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Measuring buccolingual inclination of mandibular canines and first molars using CBCT

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Structured Abstract

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Objectives – To develop a reliable method to measure buccolingual inclination of mandibular canines and first molars, and to evaluate a possible correlation between buccolingual inclination with their respective interdental width.

Methods – The sample consisted of 37 boys and 41 girls untreated orthodontic patients averaging 13.2 ± 0.96 years. A line tangent to the inferior border of the mandible and the long axis of the tooth measured buccolingual inclination. Intercanine and intermolar widths were measured on casts.

Results – Reliability (ICC) values were >0.94. The mean mandibular canine inclination was 98.0 ± 4.1°, with mean width 26.0 ± 2.2 mm. The mean mandibular molar inclination was 74.6 ± 4.7° with mean width 40.9 ± 2.7 mm. First molar inclination of Class II molar subjects (73.7 ± 4.2°) was significantly less ($p \leq 0.05$) than of Class I subjects (75.6 ± 4.9°). There were low correlations between interdental width and buccolingual inclination.

Conclusions – A practical and reliable method to measure buccolingual inclination of mandibular canines and first molars is here described using Cone Beam Computed Tomography and a commercially available DICOM software.

Key words: buccolingual inclination; cone beam computed tomography; cuspid; dental arch width; molar

Introduction

Orthodontists have historically been interested in the buccolingual inclination of the teeth. Buccolingual tooth inclination is one of Andrew's 'Six Keys to Normal Occlusion,' and part of the phase III clinical examination of the American Board of Orthodontics (ABO) licensure exam (1, 2). The ABO states that 'in order to establish proper occlusion in maximum intercuspation and avoid balancing interferences, there should not be a significant difference between heights of the buccal and lingual cusps of the maxillary and mandibular molars and pre-molars' (2).

Vardimon et al. evaluated third-order angulations in the normal dentition, and using methods similar to that of Andrew's study, reported a −9° torque for mandibular canines and −26° torque for mandibular first

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molars. However, it was found that the buccal crown contour was important in selecting the tangent point used for constructing the torque angle, and as such surface is not a uniform curve, it was difficult to draw a unique tangent at any given point (3).

Ross et al. (4) used dental casts to investigate the correlation between buccolingual tooth inclinations and vertical skeletal growth patterns. The authors reported a mean of −7° for mandibular first molars in a group of 21 Class I subjects and found no difference between this inclination between groups of patients with varying vertical facial proportions (4). Using a similar method, also with dental casts, Janson et al. (5) reported a mean of −7° torque for mandibular first molars in subjects with a horizontal growth pattern and −8° torque for subjects with a vertical growth pattern, with no statistically significant difference between the groups. The authors discuss how the occlusal surface inclination used does not conform to the actual long axis of the tooth, and therefore, extrapolation of the results to the long axis inclination between different tooth types cannot be gained, because of differences in dental crown anatomy (4, 5).

The use of computed tomography (CT) has been shown to be useful for the measurement of transverse dimensions (6, 7). Tsunori et al. (8) used CT scans to evaluate the relationship between mandibular first molar inclination and facial type in 39 dry skulls of male Asiatic Indians and reported statistically significant differences between short (75.8° ± 3.4), average (80.2° ± 4.6), and long facial types (82.8° ± 4.2).

The introduction of Cone Beam Computed Tomography (CBCT) has made many of the advantages of CT more accessible to the dental profession. One of the advantages is the slice by slice mode, which allows the viewing of individual teeth in any plane (9, 10). Given the clinical importance given to measuring the buccolingual inclination of lower incisors, it is likely that a better understanding of the buccolingual inclination of other teeth may have clinical importance.

The present study aims to (1) develop a reliable method to measure buccolingual inclination of mandibular canines and first molars; (2) evaluate a possible correlation between canine and molar buccolingual inclination with their respective interdental width; and (3) describe such inclinations for an untreated sample of pre-orthodontic patients.

