression of Carabelli's trait with the following gradations, as illustrated in Figure 1:

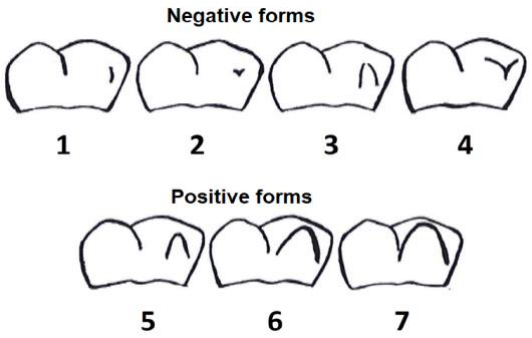

Figure 1. Dahlberg's eight-grade classification system (4,27)

Grade 0: No vertical ridges, pits or other manifestations on the mesiolingual cusp

Grade 1: Small vertical ridges and grooves

Grade 2: Small pits with minor grooves diverging from a depression

Grade 3: Double vertical ridges or slight and incomplete cusp outlines

Grade 4: Y-form: moderate grooves curving occlusally in opposite directions

Grade 5: Small tubercles

Grade 6: Broad cusp outlines or moderate tubercles

Grade 7: Large tubercles with a free apex that is in contact with a lingual groove (height often approximates that of major cusps).

The grades were grouped into three categories: absent (grade 0), negative (grades 1, 2, 3 and 4) and positive (grades 5, 6 and 7) for comparison with the results of previous studies that did not use the same system.

All available maxillary permanent molars were evaluated by one observer. The observations were performed under good lighting using a mouth mirror and probe after the teeth had been cleaned and dried. To test intra-observer agreement, 43 patients were re-evaluated at least two months after the initial scoring. A kappa correlation coefficient was used to evaluate agreement between repeated measurements.

The unilateral count method was used for statistical analysis, since no significant differences in the degrees of expression of the trait were found between the right and left sides for all types of molars ($p>0.05$). According to the unilateral count method, the grades on the right side were used for analysis, and when these were not available the ones on the left side were used.

Statistical analysis

The statistical analyses were carried out using SPSS software (version 20.0; IBM Corp., Armonk, NY, USA). The chi-square test was used to determine the total frequencies and degrees of the differences in expression between the left and right sides and between the molar types and to test whether there were any statistically significant differences between the sexes in the total frequencies and degrees of expression and asymmetry of the trait. Significance was found to be at a 95% of confidence interval. The asymmetry of the trait was evaluated with a double-entry table, in which the right and left gradations were separately distributed and with a rank differential between the sides for all molar types. Conditional probability analysis was used to evaluate the association between the permanent maxillary molars for this trait.

The intra-observer agreement value was 0.90 ($p<0.05$) with a 95% confidence interval (0.87, 0.92). This value may be interpreted as being in almost perfect agreement.

Results

The mean age of the subjects was 31.2 ± 13.0 for the 266 females, 30.7 ± 11.8 for the 196 males and 31.0 ± 12.5 for the entire sample. A total of 875 first, 851 second and 425 third maxillary molars were examined. The number of subjects and the teeth that were examined are shown in Table 1. The asymmetry analysis, which involved only subjects in whom it was possible to score on both sides of maxillary arch, included 413, 401 and 172 subjects for the first, second and third molars, respectively.

Table 1. Number of subjects and the examined teeth

Sex	Number of subjects	Number of teeth examined					
		M1		M2		M3	
		R	L	R	L	R	L
Male	196	187	179	188	181	101	105
Female	266	256	253	233	249	109	110
Total	462	443	432	421	430	210	215

