

Maxillary buccal cortical plate inclination at mini-screw insertion sites

Murat Tozlu^a; Derya Germeç Cakan^b; Feyza Ulkur^a; Fulya Ozdemir^c

ABSTRACT

Objective: To evaluate whether buccal cortical bone inclination varies for the maxillary alveolar processes of adult patients with decreased, normal, and increased facial heights.

Materials and Methods: Cone-beam computed tomography images of 135 adult patients, including 49 hypodivergent subjects (26 women, 23 men), 40 hyperdivergent subjects (24 women, 16 men), and 46 normodivergent (25 women, 21 men) were analyzed. Cortical bone inclination measurements were made relative to the occlusal plane. Cross-sectional slices of the maxilla were taken at interdental sites from the distal aspect of maxillary canine to the mesial aspect of maxillary second molar.

Results: Analysis of variance indicated significant differences ($P < .05$) between the angles formed by the line tangent to the cortical bone and the occlusal plane among the vertical facial types for the regions between canine and first premolar and between second premolar and first molar at miniscrew insertion sites.

Conclusion: The results of this study indicate that vertical facial pattern should be taken into consideration when adjusting the insertion angle of miniscrews at the maxillary buccal region. (*Angle Orthod.* 2015;85:868–873.)

KEY WORDS: CBCT; Orthodontic miniscrew; Buccal bone inclination; Facial type

INTRODUCTION

The use of orthodontic miniscrews to provide absolute anchorage has become increasingly popular. Clinically, the successful use of miniscrews depends greatly on stability, which is largely affected by the placement protocol as clinicians do not have control over such host factors as the thickness or density of the cortical bone.¹

The placement procedure, especially the angulation of the miniscrews, matters for stability such that if inserted more inclined to the surface of the bone, greater insertion torque and an increased contact with the cortical bone are provided.² On the other hand,

miniscrew slippage can occur in dentoalveolar regions of attached gingiva of mandible if the angle of insertion is $<30^\circ$ from the occlusal plane.¹ Aiming typically to avoid root contact or to gain cortical anchorage, the clinician might inadvertently slide the miniscrew under the mucosal tissue along the periosteum at sloped bony planes such as the zygomatic buttress, the retromolar pad, and the buccal cortical shelf.¹ Surgical stents can be used to guide the miniscrews to the prescribed angle and position to avoid damaging neighboring anatomic structures; however, necessary precautions could only be planned after the clear acknowledgment of the risky areas and patients.^{3,4}

The forms of the maxilla and the mandible, as well as vertical facial morphology, are largely determined by genetics and the forces generated by the muscles of mastication.^{5–7} Recent investigations carried out on cone-beam computed tomography (CBCT) have revealed the differences between the maxillary and mandibular cortical bone thickness and density among patients with different facial heights.^{8–12} Although a number of anatomic issues of the maxillofacial complex have been analyzed in various studies, the variability in the buccal cortical plate (BCP) inclination has not yet been studied. The purpose of this study was to evaluate whether the buccolingual inclinations of the maxillary BCP varies among patients with low,

^a Assistant Professor, Department of Orthodontics, Faculty of Dentistry, Yeditepe University, Istanbul, Turkey.

^b Associate Professor, Department of Orthodontics, Faculty of Dentistry, Yeditepe University, Istanbul, Turkey.

^c Professor, Department of Orthodontics, Faculty of Dentistry, Yeditepe University, Istanbul, Turkey.

Corresponding author: Dr Murat Tozlu, Department of Orthodontics, Faculty of Dentistry, Yeditepe University, Bagdat Cad. No 238 Göztepe Istanbul, Turkey (e-mail: tozlumurat@gmail.com)

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normal, and increased facial heights. A better understanding of buccal cortical plate inclination may help guide clinicians to place miniscrews at better angles for improved cortical grip.