Materials and methods

The Case Western Reserve University Institutional Review Board (IRB) approved the experimental protocol. The sample consisted of untreated pre-treatment orthodontic records taken in 2006, which included CBCT scans taken with the CB MercuRay (Hitachi Medical Systems America Co., Twinsburg, OH, USA). All scans were taken using a custom low radiation mode of 2 mA, 120 kVp, and a 12″ field of view, resulting in a voxel height (slice thickness) of 0.28 mm. The radiological settings used in this study are not available in the commercially available model of the scanner used. The scanner used has been modified by Hitachi engineers to reduce the amount of radiation and maintain good image quality (11–13).

Subjects were selected based on the following criteria: (1) age between 11 and 14 years old at the time of the records, (2) fully erupted mandibular canines and first molars, (3) no previous orthodontic treatment, based on medical and dental history form, (4) no deciduous mandibular teeth present, (5) no missing or extracted permanent teeth in mandibular arch, (6) no restoration of the dental cusps of measured teeth, (7) no severe rotations (≥90°) of mandibular canines or first molars, (8) no buccal crossbites, (9) no angle classification subdivisions, (10) clearly visible landmarks on CBCT scan (cusp tips and root apices), (11) complete records, (12) adequate oral hygiene, and (13) no evident facial or skeletal asymmetry.

From a total of 200 subjects, 78 met the selection criteria. Of the 112 patients excluded, 37 were based on age, nine had a history of previous orthodontic treatment, five had missing or supernumerary mandibular teeth, 12 had unerupted or severe rotations, 10 had mandibular deciduous teeth, six had poor images, 30 had Angle subdivisions, and 13 had incomplete records at the time of data collection. The sample consisted of 37 boys and 41 girls, with an average age of 13.2 ± 0.96 years. A commercially available software (Accurex by Cybermed Inc, Seoul, Korea) was used to analyze the CBCT data. Buccolingual inclination through the long axes of the teeth was measured separately for right and left canines and molars by a single operator (WS).

The developed technique for calculating buccolingual inclination of mandibular canine and mandibular

