Original Article

Appraisal of the relationship between tooth inclination, dehiscence, fenestration, and sagittal skeletal pattern with cone beam computed tomography

İpek Coşkun[a]; Burçak Kaya[b]

ABSTRACT

Objectives: To examine the relationship between sagittal facial pattern and dehiscence/fenestration presence in conjunction with buccolingual tooth inclination by using cone beam computed tomography.

Materials and Methods: The study was carried out on the cone beam computed tomography scans of the following three groups of patients (n = 20 in each group): Class I, Class II, Class III. Buccolingual tooth inclination, buccal dehiscence/fenestration presence, and lingual dehiscence/fenestration presence were evaluated on each tooth. Analysis of variance, Kruskall-Wallis H, Scheffe, and chi-square tests were used for statistical comparisons.

Results: Differences ($P < .05$) were observed between the groups for inclination of upper incisors and all lower teeth except for second molars. Dehiscence prevalence in the upper buccal and posterior buccal regions was higher ($P < .05$) in the Class I group when compared with the other groups. Lower buccal and anterior buccal regions showed higher ($P = .0001$) dehiscence prevalence in all groups. No difference was observed in fenestration prevalence between the groups. The upper buccal and anterior buccal regions showed higher ($P = .0001$) fenestration prevalence in all groups.

Conclusions: Orthodontists must consider concealed alveolar defects in treatment planning to avoid gingival recession or tooth mobility. (*Angle Orthod.* 2019;89:544–551.)

KEY WORDS: Inclination; Dehiscence; Fenestration; Sagittal pattern; CBCT

INTRODUCTION

Moving teeth beyond anatomical limits with orthodontic treatment increases the risk of bone loss and formation of anatomical defects such as dehiscence or fenestration.[1] Dehiscence and fenestration are alveolar defects that cause exposure of bone surface as a result of the absence of cortical bone in cervical or more apical regions.[2] Bone surfaces are covered with only periosteum and gingiva in dehiscence and fenestration areas that cause an important decrease in tooth support.[3]

[a] Private Practice, Istanbul, Turkey.
[b] Associate Professor, Department of Orthodontics, Faculty of Dentistry, Başkent University, Ankara, Turkey.
Corresponding author: Dr Burcak Kaya, Baskent Universitesi, Dis Hekimligi Fakultesi, Ortodonti Anabilim Dali, 1. Cad No: 107, 06490 Bahcelievler, Ankara, Turkey
(e-mail: burcak_kaya@hotmail.com)

Accepted: December 2018. Submitted: May 2018.
Published Online: February 11, 2019

Several factors may cause dehiscence and fenestration during orthodontic treatment such as direction of tooth movement, magnitude and frequency of orthodontic force or anatomic integrity, and volume of periodontal tissues.[4] Dental arch expansion and buccal-lingual movements of teeth can move teeth from their bone envelope and may cause dehiscence, fenestration, and gingival recession, depending on the initial morphology of alveolar bone and amount of tooth movement.[5]

Buccolingual crown inclination is one of the six keys to normal occlusion.[6] Optimum inclination of anterior teeth is necessary for obtaining normal overbite and posterior occlusion, whereas optimum inclination of posterior teeth is necessary for obtaining a proper occlusion with maximum intercuspation and for avoiding functional interferences.[7] In addition, the upright positioning of teeth in the center of the alveolus is essential for stable occlusion and better periodontal conditions.[8] On the other hand, dense cortical plates at the apical region of teeth act as biological walls during orthodontic tooth movement. Therefore, orthodontists

 DOI: 10.2319/050818-344.1

must know the anatomical limits of tooth movement to secure proper torque control and be aware of potential periodontal problems that can be aggravated during orthodontic treatment.

The relationship between vertical or sagittal skeletal patterns and dehiscence/fenestration presence was investigated in the literature.[4,9,10] Buccolingual tooth inclination and its correlation with facial skeletal pattern was also inspected, but not in all teeth or skeletal patterns.[6,8,11–15] Hence, the primary aim of this study was to examine the relationship between sagittal facial pattern and buccolingual tooth inclination in conjunction with dehiscence/fenestration presence by using cone beam computed tomography (CBCT). The H_0 hypothesis was that buccolingual tooth inclination and dehiscence/fenestration presence is similar in individuals having different sagittal facial patterns, whereas the H_1 hypothesis was that buccolingual tooth inclination and dehiscence/fenestration presence changes as a result of the sagittal facial pattern. The secondary aim of this study was to examine the diversity in dehiscence/fenestration presence between maxillary and mandibular arches and between anterior and posterior teeth.

