Original Article

Dentofacial traits in association with lower incisor alveolar cancellous bone thickness: *A multiple regression analysis*

Xuhong Qu[a]; Zhijian Liu[b]; Yunlong Wang[a]; Yi Fang[c]; Mingyuan Du[a]; Hong He[d]

ABSTRACT

Objective: To identify dentofacial anatomic traits associated with lower incisor cancellous bone thickness (LICBT) and then to assess their separate contributions and their combined contributions to the variation in LICBT.

Materials and Methods: A consecutive sample of cone beam computed tomography (CBCT) data taken in a university hospital within the same setting was retrospectively reviewed. Within the sample, CBCT data of 252 eligible subjects were reconstructed and measured for LICBT, facial traits, and mandibular symphyseal traits. A backward multiple linear regression was employed to explore the association between LICBT and seven representative dentofacial traits.

Results: Four dentofacial traits (vertical facial pattern, transverse jaw relationship, lower incisor cervical diameter, and mandibular symphyseal width) were identified as significantly associated with LICBT. The combination of these four factors could predict 64.3% of variations in LICBT (adjusted $R^2 = 0.643$). Further comparison of LICBT among different transverse jaw relationships suggested that the LICBT of the normal (5.94 ± 1.58 mm) group and the inferior convergent group (5.38 ± 1.32 mm) were significantly larger than that of the crossbite group (4.34 ± 1.27 mm) and the superior convergent group (4.53 ± 1.67 mm).

Conclusions: The bony support of lower incisors is significantly associated with several dentofacial traits. Reduced lower incisor bony support was statistically associated with increased vertical facial pattern, transverse jaw discrepancy, thinner mandibular symphyseal width, and smaller lower incisor cervical diameter. (*Angle Orthod.* 2017;87:409–415)

KEY WORDS: Lower incisor cancellous bone thickness; Dentofacial traits; Vertical facial pattern; Transverse jaw relationship; Symphyseal width; Lower incisor root diameter

INTRODUCTION

The bony support of lower incisors is of fundamental importance for orthodontic diagnosis and treatment strategy.[1] The lower incisor cancellous bone thickness (LICBT) not only limits the orthodontic lower incisor movement but also influences the entire individualized orthodontic treatment plan through the pivotal role of lower incisor position within a concatenation of dentofacial structures.[2,3]

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Previous dental and anthropological research has revealed that human lower incisor alveolar characteristics are significantly varied with several dentofacial traits. The vertical facial pattern seems to be the most relevant factor associated with LICBT. The authors of numerous studies[4–7] have suggested that mandible in short and average facial types was significantly associated with thicker lower incisor bony support, compared to those with a long facial type. There is also evidence that the morphology and dimensions of mandibular symphysis are statistically related to anteroposterior jaw relationships. It has been reported[8] that skeletal Class III patients are more likely to be associated with larger mandibular symphysis compared to Class I and Class II patients.

It has become increasingly apparent that LICBT is a complex phenotype determined by the interplay of various dentofacial traits: vertical facial pattern, anteroposterior jaw relationships, mandibular symphysis morphology, lower incisor mandibular plane angle, etc.[4,6,9] A question has arisen as to how these factors are associated with and jointly contribute to the variation of LICBT. The purpose of this study was to first identify those dentofacial anatomic traits associated with LICBT0 and to then assess their separate contributions, as well as their combined contribution, to variation in LICBT.

MATERIALS AND METHODS

Samples

A consecutive sample of cone beam computed tomography (CBCT) data taken in a university hospital radiological department within the same setting (routinely, full field of view setting for dentofacial structures) from January 2013 to December 2013 was reviewed retrospectively for eligibility to be enrolled in this study. Inclusion criteria required that subjects be older than 18 years of age, with a complete permanent dentition except for the third molars. Exclusion criteria comprised subjects with any retained deciduous teeth; any considerable periodontal lesion based on CBCT image (alveolar bone lose $\geq$4 mm); crowding of more than 4 mm in either the upper or lower arch; with craniofacial malformations; orthodontic or orthognathic surgery history; or dentofacial trauma history. The institutional review board for dental research of Wuhan University reviewed and approved the study protocol and consent forms related to this study.

