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MORPHOMETRIC VARIABLES OF DEVELOPING PRIMARY MAXILLARY FIRST MOLAR CROWNS IN HUMANS

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Summary—The following morphometric variables were examined in 18 primary maxillary first molars at various stages of development, collected from archaeological excavation sites in Israel: perimeters and areas from the occlusal view; buccolingual and mesiodistal dimensions and intercusp distances; the angle between the line joining the distobuccal, mesiobuccal and lingual cusps; and the height of the mesiobuccal cusp. An image-analysing technique comprising a photographic camera, a monitor, a computer with appropriate software and a digital caliper was used. Significant correlations were demonstrated between most variables. Teeth were divided into two groups according to their stage of development: stage one included all teeth at an early stage of development in which mesiobuccal cusp height was less than 5 mm; stage two included all teeth in later stages of development where mesiobuccal cusp height was greater than 5 mm. All external variables showed an increase in size between the two stages (while, among the internal ones, only the angle between the cusps showed a very small increase). The small sample is a limitation but the results suggest the following: (1) growth of the primary maxillary molar crown occurs with 'bursts' of development ; and (2) a change in the shape of the crown occurs during its formation where the mesiobuccal cusp moves buccally and distally, and the lingual cusp moves mesially. © 1997 Elsevier Science Ltd

Key words: Morphometrics, primary first molars, crown, intercusp distances.

INTRODUCTION

The final size and shape of a tooth crown is the end result of a long developmental process starting with the initiation of a tooth germ, the proliferation of cells of the internal enamel epithelium, and their subsequent differentiation into ameloblasts, the enamel-producing cells (Kraus and Jordan, 1965). With respect to this, intercusp distances are important in understanding the overall development of the teeth, as enamel deposition is initiated at the ameloblast–odontoblast interface at the sites of future cusp tips. Several studies have attempted to investigate quantitatively the various morphological variables of the tooth crown (Lesterel, 1974; Corrucini and Potter, 1981; Townsend, 1985). Researchers have attempted to explain the morphological changes in the tooth crown by a mathematical framework such as the 'morphologic triangle' (Keene, 1982). The rationale behind the theory was that there must be a fixed pattern for tooth formation along the lines as reported by Butler (1963).

Previous studies have proposed a gradient in cusp development of the maxillary first permanent molar, where the mesiodistal portion always develops ahead (in order and in shape) of the distolingual portion (Butler, 1967, 1968). Butler found that the intercusp distances of this tooth increased during development. This was explained as being due to the continued growth of the inner enamel epithelium into the fissures between the cusps, so that an increase in intercusp distances occurred even after calcification had begun in the cusp tips. According to this theory, the distances between cusp tips are stable only after the slopes of the cusps are calcified and the epithelium does not proliferate into the fissures any more. Butler suggested that increased divergence between cusp tips follows continued enamel apposition, because of divergence between them. This has recently been confirmed by serial computerized tomographic studies, which demonstrated differences in angulations between cusps (Smith *et al.*, 1997). A study on the primary mandibular second molar demonstrated no increase in the intercuspal distances during tooth development between the ages of 0 to 1.5 years, as deter-

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mined by the height of the mesiobuccal cusp (Peretz and Smith, 1993).

Our purpose now was to examine some morphometric variables, and the relations between them, in developing crowns of the maxillary first primary molar.

MATERIALS AND METHODS

Eighteen primary maxillary first molars at various stages of development were examined. The teeth were well preserved, of children aged 0–1.5 years, from various archaeological excavations in Israel, and were dated 300 BC. All teeth were unerupted, and were removed from the jaws for examination. Teeth were graded according to crown height development and cuspal bridging, and this was used as an estimate of chronological age after Kraus and Jordan (1965). Six teeth had three cusps (mesiobuccal, distobuccal and lingual), while the others had two cusps (mesiobuccal and lingual). Figure 1 shows the typical cusp arrangement of two- and three-cusp primary maxillary first molars in our sample.

The following variables were examined on the teeth.

1. The distance between:
   (i) the mesiobuccal (mb) and lingual (l) cusps (ML);
   (ii) the distobuccal (db) and the lingual (l) cusps (DL); and
   (iii) the mb and db cusps (MB).
2. The angle between the db, mb and l cusps (>mb).
3. Maximal perimeter of the tooth crown from occlusal view (mp).
4. Maximal area from occlusal view (ma).
5. Maximal perimeter of the occlusal table (op).
6. Maximal area of the occlusal table (oa).
7. Maximal mesiodistal (md) and buccolingual (bl) dimensions.
8. Mesiobuccal cusp height from cusp tip to edge of enamel (mbh).

