Original Article

Is there a relationship between dental crowding and the size of the maxillary or mandibular apical base?

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ABSTRACT

Objective: To determine whether apical base size is related to dental crowding.

Materials and Methods: Digital scans of dental casts were taken of 75 untreated Class I adults to measure maxillary and mandibular tooth size, dental arch perimeters, intermolar widths, and intercanine widths. Cone beam computed tomography (CBCT) images were used to measure the apical base of the maxilla and mandible, including the total cross-sectional area, five basal arch perimeters and five basal arch widths. Principal components factor analyses were performed to evaluate the relationships between the apical base size and tooth-size-arch-length discrepancies (TSALD).

Results: The dental arch and maxillary apical base measures were significantly larger in males than females. There were only limited sex differences in mandibular apical base size. The dental arch measurements were smaller in subjects with greater upper and lower TSALD. Maxillary and mandibular apical base dimensions were positively interrelated. Low-to-moderate correlations were found between the size of the maxillary apical base and TSALD. The size of the mandibular apical base was not related to upper or lower TSALD. Tooth size showed little to no relationship with TSALD.

Conclusions: Although maxillary apical base size is related to maxillary and mandibular crowding in subjects with Class I malocclusion, mandibular apical base size is not. (*Angle Orthod.* 2020;90:216–223.)

KEY WORDS: Apical base size; Dental arch; TSALD; Incisor irregularity; Factor analysis

INTRODUCTION

Class I malocclusion is more prevalent than any other type of malocclusion, even exceeding the prevalence of normal occlusion.[1] Although the etiology of crowding is multifactorial,[1] it has long been believed that crowding is due to jaws that are too small to accommodate the teeth.[2–4]

The notion that crowding is dependent on arch size is intuitive and based on studies showing greater crowding among individuals who have smaller dental arches.[4–8] However, measuring arch size based on dental measurements is problematic because crowding results from teeth erupting and moving mesially into a narrower and shorter part of the dental arch.[1] This leads to spurious associations because dental arch perimeter, length, and width will necessarily be reduced by the more mesial positioned crowded teeth.

Studies estimating jaw size based on two-dimensional cephalograms are controversial, with some reporting significant inverse relationships between jaw size and crowding,[9,10] and others reporting no significant relationships.[11] Points on dental casts adjacent to the mucogingival junction (ie, the WALA ridge, named for Will Andrews and Larry Andrews who made the discovery) have also been used, with

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significant associations reported between WALA ridge dimensions and dental arch dimensions.[12–14] These relations should be expected and are also spurious because the limits of the WALA ridge landmarks were dentally defined.

With the advent of cone beam computed tomography (CBCT), studies have investigated the relationship between jaw size and dental crowding using three-dimensional radiographic images of the apical base, located at the junction of basal and alveolar bone that houses the root apices.[15] A significant inverse relationships has been reported between the size of the apical base in the mid-symphyseal region and lower incisor irregularity in females, but not in males.[16] Bell found a weak relationship between the mandibular apical base and mandibular tooth-size-arch-length discrepancies (TSALD) in adolescents, but the posterior limit of basal bone was based on the position of the second molar.[17] Athar concluded that no significant relationship exists between mandibular apical base perimeter, measured at the level of the inferior alveolar nerve canal, and dental crowding, but he also used the dentition to define the posterior limit of basal bone.[18] The relationship between the maxillary apical base size and crowding has not been evaluated. The relationship between TSALD and the size of the apical base, independent of the dentition, has yet to be determined.

The purpose of the current study was to investigate whether there is a relationship between maxillary and mandibular jaw size, measured at the level of the apical basal bone, and dental crowding, measured as TSALD. The null hypothesis was that crowding is not related to apical base size. The secondary purpose of the study was to evaluate sex differences in apical base size.