The sample size of this study was estimated based on an applicable guide that a number of 10–20 observations per variable are necessary to avoid computational difficulties for multivariable analysis.[10,11] In this study, a total of seven independent variables were considered in the multivariable analyses. Therefore, a sample size above 140 would be appropriate to cover the analytical purposes of this study.

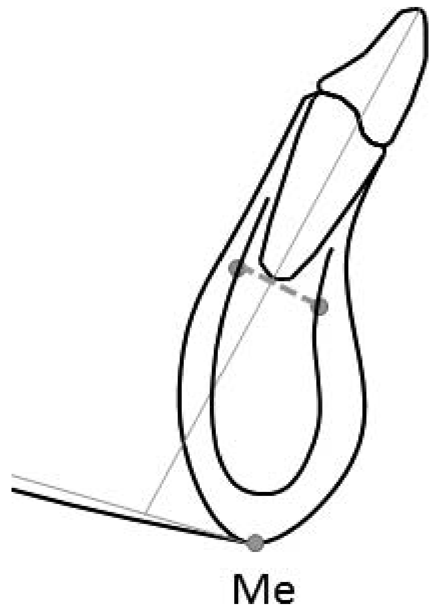

Figure 1. Lower incisor cancellous bone thickness (LICBT) measurement: the distance between the most posterior point of the buccal cortex and the most anterior point of the lingual cortex, measured perpendicular to the long axis of the lower incisor at the root apex level, measured on a cephalogram synthesized from cone beam computed tomography (CBCT) scan.

Imaging and Processing

All of the CBCT scans were obtained using a NewTom scanner (NewTom VGI, NewTom, Verona, Italy) with the same setting: 110 kvp at 2.53 mA for an exposure time of 3.6 seconds with an axial pith size of 0.3 mm and an axial thickness of 0.3 mm. The scanning results were reconstructed by Dolphin 3D software (Dolphin Imaging 11.0, Dolphin Imaging & Management Solutions, Chatsworth, Calif).

Measurements

Eligible subjects' LICBT values and other dentofacial traits were traced and measured in Dolphin software by a trained orthodontist. Randomly, 10% of the eligible sample was measured again by the same orthodontist a month later to assure the measurement reliability.

Measurements of LICBT. The distance between the most posterior point of the buccal cortex and the most anterior point of the lingual cortex, measured perpendicular to the long axis of the lower incisor at the root apex level (Figure 1), was measured.

Measurements of vertical, anteroposterior, and transverse facial traits. (1) Vertical facial pattern was determined by posterior anterior facial height ratio (S-Go/Na-Me, PA ratio) measured on a cephalogram