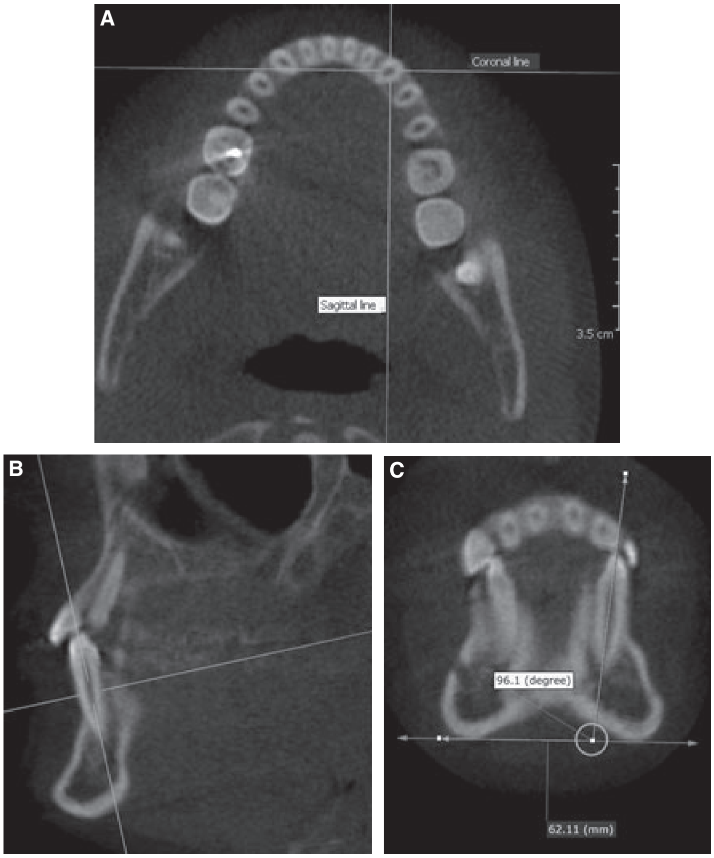

Fig. 1. Technique to calculate the buccolingual inclination of mandibular canines. (A) Adjust midsagittal plane to patient's skeletal midline, and then locate the canine in the axial view, at the point at which the root is longest in the sagittal view. (B) In the sagittal view, position the line representing the coronal slice along the long axis of the tooth. (C) In the coronal view, draw the reference line as the tangent at the inferior border of the mandible. Measure the inclination through the long axis of the tooth, and repeat steps for the contralateral canine.

molar are respectively shown and described in Figs 1 and 2. All measurements were taken between the long axis of the tooth and a tangent line to the inferior border of the mandible. The long axis of the mandibular first molar was drawn as a line passing through the central groove to the middle of root apices.

The mandibular intercanine width was calculated as the distance between the incisal tips of mandibular canines and was performed on dental plaster casts using a digital caliper accurate to 0.01 mm (Central Tools Inc, Cranston, RI, USA) (Figure 3). If incisal wear was present, the cusp tip was defined as the middle point of the wear. The mandibular intermolar width was calculated as the distance between central pits of mandibular first molars. If any restorations were present, the central pit was defined as the midpoint between the mesiobuccal and the mesiolingual cusp tips. If occlusal wear was present, the cusp tip was defined as the midpoint of the wear.

All measurements were repeated after a 3-week interval on 30 randomly selected subjects. The intraclass correlation coefficient was used to assess intra-examiner reliability of all continuous measurements. Means and standard deviations for each variable were calculated, with data for right and left sides collected separately. An independent sample t-test was used to compare measurements between two groups of variables, and a p-value ≤ 0.05 was used to assign statistical significance. A Pearson correlation was used to evaluate the relationship between tooth inclination and arch width. All statistics were calculated using the Statistical Package for the Social Sciences (SPSS 13.0; SPSS Inc., Chicago, IL, USA).

Results

All measurements showed intraclass correlation values >0.94, showing excellent reproducibility. A descriptive summary of demographics, Angle classification and crossbite status is shown in Table 1. A t-test showed no difference when comparing right and left sides, so data

