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Coll. Antropol. **35** (2011) 1: 73–78
Original scientific paper

Hypocone Reduction and Carabelli's Traits in Contemporary Jordanians and the Association between Carabelli's Trait and the Dimensions of the Maxillary First Permanent Molar

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ABSTRACT

The objective of this study is to determine the prevalence of expression and bilateralism of two dental morphological traits in contemporary Jordanians: The hypocone reduction trait on the maxillary second permanent molar and Carabelli's trait on maxillary permanent first and second molars. Furthermore, inter-trait correlation and the relationship of Carabelli's traits with upper first molar dimensions were investigated. Three hundred subjects of school children at their 10th grade and of an average age of 15.5±0.4 years were involved. Alginate impressions for the maxillary arch were taken, dental casts were reproduced. The selected accurate casts were of 132 male- and 155 female-students. The frequencies of hypocone reduction trait on the maxillary second molar and Carabelli's trait on the maxillary molars were examined. Buccolingual and mesiodistal diameters of the maxillary first molar were measured and recorded. Paired Sample t test and Nonparametric Correlation analysis were used for data analysis. Hypocone reduction trait on the maxillary second molar was found in 29.8 % of the examined students. Positive forms of Carabelli's trait on first and second molars were observed in 65.0 % and 3.8 %, respectively. Nonparametric correlation analysis revealed positive association between Carabelli's trait on first molar and hypocone reduction trait on the maxillary second molar. The presence of Carabelli's trait on first molar was strongly associated with the increase of buccolingual, but not the mesiodistal, diameter. Bilateralism was found highly significant in the tested traits and both genders ($p<0.001$). This finding might be a sign of relatively low environmental stresses in the living Jordanian population and/or great ability of its individuals to buffer the adverse effects of such stresses.

Key words: *Hypocone reduction trait, Carabelli's trait, buccolingual diameter, mesiodistal diameter, tooth size*

Introduction

For ethnic, anthropological and forensic reasons, dental morphological traits were widely investigated and used to characterize major ethnic groups[1,2,3–6].

The presence of Carabelli's trait was described in maxillary first and second molar[1,2,7–15] and second deciduous molar[12]. Bilateral expression of this trait was reported as predominate[16]. However, the morphology of maxillary second molar resembles maxillary first molar (quadricuspal), which is most common, and comes, sometimes, in a triangular outline type (tricuspal) that has the hypocone reduced. In the latter type, the distolingual cusp is poorly developed and that would make the development of the other three cusps predominate[7].

The association between the positive expression of Carabelli's trait on the maxillary first molar and reduction of the hypocone on the maxillary second molar has

Received for publication May 15, 2008

been studied by many authors and the reported correlations between these traits are conflicting. Some authors believe that these two traits are positively correlated and postulate that Carabelli's trait positive expression is increasing in size and frequency in recent human populations to enlarge the occlusal surface of the first molar and to compensate for the overall evolutionary loss of tooth material in the second and third molars[5,17–20], while others argue that these two traits are negatively associated as part of the general evolutionary trend in the human dentition toward tooth size reduction and morphological simplification[21–23]. A third group holds that there is no association between these two traits[24,25].

The relationship between the expression of Carabelli's trait on the maxillary first molar and the dimensions of this tooth has also been investigated by many researcher and the results found were contradictive. Some workers demonstrated positive correlation between the expression of this trait and the dimensions of the first molar[22,26], while others showed that this trait is independent of [27,28], or negatively associated with the size of this tooth[29].

Sexual dimorphism for dental morphological has been investigated by many workers and the reported results are not consistent. Some researchers found statistically significant male-female differences in the expression of Carabelli's trait[30–33], while others found no sex differences for this trait[34,35].

Considering the abovementioned studies and findings in different ethnic groups, it is very clear that presence of those morphological traits and inter-trait correlation remain a matter of contradiction. Therefore, it would be worthy to investigate those traits among nations who were not inspected before.