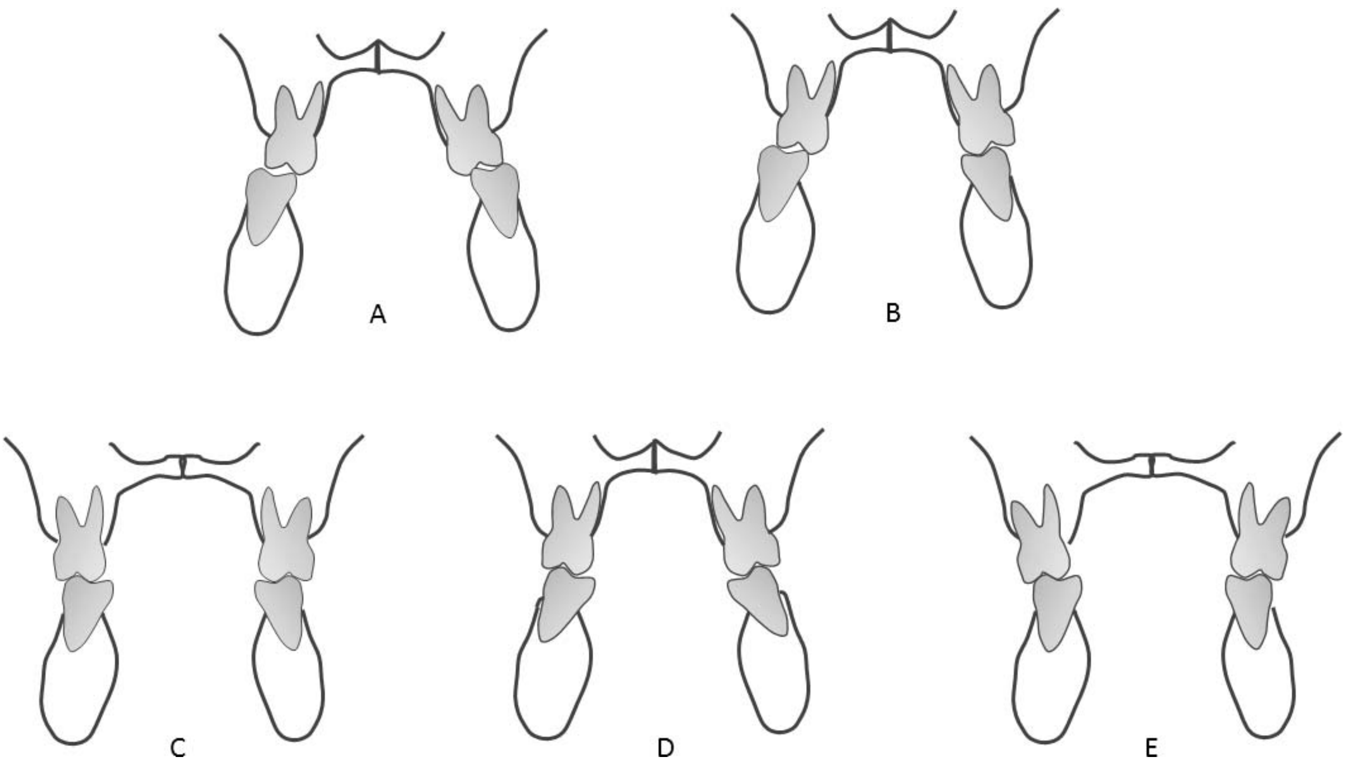

Figure 2. Classification of transverse jaw relationships. Molar crossbite group: (A) bilateral crossbite and (B) unilateral crossbite; (C) normal group; (D) superior convergent group; and (E) inferior convergent group.

synthesized from a CBCT scan. (2) Anteroposterior jaw relationships were determined by ANB angle from a synthesized cephalogram and were then categorized as skeletal Class I (ANB $= 2.7° \pm 2.0°$), skeletal Class II (ANB $> 4.7°$), and skeletal Class III (ANB $< 0.7°$). (3) Subjects' transverse jaw relationships were classified according to the method of Miner et al.[12] Briefly, all subjects were dichotomized into the permanent first molar crossbite group and the non-crossbite group. Then the non-crossbite group was further subdivided into the following three groups: normal group, superior convergent group, and inferior group; subdivision was according to the buccal-lingual inclination of the permanent first molar on the coronal slice (Figures 2 and 3).

Measurements of mandibular symphyseal traits. (1) Lower incisor cervical width was measured on a synthesized cephalogram as the widest distance perpendicular to the lower incisor long axis at the cervical level. (2) Lower incisor mandibular plan angle (IMPA) was measured on a synthesized cephalogram as the angle between the lower incisor's long axis and the mandibular plane (Me-Go) on the sagittal slice. (3) Symphyseal width and height landmarks and measures on a synthesized cephalogram adopted for mandibular symphyseal morphology analysis were based on previously reported literature.[13,14] The details are described in Figure 4.

