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Multiple Lingual Cusps Trait on Mandibular Premolars and Hypoconulid Reduction Trait on Mandibular First Molar in Living Jordanian Population. Intra- and Inter-trait Interactions

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A B S T R A C T

The objective was to determine the expression and fluctuating asymmetry of two dental morphological traits in the living Jordanians: The lingual cusp number on the lower premolars (LP1 and LP2) and the hypoconulid (distal cusp) reduction on the lower first molar (LM1). In addition, both intra- trait and inter- trait interactions were analyzed. Three hundred school children (15.5± 0.4 years) were involved. Impressions for the mandibular dental arches were taken, and dental casts were reproduced. The above-mentioned traits were observed. Paired sample t test and nonparametric correlation analysis were used for data analysis. Three-cusped LP1 was found in 11.40 % of the examined students, while the two-cusped LP1 was found in 88.60%. In comparison, the Three-cusped LP2 was found in 61.40% while the two-cusped LP2 was found in 38.60% of the observed subjects. The frequencies of the 4-cusped and 5-cusped LM1 were found to be 8.65% and 91.35%, respectively. Nonparametric correlation analysis revealed positive and statistically significant association between the expression of two lingual cusps on LP1 and on LP2 in both genders ($p<0.01$), while there was no significant correlation between expression of two lingual cusps on either LP1 or LP2 and the hypoconulid loss on LM1 in both genders ($p>0.05$). Bilateralism was highly significant in the tested traits in both genders ($p<0.001$).This finding might be a sign of relatively low environmental stresses experienced by the living Jordanians and/or great ability of its individuals to buffer the adverse effects of such stresses on dental development. This study is a useful addition to the existing literature in that it examines a previously poorly characterized population and assists in placing the contemporary Jordanian population within the current framework of human population groups globally.

***Key words**: left-right fluctuating asymmetry, buccolingual diameter, mesiodistal diameter, sexual dimorphism, bilateralism*

Introduction

For ethnic, anthropological and forensic reasons, dental morphological traits were widely investigated and used to characterize major ethnic groups[1–4].

The human dentition was described as genetically conservative and exhibit little modification over many generations[5], thus teeth are utilized extensively for determining biological affiliation and genetic relationships between human populations and for the study of human ancestors[6–14]. Among other things, dental anthropology investigates the taxonomic usefulness of teeth, looking for dental metric and non-metric morphological features that could be helpful in delineating and distinguishing hominid taxa[15]. For example, lower premolars had been extensively utilized by anthropologists for this purpose since they were found to possess taxonomically discriminating characteristics among hominid groups[16–19].

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Dental morphological traits have been shown to be largely under the control of genes and minimally affected by environmental factors[11,20,21]. However, the general evolutionary trend in modern hominid dentition has been toward morphological simplification and tooth size reduction[5]. Examples of this trend include hypocone (distolingual cusp) reduction on upper molars, hypoconulid (distal cusp) reduction on lower molars, and decreased frequency and degree of expression of the accessory distolingual cusp on lower premolars[5].

From a developmental viewpoint, all mandibular molars have four major cusps and one minor cusp (the distal cusp or the hypoconulid).The mandibular first molar (LM1) predominantly exhibits five cusps, but less often has four cusps where the distal cusp (hypoconulid) is absent or markedly reduced. The frequency of five-cusped LM1 was found to be distinctly high in all human populations, ranging from 85–100%[22]. However, the Caucasian race typically exhibit a relatively higher rate of four-cusped LM1 (hypoconulid absence), ranging from 7.8–10%[22]. It has been suggested that reduction in cusp number is associated with reduction in the tooth crown size[23]. Accordingly, an investigation of the relationship between crown dimensions and cusp number of lower molars revealed that four-cusped lower molars have smaller mesiodistal diameters than five-cusped counterparts[23].

Mandibular premolars always display a single buccal cusp (protoconid) having a well-developed independent apex[24]. However, considerable variability takes place in the expression of the lingual cusp (or cusps)[24]. In case of multiple lingual cusps expression, one of these is designated the primary lingual cusp (metaconid or deuteroconid) while the other (or others) being regarded as the accessory lingual cusp (or cusps)[22]. It has been noted that the primary lingual cusp of lower premolars exhibits tendency toward having a mesial orientation in relation to the buccal cusp while additional lingual cusps are typically distal to this primary lingual cusp[22]. When having a single accessory lingual cusp, this cusp is usually smaller than but sometimes as big as and, less often, bigger than the primary lingual cusp[22].

The extensive variation in the occlusal morphology of lower premolars rendered them a subject of intensive investigation starting from general description of the crown morphologic features[25–27] to more focus on specific population groups[28–31].