MATERIALS AND METHODS

This retrospective study was carried out using the CBCT scans of three groups of patients obtained from the archive of a private maxillofacial scanning and screening center (Tomoloji Maksillofasiyal Görüntüleme Merkezi, Ankara, Turkey) and approved by Baskent University Institutional Review Board and Ethics Committee with project number D-DA13/06. A power analysis was performed based on a 1:1 ratio between the groups by using data obtained from the literature.[4,6,10] The analysis revealed that a sample size of 20 patients per group was needed to achieve a power of 85% at $\alpha = .05$ significance level to detect statistically significant differences between the groups with a 0.30 (medium) effect size. Sample size estimation was performed by using Power Analysis and Sample Size software (Number Crunching Statistical System, Version 2000, Kaysville, Utah).

Patients were included in the study based on the following criteria: no craniofacial deformity present, permanent dentition stage, no congenitally missing or extracted teeth, no impacted or supernumerary teeth, root apices of all permanent teeth closed except for third molars, postpubertal stage (CS5, CS6) according to cervical vertebrae maturation, GonionGnathion/SellaNasion (GoGn/SN) angle between 28° and 36°, CBCT scans present involving the area from the nasal bone to chin, maximum intercuspation in CBCT scans, no periodontal disease causing horizontal or vertical proximal bone loss in CBCT scans, no restorations involving cementoenamel junction, and no history of orthodontic treatment.

Table 1. Distribution of Patients According to Gender

Gender	Class I, n (%)	Class II, n (%)	Class III, n (%)	Total, n (%)
Male	2 (10)	9 (45)	10 (50)	21 (35)
Female	18 (90)	11 (55)	10 (50)	39 (65)
Total	20 (100)	20 (100)	20 (100)	60 (100)

From a total of 201 CBCT scans, 151 were excluded and 60 scans that met the inclusion criteria in addition to being convenient for the 3 study groups according to Point A-Nasion-Point B (ANB) angle were incorporated into the study. Thus, a power of 85% was achieved. The first group consisted of 20 skeletal Class I patients ($0° \leq$ ANB $\leq 4°$). The second group consisted of 20 skeletal Class II patients (ANB $> 4°$). The third group consisted of 20 skeletal Class III patients (ANB $< 0°$). The demographic distributions of the groups are presented in Tables 1 and 2.

The scans were obtained using a CBCT device (ILUMA, IMTEC Europa, Oberursel, Germany) making 360° rotation, working with 120 kVp, 3.8 mA, scanning a 14×19.5 cm area within 40 seconds, and having 0.3 mm voxel size. The raw data obtained from CBCT scanning were reconstructed using the software provided by the manufacturer (ILUMA Vision, IMTEC Europa) and were saved as viewer files. All measurements were performed at a window level of 1000 and a window width of 4000 to provide the finest images for accurate measurements. Lateral cephalometric images were obtained from the CBCT scanning data for measuring GoGn/SN and ANB angles. Axial, coronal, and sagittal cross-sections were used for the assessment of buccolingual tooth inclination and the presence of dehiscence/fenestration.

A total of 14 permanent teeth (central incisor, lateral incisor, canine, first premolar, second premolar, first molar, second molar) were evaluated in the maxilla and mandible on the right side. Buccolingual tooth inclination, buccal dehiscence presence, lingual dehiscence presence, buccal fenestration presence, and lingual fenestration presence were evaluated on each tooth (Tables 3 to 7).

Central incisors, lateral incisors, and canines were defined as anterior teeth, whereas first premolars, second premolars, first molars, and second molars were defined as posterior teeth. Buccolingual tooth inclination measurements were performed through the long axis of the root on the buccal root in upper premolars with two roots, on the mesial root in lower molars with two roots, and on the mesiobuccal root in upper molars with three roots (Figures 1 and 2). The

Table 2. Comparison of Groups According to Age by Kruskall-Wallis H Test[a]

Group	Mean Age, y	SD	*P* Value
Class I	18,20	3.33	.788
Class II	18,25	4.92	
Class III	18,90	4.97	

[a] SD indicates standard deviation. $P \geq .05$, nonsignificant.

long axis of the root was assumed from the incisal edge to the apex in anterior teeth, from the the central fossa to the apex in posterior teeth with one root, and from the related cusp tip to the apex in roots to be measured in posterior teeth with more than one root. The angle between the long axis of the root and the palatal plane was measured for the upper teeth. The angle between the long axis of the root and the mandibular plane or corpus-tangent plane was measured for lower anterior and lower posterior teeth, respectively. The measurements were performed in a sagittal cross-section for anterior teeth and in a coronal cross-section for posterior teeth.

Inspection of dehiscence/fenestration presence was achieved in axial and cross-sectional slices in all root surfaces on both the buccal and lingual sides (Figures 3 and 4). These cross-sectional slices had 0.3 mm thickness, and images that showed no cortical bone surrounding the root surface in at least three consecutive slices were registered as having an alveolar bone defect. These defects were classified as a dehiscence if the alveolar bone height was more than 2 mm from the cementoenamel junction and as a fenestration if the defect did not involve the alveolar crest as reported previously.[9]

All measurements were performed by the same observer (Dr Coşkun). At 2 weeks after the first measurements, 30 CBCT images (10 images randomly selected from each group) were remeasured by the same observer (Dr Coşkun) to check for intraobserver reliability.

