Original Article

Relationship Between Mandibular Anterior Crowding and Lateral Dentofacial Morphology in the Early Mixed Dentition

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Abstract: Mandibular anterior crowding is identified as the discrepancy between mesiodistal tooth widths of four permanent incisors and available space in the alveolar process. However, incisor crowding is not merely a tooth-arch size discrepancy. Many variables such as direction of mandibular growth, early loss of deciduous molars, the oral and perioral musculature and incisor and molar inclination can be associated with crowding. Only few studies evaluated the relationship between mandibular anterior crowding and cephalometric measurements in the early mixed dentition. It was the aim of this study to search for dentofacial factors that might be associated with mandibular crowding in the early mixed dentition. Lateral cephalograms and dental casts of 60 children (33 girls, 27 boys) were evaluated. It was determined that patients with crowding had smaller lower incisor to NB angles, maxillary skeletal lengths, mandibular skeletal length, and mandibular dental measurements. They also had greater interincisal angles, overjet, overbite, and Wits appraisal measurements. Significant inverse correlations were found between crowding and SNB, lower incisor to NB angle, anterior cranial length, mandibular length, maxillary length, mandibular dental measurement and direct correlations between crowding and interincisal angle, overjet, overbite, and FMIA. According to these results, we conclude that crowding of the mandibular incisors is not only a tooth-arch size discrepancy. Dentofacial characteristics also contribute to this misalignment. (*Angle Orthod* 2004;74:759–764.)

Key Words: Anterior crowding, Correlation analysis, Dentofacial morphology, Mixed dentition

INTRODUCTION

Mandibular anterior crowding is one of the most frequent types of malocclusion in children and also the chief complaint of many parents referred to orthodontic departments. Mandibular anterior crowding is identified as the discrepancy between mesiodistal tooth widths of four permanent incisors and the available space in the alveolar process. However, incisor crowding is not merely a tooth-arch size discrepancy but a discrepancy among many variables.[1] Several factors can be assumed to affect the development and severity of crowding, such as direction of mandibular growth,[2,3] early loss of deciduous molars,[4] mesiodistal tooth and arch dimensions,[5] the oral and perioral musculature,[1] and incisor and molar inclination.[1]

Predicting permanent incisor crowding at an early stage is very important for preventive orthodontic treatment plans. For this aim, several longitudinal studies evaluating mandibular dental crowding were performed in primary, mixed, and permanent dentition stages.[1,5–14] Melo et al[14] evaluated indicators of crowding found in the primary dentition, which may lead to future mandibular anterior crowding in the mixed dentition stage. They found the mesiodistal size of primary maxillary canines, maxillary and mandibular dental arch lengths, and posterior cranial base lengths as elements in the early mixed dentition that could possibly be indicators for crowding.

Crowding is often related to arch dimensions. Only few studies evaluated the relationship between crowding and cephalometric measurements. Miethke and Behm-Menthel[15] reported that cephalometric measurements of patients with and without crowding did not differ significantly. The authors also could not find any correlation between mandibular anterior crowding and vertical craniofacial configuration and sagittal lower incisor inclination. In view of their results, they identified lower incisor crowding as a ''local, independent, genetically determined discrepancy between tooth width and size of supporting bone.'' Howe et al[5] and Sinclair and Little[16] also found no clinically significant associations between various mandibular parameters and incisor crowding.

On the other hand, Berg[10] evaluated crowding of the dental arches longitudinally from six to 12 years of age and

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TABLE 1. Mean Values of Chronological Ages and Degree of Crowding of the Groups[a]

	Noncrowded (n = 30)				Crowded (n = 30)				
	Mean	SD	Min	Max	Mean	SD	Min	Max	*P* Value
Chronological age	9.21	1.01	7.47	11.24	8.93	.75	7.20	10.47	.224 NS
Degree of crowding	.05	.72	−1.26	1.36	3.31	1.30	1.64	5.58	.000***

[a] NS indicates not significant.
*** $P < .001$.