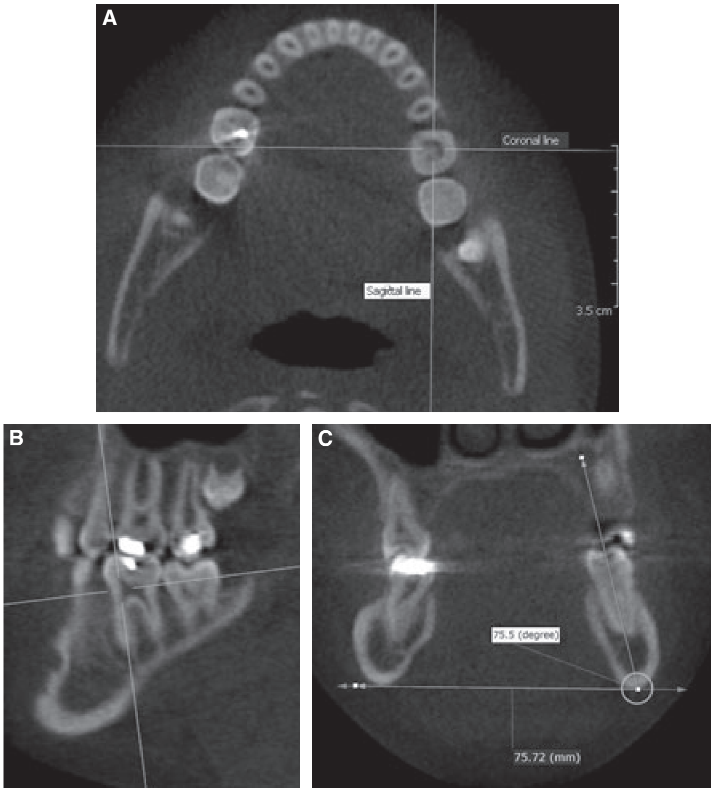

Fig. 2. Technique to calculate the buccolingual inclination of mandibular first molars. (A) Adjust midsagittal plane to patient's skeletal midline, and then locate molar in the axial view, at the point at which the mesial root is longest in the sagittal view. (B) In the sagittal view, position the line representing the coronal slice along the plane of the mesial cusp tip and the mesial root apex. (C) In the coronal view, draw the reference line tangent to the inferior border of the mandible. Measure the inclination through the long axis of the molar, and repeat steps for the contralateral first molar.

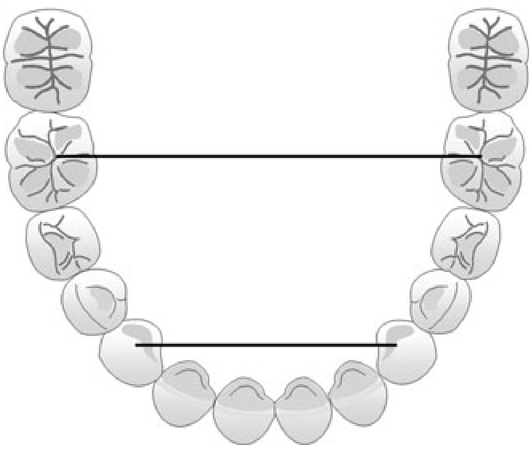

Fig. 3. Illustration showing how intercanine and intermolar width were calculated.

were pooled together for subsequent analyses. For the mandibular canines, the mean inclination was 98.0 ± 4.1 degrees and the mean intercanine width was 26.0 ± 2.2 mm. For the mandibular molars, the mean inclination was 74.6 ± 4.7° and the mean intermolar width was 40.9 ± 2.7 mm (Table 2).

The mean mandibular canine inclination was 97.6 ± 3.6° in subjects with Class I molar occlusion, 98.7 ± 4.4° in subjects with Class II molar occlusion, and 97.3 ± 4.6° in subjects with a Class III molar occlusion. The mean mandibular first molar inclination was 75.6 ± 4.9° in subjects with Class I molar occlusion, 73.7 ± 4.2° in subjects with Class II molar occlusion, and 70.8 ± 1.3° in subjects with Class III molar occlusion (Table 3).

Table 3 shows the comparison among groups. There were no statistically significant differences between age groups 11–12 and 13–14, for either buccolingual inclination or interdental width. There was also no difference between boys and girls for either inclination or interdental width. The first molar inclination in subjects with Angle Class II molar relationship was significantly less than that found for subjects with a Class I molar ($p \leq 0.05$), regardless of crossbite presence. The above comparisons between Angle classifications were not the primary objective of this paper, but were performed to better describe the present

Table 1. **Descriptive summary of demographics, Angle classification, and crossbite status of mandibular canines and molars (N = 78)**

Variables	Group	Total	Percent	Male	Female
Age	11–12 year	34	43.6	16	18
	13–14 year	44	56.4	21	23
Anthropological group	Caucasian	71	91.0	33	38
	African American	5	6.4	3	2
	Asian	2	2.6	1	1
Sex	Male	37	47.4	37	0
	Female	41	52.6	0	41
Angle Classification	Class I	41	52.6	19	22
	Class II	33	42.3	14	19
	Class III	4	5.1	4	0
Crossbite status	No crossbite	63	80.8	31	32
	Crossbite of canines	6	7.7	2	4
	Crossbite of posterior teeth	9	11.5	4	5

Table 2. **Width and inclination of mandibular canines and first molars for all subjects (n = 78). Because right and left sides were combined, there were 156 canines and 156 molars measured**

	Minimum	Maximum	Mean ± SD
Canines (°)	88.6	110.4	98.0 ± 4.1
First molars (°)	64.4	90.0	74.6 ± 4.7
Intercanine width (mm)	21.2	31.1	26.0 ± 2.2
Intermolar width (mm)	33.2	46.0	40.9 ± 2.7

sample. The results suggest differences, but proper sample sizes should be used for a truly meaningful result.