Table 4. Prevalence of Dehiscence in Buccal Root Surface[a]

Parameter	Class I, n (%)	Class II, n (%)	Class III, n (%)
U1-BucDeh	4 (20)	2 (10)	4 (20)
U2-BucDeh	3 (15)	2 (10)	2 (10)
U3-BucDeh	11 (55)	5 (25)	7 (35)
U4-BucDeh	6 (30)	2 (10)	4 (20)
U5-BucDeh	3 (15)	1 (5)	1 (5)
U6-BucDeh	2 (10)	0 (0)	2 (10)
U7-BucDeh	0 (0)	1 (5)	2 (10)
L1-BucDeh	5 (25)	9 (45)	6 (30)
L2-BucDeh	6 (30)	4 (20)	11 (55)
L3-BucDeh	12 (60)	6 (30)	8 (40)
L4-BucDeh	11 (55)	7 (35)	7 (35)
L5-BucDeh	5 (25)	4 (20)	1 (5)
L6-BucDeh	6 (30)	4 (20)	2 (10)
L7-BucDeh	2 (10)	1 (5)	1 (5)

[a] BucDeh indicates buccal dehiscence.

Statistical Analysis

Data analysis was performed using SPSS for Windows, version 20 (SPSS Inc., Chicago, Ill). Descriptive statistics were presented as percentages for gender, dehiscence, and fenestration and means and standard deviations for age and buccolingual inclination. The differences between the three study groups were analyzed by analysis of variance for variables showing normal distributions and by the Kruskall-Wallis H test for variables not showing normal distributions. The Scheffe test was used to distinguish the groups between which a statistically significant difference was observed if the analysis of variance revealed a significant difference. The chi-square test was used for the analysis of the differences between

Table 3. Comparison of Buccolingual Inclination (°) Between Groups by Analysis of Variance[a]

	Class I		Class II		Class III			
Parameter	Mean	SD	Mean	SD	Mean	SD	*P* Value	Scheffe Test
U1-Inc	108.8	7.6	101.4	10.8	114.8	7.3	.000***	Cl 1–2, Cl 2–3
U2-Inc	107.5	7.9	105.4	7.6	115.5	6.2	.000***	Cl 1–3, Cl 2–3
U3-Inc	101.3	7.5	97.1	8.3	100.6	6.5	.177	–
U4-Inc	90.3	4.9	89.5	6.5	93.5	5.6	.066	–
U5-Inc	90.6	6.4	90.9	6.5	94.6	4.6	.062	–
U6-Inc	85.0	7.6	83.4	5.9	85.7	8.8	.626	–
U7-Inc	97.7	6.8	92.9	8.9	97.2	10.6	.179	–
L1-Inc	93.3	5.5	101.4	11.9	82.2	8.9	.000***	Cl 1-2, Cl 1-3, Cl 2-3
L2-Inc	91.1	6.5	97.4	11.3	81	8.7	.000***	Cl 1-3, Cl 2-3
L3-Inc	94.9	6.1	98.7	3.9	91.9	4.1	.000***	Cl 1-2, Cl 2-3
L4-Inc	90.6	4.3	93.4	4.7	86.3	4.4	.000***	Cl 1-3, Cl 2-3
L5-Inc	81.5	6.9	84.6	4.1	77.5	6	.002**	Cl 2-3
L6-Inc	74.7	5	77.3	5.7	69.3	5.2	.000***	Cl 1-3, Cl 2-3
L7-Inc	68.3	5.2	69.5	5.3	64.4	8.5	.052	–

[a] SD indicates standard deviation. $P \geq .05$, nonsignificant. Inc indicates inclination and Cl indicates Class.
** $P < .01$, *** $P < .001$.

Table 5. Prevalence of Dehiscence in Lingual Root Surface[a]

Parameter	Class I, n (%)	Class II, n (%)	Class III, n (%)
U1-LinDeh	0 (0)	1 (5)	3 (15)
U2-LinDeh	1 (5)	1 (5)	1 (5)
U3-LinDeh	4 (20)	1 (5)	2 (10)
U4-LinDeh	2 (10)	1 (5)	2 (10)
U5-LinDeh	3 (15)	2 (10)	0 (0)
U6-LinDeh	5 (25)	0 (0)	2 (10)
U7-LinDeh	2 (10)	1 (5)	3 (15)
L1-LinDeh	10 (50)	9 (45)	6 (30)
L2-LinDeh	2 (10)	1 (5)	3 (15)
L3-LinDeh	1 (5)	2 (10)	1 (5)
L4-LinDeh	1 (5)	0 (0)	0 (0)
L5-LinDeh	0 (0)	0 (0)	0 (0)
L6-LinDeh	0 (0)	0 (0)	1 (5)
L7-LinDeh	0 (0)	0 (0)	0 (0)

[a] LinDeh indicates lingual dehiscence.