MATERIALS AND METHODS

The sample of this retrospective study comprised CBCT records of 135 orthodontic patients (age range = 20 to 45 years) was obtained from the archives of the Oral Radiology Department of Yeditepe University Dental School. Patients with excessive facial asymmetries, cleft lip and/or palate, periodontal disease with alveolar bone loss, missing teeth in the measurement sites, diagnosed systemic diseases, and severe craniofacial dysmorphology were excluded. Patient data were handled according to the requirements and recommendations of the Declaration of Helsinki. Ethical approval was obtained from the institutional board of Yeditepe University. The CBCT images were taken with a focal spot of 3.3 mm, voxel size 0.093 mm, using an Iluma (IMTEC Corporation, Tulsa, OK, USA) CBCT unit with an amorphous silicon flat-panel image detector. Images were obtained at 120 kVp and 3.8 mA, with an exposure time of 40 seconds, and were saved as Iluma vision viewer files.

The CBCT data were used for cephalometric measurements in assigning the images to one of the vertical facial groups. Using one angular (S-N/Go-Me) and one linear (S-Go/N-Me) measurement, patients were divided into normal, high, or low angle groups. For S-Go/N-Me, a ratio <61% indicated hyperdivergency, a ratio between 61% and 69% indicated normodivergency, and a ratio >69% indicated hypodivergency. For the S-N/Go-Me angle, <27° indicated hypodivergency, between 27° and 37° indicated normodivergency, and >37° indicated hyperdivergency. Images in which the two measurements fell into different classifications were excluded from the study. When all exclusion criteria were applied, the CBCT images of 135 subjects remained. The mean ages of the hypodivergent, normodivergent, and hyperdivergent patients were 30.18 ± 8.84 , 30.39 ± 9.14 , and 28.85 ± 7.92 years, respectively. The hypodivergent group had 23 men (46.9%) and 26 women (53.1%), the normodivergent group had 21 men (45.6%) and 25 women (54.4%), and the hyperdivergent group had 16 men (40.0%) and 24 women (60.0%).

The images were oriented in three planes of space so that the measurement errors produced from nonstandardized head postures could be minimized. The horizontal axis of the software was aligned parallel to the anatomic occlusal plane in the sagittal view and was adjusted to pass through the buccal cusps of maxillary first molars in the coronal and axial view (Figure 1).

The BCP inclination of the maxilla was measured 4 mm apical from the alveolar crest, which represents the height where the mucogingival junction is generally situated.¹³ Interdental sites from the distal aspect of the maxillary canine to the mesial aspect of the maxillary second molar were examined at four sites: inter-radicular areas between the canine and the first premolar (3–4), first and second premolars (4–5), second premolar and first molar (5–6), and first and second molars (6–7).

On the sagittal slice, 4 mm apical of the alveolar crest was determined as the measurement site (Figure 2A). On the coronal slice, a line tangent to the buccal cortical bone surface at 4 mm was drawn. Also, on the coronal slice, the transverse occlusal plane was established by drawing a line to connect the buccal cusp tips of the molars (Figure 2B). Measurements were taken for each patient relative to the occlusal plane. The measurements consisted of inner angles formed between the occlusal surface and lines tangent to the BCP surface. The measurements were carried out by one investigator and recorded in a Microsoft Excel file (Microsoft Office Excel 2013, Albuquerque, New Mexico, USA). Thirty randomly selected images (10 images from each group) were remeasured to test for intraobserver variations. The data obtained were evaluated statistically.

Statistical calculations were carried out with NCSS 2007 software (East Kaysville, Utah, USA) for Windows. Besides descriptive statistics (mean, standard deviation), in the groups showing normal distribution, one-way analysis of variance was used for intergroup comparisons, and the Tukey multiple comparison test was used for group comparisons. For the comparison of the independent set of data, an independent *t* test was performed. The results were evaluated at the $P < .05$ significance level, with a 95% confidence interval. Intraclass correlation coefficients were used to determine intrarater agreement for measurements.

RESULTS

No statistically significant differences were found between the hypodivergent, normodivergent, and hyperdivergent groups regarding mean ages ($P = .558$) or sex distribution ($P = .306$).