Pedersen (1949)[28] looked at the number of cusps on the lower first premolar (LP1) among East Greenland Eskimos and reported that the expression of a single lingual cusp on this tooth appears to be the general rule. He claimed that the expression of multiple lingual cusps on this tooth is rarely observed among this population.

Kraus and Furr (1953)[29] studied the morphological variation of LP1; multiple features of this tooth were identified in a number of various ethnic groups, such as: Papago Indians, Caucasoid, Yaqui Indians, Mexicans, Chinese, and Negroes. Regarding the number of lingual cusps, at least one lingual cusp was assigned to each premolar even if the single lingual cusp is fused to the buccal cusp and lacks a free apex. According to their operational definition of an accessory cusp as an elevation exhibiting free apex, no matter how slight, two, three or four lingual cusps were also identified. However, only one example of five lingual cusps had been observed in their material.

Ludwig (1957)[30] described seven morphological traits of the lower second premolar (LP2) in four ethnic groups: Caucasoid, Mongoloid, Negroid and Caucaso-Mongoloid. The finding of his study showed apparent variation in the frequency of expression of multiple lingual cusps among these major population groups. In addition, this study revealed that predominant form of LP2 in all studied groups is the bicuspid form exhibiting a single lingual cusp.

Sexual dimorphism for dental morphological has been investigated by many workers and the reported results are conflicting. Some researchers found statistically significant male-female differences in the expression of some dental morphology traits[32–35], while others found no sex differences for these traits[36,37].

Considering the abovementioned studies and findings in different ethnic groups, it is very clear that total frequency and degree of expression of dental morphological traits show inter-population variations. 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, bilateralism and sexual dimorphism of two dental morphological traits: hypoconulid absence on the lower first molar and the expression of multiple lingual cusps on the lower premolars among the living Jordanian population, second, to test intra-trait and inter-trait correlations, and third, to analyze the relationship of these non-metric traits with the crown size of the corresponding 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 mandibular arches 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 eleven subjects were excluded due to technical errors such as; air bubbles and excessive trimming. The remaining casts were of 132 male- and 157 female students. Morphologic traits that were then observed included the lingual cusp number on the mandibular first and second premolars (LP1 & LP2) and the hypoconulid (distal cusp or cusp5) reduction trait on the mandibular first molar (LM1). All observations were carried out under good lighting and using 10x hand lenses.

The mandibular first molar was considered 4-cusped if the hypoconulid (distal cusp or cusp5) is absent or markedly reduced, and 5-cusped if the hypoconulid is distinctly present. Although the hypoconulid exhibits variation in size, most researchers focus on the frequency of 4-cusped or 5-cusped mandibular molars[24]. Absence (or marked reduction) of the hypoconulid was assigned grade 0 while presence of this trait was assigned grade 1. Lower premolars lingual cusp number was evaluated for the first and second lower premolars using the grade classification developed by Kraus and Furr (1953)[29] for LP1 and the one employed by Ludwig (1957)[30] for LP2. Because three or more lingual cusps were extremely rare or absent in the present sample, they were not observed and only two grades were used herein: grade 0, one lingual cusp; and grade 1: two lingual cusps. A lingual cusp for lower premolars is defined by Kraus and Furr (1953) [29] as having an independent apex that is easily distinguishable and may be palpated, no matter how slight. By convention, if a lower premolar demonstrates a single lingual cusp that is fused with the central occlusal ridge of the buccal cusp, thus lacking free apex, this fused cusp is, nevertheless, scored as one lingual cusp. Therefore, by definition, the minimum score assigned for any mandibular premolar is having one lingual cusp.

All observations for these two morphological traits (lingual cusp number on LP1 and LP2, and the hypoconulid reduction trait on LM1) were carried out by one well-trained observer. Intra-observer reliability for scoring these traits was assessed according to Nichol and Turner criteria (1986)[38]. 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 289 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% (lingual cusp number on LP1: 4.5%; lingual cusp number on LP2: 4.7%; and for hypoconulid reduction trait on LM1: 7.1%). In addition, the Net Mean Grade Difference (NMGD) between the two scoring sessions was calculated for both traits using the formula

$$\text{NMGD} = (\sum(X_2 - X_1)/n) \times 100$$

Where X_1 = the grade number assigned to a cast for a trait in the first scoring session; X_2 = 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 lower premolars lingual cusp number is 1 (grades 0–1; one vs. two lingual cusps) and for hypoconulid reduction trait is also 1 (grades 0–1; absence vs. presence), the critical level of NMGD for both traits is 5%. The calculated NMGD values for both traits considered here were found to be below the critical levels of NMGD for these traits (lingual cusp number on LP1: 2.1%; lingual cusp number on LP2: 2.4%; and for hypoconulid reduction trait on LM1: 3.7%). 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[38,39].

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[38].