Table 7. Prevalence of Fenestration in Lingual Root Surface[a]

Parameter	Class I, n (%)	Class II, n (%)	Class III, n (%)
U1-LinFen	0 (0)	0 (0)	0 (0)
U2-LinFen	0 (0)	0 (0)	0 (0)
U3-LinFen	0 (0)	0 (0)	0 (0)
U4-LinFen	0 (0)	0 (0)	0 (0)
U5-LinFen	0 (0)	0 (0)	0 (0)
U6-LinFen	1 (5)	1 (5)	2 (10)
U7-LinFen	5 (25)	2 (10)	4 (20)
L1-LinFen	0 (0)	1 (5)	1 (5)
L2-LinFen	0 (0)	0 (0)	0 (0)
L3-LinFen	0 (0)	0 (0)	1 (5)
L4-LinFen	0 (0)	0 (0)	0 (0)
L5-LinFen	0 (0)	0 (0)	0 (0)
L6-LinFen	0 (0)	0 (0)	0 (0)
L7-LinFen	0 (0)	2 (10)	1 (5)

[a] LinFen indicates lingual fenestration.

the frequencies of categorical variables between multiple groups. A P value less than .05 was considered statistically significant with a 95% confidence interval. Intraobserver reliability was determined by Wilcoxon signed test for continuous variables and by Kappa test for categorical variables using data obtained from the remeasurement of 30 CBCT images. The observer was found to be consistent for all variables in the repeated measurements ($P > .05$ and $0.65 < \kappa < 1$).

RESULTS

No significant difference was found between the skeletal Class I, Class II, and Class III groups for mean age (Table 2). However, significant differences ($P <$ .05) were observed between the groups for buccolingual inclination of the upper incisors and all lower teeth except for second molars (Table 3).

The dehiscence prevalence observed in the upper buccal region demonstrated significant differences ($P < .05$) between the three groups and was higher in

Table 6. Prevalence of Fenestration in Buccal Root Surface[a]

Parameter	Class I, n (%)	Class II, n (%)	Class III, n (%)
U1-BucFen	3 (15)	3 (15)	3 (15)
U2-BucFen	3 (15)	10 (50)	5 (25)
U3-BucFen	5 (25)	8 (40)	7 (35)
U4-BucFen	8 (40)	8 (40)	5 (25)
U5-BucFen	2 (10)	5 (25)	1 (5)
U6-BucFen	6 (30)	5 (25)	3 (15)
U7-BucFen	0 (0)	0 (0)	0 (0)
L1-BucFen	3 (15)	1 (5)	3 (15)
L2-BucFen	4 (20)	6 (30)	4 (20)
L3-BucFen	1 (5)	6 (30)	5 (25)
L4-BucFen	0 (0)	2 (10)	2 (10)
L5-BucFen	2 (10)	2 (10)	2 (10)
L6-BucFen	1 (5)	0 (0)	4 (20)
L7-BucFen	0 (0)	1 (5)	0 (0)

[a] BucFen indicates buccal fenestration.