MATERIALS AND METHODS

Subject Selection

Subjects were selected from two private practices based on: having pretreatment CBCT radiographs and plaster dental models, being 18 years or older, having an ANB angle within ±1 standard deviation of age- and sex-specific norms, having Class I molar relationships, and having complete permanent maxillary and mandibular dentitions (excluding third molars). Exclusion criteria included previous orthodontics or orthognathic surgery, significant bone loss or periodontal disease, and a mandibular plane angle greater than two standard deviations above age- and sex-specific norms. A total of 75 consecutive patients were identified who met the selection criteria. There were 24 males (38.5 ± 12.9 years of age) and 51 females (44.5 ± 11.7 years of age). The study was approved by the Texas A&M University Institutional Review Board.

Dental Model Analysis

The maxillary and mandibular dental casts were scanned using an iOC iTero Scanner (Align Technology, San Jose, CA) and uploaded into the OrthoCAD (Align Technology, San Jose, CA. version 5.2.1.290) diagnostic software to measure tooth size, arch perimeter, intercanine width, and intermolar width. Overall tooth size was calculated as the sum of the mesiodistal widths, contact point to contact point. Replicate analyses of 15 cases showed no systematic measurement errors, method errors ranging from ±0.4 to ±0.5 mm, and intraclass correlations ranging from 0.983 to 0.989.

Arch perimeters were estimated using the technique described by Huckaba.[19] A digital curve, extending between the mesial contacts of the first molars, was fit to lie over the incisal edges of the anterior teeth and mesiodistal contact points of the posterior teeth (Figure 1), with adjustment if the anterior teeth were too upright or tipped. TSALD was calculated by subtracting the overall maxillary and mandibular tooth widths from their respective arch perimeters. Fifteen replicates showed no systematic differences, method errors ranging from ±0.4 to ±0.5 mm and intraclass correlations ranging from 0.918 to 0.969.

Intercanine widths were measured by the line connecting the midpoint of the cingulum at the lingual gingival border of each canine. Maxillary intermolar widths were measured from the lingual groove at the gingival margin of each maxillary first molar. Mandibular intermolar widths were measured from the midpoint of the mesiodistal crown width at the lingual gingival margin of each first molar. Fifteen replicates showed no systematic measurement errors, method errors ranging from ±0.3 to ±0.6 mm, and intraclass correlations ranging from 0.986 to 0.996.

Apical Base Analysis: Orientation

Using Dolphin Imaging 3D software, the axial plane of the CBCT was oriented by bisecting the cusp tips of the right first mandibular molar and the right first mandibular premolar (Figure 2A). The left side was checked to ensure a parallel plane. The coronal plane was defined perpendicular to the axial plane and the sagittal plane was defined perpendicular to the axial plane, bisecting the incisive foramen.

For the maxillary apical base, the axial plane was defined perpendicular to the coronal and sagittal planes at the level of the mesiobuccal root apex of the upper right first molar (Figure 2B). The posterior limit of the maxilla was defined by the most posterior