The aims of this study were, first, to investigate the prevalence and bilateralism of hypocone reduction trait on the maxillary second molar and Carabelli's trait on maxillary first and second molars in the living Jordanian population, second, to test inter-trait correlation, and third, to analyze the relationship of Carabelli's traits on the first maxillary molar with the size of this tooth indicated by its buccolingual (BL) and mesiodistal (MD) diameters.

Materials and Methods

A random stratified sample was obtained by examining three hundred subjects of school children, from ten public and two private schools in the middle of Jordan. Children were at their 10th grade and of an average age of 15.5±0.4 years. They were examined before the lunch break to select the needed cases with the following criteria; all subjects were apparently healthy with no history of serious childhood illnesses, having erupted second molars, showing well aligned arches with no supernumerary teeth and no history of orthodontic treatment, showing normal appearing teeth, no large restorations or fixed replacements, and no marks of caries or attrition.

Alginate impressions for the maxillary arch were taken (Lascod S.p.A, Firenze, Italy) with the use of stock trays. Impressions were poured with type IV dental stone (Elite stone, Zhermack S.p.A, Badia Polesine, Italy) within one hour of impression taking. Dental casts were trimmed but not soaped or waxed, for proper inspections. Casts of thirteen subjects were excluded due to technical errors such as; air bubbles and excessive trimming. The remaining casts were of 132 male- and 155 female-students. Morphologic traits that were then observed included the presence of hypocone reduction trait on the maxillary second molar and Carabelli's trait on the maxillary first and second molars. All observations were carried out under good lighting and using 10x hand lenses.

The maxillary second molar was considered displaying hypocone reduction phenotype when the distal ridge of the mesiolingual cusp was confluent with that of the distobuccal cusp forming a triangular occlusal outline, which is equivalent to grade 3 or 3+ on Dahlberg classification scale for the hypocone phenotype of maxillary molars[7]. Absence of the hypocone reduction trait was given grade 0 while presence of this trait was given grade 1. Carabelli's trait was evaluated for the first and second maxillary molars using the Kraus grade classification which included the following grades: grade 0: No evidence of Carabelli's trait; smooth surface with the absence of pits or fissures, grade 1: Pits or fissures (single, double or y-shaped fissures), grade 2: Slight protuberance or small cusp lacking free apex, and grade 3: large cusp having free apex. Grades considered as positive expression of Carabelli's trait were 2 and 3 while grade 1 was considered as negative expression of this trait.

All observations for these two morphological traits (Carabelli's and hypocone reduction traits) were carried out by one well-trained observer. Intra-observer reliability for scoring these traits was assessed according to Nichol and Turner criteria (1986)[36]. 50 dental casts out of the present sample were selected, showing least attrition and/or caries, to be scored by the single observer, and rescored by the same observer three months later. Care was taken to reproduce the percentages of males and females in this sample as in the original sample of 287 casts. Percentages of disagreements that are of two grades or more between the two scoring sessions (>1 Grade Variant Scoring %) were calculated for both traits considered here and found to be less than the critical value of 10% (Carabelli's trait on UM1: 4.8%; Carabelli's trait on UM2: 2.1%; and for Hypocone reduction trait on UM2: 0.0%). In addition, the Net Mean Grade Difference (NMGD) between the two scoring sessions was calculated for both traits using the formula

$$NMGD=(\Sigma(X2–X1)/n)x100$$

where X1 = the grade number assigned to a cast for a trait in the first scoring session; X2 = the grade number assigned to the same cast for the same trait in the second scoring session and n = the number of casts that were observed in both of the scoring sessions.

The critical level of NMGD for a particular trait is >5% multiplied by the number of the highest grade on the grading standard for the trait. Since the highest grade number used here for Carabelli's trait is 3 (grades 0–3) and for hypocone reduction trait is 1 (grades 0–1; absence *vs*. presence), the critical level of NMGD for Carabelli's trait is 15%, and for hypocone reduction trait is 5%. The calculated NMGD values for both traits considered here were found to be below the critical levels of NMGD for these traits (Carabelli's trait on UM1: 8.6%; Carabelli's trait on UM2: 4.3%; and for Hypocone reduction trait on UM2: 2.7%). Furthermore, the differences between the mean scores of the two scoring sessions for both traits were estimated using the paired sample t-test and the t-values were found to be below the critical 0.05 probability level adjusted by Bonferroni's method[36,37].