TABLE 2. Cephalometric Angular and Linear Measurements

Angular Measurements	Linear Measurements
1 SNA angle	14 Upper incisor to NA distance
2 SNB angle	15 Lower incisor to NB distance
3 ANB angle	16 Overjet
4 Upper incisor to NA angle	17 Overbite
5 Lower incisor to NB angle	18 WITS appraisal
6 Interincisal angle	19 Anterior cranial length (N-S)
7 Occlusal to SN angle	20 Posterior cranial length (S-Ba)
8 Gonion-gnathion to SN angle	21 Posterior anterior face height ratio (S-Go/N-Me)
9 Y axis	22 Mandibular length (Co-Gn)
10 N-S-Ba angle	23 Maxillary length (Co-A)
11 FMA	24 Maxillary dental (upper incisor to A vert.)
12 IMPA	25 Mandibular dental (lower incisor to A-Po line)
13 FMIA	

reported a significant negative correlation between S-N and lower facial length dimensions at the age of six years. He also found that, when compared with normal subjects, children with crowding were characterized by significantly lower mean values for mandibular length. Leighton and Hunter[8] compared the skeletal morphology of cases with and without crowding. They reported that cases with crowding had larger Frankfort-mandibular and occlusal plane angles, shorter posterior face heights and mandibular bodies, and less protrusive lower incisors. Sakuda et al[17] reported a significant correlation between an increase in lower incisor crowding and high mandibular plane angles, short mandibular body lengths, great upper face height, and small vertical dimensions in the upper posterior segments.

The aims of this study were (1) to determine if the dentofacial configuration of patients with and without crowding differ, (2) to determine the dentofacial factors that might be associated with mandibular anterior crowding, and (3) to determine the possible indicators of crowding from cephalograms in the early mixed dentition.

MATERIALS AND METHODS

Lateral cephalograms and dental casts of 60 children (33 girls, 27 boys) referred to Suleyman Demirel University, Department of Orthodontics, were evaluated in this study. The mean age of the subjects was 9.1 ± 0.89 years (range 7.2–11.24). These subjects were selected according to the following criteria: (1) class I skeletal pattern, (2) early mixed dentition stage (fully erupted four permanent mandibular incisors, deciduous canines, deciduous molars, and permanent first molars), (3) no congenitally missing permanent teeth or premature loss of deciduous or permanent teeth, (4) minimal loss of tooth dimension by caries or attrition, (5) no previous orthodontic treatment.

None of the subjects had undergone previous orthodontic treatment. Two groups were formed according to the severity of mandibular anterior crowding. Because sex distribution for the samples showed little difference between the groups (noncrowded group: 15 girls, 15 boys; crowded group 18 girls, 12 boys), the measurements for males and females were pooled in the statistical procedures. Crowding was measured on plaster models with a digital caliper to the nearest 0.01 mm. Available incisor space was measured between mesial surfaces of the deciduous canines by dividing the dental arch into two straight line segments. Total incisor width was subtracted from available incisor space to calculate the severity of crowding. Because 1.6 mm of mandibular anterior crowding was reported as normal at this stage,[18–20] subjects who had anterior crowding less than or equal to 1.6 mm were included in the noncrowded group, and those who had anterior crowding of more than 1.6 mm were included in the crowded group. Each group was composed of 30 subjects. Mean values of chronological ages and degree of crowding of the groups are shown in Table 1.

Cephalometric landmarks were marked and digitized by one author to avoid interobserver variability. Angular and linear variables were established and measured by Vistadent™ AT software (GAC International Inc., New York, NY) (Table 2). All the cephalometric measurements of 20 subjects were redone two weeks later to determine measure-

TABLE 3. Reliability Coefficients of the Measurements

	r Value
SNA angle	.9954
SNB angle	.9957
ANB angle	.9915
Upper incisor to NA distance	.9806
Upper incisor to NA angle	.9608
Lower incisor to NB distance	.9777
Lower incisor to NB angle	.9676
Interincisal angle	.9607
Occlusal to SN angle	.9820
Gonion-gnathion to SN angle	.9864
Y axis	.9803
Overjet	.8889
Overbite	.9298
N-S-Ba angle	.8975
WITS appraisal	.9517
FMA	.9808
IMPA	.9817
FMIA	.9639
Anterior cranial length	.9274
Posterior cranial length	.9638
Posterior anterior face height ratio	.9892
Mandibular length	.9338
Maxillary length	.9149
Maxillary dental	.9868
Mandibular dental	.9737

ment error. The reliability coefficients of the measurements are shown in Table 3. Descriptive statistics including the mean and standard deviation were calculated for all measurements. Statistical comparison of two groups was performed with independent samples *t*-test. Pearson correlations were examined for interrelationships between crowding and cephalometric measurements. To build a predictive model of crowded and noncrowded groups, discriminant analysis was used. All the statistical analyses were performed by using SPSS for Windows release 11.0 (SPSS Inc., Chicago, Ill.).