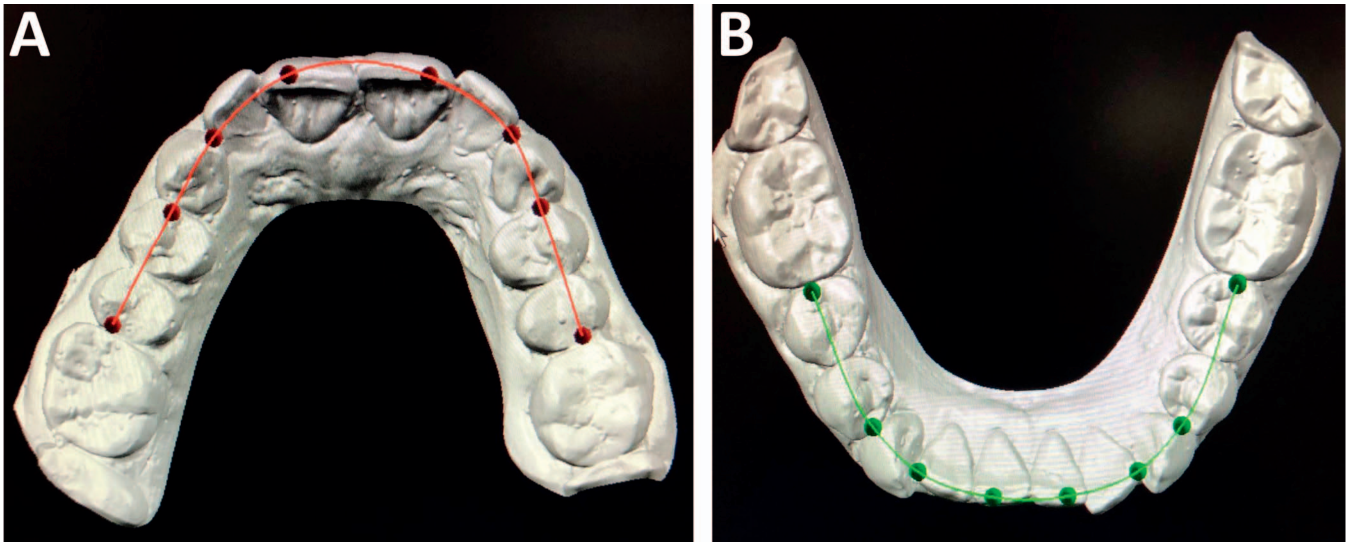

Figure 1. Maxillary and mandibular dental arch length analysis.

aspects of the right and left maxillary tuberosities. Using the Digitize/Measure tab in Dolphin, the apical base was outlined and its cross-sectional area was calculated. The 2D Path tool was used to measure 4 apical base perimeters extending 5 mm (Mx 5P), 10 mm (Mx 10P), 20 mm (Mx 20P), and 30 mm (Mx 30P) from the anterior aspect of overall arch perimeter (Figure 3A). Using the 2D Line tool and the symmetry caliper, 4 apical base widths were measured 5 mm (Mx 5W), 10 mm (Mx 10W), 20 mm (Mx 20W), and 30 mm (Mx 30W) from the most anterior aspect of maxillary arch perimeter (Figure 3). Maxillary widths and perimeters at 40 mm were measured but not included in the analyses because many of the arches were not sufficiently long. Maximum posterior apical base perimeter (Mx Basal P) and width (Mx MaxW) were measured at the tuberosities. Replicate analyses of 15 cases showed no systematic errors, method errors ranging from ±0.8 to ±1.2 mm for the perimeters and widths, and ± 19.3 mm^2 for cross-sectional area. The intraclass correlations ranged from 0.976 to 0.990.

The mandibular apical base was digitized and measured in the axial plane, parallel to the functional occlusal plane, at the superior border of the right mental foramen. The apical base extended posteriorly to a coronal plane passing through the most superior point of the right coronoid process (Figure 2C). As described for the maxillary apical base measures, corresponding mandibular landmarks were digitized to quantify the mandibular apical base cross-sectional area, overall perimeter, four apical base perimeters, and five apical base widths (Figure 3B). Fifteen replicates showed no systematic errors, method errors ranging from ±0.6 to ±1.2 mm for perimeters/widths and ±17.7 mm^2 for cross-sectional area. The intraclass correlations ranged from 0.980 to 0.995.

Statistical Methods

Skewness and kurtosis showed that the distributions were normal. Independent sample t-tests were used to evaluate sex differences. Pearson product-moment correlations were used to evaluate bivariate relationships. Due to the number of apical base variables,