Upon completion of the morphologic examination, metric measurements for LP1, LP2 and LM1 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 LP1, LP2 and LM1 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 in two ways: Firstly, by computing the standard deviation for the measurement error using the following formula based on Dahlberg statistics[40]:

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

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. Secondly, by calculating the Coefficient of reliability[41] using the following formula:

$$1 - S_e^2 / S_t^2$$

Where S_e^2 is the variance due to random errors, and S_t^2 is the total variance of the measurement. The result obtained with Dahlberg statistics was 0.14 and that of coefficient of reliability was 0.996. This indicated that the obtained results were reliable and the random errors in recording measurements were insignificant[23,42].

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 the living Jordanian population.

Descriptive statistics were also calculated for the BL and MD measurements including the range of measurements, minimum and maximum values, the mean, standard deviation, and skewness to examine natural distribution of obtained values.

Bilateralism of the tested morphological traits (lingual cusp number on LP1 and LP2, and the hypoconulid reduction trait on LM1) was examined by performing *t* test and calculating Spearman correlation coefficient (*r*). Nonparametric Correlation analysis (Spearman's correlation coefficient; *r*) was made and the *r* value was calculated to investigate the relationship between different traits. Similarly, the relationship between the tested non-metric traits and corresponding tooth crown diameters was tested. Independent Sample *t* test was used to test any significant difference in trait expression or teeth size between males and females. Significant p (<0.05) and positive *r* (between 0.00 and 1.00) values would indicate a stronger correlation or association.

Results

Table 1 summarizes the detailed prevalence of hypoconulid reduction trait on the LM1 and lingual cusp number on LP1 and LP2 regarding gender and location. The prevalence of two lingual cusps on LP1 was 11.40% in the Jordanian population, where males show a higher

TABLE 1
FREQUENCIES (%) OF EXPRESSION OF TWO LINGUAL CUSPS ON LP1 AND LP2, AND OF HYPOCONULID ABSENCE ON LM1 (4-CUSPED LM1)

	% Males (N=132)			% Females (N=157)			Z-Values	% Total (pooled) (N= 289)		
	Right	Left	Average	Right	Left	Average		Right	Left	Average
LP1-2LC	15.20	15.20	15.20	8.30	7.00	7.65	2.0289	11.75	11.10	11.4
LP2-2LC	62.90	59.80	61.35	63.10	59.90	61.50	–0.002615	63.00	59.85	61.4
LM1-4C	7.60	5.30	6.45	11.50	10.20	10.85	–1.3083	9.55	7.75	8.65

N: Absolute number of subjects, LP1-2LC: Lower first premolar exhibiting two lingual cusps, LP2-2LC: Lower second premolar exhibiting two lingual cusps, LM1-4C: 4-cusped lower first molar (hypoconulid absence). Z-values are for comparing the average percentages in males with those of females (absolute Z-values >0.95 is considered statistically significant).

TABLE 2
DESCRIPTIVE DATA ANALYSIS FOR BUCCOLINGUAL AND MESIODISTAL MEASUREMENTS (mm) OF LP1, LP2 AND LM1 IN MALES

	N	Range	Minimum	Maximum	Mean		STD	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error
BLD LP1-R	132	2.95	6.75	9.70	8.0247	0.05268	0.60526	0.147	0.211
BLD LP1-L	132	3.38	6.57	9.95	8.0475	0.05884	0.67607	0.214	0.211
BLD LP2-R	132	3.40	6.97	10.37	8.7522	0.05333	0.61267	0.128	0.211
BLD LP2-L	132	3.04	7.34	10.38	8.7689	0.05387	0.61891	0.186	0.211
BLD LM1-R	132	3.88	8.37	12.25	10.8719	0.05483	0.62995	–0.288	0.211
BLD LM1-L	132	2.91	9.67	12.58	10.8736	0.04803	0.55180	0.308	0.211
MDD LP1-R	132	2.31	6.05	8.36	7.1719	0.03864	0.44398	0.234	0.211
MDD LP1-L	132	2.16	6.26	8.42	7.2126	0.04016	0.46145	0.347	0.211
MDD LP2-R	132	2.72	6.05	8.77	7.1813	0.04413	0.50707	0.245	0.211
MDD LP2-L	132	2.90	6.03	8.93	7.2233	0.04238	0.48687	0.441	0.211
MDD LM1-R	132	3.46	9.70	13.16	11.1732	0.05091	0.58494	–0.077	0.211
MDD LM1-L	132	3.31	9.85	13.16	11.2786	0.04993	0.57369	–0.071	0.211
Valid N (listwise)	132								

N: Absolute number of subjects, STD: standard deviation, Std.: Standard, BLD: Buccolingual diameter, MDD: Mesiodistal diameter, LP1: Lower first premolar, LP2: Lower second premolar, LM1: Lower first molar, R: Right, L: Left.