The correlation between mandibular canine buccolingual inclination and intercanine width was 0.3 for the right side and 0.5 for the left side. For the first molar, the correlation to the intermolar width was 0.4 for both left and right sides.

Discussion

The primary objective of this study was to develop a reliable method to measure buccolingual inclination of mandibular canines and first molars. When deciding on the plane of reference to use, it was noted that studies using dental casts used the occlusal plane, but studies using CT used the mandibular plane (3, 4, 8, 14). Similar to a commonly used buccolingual assessment, the Incisor to Mandibular Plane Angle (IMPA), it was decided to use the mandibular plane as the reference plane.

Commercially available software limitations prevent at this point the on screen presence of a reference plane while the image is rotated. The use of a non-commercially available software would limit the immediate applicability of such methods, so the latter option was discarded. Each tooth was assessed individually, and a different image was created separately for both left and right sides, but the approach to the tooth was not exactly perpendicular to the buccolingual plane. This choice was purposely made, as when approaching the tooth in a perpendicular fashion, the lower border of the mandible was not clearly and reliably seen. The parallel to midline approach used has also been the choice for the other two CT studies that evaluated buccolingual inclination (8, 14). Mathematically, analyzing the bucco-lingual inclination at an angle has the mesio-distal inclination of the tooth playing a role in the final result. The decision to choose such approach did not come lightly, and several tests were performed to assess possible influences of mesio-distal inclinations. A pilot study including CBCT images of 51 patients had the bucco-lingual inclination of mandibular canines assessed on a perpendicular approach, and by using the approach parallel to the midline, as used in the present article. The difference between both methods was approximately 2° and had no statistically significant difference. The approach parallel to the midline was finally selected, as, in addition to previously mentioned reasons, it presents a more reproducible and faster method, which may have a higher impact in clinical situations.

The present study showed that the inferior border of the mandible can be used as a reproducible reference plane. Unlike the occlusal plane, the mandibular plane is less likely to be influenced by orthodontic tooth movement, which makes the method useful for studying post-treatment changes in tooth inclination. It is likely that the inclination of any mandibular tooth could be measured using this method.

The present results for the intercanine and intermolar width are consistent with reports by both Housley and Erdinc (15, 16). The correlation between

Table 3. **Comparison of collected values by age, gender, and Angle classification**

Variables	Canine inclination (°) Mean ± SD	First molar inclination (°) Mean ± SD	Intercanine width (mm) Mean ± SD	Intermolar width (mm) Mean ± SD
Age				
11–12 year (n = 34)	98.1 ± 3.8	74.7 ± 5.1	26.4 ± 1.8	41.0 ± 2.9
13–14 year (n = 44)	97.9 ± 4.3	74.5 ± 4.3	25.6 ± 2.4	40.7 ± 2.6
Sex				
Male (n = 37)	97.7 ± 4.2	74.7 ± 4.6	26.0 ± 2.3	41.4 ± 2.3
Female (n = 41)	98.3 ± 3.9	74.4 ± 4.7	25.9 ± 2.1	40.4 ± 3.0
Angle Classification				
Class I (n = 41)	97.6 ± 3.6	75.6 ± 4.9*	26.1 ± 2.3	41.1 ± 2.4
Class I without crossbite (n = 33)	97.6 ± 3.6	75.7 ± 4.9**	26.1 ± 2.4	40.9 ± 2.4
Class I crossbite (n = 8)	97.5 ± 3.6	75.5 ± 5.1	26.0 ± 2.1	42.1 ± 2.3
Class II (n = 33)	98.7 ± 4.4	73.7 ± 4.2*	25.9 ± 2.0	40.8 ± 3.1
Class II without crossbite (n = 27)	98.9 ± 4.5	73.5 ± 3.7**	26.0 ± 2.1	40.9 ± 3.0
Class II crossbite (n = 6)	97.8 ± 4.1	74.7 ± 6.2	25.6 ± 1.5	40.2 ± 3.9
Class III (n = 4)	97.3 ± 4.6	70.8 ± 1.3	25.4 ± 3.1	39.3 ± 3.1
Class III without crossbite (n = 2)	97.0 ± 4.0	70.2 ± 1.0	27.3 ± 2.1	39.7 ± 5.4
Class III crossbite (n = 2)	97.7 ± 7.2	71.3 ± 2.7	23.6 ± 3.4	39.0 ± 0.8