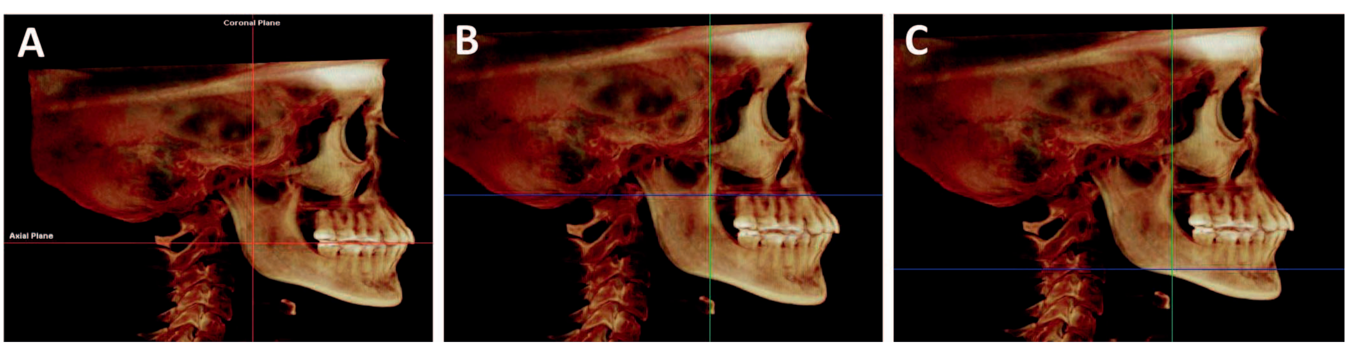

Figure 2. (A) Standardized orientation. (B) maxillary apical base analysis orientation. (C) mandibular apical base analysis orientation.

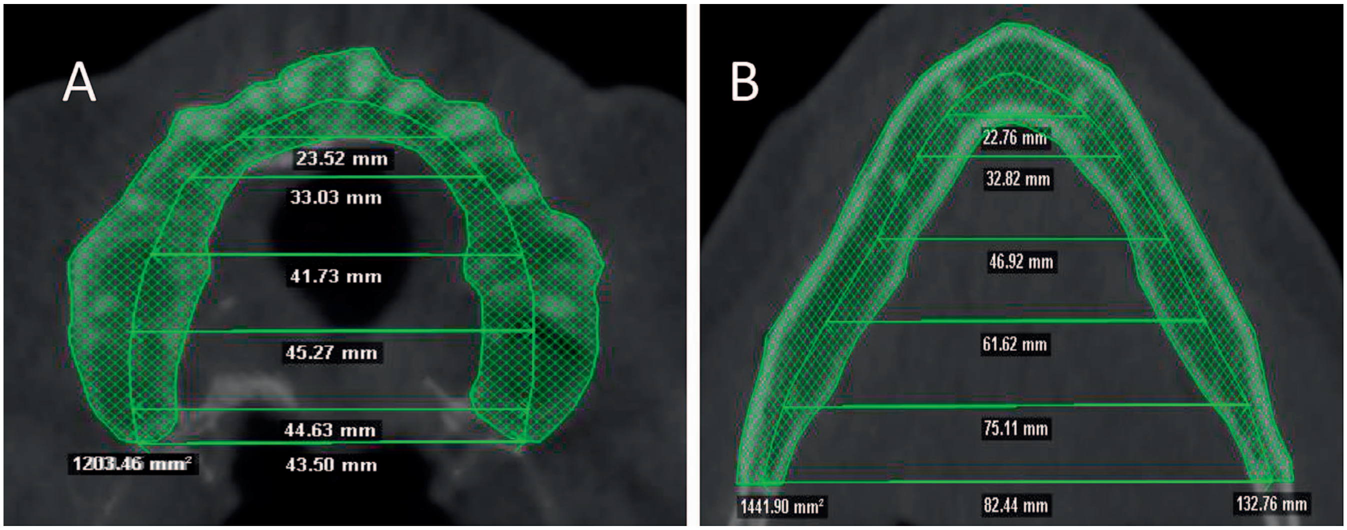

Figure 3. (A) Maxillary and (B) mandibular basal bone cross-sectional area (stippled area), widths, and perimeters.

principal components factor analyses with varimax rotation were performed to create multivariate factors of jaw size. Partial correlations were performed to control for potentially confounding variables. Analyses were performed using IBM SPSS Statistics Version 23 using a 0.05 significance level.

RESULTS

Dental Arch Measurements

Females were older than males and had smaller tooth sizes and arch dimensions. There were statistically significant ($P < .05$) sex differences for age, mandibular tooth size, maxillary and mandibular arch perimeters, maxillary TSALD, and maxillary arch widths (Table 1). There were no significant sex differences for the ANB and MPA angles, maxillary tooth size, mandibular TSALD, and mandibular arch widths.