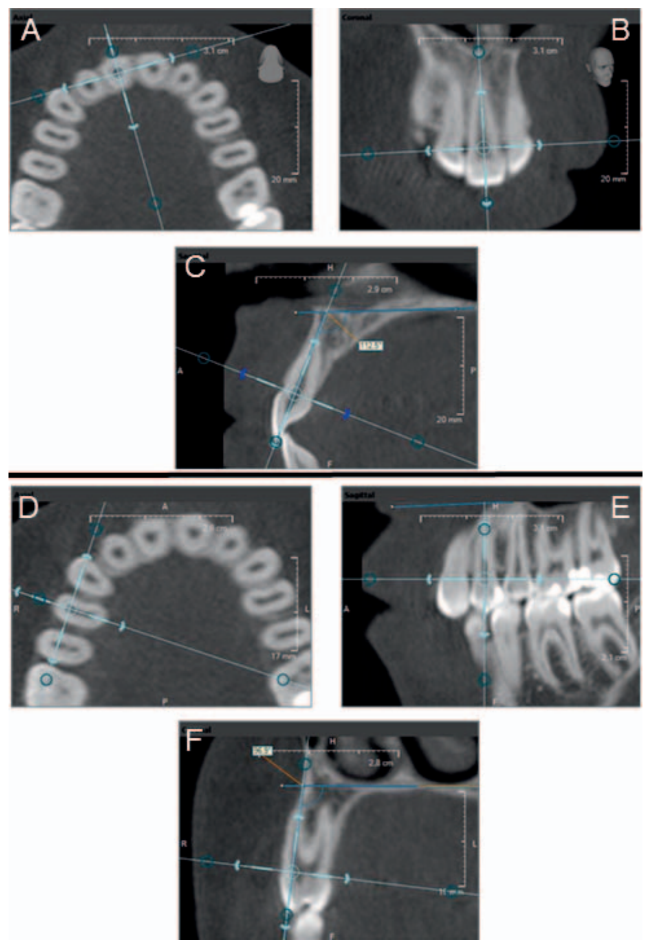

Figure 1. Orientation of right maxillary central incisor in axial (A) and coronal (B) cross-sections. Measurement of right maxillary central root inclination in relation to the palatal plane in the sagittal cross-section (C). Orientation of right maxillary first premolar in the axial (D) and sagittal (E) cross-sections. Measurement of right maxillary first premolar root inclination in relation to the palatal plane in the coronal cross-section (F).

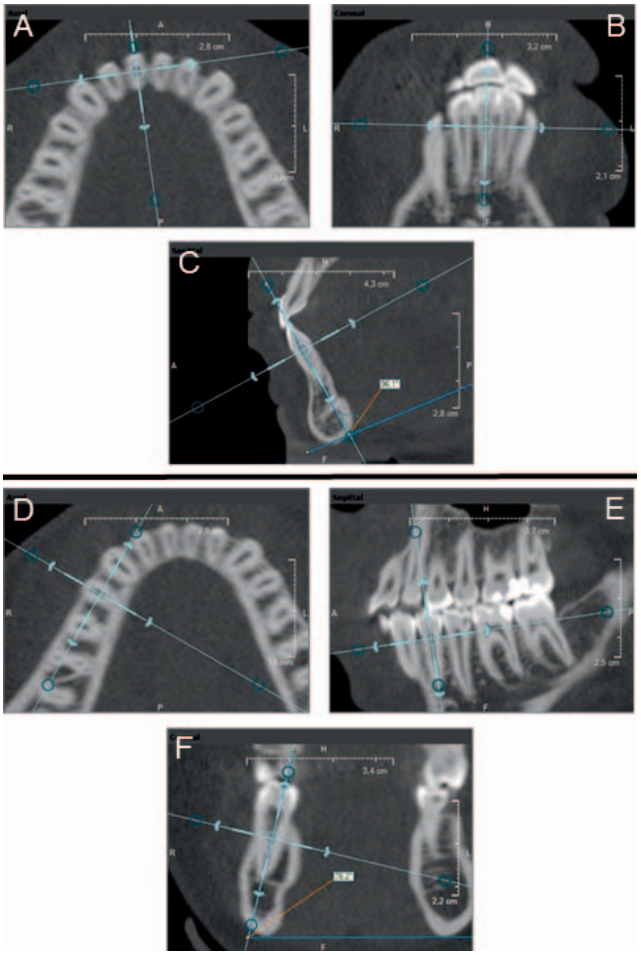

Figure 2. Orientation of right mandibular central in axial (A) and coronal (B) cross-sections. Measurement of right mandibular central root inclination in relation to the mandibular plane in the sagittal cross-section (C). Orientation of right mandibular first premolar in the axial (D) and sagittal (E) cross-sections. Measurement of right mandibular first premolar root inclination in relation to the line tangent to the lower border of the corpus from right to left in the coronal cross-section (F).

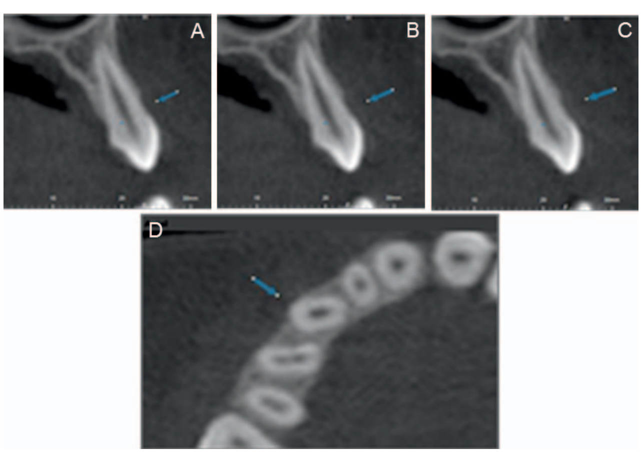

Figure 3. Consecutive cross-sectional (A,B,C) and axial (D) slices indicating dehiscence presence on the buccal surface of the right maxillary canine.