The frequencies according to sex and molar types for total expression of the trait and for each grade and the grouped grades are shown in Table 2. The frequencies for total, positive and negative expressions of the trait were 64.5%, 37.7% and 26.8%, respectively, on the first molars, 27.1%, 19.6% and 7.6% on the second molars and 10.3% 8.7% and 1.6% on the third molars. Statistically significant differences were found between males and females for the first ($\chi2(2)=13.35$, $p=0.000$) and second maxillary molars ($\chi2(2)=6.56$, $p=0.001$) but not for the third molars ($\chi2(2)=0.10$, $p=0.749$). There were higher total frequencies of the trait on the first and second molars among males (74% for first molars; 33.3% for second molars) than among females (57.5% for first molars and 22.5% for second molars). The frequencies of positive forms on all molars were higher in males than in females; however, the differences in the degrees of expression of the trait between the sexes was not statistically significant ($p>0.05$). The trait was most frequently expressed as a small tubercle for all molar types (16.9% on the first molars, 13.3% on the second molars and 7.5% on the third molars). No y-forms of the trait were observed on the second and third molars and no double vertical ridges of the trait were seen on the third molars.

Table 2. Total frequency and degree of expression of Carabelli's trait in maxillary permanent molars according to sex

Tooth	n	Absence (%)	Grade of expression: Negative forms (%)					Positive forms (%)				Total trait frequency
		0	1	2	3	4	1-4	5	6	7	5-7	
M1												
Male	196	26	11.2	7.7	8.7	1	28.6	20.4	13.8	11.2	45.4	74
Female	266	42.5	10.2	6	7.9	1.5	25.6	14.3	14.7	3	32	57.5
Total	462	35.5	10.6	6.7	8.2	1.3	26.8	16.9	14.3	6.5	37.7	64.5
M2												
Male	192	66.7	1.6	3.6	2.6	-	7.8	16.1	6.8	2.6	25.5	33.3
Female	258	77.5	1.9	3.5	1.9	-	7.4	11.2	3.1	0.8	15.1	22.5
Total	450	72.9	1.8	3.6	2.2	-	7.6	13.3	4.7	1.6	19.6	27.1
M3												
Male	119	89.1	0.8	-	-	-	0.8	7.6	0.8	1.7	10.1	10.9
Female	134	90.3	1.5	0.7	-	-	2.2	7.5	-	-	7.5	9.7
Total	**253**	**89.7**	**1.2**	**0.4**	**-**	**-**	**1.6**	**7.5**	**0.4**	**0.8**	**8.7**	**10.3**

The total frequencies were higher on the first molars than on the second molars and also higher on the second molars than on the third molars, and this was statistically significant ($\chi 2(2)=242.18$, $p=0.000$). Table 3 shows the association for the trait between the permanent maxillary molars. If the trait is present on the second molars, it appears with 90% probability on the first molars. If the trait is present on the third molars it appears on the first and second molars, respectively, with 85% and 77% probabilities.

Table 3. The association among maxillary permanent molars for the occurrence of Carabelli's trait

		M2		Total			M3		Total			M3		Total
		0	1				0	1				0	1	
M1	0	147	12	159	M1	0	79	4	83	M2	0	157	6	163
	1	182	110	292		1	148	22	170		1	62	20	82
Total		329	122	451	Total		227	26	253	Total		219	26	245

The trait most frequently occurred bilaterally and symmetrically. Table 4 shows the bilateralism with respect to the occurrence of Carabelli's trait in all molars. No statistically significant difference in the asymmetry of the trait was found between the sexes for all molar types, and data were combined for later analyses. Table 5 presents the association between the grouped grades of the trait on the right and left sides for the first, second and third molars. Table 6 shows differences in rank of 1, 2 and 3 as well as more grades, the presence-absence asymmetries and any degrees of asymmetry. When bilateral absence categories were excluded, to eliminate the effect of total frequency on asymmetry as in the study of Stamfelj et al. (17), the asymmetry frequencies increased, especially in the second and third molars. A statistically significant

difference in the presence-absence asymmetry of the trait was found for the molar types ($\chi2(2)=31.082$ $p<0.05$), while there was no statistically significant difference in any degree of asymmetry of the trait ($p>0.05$). Although a 3 and above rank differential of the asymmetry of the trait was observed more frequently on the second and third molars than on the first molars ($\chi2(2)=38.318$ $p<0.05$), there was no statistically significant difference in the rank for the trait asymmetry between the second and third molars ($p>0.05$).