The methods of measurement were previously described in detail (Peretz and Smith, 1993; Peretz *et al.*, 1996). In brief, all the variables except the >mb were measured with an image-analyser computer program (CUE 4; Galai Co., Migdal HaEmek, Israel). A digital caliper with an accuracy of 0.01 mm (Beerendonk; Dentaurum Co., U.S.A.) was used to measure the mesiobuccal cusp height from the cusp tip to the lowest border of the enamel (or cementum–enamel junction if the crown was complete). All measurements were made by one observer (N.N.). In order to determine intraobserver variation, 20 teeth were measured three times, and the percentage mean difference between measurements was 1.68%. A correlation analysis was used to examine any association between the variables. Scatter plots showed that variables separated into two stages of development according to a mesiobuccal cusp height of greater or less than 5 mm. The Wilcoxon matched-pair test was used later to compare variables in each stage of development. The level of significance was chosen at $p < 0.05$.

RESULTS

There was no significant difference between teeth with two cusps and teeth with three cusps in any of the variables; therefore the scores for both types of teeth were pooled. Table 1 shows the means and SDs of the variables for the first primary molar in stage 1 and stage 2 (see below) of crown development, and for the total developmental process. All external variables demonstrated an increase in

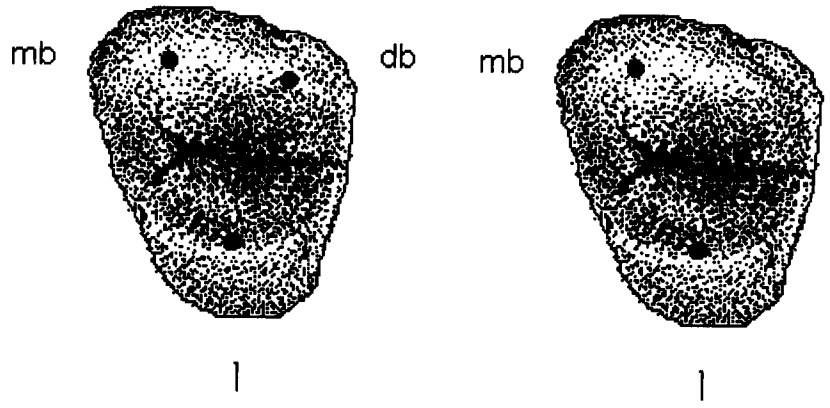

Fig. 1. Three-cusp (left) and two-cusp (right) primary maxillary first molars (abbreviations explained in text).

Table 1. Means and SD of the variables at each developmental stage and for the total process (all in mm except >mb in degrees)

Variable	Stage	*n*	Mean	SD	Minimum	Maximum	*p*
MB	1	3	3.05	0.48	2.5	3.4	0.028
	2	3	3.16	0.38	2.85	3.59	
	Total	6	3.11	0.40			
ML	1	9	4.23	0.29	3.91	4.84	0.000
	2	9	4.75	0.24	4.27	5.02	
	Total	18	4.50	0.38			
DL	1	3	4.2	0.4	3.85	4.65	0.027
	2	3	4.32	0.77	3.52	5.06	
	Total	6	4.26	0.56			
>mb	1	3	67.18	11.87	56.53	79.98	0.028
	2	3	63.87	14.34	51.61	79.63	
	Total	6	65.52	11.91			
mp	1	10	25.75	2.06	22.83	28.49	0.000
	2	8	29.08	1.11	27.22	30.5	
	Total	18	27.23	2.38			
ma	1	9	39.32	4.62	33.71	45.28	0.000
	2	9	52.34	3.78	47.98	59.68	
	Total	18	45.83	7.86			
op	1	9	19.38	2.15	16.41	22.67	0.000
	2	9	20.97	0.95	19.69	22.22	
	Total	18	20.17	1.82			
oa	1	9	21.87	4.17	16.61	28.69	0.000
	2	9	26.82	1.91	23.11	28.84	
	Total	18	24.35	4.05			
bl	1	9	7.14	0.5	6.34	7.87	0.000
	2	9	8.54	0.72	7.12	9.35	
	Total	18	7.84	0.94			
md	1	9	7.08	0.53	6.8	8.3	0.000
	2	9	7.69	0.68	7.12	9.2	
	Total	18	7.38	0.66			
mbh	Total	18	5.20	0.88			

ML, mesiobuccal (mb) and lingual (l) cusps; DL distobuccal (db) and l cusps; MB, mb and db cusps; >mb, angle between db, mb and l cusps; mp, maximal perimeter of tooth crown from occlusal view; ma, maximal area from occlusal view, op, maximal perimeter of occlusal table; oa, maximal area of occlusal table; md, maximal mesiodistal dimensions; bl, maximal buccolingual dimensions; mbh, mesiobuccal cusp height from cusp tip to edge of enamel.

dimensions, whereas among the internal ones there was a significant increase in the ML distance only. The mb angle (>mb) demonstrated a very small increase throughout crown formation. A slight increase in the DL distance was noted. A statistically significant difference between stage 1 and stage 2 was indicated in the following variables: ML, mp, ma, oa, bl, and md ($P < 0.05$). Figure 2 shows diagrams of the correlation between mbh and MB, ML, DL, bl and md. According to the stage of development, teeth were divided into two groups:

1. Stage 1—included all teeth at an early stage of development in which mbh was less than 5 mm.
2. Stage 2—included all teeth in later stages of development, where mbh was greater than 5 mm.