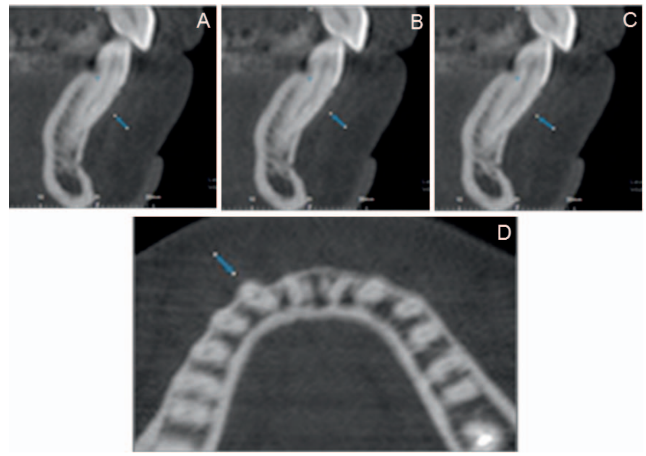

Figure 4. Consecutive cross-sectional (A,B,C) and axial (D) slices indicating fenestration presence on the buccal surface of the right mandibular canine.

Class I individuals. IN addition, the lower buccal region showed significantly ($P = .0001$) higher dehiscence prevalence when compared with other regions in all groups (Table 8).

Dehiscence prevalence observed in the posterior buccal region demonstrated significant differences ($P < .05$) between the three groups and was higher in Class I individuals. The anterior buccal region showed significantly ($P = .0001$) higher dehiscence prevalence when compared with other regions in all groups (Table 9).

No significant difference was observed in fenestration prevalence between the three groups in any anatomic region (Tables 10 and 11). However, the upper buccal region showed significantly ($P = .0001$) higher fenestration prevalence when compared with other regions in all groups (Table 10). On the other hand, the fenestration prevalence observed in the anterior buccal region was significantly ($P = .0001$) higher when compared with other regions in all groups (Table 11).

DISCUSSION

Achieving a high-quality occlusion, facial esthetics, and stability requires appropriate tooth torque.[8] On the other hand, underestimated or misdiagnosed buccal alveolar bone defects are reported to cause treatment relapse or gingival recession.[10,16] Thus, providing safe treatment that can protect patients from iatrogenic bone loss and maintaining a healthy periodontal condition is necessary for orthodontists. Therefore, identification of alveolar bone defects is critical before orthodontic treatment planning.

Buccolingual tooth inclination was investigated for one or teeth teeth in most previous CBCT studies.[6,8,14,15] Only one study evaluated the inclination of

Table 8. Comparison of Dehiscence Incidence Between Groups in Addition to Upper/Lower and Buccal/Lingual Regions by Chi-Square Test[a]

Dehiscence	Class I, n (%)	Class II, n (%)	Class III, n (%)	*P* Value
Upper buccal	29 (20.7)	13 (9.3)	12 (8.6)	.048*
Upper lingual	17 (12.1)	7 (5.0)	13 (9.3)	.104
Lower buccal	47 (33.6)	35 (25.0)	36 (25.7)	.243
Lower lingual	14 (10.0)	12 (8.6)	11 (7.8)	.834
P value	.0001***	.0001***	.0001***	

[a] $P \geq .05$, nonsignificant.
* $P < .05$, *** $P < .001$.

Table 10. Comparison of Fenestration Incidence Between Groups in Addition to Upper/Lower and Buccal/Lingual Regions by Chi-Square Test[a]

Fenestration	Class I, n (%)	Class II, n (%)	Class III, n (%)	*P* Value
Upper buccal	27 (19.3)	39 (27.9)	24 (17.1)	.085
Upper lingual	6 (4.3)	3 (2.1)	6 (4.3)	.521
Lower buccal	11 (7.9)	18 (12.8)	20 (14.3)	.196
Lower lingual	0 (0.0)	3 (2.1)	3 (2.1)	–
P value	.0001***	.0001***	.0001***	

[a] $P \geq .05$, nonsignificant.
*** $P < .001$.

all teeth, but that study did not include all sagittal skeletal patterns.[13] Dehiscence/fenestration presence in different vertical or sagittal skeletal patterns was inspected in some studies.[4,9,10] However, none of those studies examined the relationship between tooth inclination, alveolar bone defects, and sagittal skeletal pattern, which may be influenced by each other. Therefore, the primary objective of this study was to understand the relationship between sagittal facial pattern and tooth inclination in association with the presence of dehiscence/fenestration. The secondary objective of this study was to examine the diversity in dehiscence/fenestration presence between the upper and lower as well as anterior and posterior teeth for developing a guide for limitations and potential risks of orthodontic tooth movements specified for each anatomic region.

Individuals in the postpubertal stage were included in this study, as previous studies showed that hormonal and functional changes associated with age influenced cortical bone thickness.[17,18] In addition, patients with only normal vertical growth patterns were included in the groups to eliminate the effect of vertical growth pattern on dentoalveolar bone morphology.

