Original Article

Cone beam computed tomography measurement of the collum angle of maxillary central and lateral incisors in Taiwanese individuals

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Running title: the collum angle of maxillary central and lateral incisors

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Abstract

Aims: *The crown positioning of anterior teeth directly impacts facial aesthetics. However, crown position is affected by the angle between the crown and the root of the tooth; therefore, this angle must be specifically evaluated before orthodontic and prosthodontic treatment to achieve aesthetically pleasing and functional therapeutic results. To ensure good aesthetics and effective cutting function of maxillary central and lateral incisors, the anterior region should be torqued during orthodontic treatment. Moreover, bone grafting or a cement-retained implant prosthesis is required during implant treatment.*

Materials and Methods: *We obtained cone beam computed tomography (CBCT) images of patients from the China Medical University Hospital Department of Dentistry and measured their collum angles using MIMICS 15.0 software. We selected 19 patients with Class I and 42 patients with Class II, division 1 (Class II/1) occlusal relationships, based on Angle's classification, for comparison. The patients were aged 6–66 years (mean: 26.5 years). The correlation between collum angle and the right and left sides or occlusal classification was determined.*

Results: *No significant difference was observed in collum angle between Class I or II/1 left and right central incisors or between left and right lateral incisors (paired t-test $p > 0.05$). Although no significant difference was observed in collum angle between Class I central and lateral incisors, a significant difference was observed between Class II/1 central and lateral incisors. No significant difference in collum angle was observed between Class I and Class II/1 central incisors, but a significant difference was observed between Class I and Class II/1 lateral incisors (Student's t-test, $p = 0.04$).*

Conclusion: *In both orthodontic and prosthodontic treatment, more attention should be paid to collum angle size, especially that of the lateral incisors, to ensure the preservation of a safe space during the treatment process to avoid irreversible injuries.*

Key words: cone beam computed tomography, collum angle, maxillary central incisors, maxillary lateral incisors

Introduction

The collum angle, which is the angle formed by the long axis of the crown and the root of the tooth, is of critical aesthetic importance in orthodontics and prosthodontics.[1] The angle may limit the extent to which the root can be torqued to the lingual cortical plate, the angle at which implants can be placed, or how prostheses are secured. For patients needing to undergo such orthodontic treatments, the dentist must be careful about the degree of palatal torque to avoid impinging on the cortical palatal bone, which could result in irreversible root resorption. The collum angle of the maxillary central incisor is significantly different between Angle's classification Class II/1 and Class II, division 2 (Class II/2).[2,3] Previous studies have found no significant difference in maxillary central incisors between the right and the left side,[4] between different races,[5,6] between males and females, and between different age groups,[7] but inter-individual differences between labial crown morphology and the collum angle of maxillary anterior teeth can be large.[8] There is no consistency in the associations between collum angle and different skeletal relationships[7,9] and apical root resorption before or after comprehensive orthodontics.[10]

In orthodontics, torque is used for labiolingual or buccolingual tilting of the teeth. A large collum angle is often observed in some patients with deep overbites[11] and Class II/2, Class II/1, or Class III malocclusions.[12] The clinical significance of this study is its attempt to increase awareness of the collum angle during orthodontic and prosthodontic treatment, especially in cases of teeth with large angles that need to be torqued in order to avoid root contact with the cortical plate and perforation of the alveolar bone on the buccal side. Patients with missing teeth that require implants have large collum angles, and the angle between the implant and the abutment teeth may be excessively large. In such cases, abutment teeth with an appropriate angle may be necessary to create aesthetically pleasing prostheses. In addition, inappropriate implant placement may cause gingival recession by concentrating stress on the alveolar bone on the buccal side of the implant, thus affecting aesthetics.

This study explored whether there were differences in the collum angle between maxillary central incisors and lateral incisors in patients with Class I or Class II/1 occlusal patterns.

Material & methods

This study was approved by the Institutional Review Board (CMUH 108-REC2-083). Cone beam computed tomography (CBCT) images of 33 female and 28 male patients aged 6–66 years (mean: 26.5 years; median: 24 years; mode: 21 and 27 years) were obtained from the Department of Dentistry of China Medical University Hospital. The inclusion and exclusion criteria were as described by Khalid et al.[7] Our inclusion criteria were clear visibility of roots and crowns on CBCT images, the absence of orthodontic appliances in the patient, and the absence of craniofacial syndromes. The exclusion criteria were the presence of fractured anterior teeth and fabricated dentures.