Table 1. Sex Differences in Age, ANB Angle, Mandibular Plane Angle (MPA), Tooth Size, Dental Arch Measurements, and TSALD[a]

	Males		Females		Differences, Prob
	Mean	SD	Mean	SD	
Age	38.52	13.0	44.6	11.7	0.048*
ANB	2.69	1.4	3.04	1.5	0.353
MPA	31.8	5.2	33.9	4.1	0.069
Mx tooth size	75.3	3.4	73.6	3.7	0.059
Md tooth size	65.7	2.7	64.3	3.3	0.041*
Mx Arch perimeter	76.3	4.1	73.1	4.2	0.003**
Md Arch perimeter	64.3	4.7	61.8	3.6	0.016**
Mx TSALD	1.0	2.8	−0.5	2.1	0.013
Md TSALD	−1.4	3.3	−2.3	2.4	0.192
Mx IMW	36.7	3.4	34.5	2.8	0.004**
Mx ICW	25.3	2.8	23.6	2.2	0.007**
Md IMW	33.5	3.2	32.1	2.9	0.055
Md ICW	19.6	2.6	18.5	2.0	0.052

[a] TSALD indicates tooth-size-arch-length discrepancies; Mx indicates maxilla, Md indicates mandible, IMW indicates intermolar width, ICW indicates intercanine width; * prob $< .05$; ** prob $< .001$.

Maxillary TSALD showed low to moderately low positive relationships with mandibular tooth size, maxillary and mandibular arch perimeters, and maxillary arch widths (Table 2). Mandibular TSALD was significantly related to both maxillary and mandibular arch perimeters, intermolar widths, and intercanine widths. Maxillary TSALD was moderately and positively related to mandibular TSALD ($R = 0.55$; $P < .001$).

Apical Base Measurements

Male apical base measures were consistently larger than the corresponding female measures. All of the maxillary basal bone measurements showed statistically significant sex differences (Table 3). The mandibular basal bone measurements showed significant sex differences for overall area, overall perimeter, and maximum basal arch width.

There were low to moderately low correlations between maxillary TSALD and the size of the maxillary apical base (Table 4). Mandibular TSALD was also related to the size of the maxillary apical base, but to a lesser extent. Except for Md 5P, which showed a low positive correlation with maxillary TSALD, none of the other mandibular apical base measures were related to maxillary or mandibular TSALD (Table 5).

Maxillary intermolar and intercanine widths were moderately and positively related to the size of the maxillary apical base (Table 6). Mandibular intermolar width was significantly related to the mandibular apical base arch perimeter and the mandibular maximum width. Mandibular intercanine width was significantly

Table 2. Bivariate Correlations Between TSALD and Dental Arch Measurements[a]

	Mx Tooth Size	Md Tooth Size	Mx Arch Perimeter	Md Arch Perimeter	Mx IMW	Mx ICW	Md IMW	Md ICW
Mx TSALD								
R	−0.113	0.257*	0.515**	0.427**	0.489**	0.549**	0.208	0.232*
Prob	0.334	0.026	<0.001	<0.001	<0.001	<0.001	0.074	0.046
Md TSALD								
R	0.219	−0.075	0.392**	0.625**	0.426**	0.533**	0.447**	0.568**
Prob	0.059	0.520	0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[a] TSALD indicates tooth-size-arch-length discrepancies; Mx indicates maxilla; Md indicates mandible; IMW indicates intermolar width, ICW indicates intercanine width;* prob < .05.; ** prob < .01.

