

The Association between Lower Incisal Inclination and Morphology of the Supporting Alveolar Bone — A Cone-Beam CT Study

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Abstract

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Aim To investigate the relationship between the positioning of the lower central incisor and physical morphology of the surrounding alveolar bone.

Methodology Thirty-eight patients (18 males, 20 females), with mean age of 13.4 years, were included in this study. As part of orthodontic treatment planning the patients were required to take dental Cone-beam CT (CBCT) covering the region of lower incisors, the surrounding alveolar bone and the mandibular symphysis. The cephalometric parameters were designed and measured

to indicate the inclination of lower central incisor and physical morphology of the adjacent alveolar bone. Computer-aided descriptive statistical analysis was performed using SPSS 15.0 software package for Windows. A correlation analysis and a linear regression analysis between the incisor inclination and the alveolar bone morphology were performed.

Results Significant positive correlations were found between the lower central incisor inclination and the morphological contour of the alveolar bone ($P < 0.05$). The lower central incisor root apex was closer to the lingual alveolar crest when it was buccally inclined.

Conclusion The morphology of the alveolar bone may be affected by incisal inclination.

Keywords Cone-beam CT (CBCT), alveolar bone, incisor inclination

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Introduction

One of the key elements to a successful orthodontic treatment is the detailed evaluation of treatment outcomes. The position of the lower incisors in relation to their supporting bone is an important factor in orthodontic treatment planning, assessment of treatment progress, as well as determination of treatment outcome (Aasen *et al.*, 2005). The period between 10 and 14 years of age is a stage at which corrective orthodontic treatment is usually applied. Therefore, the evaluation of the changes in incisal positions occurring during this period could provide valuable information for

treatment planning and assessment of post treatment stability (Ceylan *et al.*, 2002). For reasons of both function and appearance, it is necessary to assess incisor inclination before, during, and at the end of orthodontic treatment. Tooth arrangements showing central incisors with ideal axes are more attractive. Slight changes in the angulation of one or both lateral incisors do not influence attractiveness negatively (Wolfart *et al.*, 2005). Turk's study indicated that the determination of the centre of resistance location with consideration of alveolar bone support, root morphology and tooth inclination would be more reliable. The examination of the relationship between the individual centre of

resistance and the line of action of force, the observation of tooth movement occurring during treatment and changes in treatment mechanics would be helpful in obtaining desired tooth movement (Turk *et al.*, 2005). It is widely accepted that the anteroposterior thickness of the alveolar bone in the symphysis region determines the distance available for orthodontic movement of the incisors. The labio/lingual inclination of the central incisor significantly correlates with the labiolingual inclination of the associate alveolar bone (Yamada *et al.*, 2007). Numerous studies have shown that if the incisor root apex is moved against the cortical plate of the alveolar or beyond the alveolar, severe root resorption and bony dehiscence may occur (Richmond *et al.*, 1998; Apajalahti *et al.*, 2007). To evaluate the precise position of the lower incisor root apex within the alveolar bone is therefore essential before orthodontic treatment.

The alveolar bone is the part of the mandible that holds the tooth roots, periodontal ligament, and the lamina durra that envelops the periodontal space. It is also the part of the mandible where most pathologic conditions occur. A traditional cephalographic radiograph is often used to measure the incisal inclination, but this approach is not accurate enough to determine the geographic relation and physical intimacy between the incisors and their surrounding alveolar bone because the superimposing effects of radiograph often overshadow or block the real manifestation of the alveolar bone in symphysis area. The cone-beam computed tomography (CBCT), a high resolution imaging technique, has enjoyed increased application in medical fields, and the scope of CBCT in dentistry has broadened (Bohm *et al.*, 2000). Dental CBCT is now regarded as the most reliable tool to locate impacted teeth and pin-point accuracy, to reveal tooth morphology in 3 dimensions and also to detect pathological developments within alveolar regions. More importantly the dental CBCT image system has allowed for accurate display of the vertical as well as the important buccal-lingual dimensions of the mandible in actual size (Gahleitner *et al.*, 2003). As a result of the advances in CBCT and software development, dental CBCT now also offers the additional possibility of determining the topographical location of

the lower incisors (Gahleitner *et al.*, 2004). It also has the advantage of registering the tooth inclination in various planes. With CBCT, both the lower incisor and its surrounding alveolar bone can be shown in a multiplane, true-to-scale image without distortion, and without the disadvantage of object-related, non-uniform magnifications (Robinson *et al.*, 2002; Gahleitner *et al.*, 2004).

