

Posterior tooth morphology and lower incisor crowding

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ABSTRACT Frequently, only the mesiodistal dimensions of mandibular posterior teeth have been investigated in relation to lower incisor crowding. The aim of the present study was to investigate any relationship between lower incisor crowding and mesiodistal widths, buccolingual dimensions, occlusal area and occlusal perimeter of mandibular posterior teeth. Mandibular dental casts of 50 Caucasians (25 males and 25 females) were used. Mesiodistal widths, buccolingual dimensions, occlusal area and occlusal perimeter were measured using

image analysis techniques. Lower incisor crowding was determined using (1) Little's irregularity index and (2) anterior-tooth size arch length discrepancy. Using Pearson correlation, the occlusal area, perimeter, mesiodistal widths and buccolingual dimensions of the lower first molar were significantly, positively correlated with Little's irregularity index. The significant correlation between occlusal area and crowding did not appear to be secondary to larger mesiodistal widths. *Dental Anthropology* 2005;18(2):37-42.

Crowding in the lower arch most commonly is seen in the anterior segment. The etiology of dental crowding seems to be multifactorial and tooth morphology has been suggested as an important component. No single factor has so far been demonstrated to be a major cause of anterior crowding.

Some workers have found a positive correlation between lower incisor and posterior tooth mesiodistal width (MD) and lower arch crowding (Peck and Peck, 1972a,b; Norderval *et al.*, 1975; Doris *et al.*, 1981); others (Mills, 1964; Howe *et al.*, 1983; Radzic, 1988) have failed to find evidence of such an association. There is coordinated development between different tooth types in the dental arch in size, such that subjects with larger mesiodistal dimensions of lower incisors may have larger tooth size elsewhere in the dental arch (Harris and Bailit, 1988). However, studies of lower incisor crowding and posterior tooth morphology have been limited to measuring only the mesiodistal width. Therefore, the aim of this study was to investigate the relationship between lower incisor crowding and the occlusal surface area, buccolingual and mesiodistal dimensions of mandibular posterior teeth.

MATERIALS AND METHODS

The sample consisted of dental casts of the mandibular teeth of 50 adult Caucasians (25 males and 25 females).

A computerised image analysis technique was used to analyse the dental casts (Brook *et al.*, 1998). The apparatus consisted in part of a 32-bit digital camera

(Kodak, Nikon DCS 410). Adobe PhotoShop (version 5.0, Adobe Systems Ltd., Europe) was used to acquire images of the teeth. From all models an occlusal image of each posterior tooth was captured, starting from the lower left first permanent molar to the lower right first permanent molar. For all images the position of the tooth was such that the lens of the camera was focused at right angles to the long axis of the clinical crown.

The following measurements were carried out using Image Pro Plus (version 4.0, Media Cybernetics, USA):

1. Area and perimeter: The maximal contour of the occlusal surface of the posterior teeth (from first molar to canine) was traced (Fig. 1) giving rise to area (A) and perimeter (P) measurements.
2. Mesiodistal width (MD): This was measured between the anatomical mesial and distal contacts (Fig. 1).
3. Buccolingual diameter (BL): The buccolingual diameter was measured as perpendicular to and at the midpoint of the mesiodistal diameter (Fig. 1).
4. Lower incisor crowding: Little's irregularity index (II5; Little, 1975) and anterior tooth size-arch length discrepancy (ATSALD) were used to quantify lower incisor crowding. The II5 is the sum of five contact

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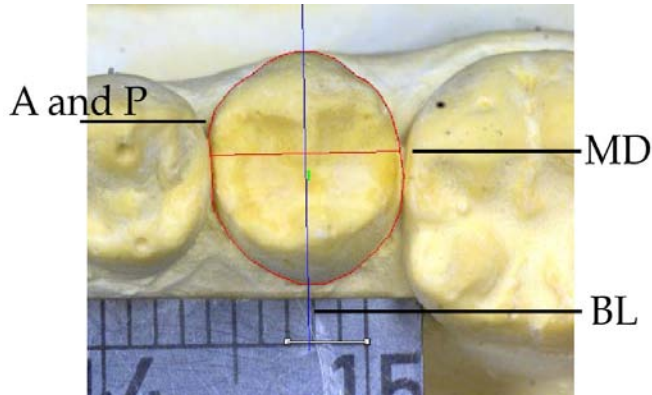


Fig. 1. An image of a lower right second premolar with mesiodistal (MD), buccolingual (BL), area (A) and perimeter (P) dimensions. The steel rule allows linear calibration of each image.

displacements between the lower anterior teeth. It was measured manually using digital calipers (Mitutoyo, Japan).