Cortical bone inclinations did not differ with respect to gender (Table 1). The intraclass correlation coefficients (between 0.889 and 0.985) revealed that the operator was consistent with the repeated measurements. The mean values and standard deviations of the inclinations of maxillary BCP in the three facial-type groups and the evaluation of the differences between the measurements are listed in Table 1 and 2.

The mean values of angles between the occlusal plane and the tangent line at maxillary BCP in

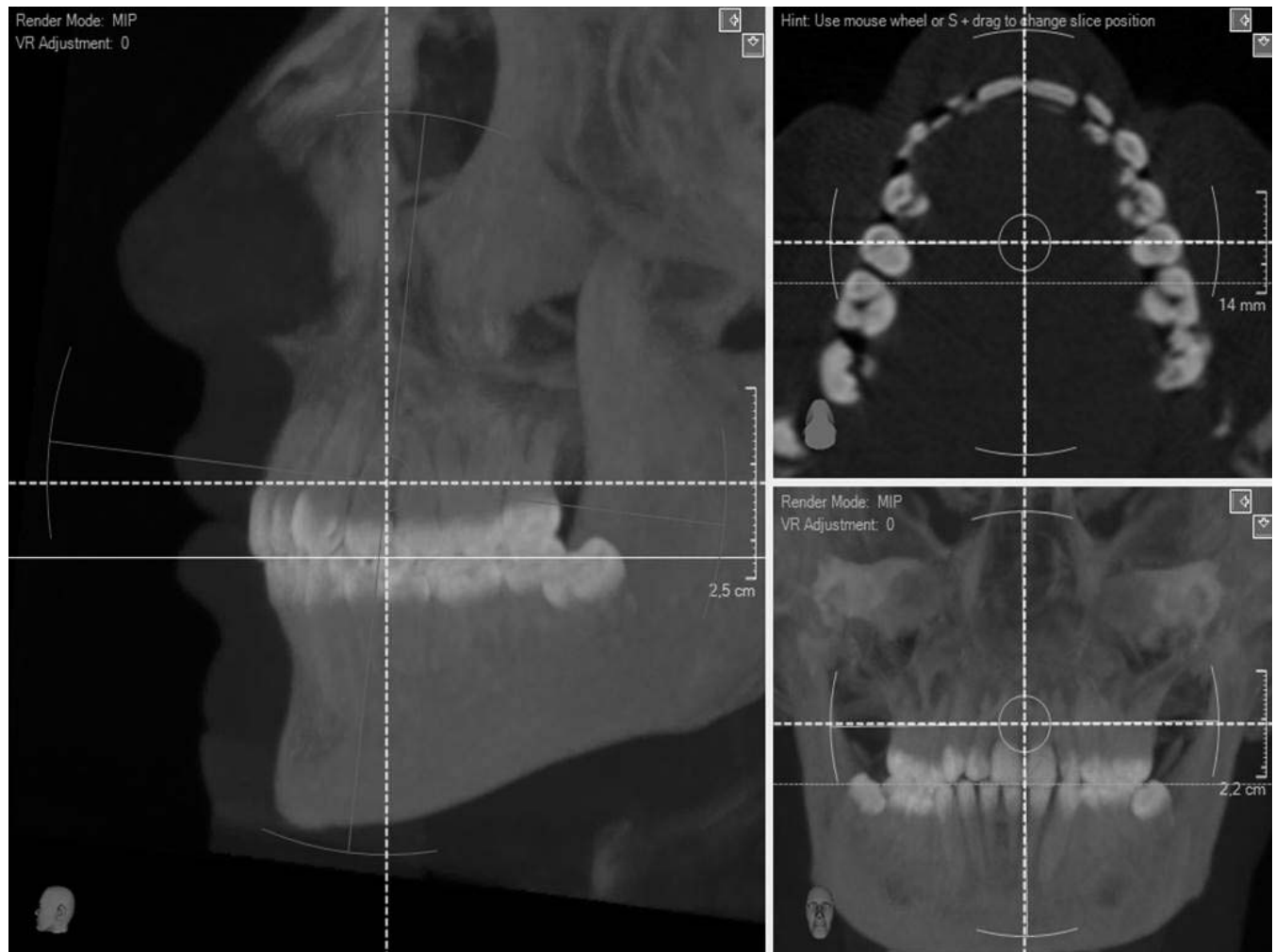


Figure 1. Orientation of the images. From the sagittal view, the images were oriented using the occlusal plane. From the axial and frontal views, the images were adjusted using a line passing through the buccal cusps of maxillary first molars.