Significant differences were observed between the groups for buccolingual inclination of the upper incisors and all lower teeth except for second molars. Upper incisors were retroclined in Class II individuals and proclined in Class III individuals. All lower teeth were inclined buccally in Class II individuals and inclined lingually in Class III individuals. These findings can be attributed to the compensation mechanism that is naturally observed in skeletal discrepancies in the anterior alveolus in the maxilla and in both the anterior and posterior alveolus in the mandible. Anterior tooth inclinations compensated for sagittal discrepancies between jaws, whereas posterior tooth inclinations compensated for transverse discrepancies that occurred as a result of sagittal differences between jaws. Buccolingual inclinations of each tooth in relation to all different sagittal skeletal patterns is one of the unique findings of this study. The results related to tooth inclinations can be compared with only a few previous studies and were comparable.[13,14] Hence, these complete data regarding buccolingual tooth inclination can be used as a comprehensive reference for skeletal Class I, Class II, and Class III individuals with a normal vertical facial pattern.

Dehiscence was frequently observed in all sagittal skeletal patterns especially for buccal root surfaces, similar to that found in previous studies.[4,9,10] Dehiscence prevalence in the upper buccal region demonstrated significant differences among the three groups and was higher in Class I individuals. This finding can be explained by crowding of the teeth, which is a common feature of Class I malocclusion, causing misalignment of tooth crowns and roots. Buccolingual inclination of teeth as a factor for dehiscence presence was not detected in this study; tooth inclinations were not related with dehiscence frequencies. This result

Table 9. Comparison of Dehiscence Incidence Between Groups in Addition to Anterior/Posterior and Buccal/Lingual Regions by Chi-Square Test[a]

Dehiscence	Class I, n (%)	Class II, n (%)	Class III, n (%)	*P* Value
Anterior buccal	41 (34.2)	28 (23.3)	36 (30.0)	.157
Anterior lingual	18 (15.0)	15 (12.5)	16 (13.3)	.853
Posterior buccal	35 (21.9)	20 (12.5)	20 (12.5)	.041*
Posterior lingual	13 (8.1)	4 (2.5)	8 (5.0)	.075
P value	.0001***	.0001***	.0001***	

[a] $P \geq .05$, nonsignificant.
* $P < .05$, *** $P < .001$.

Table 11. Comparison of Fenestration Incidence Between Groups in Addition to Anterior/Posterior and Buccal/Lingual Regions by Chi-Square Test[a]

Fenestration	Class I, n (%)	Class II, n (%)	Class III, n (%)	*P* Value
Anterior buccal	19 (15.8)	34 (28.3)	27 (22.5)	.066
Anterior lingual	0 (0.0)	1 (0.8)	2 (1.7)	–
Posterior buccal	19 (11.9)	23 (14.3)	17 (10.6)	.585
Posterior lingual	6 (3.8)	5 (3.1)	7 (4.4)	.828
P value	.0001***	.0001***	.0001***	

[a] $P \geq .05$, nonsignificant.
*** $P < .001$.

was in accordance with the study of Evangelista et al.[9] except there was no Class III group and tooth inclinations were not evaluated in that study.

The lower buccal region showed higher dehiscence prevalence in all groups. This may have been associated with a relatively small buccolingual width of the mandibular alveolus causing lower teeth to be positioned more buccally because of a lack of space or dentoalveolar decompensation. This finding was comparable with the findings of Evangelista et al.[9] and Yagci et al.,[10] although these studies did not evaluate dehiscence presence separately for specific anatomical regions in detail.

Dehiscence prevalence in the posterior buccal region demonstrated significant differences among the three groups and was higher in Class I individuals. This finding can also be related with crowding of the teeth, which is usually observed in Class I malocclusions. No connection between buccolingual tooth inclinations and dehiscence prevalence were observed.

The anterior buccal region showed higher dehiscence prevalence in all groups. This may be attributable to the thinner cortical bone layer on the buccal root surface and smaller buccolingual width of the anterior alveolus. This was another unique finding of this study as dehiscence prevalence for the anterior and posterior regions was not evaluated separately and compared in previous studies.[4,9,10]

No significant difference was observed in fenestration prevalence among the three groups in any anatomic region. This is compatible with the study of Evangelista et al.,[9] but incompatible with the study of Yagci et al.[10] The incompatibility between the results may be a result of differences in the malocclusion characteristics of patients in the different studies.

The upper buccal region showed higher fenestration prevalence in all groups. This may be explained by the morphological structure of the maxilla as it narrows from the cervical to the apical level of teeth, resulting in resorption of cortical bone covering the root surfaces at apical levels. This finding was also comparable with other studies, although those did not evaluate fenestration presence separately for distinct anatomical regions in detail.[9,10]

Fenestration prevalence in the anterior buccal region was higher in all groups. This can also be associated with the thin buccal cortical bone layer and the buccolingually narrow anterior alveolus. Accordingly, this result was unique as fenestration prevalence for the anterior and posterior regions was not assessed separately in previous studies.[4,9,10]

In light of these findings, orthodontists must be aware of possible alveolar bone defects, recognize the limits and potential risks of orthodontic tooth movements identified for each anatomic region, and be careful during treatment planning to avoid gingival recession or tooth mobility.