Based on Angle's classification, 19 patients were classified with a Class I occlusal pattern and 42 patients with a Class II/1 occlusal pattern. CBCT images were imported into and opened in MIMICS 15.0 software (Materialise, Leuven, Belgium) for obtaining measurements of the maxillary central and lateral incisors on the left and right sides. As CBCT produces multiplanar reconstructed images, any suitable section could be selected for measurement. When searching for a suitable section, the primary focus was to identify a clear cementoenamel junction CEJ(Figure 1). The collum angle is formed by the long axis of the crown and the long axis of the root apex and is defined as 0°

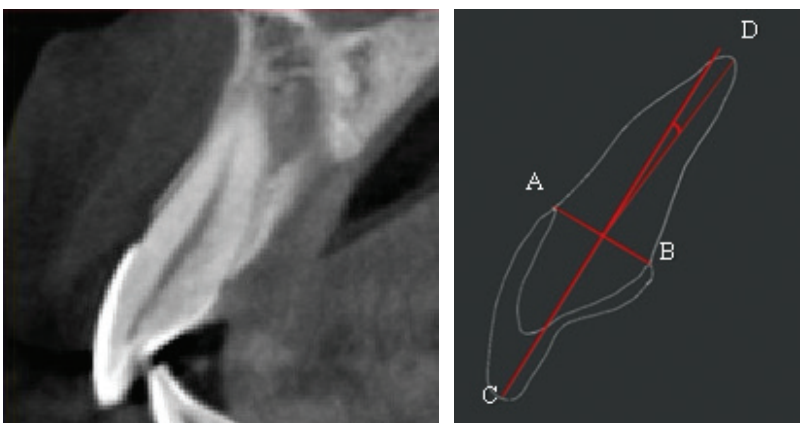

Figure 1. A screenshot of the research method using MIMICS 15.0 software image (left). Collum angle of the central incisor of the upper jaw (right). A: Facial CEJ; B: palatal CEJ; C: incisor edge; D: root apex (self-drawn schematic diagram).

when the two lines coincide. When the long axis of the root is on the lingual side of the long axis of the crown, the collum angle is defined as positive. When the long axis of the root is on the labial side of the long axis of the crown, the collum angle is defined as negative (Figure 2). In the present study, the collum angle of the central and lateral incisors of all cases was measured by a trained specialist using the same method. IBM SPSS Statistics for Windows, version 19 (IBM Corp., Armonk, NY, USA) was used to perform Student's t-test to determine whether the relationship between the angle and tooth laterality and occlusal classification was significantly different.

Step 1: CBCT images were imported into Mimics 15.0, and cross-sections were obtained. Then, the interface was scrolled to display the clear section of the upper row of teeth; the incisors were resliced to obtain a cross-section of the teeth (Figure 3). As CBCT data are multiplanar reconstructed images, oblique sections can be used for more accurate measurement of the collum angle.

Step 2: The maximum width of the bone and enamel in the cross-section was identified, and a line was drawn connecting the root and crown of the tooth through the midpoint of the maximum width of the bone and enamel.

1. Segment 1: The widest part of the bone and enamel was drawn, and the midpoint (M) was identified.
2. Segment 2: The most apical point of the root was located and the midpoint was connected to it.
3. Segment 3: The incisal end of the crown was located, and the line was extended through the midpoint.

The angle formed by line segments 2 and 3 was defined as the collum angle (Figure 4).

Step 3: IBM SPSS Statistics for Windows, version 19 (IBM Corp.) was used for paired t-tests of the collum angle of the left and right central and lateral incisors and the collum angle of the maxillary central and lateral incisors in cases of Class I and Class II/1 malocclusion.