*Statistically significant difference detected ($p \leq 0.05$) when comparing Class I and Class II.
**Statistically significant difference detected ($p \leq 0.05$) when comparing Class I without crossbite and Class II without crossbite.

arch width and inclination, however, was low, suggesting that tooth inclination is independent of width.

Only a few other attempts have been made to quantify mandibular molar inclination (3, 4, 8, 16). Tsunori et al. (8) found 75.8 ± 3.4° and 80.2 ± 4.6° torque for mandibular first molar inclination in an short and average facial type, respectively. Kasai et al. (16) found the mandibular inclination of 40 modern Japanese skulls to be 76.7 ± 4.2°, which is similar to the presently reported 75.6 ± 4.9° for Angle Class I subjects.

It has been reported that maintaining the mandibular intercanine width during treatment may reduce the possibility of orthodontic relapse (17–20). Because a negative torque in the mandibular canine bracket is usually found, some clinicians may believe that a canine should lean lingually; however, the present findings show that almost all mandibular canines, regardless of Angle classification, actually lean buccally.

Previous studies did not remove subdivision malocclusion from Class I or Class II patients; therefore, differences between Class I and Class II were not seen to the degree observed in this study. The present results showed that mandibular first molar inclination in subjects with class II molar (n = 27) was significantly less than those with class I molar (n = 33). This may be a dental compensation to maxillary transverse deficiency which is typical in Class II malocclusion. McNamara has suggested that the position of the lower teeth may depend more on maxillary morphology than mandibular morphology (20). Of all Class II subjects, 82% did not have a posterior crossbite. This suggests that the absence of a crossbite does not necessarily mean that the maxilla is of normal width, because dental compensations may mask the skeletal discrepancy.

Changes in tooth inclination may be a considerable factor in the stability of the dentition. Pre-treatment mandibular canines appear to be buccally inclined, while mandibular molars tend to be lingually inclined. One possible use of pre-treatment CBCT images could be to assess tooth inclination. Tooth inclination seems to be influenced by dental adaptation or compensation to skeletal discrepancies, and their evaluation could contribute to a more detailed treatment plan. Further studies are necessary to show evidence-based contribution of such analysis to comprehensive orthodontic treatment, and to further establish the stability of the mandibular plane as a source of reference overtime.

Conclusions

A practical and reliable method to measure buccolingual inclination of mandibular canines and first molars is here described using CBCT and a commercially available DICOM software. The CBCT image provides an unobstructive view of canines and molars, allowing a transverse analysis that could potentially help differentiate between skeletal and dental transverse discrepancies. In addition to the additional diagnostic information, such measurement can also be useful for outcome assessment analysis, complementing what is currently measured using dental casts.

Clinical relevance

Buccolingual inclination has been part of orthodontic outcome assessment for many years. With CBCT, we can now measure this inclination using the long axis of the tooth rather than the labial surface. The present project tests the reliability of a method designed to evaluate the buccolingual inclination of mandibular canines and molars. This could be the first step to eventually create norms that could be used to better differentiate cases needing extractions or changes that could result in higher probability of relapse.

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