CONCLUSIONS

- Skeletal Class I, Class II, and Class III individuals had differences in the buccolingual inclination of the upper incisors and all lower teeth except for second molars.
- Skeletal Class I individuals had higher dehiscence prevalence in the upper buccal and posterior buccal regions.
- The H_0 hypothesis was rejected, and the H_1 hypothesis was not rejected.
- Dehiscence prevalence was higher in the lower buccal region.
- Fenestration prevalence was higher in the upper buccal region.
- Dehiscence and fenestration prevalence was higher in the anterior buccal region.

ACKNOWLEDGMENTS

We would like to thank our radiology technician Sadettin Gürer and our biostatistician Dr Ahmet Gül for their contributions in this work, which was supported by the Baskent University Research Board with project number D-DA13/06.

REFERENCES

1. Jäger F, Mah JK, Bumann A. Peridental bone changes after orthodontic tooth movement with fixed appliances: a cone-beam computed tomographic study. *Angle Orthod* 2017;87:672–680.
2. Lindhe J, Karring T, Araujo M. The anatomy of periodontal tissues. In: Lindhe J, Karring T, Lang NP, eds. *Clinical Periodontology and Implant Dentistry, 4th Edition*. Copenhagen, Denmark: Blackwell Munksgaard; 2003:3–48.
3. Carranza FA, Bernard GW. The tooth-supporting structures. In: Newman MG, Takei HH, Carranza FA, eds. *Clinical Periodontology, 9th Edition*. Philadephia: Saunders; 2002:45–52.
4. Enhos S, Uysal T, Yagci A, Veli I, Ucar FI, Ozer T. Dehiscence and fenestration in patients with different vertical growth patterns assessed with cone-beam computed tomography. *Angle Orthod*. 2012;82:868–874.
5. Garib DG, Yatebe MS, Ozawa TO, Silva-Filho OG. Alveolar bone morphology under the perspective of the computed tomography: defining the biological limits of tooth movement. *Dental Press J Orthod*. 2010;15:192–205.
6. Shewinvanakitkul W, Hans MG, Narendran S, Martin Palomo J. Measuring buccolingual inclination of mandibular canines and first molars using CBCT. *Orthod Craniofac Res*. 2011;14:168–174.
7. Andrews LF. The six keys to normal occlusion. *Am J Orthod*. 1972;62:296–309.
8. Tian YL, Liu F, Sun HJ, et al. Alveolar bone thickness around maxillary central incisors of different inclination assessed

with cone-beam computed tomography. *Korean J Orthod*. 2015;45:245–252.
9. Evangelista K, Vasconcelos KF, Bumann A, Hirsch E, Nitka M, Silva MA. Dehiscence and fenestration in patients with class I and class II division 1 malocclusion assessed with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2010;138:133.e1–133.e7.
10. Yagci A, Veli I, Uysal T, Ucar FI, Ozer T, Enhos S. Dehiscence and fenestration in skeletal Class I, II and III malocclusions assessed with cone-beam computed tomography. *Angle Orthod*. 2012;82:67–74.
11. Tsunori M, Mashita M, Kasai K. Relationship between facial types and tooth and bone characteristics of the mandible obtained by CT scanning. *Angle Orthod*. 1998;68:557–562.
12. Masumoto T, Hayashi I, Kawamura A, Tanaka K, Kasai K. Relationship among facial type, buccolingual molar inclination and cortical bone thickness of the mandible. *Eur J Orthod*. 2001;23:15–23.
13. Sendyk M, de Paiva JB, Abrão J, Rino Neto J. Correlation between buccolingual tooth inclination and alveolar bone thickness in subjects with class III dentofacial deformities. *Am J Orthod Dentofacial Orthop*. 2017;152:66–79.
14. Alkhatib R, Chung CH. Buccolingual inclination of first molars in untreated adults: a CBCT study. *Angle Orthod*. 2017;87:598–602.
15. Sayania B, Merchant M, Josephs P, Chung CH. Changes in the buccolingual inclination of first molars with growth in untreated subjects: a longitudinal study. *Angle Orthod*. 2017; 87:681–687.
16. Rothe LE, Bollen AM, Little RM, et al. Trabecular and cortical bone as risk factors for orthodontic relapse. *Am J Orthod Dentofacial Orthop*. 2006;130:476–484.
17. Usui T, Uematsu S, Kanegae H, Morimoto T, Kurihara S. Change in maximum occlusal force in association with maxillofacial growth. *Orthod Craniofac Res*. 2007;10:226–234.
18. Farnsworth D, Rossouw PE, Ceen RF, Buschang PH. Cortical bone thickness at common miniscrew implant placement sites. *Am J Orthod Dentofacial Orthop*. 2011; 139:495–503.