Given the foregoing values (the values of >1 Grade Variant Scoring %, of NMGD and the t-values), it can be concluded that the scoring of these traits is reliable and that the intra-observer error in scoring these traits can be considered random and statistically insignificant.

Upon completion of the morphologic examination, metric inspections for the permanent maxillary first molars were performed. This was achieved by using a sliding digital caliper with an accuracy of 0.01mm and having modified caliper peaks to access the narrow interproximal spaces (ORTEAM S.p.A, P.zza Carbonari, Milano, Italy).

The measured BL diameter was the greatest distance between the buccal and the lingual surfaces of the tooth crown. Likewise, MD diameter was measured as the greatest distance between the approximate surfaces of the crown. BL diameter was measured with sliding caliper held at right angle to the mesiodistal diameter of the tooth. Accordingly, the MD diameter was measured with sliding caliper parallel to the occlusal and vestibular surfaces of the crown. Measurements were carried out for right and left first molars directly on the casts.

One well-trained examiner recorded the entire measurements of the present investigations in order to decrease observation errors. Furthermore, dental casts were examined on separate occasions and in groups of 30 casts each to reduce fatigue-caused errors. Ten percent of the casts were selected randomly and retested to examine reliability and repeatability of readings. Reliability was assessed by computing the standard deviation for the measurement error using the following formula:

$$d=\sqrt{\frac{\Sigma(X_1-X_2)^2}{2n}}$$

where X_1 is the first measurement and X_2 is the repeated measurement, and n is the number of subjects. The *d* value is read as the average difference between measurement sessions and was 0.13 for the tested situation. This indicated that the obtained results were reliable and the random errors in recording measurements were insignificant[38,39].

Social Science Statistical Package Software (SPSS, Version 12.0, Inc., Chicago, IL) was used to analyze the data. Frequencies were calculated for each trait to demonstrate its relative prevalence among Jordanian population.

Bilateralism of Carabelli's trait on maxillary molars and hypocone reduction trait on the maxillary 2nd molar was demonstrated by performing t-test and calculating Spearman correlation coefficient (r). Nonparametric Correlation analysis was computed and the r value was calculated to investigate the relationship between different traits. Similarly, the relationship between Carabelli's trait on maxillary first molar and tooth diameters was tested. Significant p (<0.05) and Positive r (between 0.00 and 1.00) values would indicate a stronger correlation or association.

Results

Table 1 summarized the detailed prevalence of hypocone reduction trait on the maxillary second molar and Carabelli's trait in maxillary first and second molars regarding gender and location. A total frequency of 29.8% of the examined students showed hypocone reduction trait on the maxillary second molar. Carabelli's trait on first molar was observed in 65.0% and in 3.8% on the second molar.

Descriptive data analyses for the BL and MD diameters of the maxillary first molar were calculated for both genders (Table 2 and 3). Skewness of MD and BL measurements indicated normal distribution for the data observed (Skewness <1.0).

TABLE 1
FREQUENCIES IN PERCENTAGE OF HYPOCONE REDUCTION TRAIT ON THE MAXILLARY SECOND MOLAR AND CARABILLI'S TRAIT ON MAXILLARY 1ST AND 2ND MOLARS

	Males (N=132)			Females (N=155)			Total		
	Right	Left	$\overline{X}$	Right	Left	$\overline{X}$	Right	Left	$\overline{X}$
HMM2	24.2	21.2	22.7	36.1	35.5	35.8	30.7	28.9	29.8
CMM1	72.7	70.5	71.6	58.7	60.0	59.4	65.2	64.8	65.0
CMM2	6.1	6.1	6.1	1.9	1.9	1.9	3.8	3.8	3.8