TABLE 3
DESCRIPTIVE DATA ANALYSIS FOR BUCCOLINGUAL AND MESIODISTAL MEASUREMENTS (mm) OF LP1, LP2 AND LM1 IN FEMALES

	N	Range	Minimum	Maximum	Mean		STD	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error
BLD LP1-R	157	2.61	6.73	9.34	7.8663	0.03828	0.47962	0.285	0.194
BLD LP1-L	156	3.31	5.91	9.22	7.9046	0.03921	0.48979	–0.457	0.194
BLD LP2-R	156	2.93	6.97	9.90	8.5481	0.04041	0.50475	–0.033	0.194
BLD LP2-L	157	3.09	6.96	10.05	8.5664	0.04336	0.54332	–0.170	0.194
BLD LM1-R	156	2.46	9.37	11.83	10.5772	0.03903	0.48753	0.004	0.194
BLD LM1-L	155	2.60	9.16	11.76	10.5440	0.03971	0.49440	–0.094	0.195
MDD LP1-R	157	2.27	5.73	8.00	6.9931	0.03168	0.39699	–0.021	0.194
MDD LP1-L	157	2.02	6.07	8.09	7.0099	0.03127	0.39177	0.084	0.194
MDD LP2-R	157	2.50	6.01	8.51	7.0053	0.03550	0.44478	0.283	0.194
MDD LP2-L	157	2.15	6.18	8.33	7.0645	0.03383	0.42388	0.174	0.194
MDD LM1-R	157	2.83	9.52	12.35	10.8738	0.04413	0.55292	–0.094	0.194
MDD LM1-L	157	2.45	9.11	11.56	10.2055	0.03683	0.46149	0.251	0.194
Valid N (listwise)	153								

N: Absolute number of subjects, STD: standard deviation, Std.: Standard, BLD: Buccolingual diameter, MDD: Mesiodistal diameter, LP1: Lower first premolar, LP2: Lower second premolar, LM1: Lower first molar, R: Right, L: Left.

prevalence of two lingual cusps on LP1 (15.20%) than females (7.65%). On the other hand, the prevalence of two lingual cusps on LP2 was 61.40% with similar rates in both males (61.35%) and females (61.50%). A low prevalence of four cusped LM1 (hypoconulid absence or marked reduction) was observed (8.65%), where females display a higher incidence of four-cusped LM1 (10.85%) than males (6.45%). (Table 1)

Descriptive data analyses for the BL and MD diameters of the examined teeth (LP1, LP2 and LM1) were calculated for both genders. Skewness of MD and BL measurements indicated normal distribution for the data observed (Skewness <1.0). (Table 2 and 3)

Nonparametric correlation analysis (Spearman's correlation coefficient; r) revealed that the expression of two lingual cusps on LP1 was positively and significantly correlated to the expression of two lingual cusps on LP2 in both genders ($p<0.01$), and to the BL and MD diameters of LP1 in males ($p<0.01$) but insignificantly in females ($p>0.05$). On the other hand, this trait was weakly and insignificantly correlated to the hypoconulid absence on LM1 in both sexes ($p>0.05$). (Table 6)

The presence of two lingual cusps on LP2 was positively and significantly correlated to the BL and MD diameters of this tooth in both males and females ($p<0.05$). On the other hand, this trait was negatively but insignificantly correlated to the hypoconulid absence on LM1 in both genders ($p>0.05$). (Table 6)

The hypoconulid absence on LM1 was negatively and significantly correlated to the MD diameter of this tooth in females ($p<0.05$) but insignificantly in males ($p>0.05$). By contrast, this trait was insignificantly correlated to the BL diameter of this tooth in both sexes ($p>0.05$). (Table 6)

Bilateralism was found strong and highly significant in all the observed morphological traits and in both genders ($p<0.001$), with high positive values of Spearman's Correlation Coefficient ranging from 0.699 to 0.941 (Table 4).

TABLE 4
BILATERALISM OF EXPRESSION OF TWO LINGUAL CUSPS ON LP1 AND LP2, AND OF HYPOCONULID ABSENCE ON LM1 (4-CUSPED LM1) DEMONSTRATED BY t TEST

	Spearman's Correlation Coefficient	Significance (2-tailed)	df
LP1-2LC right and left	0.941[a]	0.000	289
LP2-2LC right and left	0.810[a]	0.000	289
LM1-4C right and left	0.699[a]	0.000	289

[a] Correlation is significant at the 0.01 probability level.
LP1-2LC: Lower first premolar exhibiting two lingual cusps, LP2-2LC: Lower second premolar exhibiting two lingual cusps, LM1-4C: 4-cusped lower first molar (hypoconulid absence).