Using dental CBCT, the present study aims to investigate the lower central incisor indications, the root apex position and their relationship with the alveolar bone morphology in the alveolar bone.

Materials and methods

Subjects and CBCT scanning

Thirty-eight patients (18 males, 20 females), with mean age of 13.4 years, were recruited for this study. The inclusion criteria were mild to moderate malocclusion without prior orthodontic treatment, reasonably aligned lower incisors without severe crowding, and acceptable oral hygiene without periodontal conditions. The patients were required to take CBCT covering the lower incisors and the surrounding alveolar bone of the mandible (Shanghai Ninth People's Hospital Affiliated to Shanghai Jiao Tong University).

A CBCT imaging system (J. Morita Mfg. Corp., UK) was used with exposure dosage of 80.0 kV, 5.0 mA and slice thickness of 1 mm. The scanning planes were parallel to the mandible plane, and scanning covered the region from the incisal edge of the central incisor to the point Me of the mandibular symphysis (Figure 1).

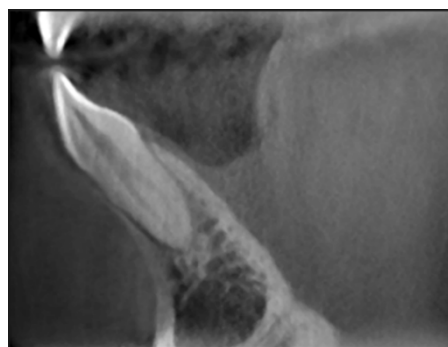


Figure 1 The dental CT images of the lower incisors region

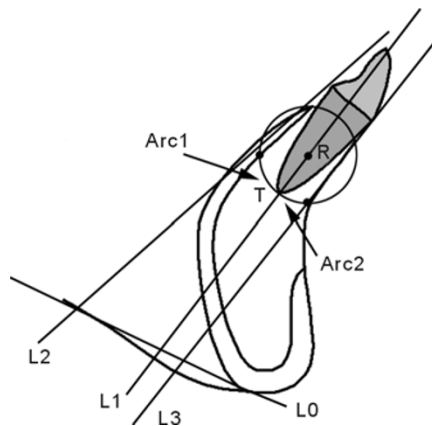


Figure 2 The land marks and reference lines used in the dental CT image measurement

L0: the plane through point Go and point Me; L1: a line through the midpoint of the incisor edge and the root apex; L2: a line through the most postero-superior point and the most posterior point of the mandibular alveolar bone; L3: a line through the most antero-superior point and the most posterior point of the mandibular alveolar bone. Arc1 and Arc2: the arc length between the root apex and lingual/ buccal wall of alveolar bone. R: the midpoint of the embedded portion of the root. T: the root apex.

Measuring parameters

The following landmarks and reference lines were designated to indicate mandibular incisal positioning and its relation with the surrounding alveolar bone (Figure 2) (Yamada *et al.*, 2007):

Centre of rotation (R): This was defined as the midpoint of the incisor root position embedded in alveolar bone.

Line L0: a line through the point Me and tangent to the most superior point in inferior border of the mandibular body. L0 was constructed to serve as a reference plane.

Line L1: a line through the tip of incisal edge and the root apex of the lower central incisor. L1 was constructed to indicate the inclination of mandibular central incisor.

Line L2: a line tangent to the most superior-posterior point of the lingual surface of the mandibular alveolar bone. L2 was used to indicate the morphological contour of alveolar bone in lingual side.

Line L3: a line tangent to the most superior-posterior point of the labial surface of the man-

dibular alveolar bone. L3 was used to indicate the morphological contour of alveolar bone in labial side.