RESULTS

Statistical comparison of the groups

Statistical comparison of the groups is shown in Table 4.

Angular measurements

Among the angular measurements, only two of 13 variables (lower incisor to NB and interincisal angles) exhibited statistically significant differences between the groups at $P < .05$ level. Patients with crowding had smaller values of lower incisor to NB angle but larger values of the interincisal angle. The other dentofacial angular measurements did not show any significant difference.

TABLE 4. *t*-Test Comparison of the Measurements[a]

	Noncrowded (n = 30)		Crowded (n = 30)		
	Mean	SD	Mean	SD	*P* Value
SNA angle	79.60	3.44	78.81	3.14	.355 NS
SNB angle	76.56	3.22	75.15	3.22	.094 NS
ANB angle	3.05	1.84	3.67	1.77	.191 NS
Upper incisor to NA distance	2.48	1.83	2.09	2.18	.460 NS
Upper incisor to NA angle	21.02	6.06	18.86	5.9	.167 NS
Lower incisor to NB distance	3.81	1.92	3.34	1.88	.349 NS
Lower incisor to NB angle	26.74	5.07	23.66	5.39	.026*
Interincisal angle	129.19	7.95	133.81	8.59	.035*
Occlusal to SN angle	20.36	3.88	20.03	4.65	.771 NS
Gonion-gnathion to SN angle	33.17	5.19	33.42	5.41	.852 NS
Y axis	59.08	3.77	60.21	3.70	.247 NS
Overjet	2.47	1.14	3.27	1.70	.036*
Overbite	1.60	2.21	2.93	1.84	.014*
N-S-Ba angle	132.00	3.99	133.07	4.42	.331 NS
WITS appraisal	−1.96	2.87	−.17	2.71	.016*
FMA	25.07	4.85	25.06	4.97	.990 NS
IMPA	95.73	7.24	94.15	6.61	.381 NS
FMIA	57.54	9.35	60.80	5.65	.108 NS
Anterior cranial length	67.98	2.73	66.79	2.45	.080 NS
Posterior cranial length	31.64	2.58	30.80	2.56	.212 NS
Posterior anterior face Height Ratio	.62	.42	.62	.45	.700 NS
Mandibular length	106.48	4.76	102.76	4.15	.002**
Maxillary length	84.47	3.54	81.76	3.44	.004**
Maxillary dental	2.14	2.34	1.34	2.19	.177 NS
Mandibular dental	1.78	1.76	.78	1.96	.042*

[a] NS indicates not significant.
* $P < .05$.
** $P < .01$.

TABLE 5. Pearson Correlation Coefficients of the Measurements[a]

	Crowding	
	r	*P*
SNA angle	−.146	.132 NS
SNB angle	−.246	.029*
ANB angle	.172	.95 NS
Upper incisor to NA distance	−.156	.117 NS
Upper incisor to NA angle	−.186	.077 NS
Lower incisor to NB distance	−.178	.087 NS
Lower incisor to NB angle	−.339	.004**
Interincisal angle	.310	.008**
Occlusal to SN angle	.101	.222 NS
Gonion-gnathion to SN angle	.120	.181 NS
Y axis	.073	.289 NS
Overjet	.253	.025*
Overbite	.222	.044*
N-S-Ba angle	.127	.167 NS
WITS appraisal	.195	.068 NS
FMA	−.133	.155 NS
IMPA	−.202	.061 NS
FMIA	.301	.010**
Anterior cranial length	−.233	.037*
Posterior cranial length	−.092	.243 NS
Posterior anterior face height ratio	−.056	.335 NS
Mandibular length	−.300	.010**
Maxillary length	−.280	.015*
Maxillary dental	−.057	.333 NS
Mandibular dental	−.283	.014*

[a] NS indicates not significant.
* $P < .05$.
** $P < .01$.

Linear measurements

Among the linear measurements, six of 12 variables exhibited statistically significant differences between the groups. Overjet, overbite, and WITS appraisal values were significantly greater in the crowded group. In addition, maxillary and mandibular skeletal lengths and mandibular dental measurements were significantly smaller in the crowded group than in the noncrowded group.