The ATSALD was measured as the difference between the sum of the individual mesiodistal widths of the four lower incisors and the dental arch length, using the image analysis method. The latter was measured on both sides of the arch from the mesial contact point of canine to the contact between the mesial contact points of central incisors. If there was no contact between the central incisors, it was measured between the mesial contact of the canine and the mesial contact point of the central incisor, which was thought to be in normal position.

Repeatability

All teeth were re-imaged and re-measured on a separate occasion after an interval of one week, to assess the reliability of the method.

The error of II5 was calculated by re-measuring the index manually, on ten models on two separate occasions, one week apart. To examine the reliability of ATSALD, twenty models were re-imaged and re-measured after a one-week interval.

Systematic error was calculated using paired *t*-tests, and random error was estimated with intra-class

correlation coefficients. Descriptive statistics and the Pearson and Spearman correlation coefficients were used to assess the correlation between lower incisor crowding and posterior tooth parameters.

RESULTS

Measurement reliability

From Table 1 it can be seen that the range of error variance for different tooth types for MD dimensions of posterior teeth was between 3% and 6%, and for BL tooth dimensions of posterior teeth between 3% and 10%. For area and perimeter measurements error variance ranged from 1 to 3% among the different tooth types. The mean differences between the first and second measurements after re-imaging the teeth were not statistically significant.

Tooth dimensions and crowding indices

The mean and range of MD, BL, A and P for canines, premolars and first molars of males are given in Table 2 and for females in Table 3.

In the male group some first molar and second premolar variables showed significant correlations with the crowding indices (Table 4). For the occlusal surface of first molars MD, BL, A and P were significantly correlated at the 5% level with II5 (Table 4). First molar MD dimension showed significant correlation with ATSALD ($P = 0.04$), and A and P approached significance ($0.10 > P > 0.05$). However, the correlation coefficients between these variables and the crowding indices ranged from 0.39 to 0.48, indicating that although an association may exist, it is not high.

From Table 4 it can be seen that for second premolars MD and A were significantly correlated with II5, with P approaching significance ($0.10 > P > 0.05$). Only MD approached a significant association ($P = 0.06$) with ATSALD, and the remaining three variables of the second premolar showed no evidence of association with ATSALD. First premolar and canine variables showed no significant correlation.

In contrast, in the female group no evidence was found of an association with either II5 or ATSALD. The Pearson correlation coefficients (*r*) ranged from zero to

TABLE 1. Intraclass correlation coefficients for re-imaging error of posterior teeth¹

Tooth type	MD	BL	Area	Perimeter
First molar	0.96 (4%)	0.90 (10%)	0.98 (2%)	0.97 (3%)
Second premolar	0.94 (6%)	0.97 (3%)	0.98 (2%)	0.97 (3%)
First premolar	0.95 (5%)	0.95 (5%)	0.98 (2%)	0.98 (2%)
Canine	0.97 (3%)	0.97 (3%)	0.99 (1%)	0.99 (1%)

¹Figures in parenthesis indicate proportion of variance in measurements due to method error

TABLE 2. Measurements (in mm or mm²) for first molar, premolars and canine in the male group

	First molar		Second premolar		First premolar		Canine	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
MD	10.88	9.8-12.13	7.19	6.27-8.14	7.11	6.21-8.01	6.91	5.70-7.89
BL	10.49	9.35-11.86	8.53	7.21-9.62	7.96	6.66-9.29	7.90	5.82-9.57
A	100.64	84.8-124.9	50.04	37.62-67.21	44.17	32.9-54.73	41.6	33.45-56.4
P	35.58	23.7-40.18	25.37	21.11-29.44	23.79	20.45-26.59	23.98	21.19-35.5

0.37 (Table 5).

Spearman's correlation coefficients were calculated for all the significant results to check that these were not due to outliers (Table 6). The correlation between II5 and first molar variables remained significant. However, the correlation between MD of first molar and ATSALD, and MD and A of second premolar and II5 lost significance. This showed that the latter significant result was probably due to the presence of an outlier in the data.

DISCUSSION

In the present study, the error variance for posterior tooth variables did not exceed 10% for different tooth types. Crown area represented the overall size of the tooth and takes into account both MD and BL dimensions. The area of the posterior teeth showed the least error variation in relation to the total variation in the materials studied (1 to 2%). This can be interpreted as suggesting that crown area would be a better single indicator of biological variation than either MD or BL alone, where the error variation was 3 to 10% of the total variation. However, combination of the parameters measured is important in considering the shape of teeth, as two teeth with different shapes may have similar area measurements.