interradicular area of canine and first premolar were lower in the hypodivergent group than those measured for the normodivergent and hyperdivergent groups ($P < .01$). On the other hand, patients with normal vertical facial pattern had similarly inclined BCP with hyperdivergent patients ($P > .05$) at maxillary canine-first premolar area.

At region 5–6, the hyperdivergent group had larger values than the normal and hypodivergent groups ($P < .01$), whereas same inclinations of BCP were observed at region 5–6 between normal and hypodivergent groups ($P > .05$). Maxillary BCP inclinations did not differ at first and second premolar and first and second molar regions among the study groups.

DISCUSSION

The purpose of this study was to investigate the anatomy of the maxillary BCP by using 3-dimensional (3D) images generated with CBCT technology. This is

the first study that has evaluated inclinations of maxillary BCP at miniscrew insertion sites. Recent CBCT studies have found differences between the density and thickness of the maxillary BCP among the patients with different facial heights.^{11,12} In the maxillary buccal region, cortical plate thickness was reported to decrease from anterior to posterior.¹¹ Besides, Kim et al.¹⁴ showed the variability of the soft tissue thickness at different levels of maxillary buccal alveolar crest and concluded that, based on anatomic characteristics, placement of miniscrew implants for orthodontic anchorage in the maxillary molar region requires consideration of the placement site and angle. Therefore, the aim of this study was to determine if there is a relationship between the maxillary BCP inclination in the probable miniscrew placement areas and the vertical dimension of the face.

Our results show that normodivergent and hypodivergent patients had more buccally inclined BCPs at maxillary area between second premolar and first