Significant sexual dimorphism was observed in the prevalence of hypoconulid absence on LM1 and of the expression of two lingual cusps on LP1 (z-value>0.95), but not on LP2 (z-value<0.95), as illustrated with the trait data in Table 1. On the other hand, sexual dimorphism was observed significantly with regard to tooth size where males have significantly larger BL and MD dimensions for the examined teeth herein (LP1, LP2 and LM1). (Table 5)

TABLE 5
SEXUAL DIMORPHISM IN CROWN DIMENSIONS DEMONSTRATED BY INDEPENDENT SAMPLES TEST

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
BLD-LP1-R	Equal variances assumed	7.868	0.005	2.481	287	0.014	0.15839	0.06384	0.03274	0.28404
	Equal variances not assumed			2.432	247.829	0.016	0.15839	0.06512	0.03013	0.28665
BLD-LP1-L	Equal variances assumed	15.892	0.000	2.075	286	0.039	0.14295	0.06889	0.00734	0.27855
	Equal variances not assumed			2.021	234.161	0.044	0.14295	0.07071	0.00363	0.28227
BLD-LP2-R	Equal variances assumed	4.215	0.041	3.100	286	0.002	0.20412	0.06585	0.07451	0.33373
	Equal variances not assumed			3.051	253.902	0.003	0.20412	0.06691	0.07235	0.33589
BLD-LP2-L	Equal variances assumed	2.084	0.150	2.961	287	0.003	0.20251	0.06838	0.06792	0.33710
	Equal variances not assumed			2.928	263.026	0.004	0.20251	0.06915	0.06634	0.33867
BLD-LM1-R	Equal variances assumed	5.621	0.018	4.472	286	0.000	0.29471	0.06591	0.16499	0.42444
	Equal variances not assumed			4.379	244.379	0.000	0.29471	0.06731	0.16214	0.42729
BLD-LM1-L	Equal variances assumed	1.479	0.225	5.335	285	0.000	0.32956	0.06177	0.20797	0.45115
	Equal variances not assumed			5.288	265.704	0.000	0.32956	0.06232	0.20686	0.45226
MDD-LP1-R	Equal variances assumed	1.948	0.164	3.612	287	0.000	0.17877	0.04949	0.08136	0.27618
	Equal variances not assumed			3.577	265.549	0.000	0.17877	0.04997	0.08038	0.27716
MDD-LP1-L	Equal variances assumed	4.740	0.030	4.038	287	0.000	0.20264	0.05019	0.10386	0.30142
	Equal variances not assumed			3.981	258.244	0.000	0.20264	0.05090	0.10241	0.30287
MDD-LP2-R	Equal variances assumed	4.412	0.037	3.143	287	0.002	0.17600	0.05600	0.06578	0.28623
	Equal variances not assumed			3.107	262.916	0.002	0.17600	0.05664	0.06448	0.28752
MDD-LP2-L	Equal variances assumed	1.156	0.283	2.964	287	0.003	0.15880	0.05358	0.05334	0.26426
	Equal variances not assumed			2.929	261.865	0.004	0.15880	0.05422	0.05203	0.26557
MDD-LM1-	Equal variances assumed	0.703	0.402	4.466	287	0.000	0.29942	0.06705	0.16746	0.43139
	Equal variances not assumed			4.444	272.575	0.000	0.29942	0.06737	0.16678	0.43206
MDD-LM1-L	Equal variances assumed	4.149	0.043	17.618	287	0.000	1.07302	0.06090	0.95314	1.19289
	Equal variances not assumed			17.294	250.141	0.000	1.07302	0.06205	0.95082	1.19522

BLD: Buccolingual diameter, MDD: Mesiodistal diameter, LP1: Lower first premolar, LP2: Lower second premolar, LM1: Lower first molar, R: Right, L: Left.

Discussion

This study revealed that the frequency of expression of two lingual cusps on the LP1 is relatively low among the Jordanian population, accounting for 11.4%. The literature on the frequency of expression of multiple lingual cusps on this tooth is scarce, especially in recent or living human populations, probably because the focal tooth used for observing this trait for the purpose of population comparisons is LP2[22]. However, Pedersen (1949)[28] examined this trait on LP1 among East Greenland Eskimos and reported that the expression of a single lingual cusp on this tooth appears to be the general rule. He also claimed that the expression of multiple lingual cusps on this tooth is rarely observed among this population. In addition, he pointed out that Eskimo and Whites are almost identical in the expression of this trait[28]. Another study on the Thai tribe, which belongs to the principal ethnic group of Southeast Asia and has the Sundadont characteristics typical of this population group, found that frequency of expression of two lingual cusps on LP1 was 17.7% among this group[43]. Bailey (2002b)[44] reported the following rates for the expression of multiple lingual cusps on LP1 as characteristic of the following contemporary human populations based on the observation of archaeologically derived skeletal remains: Near Eastern represented by skeletal populations from Jericho and Tel Hesi (50.0%), Australasian represented by Australian aboriginals and New Guineans (43.8%), Europeans (40.0%), West Africans (21.1%), Indians (20%), North Africans (19.0%), and Northeast Asian (9.1%). Our finding does not agree with the frequency of this trait reported by Bailey (2002b) for Near Eastern, probably because the living Jordanian population is genetically not so related to the skeletal populations of Jericho and Tel Hesi. This might indicate that significant admixture (gene flow) has taken place in the Middle/ Near East population. Although our finding for this trait is closest to the frequency reported in Northeast Asians (Sinodonty), the implication of that is unclear. As Jordan and the Middle/Near East, in general, have not been subject to considerable migration from the Mongoloid race, this character cannot be considered as a Sinodont/ Mongoloid feature of the living Jordanian population. It is noteworthy that this trait appears to shows considerable geographic variation among contemporary human populations, thus may serve, in combination with other dentomorphic traits, as a good discriminator between various contemporary ethnic groups.