Statistical Analyses

In data analyses, the measurement reliability of this study was assessed by intraclass correlation coefficient (ICC). Next, a backward multiple linear regression was employed to explore dentofacial traits associated with lower incisor alveolar cancellous bone thickness, with LICBT as a dependent variable and with seven other dentofacial traits (anteroposterior jaw relationship, vertical jaw relationship, transverse jaw relationship, lower incisor cervical width, IMPA, symphyseal width, and symphyseal height) as independent variables. Finally, one-way analysis of variance (ANOVA) and post hoc Bonferroni's multiple comparisons were performed to determine subgroup differences for variables that were identified as significant in the regression model. The statistical software IBM SPSS 21.0 for Windows (IBM Corp, Armonk, New York, NY) was used for all of the statistical analyses. The level of statistical significance was set at .05.

RESULTS

Two hundred fifty-two subjects who met the inclusion and exclusion criteria were enrolled in this study. These subjects ranged in age from 18 to 37 years, with a median age of 20.6 years (interquartile range of 1.8 years), and approximately 60% (161 of 252) were

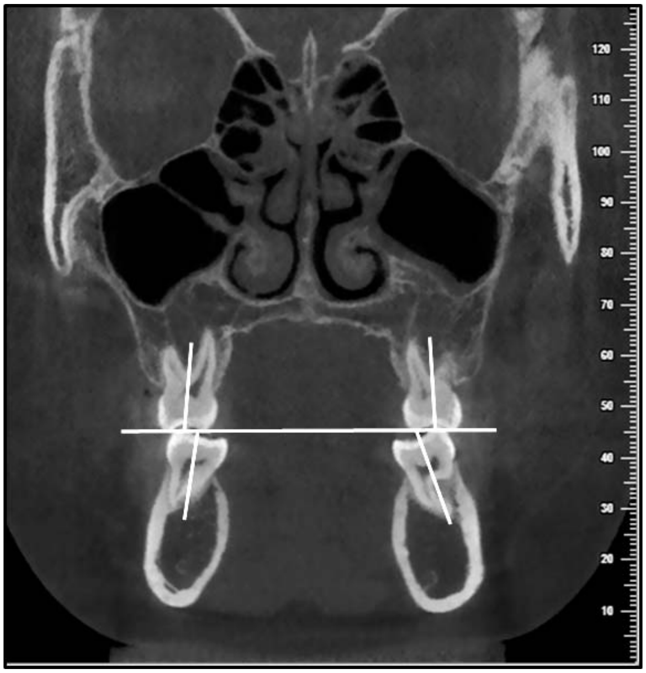

Figure 3. Measurement of buccal-lingual inclination of permanent first molar on the coronal slice.

female. The ICC for measurement reliability was 0.96 (95% confidence interval [CI]: 0.994–0.998).

Dentofacial Traits Associated With Lower Incisor Bony Support

The results of multiple linear regression suggested that four dentofacial traits—PA ratio (ie, vertical facial pattern); transverse jaw relationship; lower incisor cervical diameter; and mandibular symphyseal width—were statistically significantly associated with LICBT (Table 1). Thicker lower incisor cancellous bone was significantly associated with higher PA ratio, wider lower incisor cervical diameter, wider mandibular symphyseal width, and normal or inferior convergent transverse jaw relationships. The combination of these four factors could predict 64.3% of variations in LICBT (adjusted $R^2 = 0.643$). Other dentofacial traits (anteroposterior jaw relationship, IMPA, symphyseal height) were revealed as insignificant in the regression model of this study.

Transverse Jaw Relationship and Lower Incisor Bony Support

In the following ANOVA analysis of LICBT there was a significant difference among four transverse jaw relationship groups ($P < .001$). Subsequently, by comparing LICBT between each two groups, Bonferroni's multiple comparisons suggested that the LICBT values of the normal group (5.94 $\pm$ 1.58 mm) and the