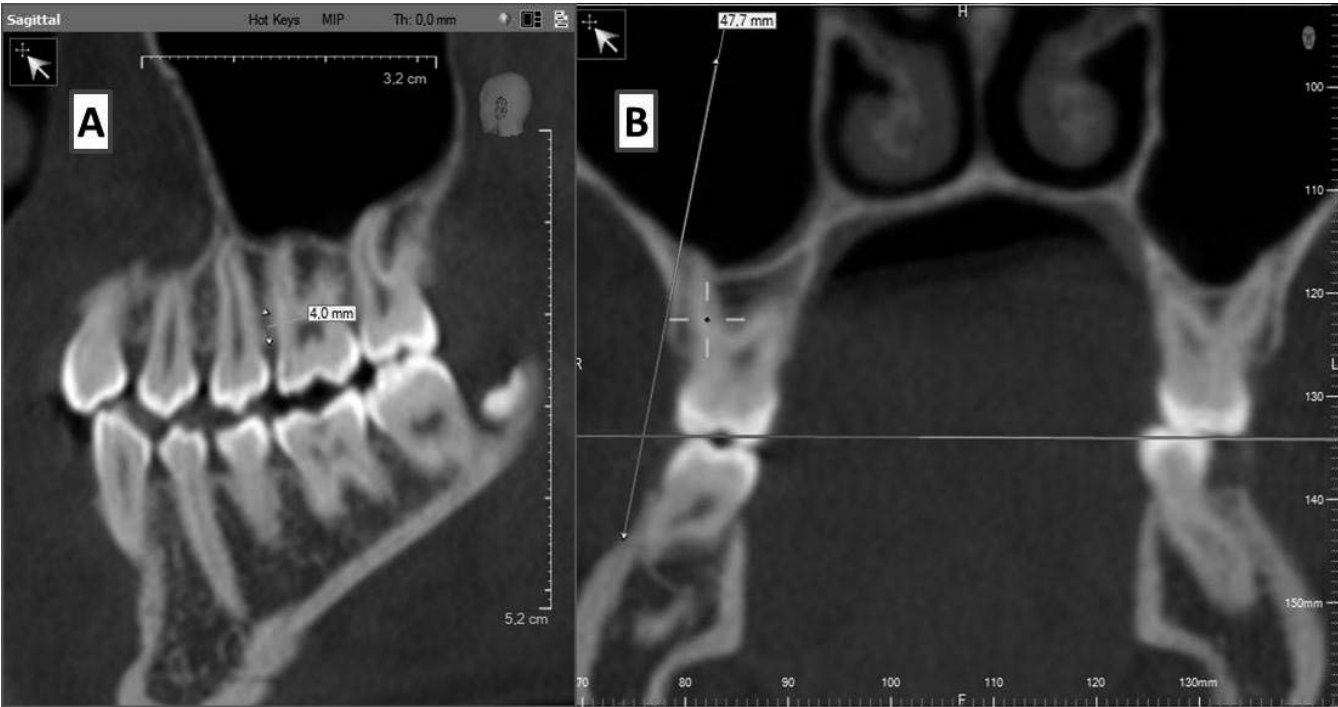


Figure 2. (A) Determination of the measurement site 4 mm apical of the alveolar crest on the sagittal slice. (B) The tangent line at the measurement point and the transversal occlusal line connecting the buccal cusp tips of the molars on the coronal slice.

molar than the hyperdivergent group. There are no studies evaluating the inclination of bone at the maxillary buccal region; however, there are studies evaluating the positions of teeth, dental arch forms, mandibular structures, and molar inclinations.^{8–10,15–17} There is a significant association between masticatory function and vertical facial morphology.¹⁸ Strong masticatory muscles are associated with reduced anterior facial height.¹⁹ Kasai and Kawamura¹⁷ evaluated the correlation between the buccolingual inclination and wear score of the mandibular teeth in Japanese people and concluded that the mandibular molars are more buccally oriented in subjects with strong masticatory function. Masumoto et al.¹⁰ and

Tsunori et al.¹⁵ reported that gonial angle and mandibular plane angle had a significant effect on the inclination of molars. These studies showed that masticatory function determined the inclination of teeth. As form follows function, different masticatory characteristics may affect alveolar bone inclinations and teeth inclinations.

The results of the present study indicated that in this particular population of patients, subjects with increased S-Go/N-Me ratio and decreased mandibular plane angle had more inclined bones between the canine and the first premolar. The premolar-canine region might be subjected to greater strains during mastication in low-angle patients than high-angle patients because the maxillary canines serve as the cornerstones of the arch and experience heavy occlusal forces. Heavier forces and strains acting on canines may be the reason for the increased inclination.

Table 1. Comparison of the buccal cortical plate inclinations of male and female subjects

Vertical Facial Type	Region	Men	Women	P
Normodivergent	3–4	83.4 ± 14	81.18 ± 11.74	.563
	4–5	90.04 ± 11.51	84.74 ± 10.57	.111
	5–6	83.32 ± 9.91	81.08 ± 9.93	.450
	6–7	92.85 ± 11.61	89.84 ± 9.45	.336
Hypodivergent	3–4	79.5 ± 10.46	74.3 ± 9.74	.078
	4–5	86.07 ± 11.36	80.77 ± 14.92	.173
	5–6	85.52 ± 18.02	82.32 ± 10.11	.441
	6–7	95.46 ± 8.39	91.51 ± 4.53	.052
Hyperdivergent	3–4	84.83 ± 8.95	84.52 ± 13.38	.936
	4–5	87.76 ± 14.86	86.95 ± 13.28	.859
	5–6	89.67 ± 11.4	90.58 ± 13.58	.828
	6–7	95.13 ± 9.76	92.47 ± 11.36	.449

Table 2. Comparison of buccal cortical plate inclinations among the groups using analysis of variance and the Tukey multiple comparison test^a