Correlations of the measurements

Correlations of the measurements are shown in Table 5. Significant inverse correlations were found between crowding and SNB ($r = .246$; $P < .05$), lower incisor to NB angle ($r = .339$; $P < .01$), anterior cranial length ($r = .233$; $P < .05$), mandibular length ($r = .300$; $P < .01$), maxillary length ($r = .280$; $P < .05$), and mandibular dental measurements ($r = .283$; $P < .05$). The interincisal angle ($r = .310$; $P < .01$), overjet ($r = .253$; $P < .05$), overbite ($r = .222$; $P < .05$), and FMIA ($r = .301$; $P < .01$) were directly correlated with crowding.

TABLE 7. Classification Results of Discriminant Analysis[a]

	Groups	Predicted Group Membership	
		Noncrowded	Crowded
Original group			
Count	Noncrowded	25	5
	Crowded	6	24
Percentage	Noncrowded	83.3	16.7
	Crowded	20.0	80.0

[a] Original grouped (81.7%) cases were correctly classified.

Discriminant analysis

Discriminant analysis was performed using eight variables that exhibit significant difference between groups. Table 6 represents Fisher's linear discriminant functions coefficients of the variables and constants. According to the results using the abovementioned eight variables, 81.7% of the original grouped cases were correctly classified (Table 7).

DISCUSSION

Finding possible factors associated with mandibular anterior crowding in the early mixed dentition is of great importance in preventive orthodontics and further treatment planning. A review of the literature indicated conflicting results about the factors contributing to mandibular anterior crowding. Crowding is often related to arch dimensions, however, incisor crowding is not merely a tooth-arch size discrepancy, but a discrepancy among many variables. Only a few studies have evaluated the relationship between crowding and cephalometric measurements. It was the aim of this study to find out whether a relationship existed between mandibular anterior crowding and dentofacial configuration.

Incisor inclination

Because orthodontics makes it possible to alter the dentoalveolar tooth position, it is very important to determine whether incisor position and inclination contribute to crowding. Retrusion of lower incisors has been found to be significantly correlated with mandibular anterior crowding. Hunter[21] reported that the inclination of lower incisors rel-

TABLE 6. Fisher's Linear Discriminant Functions Coefficients[a]

	Constant	1	2	3	4	5	6	7	8
Noncrowded	−1205.81	14.491	10.499	20.771	−8.199	−.243	6.302	−.592	3.786
Crowded	−1190.52	14.461	10.593	21.137	−7.906	−.0914	6.315	−.953	4.112

[a] 1, indicates lower incisor to NB angle; 2, interincisal angle; 3, overjet; 4, overbite; 5, WITS appraisal; 6, mandibular length; 7, maxillary length; and 8, mandibular dental.

ative to the mandibular plane was significantly greater in the spaced cases at nine years. Sanin and Savara[1] also found in their longitudinal study that children who presented no crowding in the permanent dentition had more labially inclined mandibular incisors in the mixed dentition. On the other hand, Bishara et al[11] stated that the uprighting of the incisors could not, by itself, be a determinant of the severity of the anterior or total change in arch length discrepancy.

Our results revealed that inclination of the lower incisor is associated with mandibular anterior crowding in the mixed dentition stage. All measurements related to lower incisors were smaller in the crowded group. Among these, statistically significant differences were noted in lower incisor to NB angle, interincisal angle, and mandibular dental measurements.

It is well known that retrusion of teeth results in available arch loss. Therefore, oral habits like thumb or lip sucking must be avoided in the mixed dentition stage. These habits often cause retrusion of lower and protrusion of upper incisors and result in mandibular anterior crowding.

The interincisal angle is very important in controlling continuous alveolar eruption of incisors. An increased interincisal angle is often associated with increased overbite. Lingual inclination of the upper incisors forces lower incisors backward and causes crowding. Axial inclinations of the incisors must be proper so as to function as an occlusal stop for continuous alveolar eruption.

Overjet and overbite

According to our results, both overjet and overbite measurements were significantly greater in the crowded group. The lower incisor inclination was strongly related with both overjet and overbite. Retrusion of the lower incisors may be associated with an increase in overjet and overbite. Therefore, it was an expected result to find a difference in overjet and overbite between the crowded and noncrowded group.

Cranial base dimensions

Melo et al[14] compared cephalometric measurements of patients with and without crowding and could not find any difference between groups except in the S-SE (anterior cranial base) variable. The normal group showed a tendency for larger values in the measurements of the anterior cranial base when compared with the crowded group. They also assumed that the subjects in the normal group had longer anterior cranial base lengths, whereas subjects in the crowded group had longer posterior cranial base lengths. We also found a significant inverse correlation between crowding and anterior cranial base length, but the relationship was not strong enough to differentiate the crowded group from the normal group. According to these results, we could assume that anterior cranial base dimensions have little effect on crowding.