Table 4. Bilateralism in Carabelli's trait on all molars in terms of absence-presence

Tooth	Bilateral absence	Bilateral presence	Unilateral presence	Total
M1				
Male	38 (22.3%)	122 (71.8%)	10 (5.9%)	170 (100%)
Female	94 (38.7%)	137 (56.4%)	12 (4.9%)	243 (100%)
Total	**132 (32%)**	**259 (62.7%)**	**22 (5.3%)**	**413 (100%)**
M2				
Male	112 (63.3%)	58 (32.8%)	7 (3.9%)	177 (100%)
Female	169 (75.4%)	40 (17.9%)	15 (6.7%)	224 (100%)
Total	**281 (70.1%)**	**98 (24.4%)**	**22 (5.5%)**	**401 (100%)**
M3				
Male	75 (86.2%)	6 (6.9%)	6 (6.9%)	87 (100%)
Female	72 (84.7%)	8 (9.4%)	5 (5.9%)	85 (100%)
Total	**147 (85.5%)**	**14 (8.1%)**	**11 (6.4%)**	**172 (100%)**

Table 5. Asymmetry of Carabelli's trait on all molars for the grouped grades

		Left											
		M1			Total	M2			Total	M3			Total
		0	1-4	5-7		0	1-4	5-7		0	1-4	5-7	
Right	0	**132**	6	0	138	**281**	3	9	293	**147**	1	5	153
	1-4	11	**103**	3	117	0	**31**	1	32	0	**3**	0	3
	5-7	5	5	**148**	158	10	0	**66**	76	5	0	**11**	16
Total		148	114	151	413	291	34	76	401	152	4	16	172

Table 6. Asymmetry in the expression of Carabelli's Trait*

	n	Rank Differential between right and left sides (%)				Any degree of asymmetry (%)	Presence-absence asymmetry (%)
		0	1	2	3+		
M1	413(281)	84.3(76.9)	9.2(13.5)	2.7(3.9)	3.9(5.7)	15.7 (23.1)	5.3 (7.8)
M2	401(120)	91.8(72.5)	2.0(6.7)	1.2(4.2)	5(16.7)	8.2 (27.5)	5.5 (18.3)
M3	172(25)	93.6(56.0)	0.0(0.0)	0.6(4.0)	5.8(40.0)	6.4 (44.0)	6.4 (44.0)

*Parentheses indicate the values when bilateral absence was excluded.

Discussion

The frequency and degree of expression of Carabelli's trait differ among populations. European or European-derived and African populations have high total frequencies of Carabelli's trait, whereas the trait is less commonly found in Asian or Asian-derived populations. Also, the frequency of tubercle expressions (positive forms) has been found to be highest in European populations (4, 5, 16). Figure 2 shows a comparison between the present study and data from previous studies for various populations (1, 3, 4, 6,11-17, 21, 26, 28-33).