CMM1 – Carabelli's trait on maxillary 1st molar, CMM2 – Carabelli's trait on maxillary 2nd molar, HMM2 – hypocone reduction trait on the maxillary 2nd molar. N is the number of subjects

TABLE 2
DESCRIPTIVE DATA ANALYSIS FOR BUCCOLINGUAL AND MESIODISTAL MEASUREMENTS OF MAXILLARY 1ST MOLAR IN MALES (IN MILLIMETERS)

	N	Range	Minimum	Maximum	$\overline{X}$	SEM	SD
BLD Right	132	3.05	10.35	13.40	11.67	0.05	0.61
BLD Left	132	3.23	10.30	13.53	11.65	0.05	0.57
MDD Right	132	3.48	9.17	12.65	10.41	0.04	0.52
MDD Left	132	2.28	9.35	11.63	10.33	0.04	0.45

SEM – standard error of mean, SD – standard deviation, $\overline{X}$ – mean, BLD – buccolingual diameter of maxillary 1st molar, MDD – mesiodistal diameter of maxillary 1st molar. N is the number of subjects

TABLE 3
DESCRIPTIVE DATA ANALYSIS FOR BUCCOLINGUAL AND MESIODISTAL MEASUREMENTS OF MAXILLARY 1ST MOLAR IN FEMALES (IN MILLIMETERS)

	N	Range	Minimum	Maximum	$\overline{X}$	SEM	SD
BLD Right	155	2.95	9.95	12.90	11.35	0.04	0.54
BLD Left	155	2.75	10.00	12.75	11.35	0.04	0.55
MDD Right	155	2.58	9.10	11.68	10.25	0.04	0.51
MDD Left	155	2.45	9.11	11.56	10.21	0.04	0.46

SEM – standard error of mean, SD – standard deviation, $\overline{X}$ – mean, BLD – buccolingual diameter of maxillary 1st molar, MDD – mesiodistal diameter of maxillary 1st molar. N is the number of subjects

Bilateralism was observed significantly in the tested traits and both genders ($p<0.001$) with high positive r values, ranging from 0.809 to 0.908 (Table 4).

Nonparametric correlation analysis revealed positive association between Carabelli's trait on first molar and hypocone reduction trait on the maxillary second molar in both genders (Table 5). Negative association between Carabelli's trait on first and second molars for both genders with insignificant p and negative r values.

It was found that the relationship between the presence of Carabelli's trait on the first molar and the BL diameter of this tooth is statistically significant in females but just approaching the level of significance in males. On the other hand, Carabelli's trait on the first molar was found to be insignificantly correlated to the MD diameter of this tooth in both genders (Table 5).

TABLE 4
BILATERALISM OF CARABILLI'S TRAIT ON MAXILLARY MOLARS AND HYPOCONE REDUCTION TRAIT ON THE MAXILLARY 2ND MOLAR DEMONSTRATED BY T-TEST

	Spearman's Correlation Coefficient	p	df
HMM2 right and left	0.908	<0.001	284
CMM1 right and left	0.884	<0.001	284
CMM2 right and left	0.809	<0.001	284

HMM2 – hypocone reduction trait on the maxillary 2nd molar, CMM1 – Carabelli's trait on maxillary 1st molar, CMM2 – Carabelli's trait on maxillary 2nd molar

Discussion

The results of this study revealed that the prevalence of hypocone reduction trait on the maxillary second molar was significantly higher in females than in males. This was the opposite for the prevalence of Carabelli's trait on both maxillary molars, where it was significantly higher in males (Table 1).

Regarding tooth diameter measurements carried out on the first maxillary molars, the results emphasized the size difference between both genders. Males had significantly greater BL and MD diameters of the first molar than females (Table 2 and 3). The relatively smaller female molar size could possibly contribute to the lower frequency of Carabelli's trait and to the higher prevalence of hypocone reduction trait on the maxillary second molar in females. The apparent size dimorphism between males and females could possibly contribute to morphologic dimorphism between genders.