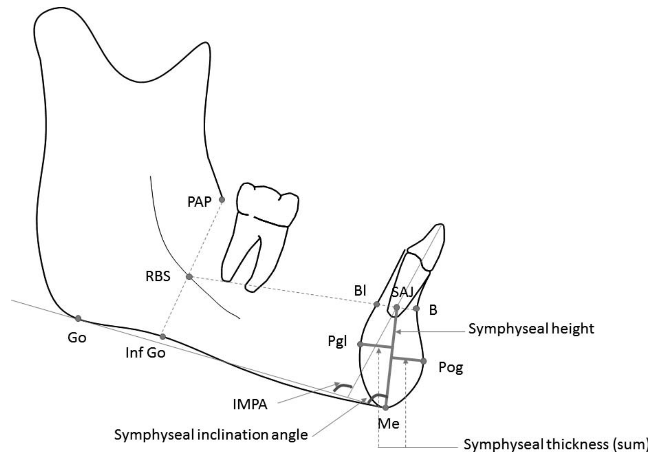

Figure 4. Mandibular symphysis landmarks and measurement: landmarks: B, supramentale; Go, gonion; Me, menton; Pog, pogonion; PAP, posterior alveolar point, most posteroinferior point on anterior border of mandibular ramus; Inf Go, inferior gonion, point on lower border of mandible at which convexity at Go merges with concavity of antegonial notch; RBS, ramus body syncline, point of intersection of line drawn from Inf Go to PAP with cortical outline of mandibular nerve; Bl, lingual point B, point of intersection of line drawn from RBS to B, with lingual contour of symphysis; saj, symphysis-alveolar junction, midpoint of line drawn from Bl to B; Pgl, lingual point pogonion, highest point on lingual contour of symphysis, located by greatest perpendicular distance from line drawn from saj to Me. Measurement items: IMPA; symphyseal inclination angle (angle between Me-Saj and mandibular plan); symphyseal height (distance between Me and Saj); symphyseal thickness (widest distance between Pgl and Pog, perpendicular to Me-Saj line).

inferior convergent group (5.38 $\pm$ 1.32 mm) were significantly larger than that of the crossbite group (4.34 $\pm$ 1.27 mm) and the superior convergent group (4.53 $\pm$ 1.67 mm). Meanwhile, there was no significant difference between the normal group and the inferior convergent group, as well as no significant difference between the crossbite group and the superior convergent group. The means and standard deviations of LICBT for each group are listed in Table 2.

DISCUSSION

Although it has already been reported by previous researchers that lower incisor bony support is significantly associated with several dentofacial traits, to the best of our knowledge this study is the first to address this issue by concurrently including typical factors from three dimensions into a single regression model. This type of analysis is preferable to separately exploring the effect from each independent variable, especially when a scientific question is hypothesized to be associated or influenced by more than one single variable.

Table 1. Dentofacial Traits Significantly Associated With Lower Incisor Cancellous Bone Thickness (Multiple Linear Regression)[a]

Independent Variable	Estimate	SE	*P*-Value	Bonferroni's Multiple Comparison
Age			.455	
Gender			.126	
PA ratio	3.572	1.725	.003	
Transverse jaw relationship			.029	(1) = (3) > (2) = (4)
(1) Normal group[b]				
(2) Crossbite group	−0.486	0.217	.032	
(3) Inferior convergent group	−0.306	0.316	.165	
(4) Superior convergent group	−0.432	0.171	.011	
Lower incisor diameter	0.439	0.213	.039	
Symphyseal width	0.382	0.064	.001	

[a] SE indicates standard error; PA, postero-anterior. Adjusted $R^2 = 0.635$.
[b] Reference category.

Nevertheless, the multiple linear regression is not without its own limitations; the most common disadvantages are its requirement of a large sample size and the difficulty in interpreting the statistical result when standard errors are high. In this study, sample size was calculated based on a common-sense guideline[10,11] to ensure that it was statistically powerful enough to cover the study's purpose. Then the standard errors were narrowed down by strategically grouping subjects into different dentofacial trait groups before performing the regression analysis.