Table 3. Sex Differences in Maxillary and Mandibular Apical Base Size

	Maxillary Apical Base					Mandibular Apical Base				
	Males		Females		Difference, *P* Value	Males		Females		Difference, Prob
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Overall area, mm^2	1518.5	221.7	1273.3	138.1	<.001*	1370.3	243.3	1204.3	170.8	0.001**
Overall perimeter, mm	115.9	8.4	108.8	5.5	<.001*	127.9	9.3	120.6	8.1	0.001**
5 mm width, mm	27.0	3.07	25.1	3.01	.015*	24.7	2.0	23.9	1.7	0.057
10 mm width, mm	35.1	3.1	32.4	3.1	.001*	34.6	2.1	33.8	1.9	0.081
20 mm width, mm	44.3	3.3	41.2	3.3	<.001*	49.2	3.1	48.7	2.7	0.469
30 mm width, mm	47.9	3.2	44.6	3.1	<.001*	62.9	3.9	62.2	3.1	0.419
Maximum width, mm	46.3	4.0	43.0	3.4	<.001*	79.3	5.4	75.3	4.4	0.001**
5 mm perimeter, mm	29.2	3.0	27.5	2.8	.019*	27.1	1.9	26.4	1.9	0.141
10 mm perimeter, mm	42.3	2.8	40.2	2.9	.003*	41.2	1.9	40.4	1.7	0.056
20 mm perimeter, mm	64.2	2.9	61.9	2.8	.001*	65.9	2.26	65.3	2.0	0.292
30 mm perimeter, mm	84.7	2.9	82.3	2.8	.001*	90.2	2.9	89.4	3.1	0.194

* prob < .05, ** prob < .01.

Table 4. Correlations Between TSALD to Measures of Maxillary Apical Base Size[a]

	Mx Area	Mx Basal P	Mx 5W	Mx 10W	Mx 20W	Mx 30W	Mx MaxW	Mx 5P	Mx 10P	Mx 20P	Mx 30P
Mx TSALD											
R	0.360**	0.309**	0.443**	0.474**	0.494**	0.445**	0.252*	0.440**	0.468**	0.503**	0.472**
Prob	0.002	0.007	<0.001	<0.001	<0.001	<0.001	0.029	<0.001	<0.001	<0.001	<0.001
Md TSALD											
R	0.223*	0.242*	0.288*	0.253*	0.283*	0.321**	0.246*	0.301**	0.280*	0.323**	0.286*
Prob	0.044	0.036	0.012	0.028	0.014	0.005	0.033	0.009	0.015	0.005	0.013

[a] TSALD indicates tooth-size-arch-length discrepancies; Mx indicates maxilla; 5W, 10W, 20W and 30W indicates widths at 5, 10, 20 and 30 mm; 5P, 10P, 20P and 30P indicates perimeter at 5, 10, 20 and 30 mm; * prob < .05; ** prob < .01.

Table 5. Correlations Between TSALD and Measures of Mandibular Apical Base Size[a]

	Md Area	Md Basal Perimeter	Md 5W	Md 10W	Md 20W	Md 30W	Md MaxW	Md 5P	Md 10P	Md 20P	Md 30P
Mx TSALD											
R	0.178	0.111	0.192	0.202	0.130	0.091	0.127	0.254*	0.212	0.145	0.122
Prob	0.127	0.342	0.098	0.083	0.266	0.435	0.279	0.028	0.068	0.216	0.299
Md TSALD											
R	0.072	0.095	0.127	0.203	0.149	0.072	0.077	0.025	0.156	0.121	0.107
Prob	0.537	0.419	0.278	0.080	0.204	0.540	0.512	0.829	0.183	0.303	0.363

[a] TSALD indicates tooth-size-arch-length discrepancies; Md indicates mandible; 5W, 10W, 20W and 30W indicates widths at 5, 10, 20 and 30 mm; 5P, 10P, 20P and 30P indicates perimeter at 5, 10, 20 and 30 mm; * prob <.05.

Table 6. Correlations of Intermolar (IMW) and Intercanine (ICW) Widths and Dental Arch Perimeter, Apical Base Perimeter, and Apical Base Width (* prob < .05)

	Dental Arch Perimeter	Basal Perimeter	5 mm Width	10 mm Width	20 mm Width	30 mm Width	Maximum Width
Mx IMW							
R	0.550**	0.640**	0.718**	0.757**	0.798**	0.774**	0.523**
Prob	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mx ICW							
R	0.725**	0.463**	0.580**	0.610**	0.649**	0.617**	0.401**
Prob	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Md IMW							
R	0.393**	0.351**	0.148	0.204	0.138	0.110	0.271*
Prob	<0.001	0.002	0.206	0.079	0.238	0.347	0.019
Md ICW							
R	0.686**	0.081	0.249*	0.289*	0.229*	0.118	0.068
Prob	<0.001	0.490	0.031	0.012	0.048	0.313	0.560

[a] Mx indicates maxilla; Md indicates mandible; * prob < .05; ** prob < .01.

related to the mandibular apical base arch perimeter, 5 mm width, 10 mm width, and 20 mm width.