The prevalence of Carabelli's trait on first molar was relatively high among Jordanians, accounting for 65%, given that this study is the first of its type to be conducted on a Jordanian sample. It has been reported by some authors that the expression of positive forms of Carabelli's trait on the first molar in Western Eurasian population ranges from 20–55%[2,22,35,40–51] except in one study conducted in contemporary Slovenes where it was found to be 10.1%[52], in Asian and Asian derived populations from 9.1–17.6%[32,53–56], in ancestral inhabitants of some European territories from 10.9–15.9%[52,57–59]. Scott and Turner cite the following rates of positive expressions as typical of the following population groups: 20–30%

TABLE 5
NONPARAMETRIC CORRELATION ANALYSIS FOR CARABILLI'S TRAIT ON MAXILLARY 1ST AND 2ND MOLARS AND TOOTH CROWN MEASUREMENTS

	Males (N=132)		Females (N=155)	
	Spearman's Correlation coefficient	p	Spearman's Correlation coefficient	p
CMM1 *vs*. HMM2	0.249	0.004	0.160	0.046
CMM1 *vs*. CMM2	–0.056	0.075	–0.018	0.144
CMM1 *vs*. BLD	0.171	0.050	0.235	0.003
CMM1 *vs*. MDD	0.132	0.132	0.074	0.363

CMM1 – Carabelli's trait on maxillary 1st molar, CMM2 – Carabelli's trait on maxillary 2nd molar, HMM2 – hypocone reduction trait on the maxillary 2nd molar, BLD – buccolingual diameter of maxillary 1st molar, MDD – mesiodistal diameter of maxillary 1st molar. N is the number of subjects

for Western Eurasians, 10–15% for Eastern Asians, and 0–10% for North Asians[60]. While Turner and Hawkey reported in their worldwide literature survey the following frequencies of positive form: Southeast Asians (12%), Africans (11%), North American Indians (9%), Near/Middle Eastern (33%), Micronesians (23%), Polynesians (17%), and North Asians (16%)[61]. While our finding is surprisingly higher than the reported frequency of positive forms in Near/Middle Eastern peoples but the reported samples showed one of the widest ranges in total frequency of the trait (5.3%–70.7%) and the mean percentage of positive forms of the trait has a wide range (12.0–49.2%)[61]. Generally speaking, the geographic pattern of Carabelli's trait appears not to be very clear but it appears that the frequency of positive forms of the trait is distinctly higher in Near/Middle Eastern dentitions than in other populations.

This study revealed that there is apparent and significant sexual dimorphism for the prevalence of Carabelli's trait on both the maxillary first and second molars (UM1: 71.6% in males *vs*. 59.4% in females, UM2: 6.1% *vs*. 1.9%). It seems that there are differences among populations since some researchers found statistically significant male-female differences in the expression of Carabelli's trait, such as Goose and Lee (1971)[30], Kaul and Prakash (1981)[31], Kieser and Preston (1981)[32] and Townsend and Brown (1981)[33], while others found no sex differences for this trait such as Gran et al. (1966a)[34] and Scott (1980)[35].

In the present study, the total frequency of Carabelli's trait differs significantly between first and second molars (males 71.6% UM1 *vs.* 6.1% UM2; females 59.4% *vs*. 1.9%). This apparent within field difference between first and second molars is consistent with Butler's field model which hypothesizes that the shape of every tooth is determined by a morphogenetic field specific to that tooth[62], and consistent with Osborn's clone model which postulates that the differences in teeth morphology are attributed to changes in the shape potential for differentiating clones of neural crest-derived mesenchyme as they migrate throughout the developing jaws during early embryonic development[63].