As a result of the current beneficial development of three-dimensional imaging technology, it is relatively easy to obtain accurate three-dimensional diagnosis information with less radiation. Numerous studies have confirmed that CBCT can not only provide accurate data with which to depict the anatomic truth of dentofacial skeletal structures,[15–19] but it also offers an accurate and reliable tool with which to measure dental alveolar thickness and height.[20,21] In this study we chose this setting (110 kvp at 4.26 mA for an exposure time of 3.6 seconds, with an axial pith size of 0.3 mm and an axial thickness of 0.3 mm) to obtain a balance between measurement accuracy and radiation exposure.

The results of this study confirmed previously reported associations between lower incisor alveolar bone thickness and vertical facial dimensions. While different measurements were used in identifying vertical facial patterns, most of the previous literature as well as this study have proved that the narrower lower incisor alveolar bone thickness is significantly associated with increased vertical facial height.

This study did not find a significant difference in lower incisor bony support among different anteroposterior jaw relationship groups, despite a recent study[8] whose authors suggested that significantly different mandibular symphysis dimensions might exist among skeletal Class I, Class II, and Class III groups. This disagreement was likely due to the fact that alveolar bony support and symphysis depth were at two different levels that were independent of each other. In addition, the results of this study also reveal that lower incisor bony support is independent from the inclination of the lower incisors (IMPA) as well as the inclination of the mandibular symphysis.

Subsequently, this study has produced a novel suggestion that the lower incisor alveolar bone thickness is significantly associated with transverse jaw relationships. In the past, different analyses have been introduced to evaluate transverse problems on conventional postero-anterior (PA) head films. However, doubt associated with the validity of those analyses has been suggested in recent studies[22–24] that compare transverse measurement result on two-dimensional2 PA films and on CBCT images. It has been reported[22] that the rate of incorrect transverse diagnosis from PA films is significantly larger than that associated with CBCT (18.0% vs 8.7%). Miner et al.[12] proposed a CBCT-based transverse analysis to classify transverse jaw problems and to differentiate related dental compensations. Adopting their approach for transverse analysis, the results of this study indicate that regardless of whether or how the upper and lower teeth compensate for transverse discrepancy, deficient maxillary width is significantly associated with narrower lower incisor bony support.

Table 2. Lower Incisor Cancellous Bone Thickness (LICBT) Among Different Transverse Jaw Relation Types

			95% Confidence Interval	
	Mean	SD	Lower Bound	Upper Bound
Normal group (1) (n = 96)	5.94	1.58	5.62	6.26
Crossbite group (2) (n = 43)	4.34	1.27	3.96	4.72
Inferior convergent group (3) (n = 45)	5.38	1.32	4.99	5.77
Superior convergent group (4) (n = 68)	4.53	1.67	4.13	4.93

Bonferroni's multiple comparisons: (1) = (3) > (2) = (4); $P < .05$.

Lastly, but most importantly, the regression model achieved in this study reveals that lower incisor bony support is significantly associated with four dentofacial traits: vertical facial pattern, transverse jaw relationship, lower incisor cervical width, and mandibular symphyseal width. These four factors combined together can predict approximately two-thirds of the variation observed in LICBT. This finding has obvious clinical implications. The first two factors (vertical facial pattern and transverse jaw relationship) correlated with LICBT are from the facial traits level. One possible explanation for their correlation may be that lower incisor bony support is influenced by vertical and transverse facial growth patterns. Another possible explanation is that a certain amount of LICBT, certain vertical facial patterns, and certain transverse jaw relationships are independent factors co-existing under a similar skeletal and masticatory functional background. Further study is needed to identify the possible causal effects among these factors. The other two factors correlated with LICBT (lower incisor cervical width and mandibular symphyseal width) could be considered local neighboring factors, which might significantly influence lower incisor cancellous bony support.

CONCLUSIONS

- The results of this study provide evidence that there is a significant association between lower incisor bony support and certain dentofacial traits.
- The combination of four dentofacial traits (vertical facial pattern, transverse jaw relationship, lower incisor cervical width, and mandibular symphyseal width) could explain 64.3% of the total variation in lower incisor bony support.

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