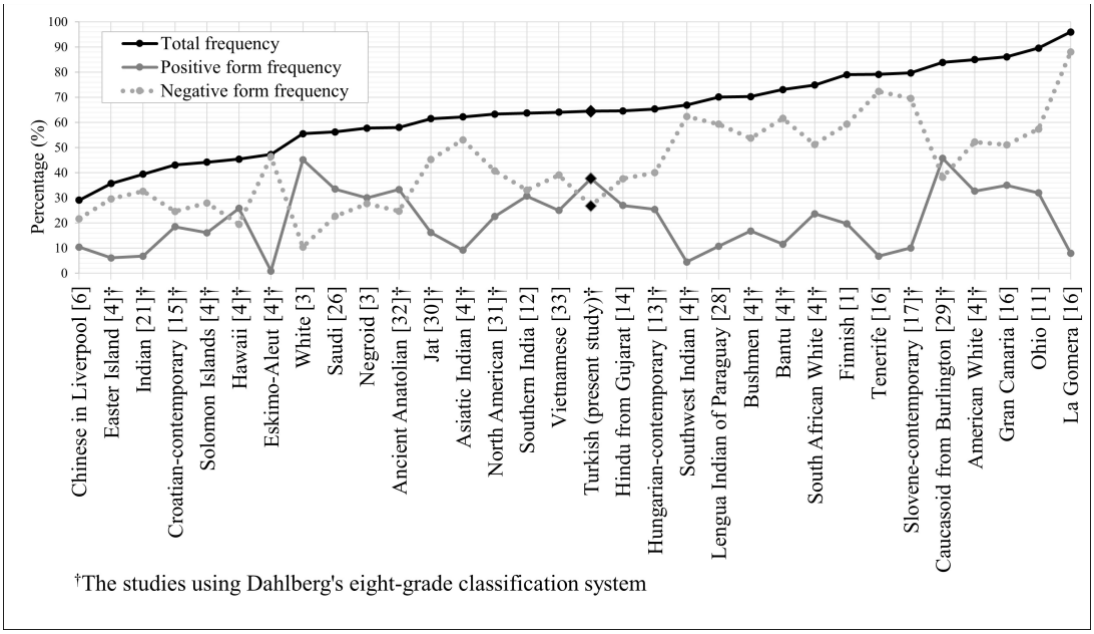

Figure 2. The frequency of Carabelli's trait on the maxillary first molar in this study compared to those in the other studies on various populations

The total frequency of Carabelli's trait on the maxillary first molar (64.5%) was found to be in the middle of the frequency range of European or European-derived populations (40% and 90%) (1-5, 11, 13, 15, 17, 29). However, the positive form frequency (37.7%) fell into the higher limit of the frequency range of previous studies on European populations (10% and 50%) (1, 3, 4, 11, 13, 15, 17, 29, 31). Total frequency of the trait was approximately the same in terms of the data published for Southwest Indian (4), Asiatic Indian (4), Lengua Indians (28) and Jats (30), although positive form frequency was considerably higher. Therefore, Turkish individuals have diverged from these populations in terms of positive forms while they show similarities to European populations. This supports Scott (4) who reported that a significant proportion of the difference between Europeans and Asiatic and American Indians is in the mode of trait expression rather than in total trait frequencies. In addition, the total frequencies of the present study are similar to those of Southern India (12), Hindu (14), Hungarian (13), North American (31) and Vietnamese (33) populations, although the distribution of the positive and negative forms differ slightly. With respect to the distribution of positive and negative forms, higher frequencies of negative forms than of positive forms have been found in most populations (4, 6, 11-17, 21, 23, 28, 30, 31, 33-35). However, in this study negative forms were observed less frequently than positive forms, and this is comparable to the results of a few other studies (3, 4, 26, 29). Furthermore, the propensity of the positive forms was not only on the first molars but also in the second and third molars. When compared to data of studies from Turkey, the frequencies in this study were higher than those in the study conducted by Kazak (36), who reported a total frequency of 47.9% in 213 individuals from Northwest Turkey, and the frequencies in the study done by Eroğlu (32), who found total and positive form frequencies of 58% and 33.3%, respectively, in ancient Anatolian populations.

Most studies have reported no significant differences between the sexes in terms of the trait frequency (1, 2, 4, 6, 11, 12, 15, 16, 21, 23, 29, 31, 32, 37). However, males have shown significantly higher frequencies of Carabelli's trait than females in some other studies as found in the present study (5, 14, 20, 30). In addition, more pronounced or greater tubercles have been found in males than in females (14, 30). As a consistent with this trend, we observed positive forms more frequently in males than in females, although there was no statistical significance. The different

results regarding sexual dimorphism with respect to Carabelli's trait may be attributed to population differences.