The results of this study revealed that the expression of two lingual cusps on LP2 was relatively high among the living Jordanian population, accounting for 61.4%. One study on Singaporean Chinese, who belong to the Sinodont dental group, reported that the prevalence of the three-cusped LP2 (two lingual cusps) was relatively low, accounting for 25.4%, and the two-cusp form (single lingual cusp) was the dominant one (66.3%) among this group[31]. Another study on the Thai tribe found that frequency of expression of two lingual cusps on LP2 was as high as 86.6% among this group[43]. Ludwig (1957)[30] reported the following frequencies for the expression of a single, double and triple lingual cusps, respectively, on LP2 in the following major ethnic groups: Caucasoid (60.1, 39.2 and 0.9%), Mongoloid (91.0, 9.0, and 0.0%), Negroid (52.8, 41.7 and 5.5%) and Caucaso-Mongoloid (65.2, 34.8, and 0.0%). Bailey (2002b)[44] reported the following frequencies for the expression of multiple lingual cusps on LP2 as characteristic of the following contemporary human populations: Australasian (87.5%), West Africans (63.2%), North Africans (58.8%), Europeans (55.9%), Northeast Asian (50.0%), Near Eastern represented by skeletal populations from Jericho and Tel Hesi (40.0%), and Indians (20.0%). Our finding for this trait is inconsistent with both Ludwig's report for the Caucasoid race and Bailey's finding for the Near East contemporary skeletal population. Again, this might indicate that the living Jordanian population is genetically not so related to the skeletal populations of Jericho and Tel Hesi. In contrast, our finding for this trait is closest to the frequency reported in North Africans and West Africans, however, the implication of that is unclear. The close similarity in the prevalence of this trait among the living Jordanians to that of the North Africans is consistent with their shared origins since they both belong to the same race (the Caucasoid race), while the similarity to that of West Africans who belong to the Negroid race is more difficult to reconcile and might be just a coincidence.

The prevalence of hypoconulid absence/ marked reduction trait on LM1 (4-cusped type) was relatively high, accounting for 8.65% among the living Jordanian population, given that this study is the first of its type to be conducted on a Jordanian sample. This finding is comparable to the published reports which showed that five-cusped LM1s (hypoconulid presence) are found in high frequency in all studied population groups, ranging from 85% to 100%[22]. Bailey (2000)[45] cited the following rates for hypoconulid absence on LM1 as typical of the following contemporary human populations: North Africans (7.7%), Northwest Europeans (6.9%), and the English (9.2%). Scott and Turner (1997)[22] cited the following frequencies for the prevalence of 4-cusped LM1 as characteristic of the following human populations: 7.8–10.0% for Western Eurasians including West and North Europeans and North Africans; 0.0–1.2% for sub-Saharan Africans including South and West Africans and Khoisans; 0.0–3.1% for Sino-Americas (Asian and Asian-derived) populations including Mongolian Chinese, Jomon (Prehistoric Japanese), Recent Japanese, Northwest and South Siberians, and North and South American Indians; 0.0–1.2% for Sunda-Pacific populations including Southeast Asians, Polynesians and Micronesians; and 0.4–4.5% for Sahul-Pacific populations including Australian Aboriginals, Melanesians and New Guineans. Our result for hypoconulid absence trait on LM1 in the living Jordanians (8.65%) is best comparable to the frequency of this trait in Western Eurasians including West and North Europeans (7.8% and 10.0%, respectively) and North Africans (10.0%), apparently because all these population groups belong to the same ethnic line, the Caucasian race. Generally speaking, the geographic pattern of hypoconulid trait appears not to be very clear and at least in forensic dentistry demands using a set of traits, rather than relying on a single one, is the preferred strategy for racial 'diagnosis'. However, it appears that the frequency of 4-cusped LM1 (hypoconulid absence) is distinctly higher in Western Eurasians than in other major ethnic groups, which possibly reflects that Caucasians are less retentive of the primitive form of the mandibular first molar (5-cusped form/hypoconulid retention) than other human races. Thus, it could be concluded that Caucasians more often express the more derived four cusp form LM1.