Arc1 and Arc2: a circle was formed with point R and the distance between R and the root apex as diameter. Arc1 was the circle fragment between T and the circle insetting with lingual surface of alveolar bone. Arc2 was the circle fragment between T and the circle insetting with the labial surface of alveolar bone. Arc1 and Arc2 were constructed to indicate the morphological relation between incisal root and alveolar bone.

The central incisor angle (L1-L0), lingual alveolar bone angle (L2-L0) and labial alveolar bone angle (L3-L0) were measured by using dental CT programme with the i-Dixel One Data Viewer software (1.2.7.100, J. Morita Mfg. Corp., UK). Arc1 and Arc2 were also measured on the dental CT program.

Data analysis

For all measurements, computer-aided descriptive statistical analysis was performed using SPSS 15.0. Differences in all variables between male and female were tested using the independent-samples *t*-test. The level of significance was set at $P < 0.05$. Additionally, Pearson correlation analysis, *i.e.* central incisor angle versus lingual alveolar bone angle, central incisor angle versus labial alveolar bone angle, central incisor angle versus Arc1, central incisor angle versus Arc2, was performed. The linear regression was also performed.

To reduce measurement error, one month after the first measurements, ten cases were randomly selected and remeasured by the same examiner (Quan Yu). The differences between the measured and mean values were used to determine the method error according to Dahlberg's formula ($\delta^2 = \Sigma d^2 / 2n$). Error estimation using the method error according to Dahlberg was below the reference value of 1.0 for all measured values.

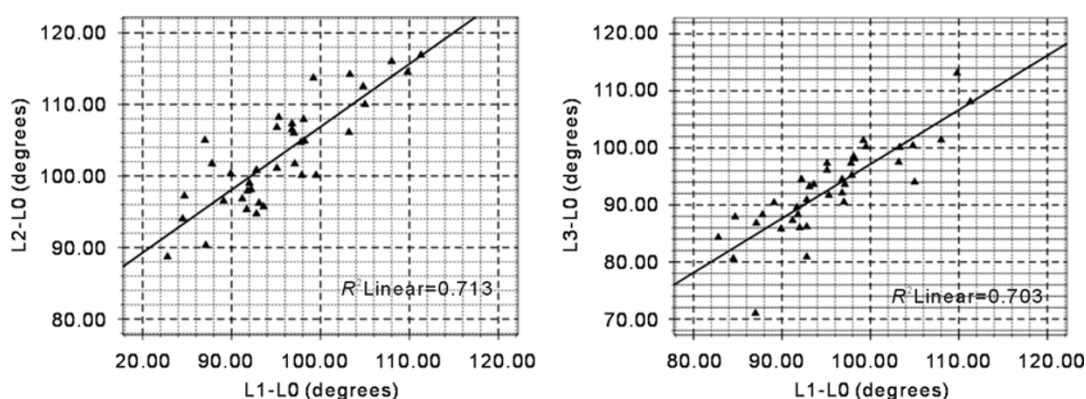
Results

Descriptive statistics are shown in Table 1. The independent-samples *t*-test showed no significant difference between female and male in incisal

Table 1 Descriptive statistical analysis of the lower incisor inclination and its relation with alveolar bone between male and female subjects

	Male (n=18)				Female (n=20)				Total (n=38)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
L1-L0 /°	96.0	18.0	82.8	109.8	94.9	6.9	84.5	111.3	95.4	6.9	82.8	111.3
L2-L0 /°	103.2	8.1	88.7	116.0	102.5	6.4	90.3	116.9	102.8	7.2	88.7	116.9
L3-L0 /°	94.0	7.5	80.9	113.1	91.7	8.0	71.0	108.1	92.8	7.8	71.0	113.1
Arc1 /mm	4.9	0.8	3.5	5.9	4.7	0.9	3.2	6.9	4.8	0.8	3.2	6.8
Arc2 /mm	5.6	1.1	3.9	7.2	5.3	1.1	4.1	7.9	5.4	1.1	3.9	7.9

SD, standard deviation.

**Figure 3** The linear regression plots for the lower central incisor inclination and dental alveolar bone measurements

(A): L1-L0 and L2-L0. (B): L1-L0 and L3-L0.