The present study agrees with the results of previous studies in a number of respects. First, the occurrence of Carabelli's trait was most frequent on the maxillary first molars (64.5%), less frequent on the second molars (27.1%) and rarest on the third molars (10.3%). Also, if the trait is present on the second and third molars it is likely that it will be found on the first molars as well (6, 12, 17, 18, 23, 29, 30, 32). The total frequencies of the trait range from 0% to 25% for second molars (6, 12, 17, 18, 23, 26, 29, 30, 32, 36), and from 0% to 17% for third molars (18, 29, 32) among various populations. The distal decreases in the frequency of the trait from the maxillary second deciduous molars to the third permanent molars have been attributed to environmental factors or epigenetic influences operating during their development, with late-developing teeth in a morphological field having greater environmental variability (16, 29, 37). This gradient and the association between the types of molars have also been reported as supporting a genetic basis for the trait (16, 29) and are consistent with Butler's field model theory and Osborn's clone model for development of the teeth (17, 29).

In this study, Carabelli's trait was most frequently bilateral and symmetrical, which is consistent with previous reports (1, 3, 4, 12, 14, 17, 21, 26, 28, 32). Symmetric trait has been attributed to the assumption that the same genetic factors control both sides of the dental arch, whereas the trait that involves fluctuating asymmetry has been thought to be caused by environmental influences during the developmental period, such as unfavourable living conditions associated with nutritional deficiencies, physical conditions, diseases, socioeconomic levels and immigration (10, 12, 16, 17, 32, 38). The frequency of presence-absence asymmetry (unilateral presence) on the first molars was 5.3% in the present study and ranged from 2% to 25% in the previous studies (3, 4,12, 14, 16, 17, 26, 39) conducted on various populations. The frequency for any degree of asymmetry was 15.7%, which is lower than the frequencies reported by Stamfelj et al. (17) for Slovenians (22.7%) and by Scott (4) for White South Africans (26.4%), White Americans (24.3%), Bantus (26.1%), Asiatic Indians (23.6%), Southwest Indians (20.6%) and populations on Easter Island (20.4%) and the Solomon Islands (17.7%). However, the 15.7% frequency for asymmetry was higher than those reported by Scott (4) for Hawaiians (13.9%), Busmen (11.4%) and Eskimo Aleut (9.2%) populations. For the first molars, the most commonly observed degree of asymmetry involved a single difference in rank between the sides in the present study. This is similar to the previous studies (4, 17, 39). However, for the second and third molars, the most commonly observed degree of asymmetry involved the differences in rank of 3 and more between the sides in the present study. This was probably due to the decrease in the variety of trait forms on the second and third molars (the absence of y-forms on the second and third molars and the double vertical ridges on the third molars) and because of the small number of second and third molars displaying the trait. Presence-absence asymmetry and any degree of asymmetry of the trait were most frequently found in the third molar, followed by the second molar, with the lowest number in the first molar. The increased amount of morphological asymmetry distally along the morphological field has been attributed to environmental influences on late-developing teeth (17, 29, 32).

In this study, the trait was scored clinically. The use of different observation methods including direct (clinically) and indirect (on cast) examinations of the trait can result in inter-observer differences in scoring trait expressions. This might result in minor differences in the frequency values among the populations. Similarly, the use of different counting methods, classification systems, the sample size and age range of the sample that is likely to affect the observations due to tooth wear may affect the interpretation of population differences.

Conclusions

Turkish individuals showed a comparatively high frequency of Carabelli's trait on the permanent maxillary first molar, which is similar to data that has been published for European populations but somewhat different from those of Asian populations. There is also a tendency toward a higher frequency of Carabelli's trait in males. In addition, the trait was most frequently bilateral and symmetrical with a comparatively low frequency of asymmetry. The trait frequency decreased from mesial to distal, while the trait asymmetry increased. These data of Carabelli's trait from contemporary Turkish population may serve for the future analyses and the applications in the fields of anthropology, forensic and clinical dentistry.

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Ethical Approval: Ethics committee approval was received for this study from Aydın Adnan Menderes University, Faculty of Dentistry local ethic committee, Institutional Review Board in accordance with the World Medical Association Declaration of Helsinki, with the approval number: 2017-006).

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