This study revealed that there is apparent and significant sexual dimorphism for the prevalence of multiple lingual cusps on LP1, but not on the LP2 (LP1-2LC: 15.20% in males vs. 7.65% in females, z-value: 2.0289; LP2-2LC: 61.35% vs. 61.50%, z-value: –0.002615). It also showed statistically significant difference between males and females in the frequency of hypoconulid loss (the occurrence of 4-cusps) on LM1 (LM1-4C: 6.45% in males vs. 10.85% in females, z-value: –1.3083). It seems that there are differences among populations since some researchers found statistically significant male-female differences in the expression of some dental morphologic traits[32–35] while others found no sex differences for these traits[36,37].

In the present study, data analysis demonstrated that bilateralism is highly significant for the tested morphological traits in both genders (Table 4). Left-right fluctuating asymmetry in the expression of dental morphological traits has been shown to be a reflection of environmental stresses such as disease and malnutrition during tooth development in non-primates[46–50], primates[51,52] and humans[53–55]. Thus, it could be inferred that the living Jordanian population have not been experiencing profound environmental stresses and/or that this population has a pronounced ability to buffer against the adverse effects of such stresses on the development of the dentition.

Regarding tooth diameter measurements carried out on LP1, LP2 and LM1 the results emphasized the size difference between both genders, where males have significantly greater BL and MD diameters of these teeth than females (Table 5). The relatively smaller female teeth size could possibly contribute to the lower frequency of expression of an accessory distolingual cusp on LP1 and to the higher prevalence of hypoconulid absence on LM1 in females. The apparent size dimorphism between males and females could possibly contribute to morphologic dimorphism between genders. However, the finding of this study opposes the result obtained from another study on Jordanian school children which showed that there were no significant differences in the teeth size between males and females[56]. This difference might be related to differences in sample size and test methodologies that have been used.

A positive and significant association between the expression of two lingual cusps on LP1 and LP2 was demonstrated in both genders. This finding is reasonable since we are looking at the relationship among the same trait (multiple lingual cusp expression) within the same dental field (the lower premolar field).As a rule, within-field correlations are positive and statistically significant across different dental morphologic traits, suggesting a common genetic basis for variation of each trait within a tooth class. The results, also, showed that the expression of two lingual cusps on either LP1 or LP2 was not significantly correlated to the hypoconulid absence on LM1 in both sexes. This finding, initially, seems incompatible with the general evolutionary trend in the human dentition toward tooth size reduction and morphological simplification[57–59]. If all teeth types display this trend to the same extent, it would be expected to find negative and statistically significant correlation between the expression of an accessory distolingual cusp on either LP1 or LP2 and the hypoconulid absence on LM1. However, it seems that various teeth exhibit different degrees of such a trend toward reduction in size and morphological simplification, reflecting variation in genotypic and phenotypic stability between various teeth. According to Butler's morphogenetic field model[60] and Osborn's clone model[61], the LM1 is considered the key or pole tooth of the molar/premolar dental field and the premolar class is considered as an anterior extension to the molar field where LP1 is the farthest tooth from the focal LM1 of this field. Therefore, LM1 is hypothesized to possess greater phenotypic stability and less variability than LP2, and the latter is more stable than LP1.

The BL and MD diameters of LP2 were positively and significantly correlated to the expression of two lingual cusps on this tooth in both genders. While the results show positive and statistically significant association between both crown diameters of LP1 and the expression of two lingual cusps on this tooth in males, but not in females, suggesting sexual dimorphism in the correlation between metric and non-metric traits for this tooth type among the living Jordanians. On the other hand, The MD diameter of LM1 was negatively and significantly correlated to hypoconulid absence on this tooth in females, but not in males. In comparison, the BL dimension of LM1 was found to be uncorrelated to hypoconulid absence on this tooth in both sexes. The latter two findings are consistent since the hypoconulid cusp is present in the MD axis of LM1, thus the loss of this cusp would be expected to decrease the MD and not to affect the BL dimension of this tooth. This result has also been reported by Dahlberg (1961)[23] who stated that four-cusped lower molar teeth are smaller in their mesiodistal dimension than the five-cusped counterparts. However, it is unclear why the MD dimension of LM1 was unaffected by hypoconulid absence on this tooth in males. However, according to Dahlberg's opinion: »Although it is not necessary to show a statistically significant relationship in every instance of comparison, such a consideration of size and pattern is helpful in clarifying and evaluating the general evolutionary trends occurring in the permanent lower molar teeth of modern hominid populations«[23].