It was hypothesized that the bilateral occurrence of Carabelli's tubercle was originally an inherited character in the molar region. However, the character might be inhibited during the process of evolution of the masticatory system and regression of the molar dentition[16]. In the present study, data analysis demonstrated that bilateralism is highly significant among the tested traits (Table 4). It might be postulated that bilateralism is a normal feature of human body symmetry and this might have its impact on forensic dentistry.

A positive and significant association between Carabelli's trait on first molar and hypocone reduction trait on the maxillary second molar was demonstrated in both genders. The results, also, showed a weak negative but not statistically significant association between Carabelli's trait on first and second molars in both males and females. The BL diameter was positively and significantly correlated to the expression of Carabelli's trait on first molar in females but just approaching statistical significance in males at the 0.05 probability level, while the MD diameter have positive but statistically insignificant association with the presence of Carabelli's trait in both sexes (Table 5).

Conclusions

This study found that the Jordanian population has a comparatively high prevalence of the positive forms of Carabelli's molar trait (65%). The Carabelli's trait on maxillary first molar and hypocone reduction trait on the maxillary second molar were found to be positively and significantly correlated, supporting the compensation theory which suggests that positive expression of Carabelli's trait tends to enlarge the occlusal surface of the maxillary first molar and to compensate for the continuous evolutionary loss of tooth material in the first and second maxillary molars. The BL, but not the MD, diameter was positively and significantly associated with the incidence of Carabelli's trait. Significant male-female differences have been shown regarding the positive expression of Carabelli's trait on maxillary molars and the prevalence of hypocone reduction trait on the second maxillary molar. Bilateralism has been shown to be highly significant for both traits in both genders, which may reflect negligible environmental stresses facing the contemporary Jordanians and/or that this population has a pronounced ability to buffer the adverse effects of such stresses.

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REDUKCIJA ZUBNE KVRŽICE I CARABELLIJEVA SVOJSTVA KOD SUVREMENIH JORDANACA I POVEZANOST CARABELLIJEVOG SVOJSTVA I PRVOG TRAJNOG KUTNJAKA GORNJE ČELJUSTI

SAŽETAK

Cilj ove studije bio je utvrditi prevalenciju ekspresije i bilateralizma na temelju dvaju dentalnih morfoloških karakteristika: redukcije zubne kvržice na drugom trajnom kutnjaku gornje čeljusti i Carabellijevog svojstva na prvog i drugom trajnom kutnjaku gornje čeljusti. Nadalje, istražena je međusobna povezanost značajki te odnos Carabellijevog svojstva i gornjih trajnih kutnjaka. Ispitivano je tri stotine učenika prosječne dobi 15,5±0,4 godina. Uzeti su alginatni otisci maksilarnog luka i reproducirani su dentalni odljevi. Odabrani su ispravni odljevi 132 učenika i 155 učenica. Analizirane su frekvencije redukcije zubne kvržice drugog maksilarnog kutnjaka te Carabellijevog svojstva maksilarnih kutnjaka. Izmjeren i zabilježen je bukolingvalni i meziodistalni promjer prvog maksilarnog kutnjaka, a t-test i korelacijska analiza su korišteni pri obradi podataka. Redukcija zubne kvržice na drugom maksilarnom kutnjaku je utvrđena kod 29,8% ispitanika, a pozitivni oblici Carabellijevog svojstva su zapaženi u 65% ispitanika kod prvih kutnjaka i 3,8% kod drugih kutnjaka. Korelacijska analiza je otkrila pozitivnu korelaciju između Carabellijevog svojstva na prvom kutnjaku i redukcije zubne kvržice na drugom maksilarnom kutnjaku. Prisutnost Carabellijevog svojstva na prvom kutnjaku je u snažnoj korelaciji s povećanim bugolingvalnim, ali ne i meziodistalnim promjerom. Bilateralizam je jasno izražen kod testiranih svojstava u oba spola ($p<0,001$). Rezultati ove studije mogli bi biti znak niske razine stresa u svakodnevnom životu u jordanskoj populaciji i/ili sposobnosti pojedinaca da se nose s negativnim posljedicama svakodnevnog stresa.