Multivariate Analyses

The factor analyses identified two primary factors explaining over 88% of the variation in maxillary size (Table 7). Factor 1 was defined as the maxillary anterior size factor; factor 2 was defined as the maxillary posterior and overall size factor. Factor analyses of the mandibular apical base measurements identified three factors explaining over 90% of the variation (Table 8). Factor 1 was defined as the mandibular anterior size factor, factor 2 was defined as a mandibular posterior size factor, and factor 3 was defined as a mandibular overall size.

Maxillary TSALD was positively and more closely correlated to the maxillary anterior size factor than the maxillary posterior + overall size factor (Table 9). Maxillary TSALD also showed a low correlation with the mandibular anterior size factor. Mandibular TSALD showed a low correlation with the maxillary anterior size factor. Controlling for maxillary TSALD, there were no relationships between mandibular TSALD and the size of the maxillary apical base. When the effects of mandibular TSALD were controlled for, only the correlation between maxillary TSALD and the maxillary general size factor was statistically significant ($R = 0.28$; $P = .018$).

The maxillary and mandibular apical base factors were significantly interrelated (Table 10). Maxillary anterior size showed low positive associations with mandibular anterior size and mandibular overall size factors. The maxillary posterior + overall size factor showed a low positive association with mandibular anterior size and a moderately low correlation with mandibular overall size.

Table 7. Maxillary Bone Factor Analysis Showing Eigenvalues (Variation Explained by Each Variable) and the Factor Loadings, With Variables Defining the Factors in Bold

	Eigenvalues	Factor 1 Mx Anterior Size	Factor 2 Mx Post. + Overall Size
Mx overall area, mm^2	0.765	0.201	**0.851**
Mx overall perimeter, mm	0.669	0.285	**0.767**
Mx 5 width, mm	0.963	**0.950**	0.245
Mx 10 width, mm	0.968	**0.880**	0.440
Mx 20 width, mm	0.916	**0.750**	0.595
Mx 30 width, mm	0.908	0.573	**0.761**
Mx Max Width, mm	0.629	0.319	**0.726**
Mx 5 perimeter, mm	0.945	**0.945**	0.231
Mx 10 perimeter, mm	0.989	**0.919**	0.379
Mx 20 perimeter, mm	0.983	**0.883**	0.450
Mx 30 perimeter, mm	0.980	**0.847**	0.466
Percent of total variance		77.78%	10.53%

DISCUSSION

Unexpectedly, the size of the mandibular apical base was not related to either maxillary or mandibular crowding. The relationship between the size of mid-symphyseal basal bone and lower incisor irregularity previously identified only measured apical base size in the sagittal plane, and found only differences for females.[16] Additionally, incisor irregularity is not the same as crowding, which is better characterized by TSALD. If mandibular jaw size does not explain the crowding of untreated subjects,[20,21] then it probably also cannot explain posttreatment malalignment. The results suggest that anterior crowding is primarily due to other factors, including space loss prior to the emergence of the permanent dentition and/or slippage of interdental contacts.[1] It is recommended that orthodontists no longer tell their patients that lower crowding is due to a small mandible.