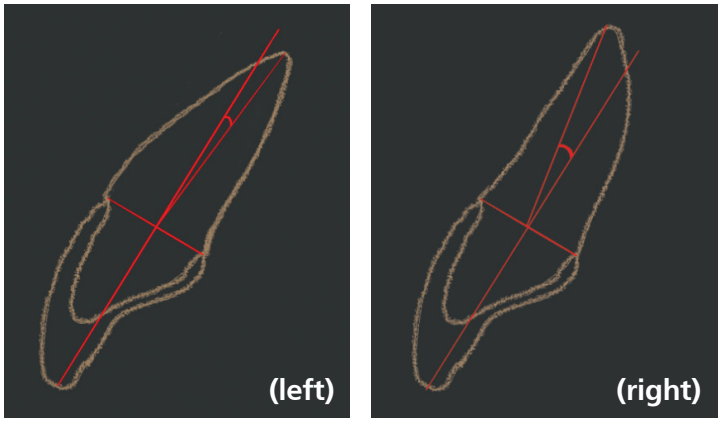

Figure 2. Schematic diagram showing positive collum angle (left) and negative collum angle (right).

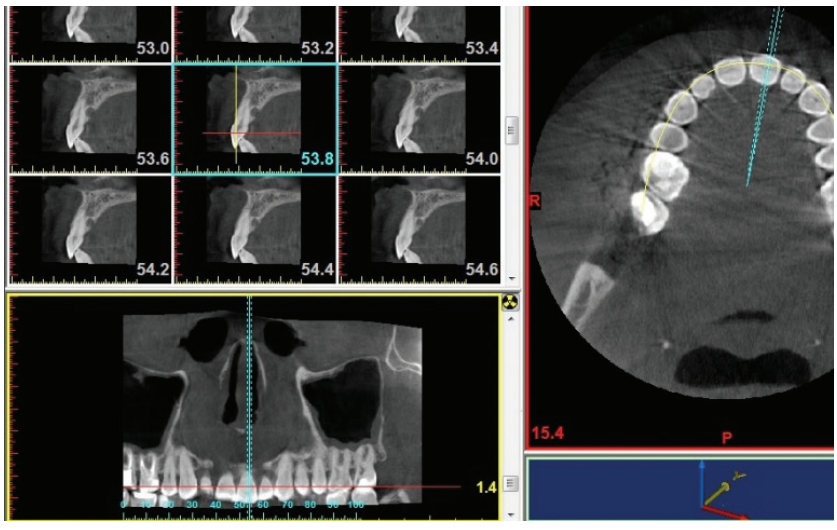

Figure 3. Cross-sectional view of the maxillary central incisor.

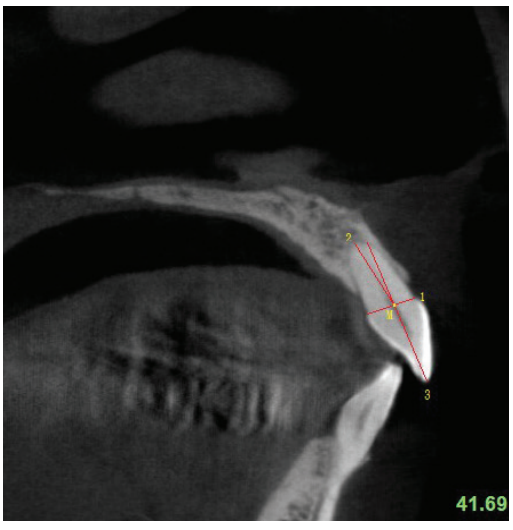

Figure 4. Steps for measuring collum angle.

Results

TIn this study, the lateral incisors were measured in addition to the central incisors to determine whether a correlation existed between the collum angles of the left and right central and lateral incisors and occlusal classification. The central and lateral incisor angles were evaluated for significant differences between the left and right sides and between different occlusal relationships. Column angle did not differ significantly between the left and right sides, irrespective of sex. Moreover, no significant differences were observed for either Class I or Class II/1 left central incisors vs. right central incisors or left lateral incisors vs. right lateral incisors (paired t-test, $p > 0.05$; Tables 1 and 2).

As no statistically significant difference between the left and right sides was identified, the two sides were pooled, and the central incisors were compared with the lateral incisors. No significant difference was observed in collum angle between the central incisors and lateral incisors for Class I, but a significant difference between the central incisors and lateral incisors was observed for Class II/1 (Tables 3 and 4).

Data from the left and right sides were pooled for Student's t-test analysis. Collum angle did not differ significantly between Class I and Class II/1 central incisors ($p = 0.487$), but a significant difference was observed between Class I and Class II/1 lateral incisors ($p = 0.04$; Tables 5 and 6).