Lower arch crowding is important not only from a clinical point of view, but it also has implications in understanding the controlling factors of tooth size. Begg (1954) reported that there was less crowding in the Aborigines and he attributed this to greater interproximal attrition, due to ingestion of coarse food in that population. Lower incisor crowding has been quantified in different ways, and Little's irregularity index (1975) and ATSALD are the two methods commonly used in orthodontic literature. Even the

ATSALD has been measured in many ways by different investigators. Harris (1987) has shown that II5 and ATSALD may not measure the same thing and the present study lends support to that suggestion.

The results show that area of posterior teeth is an important variable when investigating lower incisor crowding. Previous studies have reported a positive correlation between lower incisor crowding and MD dimension of posterior teeth, and this association was interpreted as larger teeth occupying more space in the dental arch, which may result in crowding. In this study, however, we have shown that, in males in addition to MD and BL dimensions, posterior occlusal area may be associated with lower incisor crowding, and the strengths of the association of these variables with crowding are not substantially different from each other (Table 4).

In the female group, there was no association of posterior tooth area with lower incisor crowding. It cannot be explained readily whether such an association did not exist in the first place or whether any such association was undetected.

The work opens a new dimension for future studies, as the association of MD and lower incisor crowding may be secondary to the association of larger posterior tooth area. This is partially supported by previous work (Shah, 2000) where 44 variables were measured on lower study models. The number of variables was subsequently reduced to 5 by using principal component analysis. When regression analysis was performed, area and BL width of posterior teeth entered before MD dimension in the regression equation. It was further shown that when area for posterior teeth was not included in the regression analysis, the BL dimension preceded the MD dimension in significance.

While the positive association of the MD of molars

TABLE 3. Measurements (in mm or mm²) for first molar, premolars and canine in the female group

	First molar		Second premolar		First premolar		Canine	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
MD	10.41	9.02-11.49	6.91	6.20-7.74	6.86	6.11-7.79	6.45	5.56-7.48
BL	10.22	9.00-11.19	8.32	7.14-9.59	7.60	6.67-8.3/9	7.38	6.30-8.21
A	94.27	77.87-105.00	46.48	36.84-56.87	40.51	31.77-47.64	36.49	25.81-46.01
P	34.87	31.79-36.90	24.42	21.74-27.10	22.78	20.16-24.71	21.80	18.40-24.41

TABLE 4. Pearson correlation coefficients (*r*) between lower incisor crowding and lower first molar, premolars, and canine in males

	Variable	II5 (r value)	P value	ATSALD (r value)	P value
First molar	MD	0.48	0.02*	0.40	0.04*
	BL	0.44	0.03*	0.29	0.15
	A	0.46	0.02*	0.37	0.07
	P	0.39	0.05*	0.37	0.09
Second premolar	MD	0.42	0.04*	0.38	0.06
	BL	0.31	0.13	0.20	0.16
	A	0.39	0.05*	0.30	0.15
	P	0.38	0.07	0.27	0.19
First premolar	MD	0.26	0.21	0.33	0.10
	BL	0.10	0.64	0.04	0.83
	A	0.16	0.44	0.17	0.42
	P	0.20	0.34	0.22	0.29
Canine	MD	0.12	0.57	0.17	0.41
	BL	0.05	0.82	0.05	0.79
	A	0.15	0.44	0.12	0.57
	P	0.01	0.98	0.10	0.64

* P < 0.05

with lower incisor crowding may be readily understood, the association of occlusal area of molars merits further consideration.

The literature indicates that, with age, mandibular intermolar and interpremolar widths either increase or remain unchanged (Harris, 1997; Bishara *et al.*, 1994, 1997). If the buccal teeth are drifting away from the midline, then the supporting bone ought to remodel to accommodate them. Data show that this does occur and the changes are in the predicted direction (Enlow and

Harris, 1964; Enlow *et al.*, 1976; Israel, 1979). The upper molars are slanted buccally and the increase in intermolar and interpremolar widths may be due to displacement of molars buccally by the force of occlusion (Harris, 1997). However, Haas (1980) found that by expanding the upper arch, lower intermolar and interpremolar widths also increased and it was suggested that this might be as a consequence of the altered forces of occlusion and muscle balance, with buccal tension diminishing and lingual pressure increasing. In postretention studies,

TABLE 5. Pearson correlation coefficients (*r*) between incisor crowding and lower first molar, second premolars, and canine in females