In contrast to the mandible, the size of the maxillary apical base was related to both maxillary and mandibular crowding. Individuals with smaller maxillary basal bone, particularly in the anterior region, are at

Table 8. Mandibular Bone Factor Analysis Showing Eigenvalues (Variation Explained by Each Variable) and the Factor Loadings, With Variables Defining the Factors in Bold

	Eigenvalues	Factor 1 Md Anterior Size	Factor 2 Md Posterior Size	Factor 3 Md Overall Size
Md overall area, mm²	0.671	0.036	−0.174	**0.800**
Md overall perimeter, mm	0.837	0.034	−0.001	**0.914**
Md 5 width, mm	0.940	**0.937**	0.233	0.084
Md 10 width, mm	0.939	**0.836**	0.490	0.002
Md 20 width, mm	0.938	0.427	**0.868**	−0.053
Md 30 width, mm	0.960	0.261	**0.941**	0.077
Md max width, mm	0.933	0.075	0.467	**0.842**
Md 5 perimeter, mm	0.867	**0.889**	0.253	0.112
Md 10 perimeter, mm	0.957	**0.900**	0.383	0.009
Md 20 perimeter, mm	0.961	0.649	**0.733**	−0.046
Md 30 perimeter, mm	0.953	0.474	**0.849**	0.077
Percent of total variance		60.44%	19.74%	10.32%

Table 9. Correlations Between TSALD and Basal Bone Factors[a]

	Mx Basal Bone Factors		Md Basal Bone Factors		
	Mx Ant Size	Mx Post + Overall size	Md Ant Size	Md Post Size	Md Overall Size
Mx TSALD					
R	0.406*	0.270*	0.228*	0.014	.146
Prob	<0.001	0.019	0.049	0.906	.212
Md TSALD					
R	0.227*	0.225	0.111	0.073	.074
Prob	0.050	0.053	0.343	0.536	.530

[a] TSALD indicates tooth-size-arch-length discrepancies; Mx indicates maxilla, Md indicates mandible; * prob < .05.

Table 10. Correlations Between Maxillary and Mandibular Basal Bone Factors

	Md Ant Size	Md Post Size	Md Overall Size
Mx Ant Size			
R	0.284*	0.271*	−0.083
Prob	0.014	0.019	0.478
Mx Post + Overall Size			
R	0.241*	−0.052	0.583*
Prob	0.037	0.660	<0.001

[a] * prob < .05.

greater risk of maxillary crowding and, to a lesser extent, mandibular crowding. Dental compensations to maintain occlusal function are well established,[22,23] as are compensations of the mandibular dentition following maxillary expansion.[24,25] These associations help to partially explain why expansion of maxillary basal bone alone, without any other conjunctive treatment, decreases mandibular crowding.[26] Importantly, maxillary apical base size explained 25% of individual differences in maxillary crowding and only 10% of the variation in mandibular crowding. The partial correlations emphasize that mandibular crowding depends on maxillary crowding. In other words, if the maxillary teeth are not crowded, maxillary size has no effect on mandibular crowding. Clinically, it suggests that maxillary expansion is unjustified in the absence of maxillary crowding and mandibular compensations.

The size of the upper apical base is coordinated with the size of the lower apical base. Although this relationship has not been previously assessed, metallic implants have demonstrated width increases of basal bone in both jaws, albeit greater in the maxilla than mandible.[27–29] This indicates that maxillary and mandibular basal bone compensate to maintain jaw relationships with function.

As expected, dental arch size was inversely related to crowding. The literature largely supports this relationship, with most studies showing negative correlations or significant differences in dental arch size between crowded and not crowded cases.[4–8] This simply shows that crowding causes teeth to drift mesially into a narrower and shorter portion of the dental arch.[1] By definition, the dental arch will always be too small to accommodate the teeth whenever there is crowding and the posterior teeth migrate mesially.

The present study demonstrated that tooth size has little or no effect on crowding. Some previous studies have shown relationships,[5,7,8,30] while others have not.[4,18,31] Studies showing relationships typically compared groups who were severely crowded to groups that were not crowded; they did not report correlations. Although tooth size may be a factor, it is not a primary contributor to crowding.

CONCLUSIONS

Among untreated adults with Class I malocclusions:

- The size of the mandibular apical base is not related to maxillary or mandibular crowding.
- Individuals with smaller maxillary basal bone have greater maxillary and mandibular crowding.
- Maxillary and mandibular apical base size are positively correlated.

- Males have larger apical base dimensions than females.

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