Table 2 Correlation coefficients analysis for lower incisor inclination and its relation with surrounding alveolar bone

	Pearson correlation	P-value
L1-L0/L2-L0	0.844	0.000**
L1-L0/L3-L0	0.840	0.000**
L1-L0/Arc1	-0.370	0.022*
L1-L0/Arc2	0.408	0.011*
Arc1/Arc2	0.578	0.000**

*: Correlation is significant at the 0.05 level.

**: Correlation is significant at the 0.01 level.

inclination (L1-L0) and its relation with surrounding alveolar bone (L2-L0, L3-L0, Arc1, Arc2).

The results of the Pearson correlation coefficient are shown in Table 2. Significant positive

correlations were found between L1-L0 and L2-L0 ($P<0.01$), L1-L0 and L3-L0 ($P<0.01$), L1-L0 and Arc1 ($P<0.05$), L1-L0 and Arc2 ($P<0.05$), and between the Arc1 and Arc2 ($P<0.001$).

The linear regression plots for each pair of lower incisor inclination measurements are shown in Figure 3. A correlation was found between L1-L0 and L2-L0, and the L1-L0 and L3-L0.

Discussion

The anteroposterior position of the mandibular incisors affects the fullness of the lips. In addition to playing an important functional role in overbite stability, an ideal incisor inclination contributes to an attractive facial appearance (Al-Nimri *et al.*, 2003; Aasen *et al.*, 2005). For reasons of both function and esthetics, it is therefore important to

assess incisor inclinations before, during, and after orthodontic treatment. Many cephalometric goals for post treatment positions of the mandibular incisors have been advocated. Tweed stated that the mandibular incisors should create an angle from 85° to 95° with the mandible plane if the mandible plane to the Frankfort plane angle falls in the 22° to 29° range (Tweed *et al.*, 1954). Some clinicians, however, have used Steiner chevrons to assess favorable positioning of the incisors. Ricketts determines the ideal incisal position by the tips of the mandibular incisors to the A-pogonion line (Al-Nimri *et al.*, 2003)

Steiner and Calif first suggested the concept of ideal or standard inclinations for upper and lower incisors (Steiner *et al.*, 1953). Over the succeeding years, some studies have demonstrated a remarkable uniformity for incisor inclinations in Caucasian populations, with mean values derived from 15 studies found to be 109° for the inclination of the upper incisors to the maxillary plane and 93° for the inclination of the lower incisors to the mandibular plane (Hamadan *et al.*, 2001). Along with the position on the palatal surface against which the lower incisors bite, the angle between the lower incisors and the palatal surface of the upper incisors is an important factor for determining overbite stability. Backlund demonstrated that overbite stability at the end of treatment depended upon the interaction between II A and biting position; 20° was a sufficient angle if a cingulum bite was achieved, but if the lower incisors were left contacting the palatal third of the upper teeth an angle of at least 50° was required to prevent post treatment over-eruption of the lower incisors (Ceylan *et al.*, 2002). Because the contour of alveolar bone surrounding the lower incisors, together with the mandibular symphysis in sagittal dimension is of the physical shape with irregular curvatures, it is difficult to accurately describe, either mathematically or geometrically, the morphology of alveolar bone. Consequently, its relation with the positioning of lower incisors is difficult to determine. In this study, attempts were made to resolve this dilemma. The lines tangent to either the most- posterior or most-anterior points in the outlines of the alveolar bone were constructed to reflect the physical contour, and the segmental arc was measured to indicate the thickness of the

alveolar bone surrounding the lower central incisor (Figure 2). This quantitative assessment of physical morphology of alveolar bone made it possible to examine the correlative relation between the position of the lower incisor and morphology of alveolar bone.

When measured with the conventional cephalograms, the line between the incisor tip and root apex may not reflect the inclination of the incisor in the scenario of diverse crown root angles. This radiographic technique usually records the most prominent incisor, and there may be superimposition and lack of clarity between the apices of the six anterior teeth. Shah designed a jig for measuring the inclination of the upper incisors to the maxillary plane and of the lower incisors to the mandible plane (Shah *et al.*, 2005). They concluded that the inclinations of the upper and lower incisors measured at after using the jig were accurate to within 10° of the cephalometric value on 96 per cent of occasions and to within six degrees on 76 per-cent of occasions.