	Variable	II5 (r value)	P value	ATSALD (r value)	P value
First molar	MD	0.02	0.92	0.12	0.56
	BL	0.02	0.93	0.21	0.32
	A	0.05	0.81	0.11	0.60
	P	0.11	0.58	0.05	0.80
Second premolar	MD	0.12	0.4	0.37	0.07
	BL	0.01	0.95	0.23	0.28
	A	0.00	0.98	0.26	0.21
	P	0.00	0.99	0.24	0.24
First premolar	MD	0.02	0.93	0.21	0.31
	BL	0.01	0.95	0.19	0.37
	A	0.12	0.35	0.19	0.36
	P	0.12	0.56	0.17	0.40
Canine	MD	0.02	0.92	0.17	0.41
	BL	0.19	0.36	0.21	0.31
	A	0.04	0.83	0.23	0.26
	P	0.05	0.80	0.24	0.25

TABLE 6. Spearman correlation coefficients (*r*) between incisor crowding and lower first molar and second premolar variables in males.

	Variable	II5 (<i>r</i>)	P value	ATSALD (<i>r</i>)	P value
First molar	MD	0.50	0.01*	0.23	0.20
	BL	0.45	0.02*	0.24	0.25
	A	0.48	0.01*	0.30	0.14
	P	0.38	0.06	0.31	0.13
Second premolar	MD	0.29	0.15	0.38	0.06
	BL	0.33	0.10	0.20	0.16
	A	0.31	0.13	0.30	0.15
	P	0.32	0.12	0.27	0.19

lower incisor alignment appears to be more stable in cases where upper arch expansion has been carried out (Moussa *et al.*, 1995; Elms *et al.*, 1996; Azizi *et al.*, 1999; Shah 2003). At the same time, arch length and intercanine width decrease. We also know that posterior teeth move forward as a result of mesial drift with age (Begg, 1954; Beek, 1979) and, except for the increase in intermolar and interpremolar widths, all the remaining phenomena will obviously have an adverse effect on lower incisor alignment. It may be that the simultaneous increase in intermolar and interpremolar width results in less incisor crowding.

Wolpoff (1971) concluded that as the roots of the posterior teeth are inclined forward in the jaws, so chewing forces create a mesial force vector. Therefore, the greater the chewing forces, which are determined by the nature of the diet, the higher the mesial force vector. However, as pressure is force per unit area, theoretically one would expect less pressure application to posterior teeth having a larger occlusal area, assuming there will be larger contact areas in the latter. This would cast doubt on the speculation that chewing forces might be associated with lower incisor crowding and/or mesial migration of the posterior teeth. This is supported in the present study where a larger occlusal area was positively associated with lower incisor crowding. This is further supported by Hidaka *et al.* (1999) who found that when the bite force increased with clenching intensity, occlusal contact area on the whole arch increased but the mean bite pressure (bite force per contact area) remained unchanged.

Therefore, the effect of a larger occlusal area may be operating by different mechanisms. Two possible mechanisms can be offered where larger molar occlusal area may cause more lower incisor crowding:

1. *Potential for buccal expansion may be reduced with larger posterior tooth area.* Firstly, the morphology of the crown or root of posterior teeth associated with larger posterior tooth area may not allow the buccal movement of molars and the compensatory mechanism of an increase in intermolar and interpremolar widths does not operate. Secondly, there may be a difference in the

path of eruption induced by a particular morphology and the posterior teeth might have less potential for buccal expansion. Thirdly, there may be an alteration in the direction of occlusal forces associated with larger posterior tooth area.

2. *Mesial migration of the posterior teeth may be accelerated.* Mesial migration may increase due to a larger posterior tooth area. This affect would not occur due to an increased bite force, but may be due to alteration in the directions of occlusal forces or due to alteration in the path of eruption of the posterior teeth.

For the posterior tooth variables in the female group, none was significantly correlated with the crowding indices. Why the posterior occlusal area in the female group showed no significant correlation with lower incisor crowding cannot be established. The ages of male and female subjects were comparable, but the crowding scores in the male group were higher than in the female group (Shah *et al.*, 2003). The difference in crowding between the two groups may have resulted in different relationships.

In the literature, contact area tightness has been investigated in relation to various parameters, such as head posture, tooth type, location in the jaw and time of day (Southard *et al.*, 1990; Dorfer *et al.*, 2000). However, there is no literature to investigate the relationship between posterior tooth area and the contact area tightness between adjacent teeth. It would be worthwhile to investigate any association between posterior tooth occlusal area and the contact area tightness pressure, when a given amount of bite force is applied on the molar teeth and a pilot study is being currently formulated.

CONCLUSIONS

1. Image analysis is a reliable technique for measuring the area, perimeter, MD and BL dimensions of posterior teeth.
2. Lower incisor crowding was associated in this study with mandibular posterior tooth area, MD and BL dimensions in males.

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