Table 1. Comparison of collum angle of maxillary central incisor and lateral incisor of Class I patients (the right and left sides were not pooled).

	Central incisor (L)	Central incisor (R)	Lateral incisor (L)	Lateral incisor (R)
MEAN (degree)	-0.66	-2.40	1.24	-1.52
SD (degree)	4.99	5.56	8.15	9.28

Central incisor L vs R, P value= 0.078 ; Lateral incisor L vs R, P value= 0.1811

Table 2. Comparison of collum angle of maxillary central incisor and lateral incisor of Class II, division 1 (Class II/1) patients (the right and left sides were not pooled).

	Central incisor (L)	Central incisor (R)	Lateral incisor (L)	Lateral incisor (R)
MEAN (degree)	0.14	-1.38	3.25	2.98
SD (degree)	5.97	6.58	5.81	6.39

Central incisor L vs R, P value= 0.340 ; Lateral incisor L vs R, P value= 0.481

Table 3. Comparison of collum angle of maxillary central incisor and lateral incisor of Class I patients (the right and left sides were pooled).

	Central incisor	Lateral incisor
MEAN (degree)	-1.50	-0.09
SD (degree)	5.35	8.82

Central incisor vs Lateral incisor, P value= 0.437

Table 4. Comparison of collum angle of maxillary central incisor and lateral incisor of Class II, division 1 (Class II/1) patients (the right and left sides were pooled).

	Central incisor	Lateral incisor
MEAN (degree)	-0.64	3.12
SD (degree)	6.33	6.10

Central incisor vs Lateral incisor, P value= 0.0003

Table 5. Comparison of collum angle of maxillary central incisor of Class I and Class II, division 1 (Class II/1) patients.

	Mean	SD
Class I (degree)	-1.50	5.35
Class II/1 (degree)	-0.64	6.33

Class I vs Class II/1, P value=0.487

Table 6. Comparison of collum angle of maxillary lateral incisor of Class I and Class II, division 1 (Class II/1) patients.

	Mean	SD
Class I (degree)	-0.09	8.82
Class II/1 (degree)	3.12	6.10

Class I vs Class II/1, P value=0.041

Discussion

The results of this study showed that the collum angle of the lateral incisor of the Class II/1 malocclusion group was significantly different from that of the Class I malocclusion group. Although the source of the image samples measured in this study is different from those of previous studies of orthodontic patients, the results for the upper central incisor in this study are consistent with the trend of other CBCT measurements of collum angle (Table 7). Although malocclusion was classified in different ways in previous studies, a systematic review and meta-analysis proposed pooling data obtained from lateral cranial radiographs and CBCT.[13] Compared to previous studies, collum angle values measured using CBCT were smaller (Table 7). In addition, the results for the upper central incisor in this study showed negative values unlike previous studies. We inferred that this may have been due to the influence of image sample sources that included patients from outside orthodontic departments.

Root resorption is the most undesirable occurrence in orthodontic treatment. For some patients with large collum angles, the amount of torque applied must be carefully controlled to avoid irreversible root resorption. In previous reports, the duration of orthodontic treatment and extraction was positively correlated with orthodontic treatment-induced inflammatory external apical root resorption ($p < 0.05$), which was most common in maxillary incisors. The incidence of severe root resorption after orthodontic treatment was 14.8%, with males having a higher incidence of root resorption than females.[14] Some researchers have raised reasonable concerns that palatal torquing of central incisor roots in Class II/2 patients may cause the roots to strike the palatal cortical bone, resulting in root resorption of the associated teeth.[15] The mean collum angle observed in Class II/2 cases was significantly larger (5.2° ± 1.3°) than the mean of Class I or Class II/1 cases (0.1° ± 0.7 °), suggesting that patients with morphometric features associated with large collum angles require better tooth movement planning, especially for palatal torque of the maxillary central incisors.[15]

A systematic review and meta-analysis reported that the collum angles of 4.7° in Class II/2 and 2.0° in Class III were larger than those in Class I. Most previous studies evaluated the collum angle of the maxillary central incisors in Class II/2 cases, with 13 of 17 articles using lateral cephalograms for measurement.[13] Studies on the collum angle of lateral incisors in Taiwanese individuals are rare. The results of this study demonstrated that the long axis of the root in both Class I and Class II/1 cases was located on the labial side of the long axis of the crown, and the collum angle of Class I was greater than that of Class II/1 based on quantitative CBCT images. In addition, changes in the lower lip line may have an etiological role in the development of collum angle.[16] Therefore, more samples must be collected to further evaluate