Table 2 shows a correlation matrix for all the measurements. The variables, mp, ma, op, oa, bl, md and mbh demonstrated strong and significant correlations. Significant correlations were also found between ML and most other variables except MB and DL.

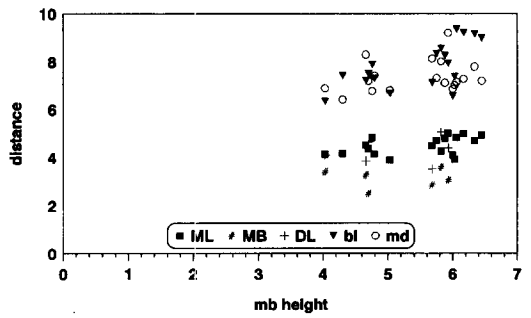

Fig. 2. Diagram of the correlations between mbh and MB, ML, bl and md (abbreviations explained in text). Note the two stages of development: stage 1 includes all teeth at an early stage of development in which mbh is less than 5 mm; stage 2 includes teeth at later stages of development where mbh is greater than 5 mm.

DISCUSSION

We found no differences in total size or shape between teeth with two cusps and teeth with three cusps, indicating that the number of cusps does not affect the final dimensions of tooth crowns. Strong correlations were noted between the external

Table 2. Correlation matrix for variables

	MB	ML	DL	>mb	mp	ma	op	oa	bl	md	mbh
MB	1										
ML	0.28	1									
DL	0.20	0.12	1								
>mb	0.01	0.42	0.91	1							
mp	0.19	0.78	0.41	0.12	1						
ma	0.08	0.81	0.30	0.03	0.98	1					
op	0.14	0.69	0.13	0.08	0.77	0.71	1				
oa	0.27	0.81	0.13	0.12	0.92	0.89	0.93	1			
bl	0.13	0.34	0.71	0.47	0.84	0.80	0.61	0.70	1		
md	0.07	0.89	0.08	0.44	0.80	0.88	0.76	0.85	0.53	1	
mbh	0.01	0.58	0.22	0.63	0.84	0.91	0.49	0.74	0.78	0.76	1

For numbers underlined, $p < 0.05$.

variables themselves (bl, md, ma, mp), when compared to some occlusal variables (ML, op, oa). Strong correlations were also found between most occlusal variables (op, oa and ML). All these variables were measured on a horizontal plane while the mbh was measured on a vertical plane; mbh showed strong correlation with all the external variables and with the op, oa and ML from the occlusal variables.

These findings, the last in particular, suggest an association between the two types of variables. As seen in Fig. 2, the increase in mbh is followed by a similar increase in ML. The explanation for this may be that in the maxillary primary first molars, the intercusp distances still increase after the initiation of calcification at 15 weeks *in utero* (Gorlin *et al.*, 1976). The increase may occur due to additional deposition of enamel along the cusp slopes or reflect divergence between cusps. This finding is in agreement with Butler (1967, 1968).

The scattergrams of the two stages of development show that growth is not a continuous process at a constant pace, but rather one with 'bursts'. Moreover, the significant differences between the intercusp distances in the two stages may also indicate a change in the shape of the crown during its formation. With regard to the mb angle, due to the small number of teeth with three cusps in our study, it was difficult to draw a definite conclusion from the small differences between the two stages of development. However, the finding that ML significantly increased and that the >mb increased only slightly suggests the possibility that, during crown formation, the mb cusp moves buccally and distally, and the lingual cusp moves mesially (Fig. 3). Therefore, in teeth with three cusps, a change in shape may be observed during crown formation. As existing data suggest that dental development is modified in people with various diseases (Garn, *et al.*, 1979; Townsend, 1983; Brown and Townsend, 1984; Peretz *et al.*, 1988, 1996), our present findings may expand the range of standards against which to assess the timing of developmental problems *in utero* or in the first postnatal months. Further research on a larger sample should obviously cast more light on pre- and postnatal development of the tooth crowns.

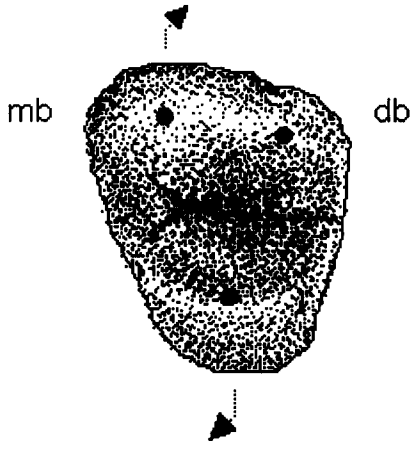

Fig. 3. Change in shape of the three-cusp primary maxillary first molar during development: the mesiobuccal (mb) cusp moves buccally and distally, and the lingual cusp moves mesially. db, distobuccal.

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