In the present study, the expression of two lingual cusps differs significantly between second and first lower premolars (males 61.35% LP2 vs. 15.20% LP1, z-value: 7.702; females 61.50% vs. 7.65%, z-value: 10.002). This apparent within field differences between first and second premolars 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 and that the phenotypic stability of a particular tooth type is directly correlated to its closeness to the key or pole tooth of the organizational dental field to which the tooth belongs[60]. According to Butler's field model LP1 and LP2 belong to the anterior extension of the molar field whose key tooth is LM1, where LP2 is closer than LP1 to the key tooth of this field[60]. Moreover, this apparent intra-trait intra- field difference between LP1 and LP2 is consistent with Osborn's clone model which postulates that the differences in teeth morphology is 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, where the derived dental primordium (LP1) developing farther from the central proliferative pole (LM1) of a clonal segment (molar/premolar segment) exhibits less phenotypic stability than the closer primordium (LP2) because it has undergone more mitotic divisions[61].

Given the emphasis on tooth morphology as an indicator of racial origin, it is noteworthy to indicate that Jordanian population is genetically stable and mainly of middle-Eastern Arab descent. Finally it should be emphasized that the limitations of using small number of tooth morphology markers in determining or analyzing racial affinities make it difficult to reach a conclusion about the racial origin of the study population. This might be overcome by increasing the number of dental morphology traits that exhibit inter-population variation.

Conclusion

Within the Limitations of this study, it was found that the living Jordanian population has a comparatively high prevalence of the multiple lingual cusps on LP2 (61.4%). This is consistently closest to the reported frequencies in contemporary North Africans (58.8%) and Europeans (55.9%), but, although hard to reconcile, close to sub-Saharan Africans (63.2%). In contrast, the prevalence of this trait on LP1 was found to be distinctly low (11.4%); surprisingly much lower than the reported rates for this trait in contemporary Near Eastern (50.0%), Europeans (40.0%) and North Africans (19.0), and closest, possibly coincidentally, to Northeast Asians (9.1%). On the other hand, hypoconulid absence on LM1 (4-cusped type) was found to be relatively high among the living Jordanian population (8.65%), which is best comparable to the frequency of this trait in Western Eurasians including West and North Europeans (7.8% and 10.0%, respectively) and North Africans (10.0%), apparently because all these population groups belong to the same race, the Caucasian. The BL and MD diameters were positively and significantly associated with the expression of multiple lingual cusps on the LP2 in both genders, but only in males for LP1. Significant male-female differences have been shown regarding the prevalence of hypoconulid loss on LM1 and the expression of multiple lingual cusps on LP1, but not on LP2. Bilateralism has been shown to be highly significant for the studied morphological traits in both genders, which may reflect negligible environmental stresses facing the living Jordanians and/or that this population has a pronounced ability to buffer the adverse effects of such stresses on dental development.

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VIŠESTRUKE LINGVALNE KVRŽICE DONJIH PREMOLARA I HIPOKONULIDNA REDUKCIJA NA PRVIM MANDIBULARNIM KUTNJACIMA MEĐU SADAŠNJOM JORDANSKOM POPULACIJOM

S A Ž E T A K

Cilj je bio utvrditi ekspresiju i flukturirajuću asimetriju dvaju dentalnih morfoloških obilježja među današnjim jordancima: broj lingvalnih kvržica na donjim pretkutnjacima (LP1 i LP2) i hipokonulidnu (distalne kvržice) redukciju na donjem prvom kutnjaku (LM1). Tri stotine školske djece (15,5 ± 0,4 godina) bilo je uključeno u istraživanje. Uzeti su otisci donje čeljusti zubnih lukova te su napravljeni zubni odljevi. LP1 s tri kvržice pronađen je u 11,40 % pregledanih učenika, dok je LP1 s dvije kvržice pronađen u 88,60 %. Za usporedbu LP2 s tri kvržice pronađen je u 61,40 %, dok je LP2 s dvije kvržice pronađen u 38,60 % slučajeva. Frekvencije LM1 s četiri i pet kvržica su 8,65 % i 91,35 %, respektivno. Analiza neparametrijske korelacije otkrila je pozitivnu i statistički značajnu povezanost između ekspresije dviju lingvalnih kvržica na LP1 i LP2 u oba spola ($p < 0,01$), dok nije bilo značajne korelacije između ekspresije dviju lingualnih kvržica na LP1 ili LP2, ili hipokonulidne redukcije na LM1 u oba spola ($p>0,05$). Bilateralizam je bio vrlo značajan za ispitivane osobine u oba spola ($p<0,001$). Ovo otkriće moglo bi biti znak relativno niskih ekoloških stresova jordanskog stanovništva. Ova je studija koristan dodatak na postojeću literaturu u kojoj se do sada nije ispitivala ova populacija.