It is important to note that the incisor angulations and tooth-size discrepancies can affect not only the anterior incisor relationship but also the buccal segment relationships (Steenbergen *et al.*, 2006; Freitas *et al.*, 2006). Evaluation of incisor angulations and tooth-size harmony should be performed when the anterior and posterior occlusions do not intercusate satisfactorily. Incorrect incisor angulations may be a significant contributor to the presence of a poor buccal segment and anterior relationship (Melgaco *et al.*, 2007). Inadequate consideration of upper and lower incisor angulations and tooth-size discrepancies could compromise anterior and buccal segment relationships during the finishing stages of orthodontic treatment (Ceylan *et al.*, 2002). Sangcharearn suggested that skeletal Class II cases may have relatively upright upper incisors and proclined lower incisors (Sangcharearn *et al.*, 2007). A near normal occlusion could therefore be observed despite an underlying mild skeletal base discrepancy. When the skeletal base discrepancy becomes more severe, natural dentoalveolar compensation is insufficient to overcome the greater discrepancy between the maxillary and mandibular skeletal bases. Natural dentoalveolar compensation in Class II division 1 malocclusions may be

normal to upright upper incisors and proclined lower incisors for the overjet to appear less severe. The proclination of the lower incisors increases the lower arch length, which could create problems with coordination between the upper and lower arches. In addition, it could also result in an inability to achieve an adequate overjet and overbite, or it may restrict adequate retraction of the upper incisors to close extraction spaces (Sangcharearn *et al.*, 2007).

In the present study, the labial/lingual inclination of the lower central incisor was correlated with the contour of the adjacent mandibular alveolar bone in both the labial and lingual regions. The linear regression analysis indicated that the adjacent alveolar bone contour correlated with the lower central incisor (Figure 3), suggesting that the morphology of alveolar bone seems to be affected by the tooth inclination. Another important and interesting phenomenon in this study was the distance between the incisor root apex to the labial/lingual wall of the alveolar bone. The correlation and regression analysis suggested a correlation between these two variables indicated by Acr1 and Arc2 (Table 2). Judging from these findings, one may come to a hypothesis that when the lower incisor tends to be more proclined, the lingual alveolar bone becomes thinner. This suggests that one should recognize the boundary limit for tooth movement during orthodontic treatment. When the lower incisors are to be proclined, a pre-treatment evaluation of the physical relationship between the incisor inclination and the adjacent alveolar bone could provide information about the limits of incisor movement, thus avoiding the root resorption caused by excessive incisal retraction.

As a result of tilted or rotated head positioning during taking lateral cephalograms, the doubled outlines resulting from the bilateral skeletal anatomies are difficult to avoid. Furthermore, overlapping outlines of anatomical structures often make it difficult to determine the exact location of the lower incisor, especially in the conventional 2 dimensional lateral cephalograms. In addition, it is recognized that the conventional standard orthodontic radiographs such as lateral cephalograms can create considerable bias and inaccuracies in identifying lower incisor position (Freitas *et al.*,

2006).

One possibility for accurate assessment of the location of dental structures is to use the computed tomogram. It allows accurate assessment of the centre line of lower incisors in all planes (Tohnaek *et al.*, 2006; Bernaerts *et al.*, 2006). CBCT, as a high-resolution imaging technique, has become a well established approach to depict morphology of lower incisors and their surrounding alveolar bone. However, compared with conventional radiographs, CBCT has the disadvantage of higher exposure to radiation dosage (Bernaerts *et al.*, 2006). Higher costs might at present also restrain the routine use of CBCT.

Conclusions

We conclude that there is significant correlation between the inclination of the lower central incisor and its associated alveolar bone shape. The dental CT could provide clear images of the lower incisor region and alveolar crest in various planes. The morphology of the alveolar crest in the lower central incisor may be affected by the incisor inclination. The lower central incisor root apex was closer to the lingual alveolar crest when it was buccal-inclined. The lower incisor position is important and should be considered in the orthodontic treatment plan.

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