Region	Normodivergent	Hypodivergent	Hyperdivergent	P
3–4	82.19 ± 12.72 ^a	76.74 ± 10.31 ^b	84.64 ± 11.68 ^a	.005*
4–5	87.16 ± 11.21	83.26 ± 13.5	87.28 ± 13.75	.231
5–6	82.11 ± 9.87 ^c	83.82 ± 14.31 ^c	90.22 ± 12.61 ^d	.008*
6–7	91.21 ± 10.48	93.36 ± 6.85	93.53 ± 10.7	.428

^a The same superscript letter indicates no significant difference.
* *P* < .01.

Forces of mastication, which are higher in low-angle patients, should be supported by the strong structure of the buccal cortical bone. Therefore, the buccal cortical bone of low-angle patients is thicker and denser than that of high-angle patients.^{11,12} Tsunori et al.¹⁵ stated that the mandibular bone inclination at the molar region is more lingually inclined. The authors added that the increased lingual inclination of bone is the result of resistance to buccally directed force at mastication. Likewise, the inclination of the mandibular molars is reported to be significantly different for high-angle patients compared with patients with low-angle growth pattern or normal vertical growth pattern.^{10,16} These authors suggested taking facial type into consideration when choosing archwires. The clinician may perform the toe-in bend or the third-order bend at the first and second mandibular molars or may require prescribed bands and tubes from the manufacturers. Likewise, miniscrew insertion may necessitate recommendations to avoid slippage and damage the anatomic structures when inserted with angulation.

In the present study, the correlation between the vertical relationship of the face determined on the basis of the SN/Go-Me ratio and the inclination of the alveolar process to the occlusal plane in the maxilla is discussed. Because the increased height of the face does not purely result from the position of the maxilla, mandibular anatomy regarding the cortical plate inclinations in patients with different facial heights can be the subject of a further study. We performed the measurements 4 mm from the alveolar crest, which is the clinically suitable area because of the presence of keratinized attached gingiva that reduce the risk of peri-implantitis.^{20–23} In this study, we used tangent lines to determine the inclinations of the cortical bones, which were previously used for multiple purposes in the literature.^{24–27}

According to the results of the present study, the alveolar cortical bones of the hyperdivergent subjects were more vertically positioned than those of the normodivergent and hypodivergent subjects between second premolar and first molar. This means that when the miniscrew is inserted with the same insertion angle relative to occlusal plane in patients with different vertical facial pattern, the miniscrew will be positioned with less inclination in the cortical plate, thereby reducing the miniscrew-bone contact for hyperdivergent subjects, who already have thinner cortical bones. Clinicians and researchers may consider this disadvantage of hyperdivergent patients during clinical applications. Furthermore, this may be among the causes for high miniscrew failure rates for hyperdivergent subjects. Besides, hyperdivergent patients may be receiving miniscrews for posterior impaction. Perpendicular insertion is favorable to

position the head of the miniscrew distant enough to apply intrusive forces. In these instances, some precautions, like using auxiliary appliances with miniscrews to increase cortical bone contact, may be preferred.²⁸

Between the canine and first premolar, hypodivergent subjects had more inclined cortical plates compared with normodivergent and hyperdivergent subjects. This increases the risk of miniscrew slippage for hypodivergent subjects when inserting the miniscrew with the same angulation for the three group of patients. Because hypodivergent subjects have thicker cortical bones, when applied using the self-drill method, the penetration of the miniscrew is more difficult and needs higher forces at thick cortices; increased insertion angle will increase the risk of miniscrew slippage under the mucosa. To avoid this, engaging bone with the miniscrew at a more obtuse angle one or two turns before increasing the inclination or pre-drilling may be recommended.

CONCLUSIONS

- BCP inclination distal to maxillary canine and mesial to maxillary first molar shows differences among hypodivergent, hyperdivergent, and normodivergent subjects.
- Vertical facial pattern should be taken into consideration when adjusting the insertion angle of miniscrews at these maxillary buccal regions.

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