Table 7. Comparison of results for maxillary central incisor of this study with those of previous studies.

year of publication		This study	2012	2018	2019	2020	2021
author			Shen[1]	Feres[15]	Wang[9]	Khalid[7]	Panezai[16]
Method		CBCT	lateral cephalometric	CBCT	CBCT	lateral cephalograms	lateral cephalograms
Sample size	Class I	19	33	16	24	25	---
	Class II/1	42	32	16	20	25	70
Collum angle of maxillary central incisor (degree)	Class I	-1.5(5.3)	6.1(5.2)	1.1(4.2)	–1.02(6.30)	5.12(3.78)	not applicable
	Class II/1	-0.64(6.33)	5.3(4.2)	0.1(0.7)	5.18(4.97)	6.10(4.58)	4.38(3.08)
Gender	Male	28	38	12	26	31	66
	Female	33	86	20	40	69	74
Age range		6-66	8-58	---	18-30	10-50	---
Average age		26.5	19.9	18.25±0.56 16.91±0.62	25.8	15.9	21.62 ± 5.96
Sample source		All clinical patient	for clinical orthodontic needs	Orthodontic Graduate Program records	for clinical orthodontic needs	from the Department of Orthodontics	Orthodontics department

Class II/1: Class II, division 1

maxillary and mandibular anterior teeth in different occlusal relationships.

Since there are few studies on the collum angle of lateral incisors, these teeth remain one of the most important factors affecting the aesthetics of the anterior region. Successful treatment results are usually achieved when dental implants are placed in the same position as natural teeth.[17] Although the data could not be analyzed by sex due to the small sample size in this study, the results indicated no statistically significant difference in collum angle between the right and left sides of Class I or Class II/1 lateral incisors and a statistically significant difference between Class I and Class II/1 lateral incisors. The preliminary results of this study may provide a reference for dentists when preparing treatment plans.

This study found that the collum angles of the central incisors and lateral incisors of Class I occlusion and the central incisors of Class II/1 occlusion were all negative, and only the lateral incisors of Class II/1 occlusion were positive. Therefore, we infer that when the occlusion relationship is Class II/1, there may be thick alveolar bone on the buccal side of the lateral incisors, which can help to avoid implant perforation when performing dental implant surgery. In addition, because the crown must meet aesthetic and functional requirements, the crown on the dental implant is more likely to be fixed with dental cement when the collum angle is positive. There is an important correlation between buccal bone responses and aesthetic results after dental implant placement. Therefore, the dental implant must have sufficient thickness of alveolar bone on the buccal side, because in a previous study, the middle and apical regions of the implants showed horizontal bone alterations of -0.57 mm and -0.19 mm after one year.[18] Thus, when the collum angle is negative, a bone graft is recommended when the crown on the dental implant is to be fixed with screws. Furthermore, because the application of immediate dental implants has the advantages of less surgery, shorter treatment time, and improved aesthetics, single dental implants, mainly incisors and premolars, are the most common treatment option. In early studies, bony morphology was a very important factor of success when immediate implants were indicated. Situations not suitable for immediate implant placement include periodontal bone loss with two and three walls missing or severe labial and circumferential defects.[19] When performing dental implants, severe labial defects at the implants may be caused if there is failure before treatment to determine whether the collum angle of the upper central or lateral incisor is negative.

A limitation of this study is that all the measurements were obtained from images. Although CBCT is a three-dimensional reconstructed image that provides better resolution, Angle's classification, which is a lateral view of the relationship between the dentition and palatal bones, may itself be a source of bias in classifying patients based on the occlusal relationship. In addition, due to the limited number of samples, this study could not determine whether there was a significant difference in collum angle between males and females.

Conclusions

Preliminary results for maxillary central and lateral incisor measurements based on CBCT images of patients showed that (1) there was no significant difference in the collum angle of the central or lateral incisors between the left and right sides of the upper jaw; (2) there was a significant difference in collum angle between the maxillary lateral incisors of Class I and Class II/1; and (3) the collum angle of the maxillary lateral incisors of Class II/1 was positive.

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