Maxillary and mandibular relationship

Among the measurements of maxillary and mandibular relationship, the only significant difference was determined in the WITS appraisal. WITS values were significantly greater in the crowded group, indicating a tendency toward a Class II jaw dysplasia. Although the difference was not significant, the mean ANB angle was also greater in the crowded group. Thus, we can state that mandibular anterior crowding is more likely to occur in retrognathic cases.

Maxillary dimensions

Melo et al[14] evaluated indicators of crowding found in the primary dentition, which may lead to future mandibular anterior crowding in the mixed dentition stage. They found maxillary and mandibular dental arch lengths were possible indicators for crowding in the early mixed dentition. In our study, maxillary skeletal lengths (Co-A) of the crowded group were significantly smaller. The SNA angle was also smaller in the crowded group, but the difference was statistically nonsignificant. Thus, we concluded that bimaxillary and bialveolar retrusion cases are more likely to experience mandibular anterior crowding than bimaxillary and bialveolar protrusion cases.

Mandible dimensions

Berg[10] compared cephalometric variables of patients with and without crowding and found that variables related to lower jaw dimensions (Ar-Po, SNB) had significantly smaller values in the crowded group. Several other reports have also indicate that crowding occurred more frequently in less prognathic cases.[4,8,22]

In our study, we used mandibular skeletal length (Co-Gn) and SNB to compare the sagittal dimensions of the mandible in cases with and without crowding. The SNB angle was greater in the crowded group, but this difference was statistically nonsignificant. Mandibular length (Co-Gn) was significantly smaller in the crowded group. Our results support the results of Leighton and Hunter[8] and Sakuda et al[17] who found shorter mandibular body lengths in cases with crowding.

Growth direction of the mandible

Leighton and Hunter[8] reported that the angles between the S-N line and the mandibular and occlusal planes were significantly larger for the cases with crowding at both mixed and permanent dentition stages. They also associated downward and deficient growth of the mandible with both upright or retroclined mandibular incisors and with crowding. On the other hand, Lundström[22] found no correlation between arch dimension changes, changes in the incisor position, and direction of mandibular growth. Our results differed from that of Leighton and Hunter[8] and did not exhibit any significant difference in measurements regarding the growth direction of the mandible (Table 4). Mean values of the occlusal plane and gonion-gnathion to SN line, Y axis, and FMA angles were all similar in crowded and non-crowded groups. Therefore, we can conclude that although both forward and backward rotating underlying patterns may have a considerable effect on the environment for the alignment of the teeth, this study failed to show an association between the growth direction of the mandible and the degree of mandibular anterior crowding at the mixed dentition stage.

Anterior and posterior facial heights

Leighton and Hunter[8] reported shorter posterior facial heights for cases with crowding. In our sample we used posterior/anterior face height ratio and found no significant difference between the groups. Therefore, our results did not confirm Leighton and Hunter's[8] findings.

Correlation with crowding

Conflicting results existed in the literature evaluating the correlation between crowding and dentofacial dimensions. Berg[10] reported significant correlation between crowding and overjet, Ar-ii, Ar-b, and Go-Ar measurements. However, Miethke and Behm-Menthel[15] reported that no correlation existed between crowding and vertical skeletal dimensions and lower incisor position.

In our sample, we found significant inverse correlation between crowding and SNB, lower incisor to NB angle, anterior cranial length, mandibular length, maxillary length, and mandibular dental measurements. We found direct correlations between crowding and interincisal angle, overjet, overbite, and FMIA. Although, correlation coefficients are not high enough to have clinical importance, any of the abovementioned dentofacial characteristics, whether alone or combination with other factors can be associated with the development of incisor crowding.

CONCLUSIONS

- Patients with and without crowding had a smaller lower incisor to NB angles, maxillary skeletal lengths, mandibular skeletal lengths and mandibular dental measurements. Besides they had greater values of the interincisal angle, overjet, overbite and Wits appraisal measurements.
- Significant inverse correlations were found between crowding and SNB, lower incisor to NB angle, anterior cranial length, mandibular length, maxillary length, mandibular dental measurements and direct correlations between crowding and interincisal angle, overjet, overbite, and FMIA.
- Crowding of the mandibular incisors is not only a tooth-arch size discrepancy. Dentofacial characteristics also can be associated with this malalignment.

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