# ความหนาของกระดูกทึบเพดานปากในผู้ป่วยไทย ที่มีโครงขากรรไกรแนวดิ่งแบบสบเปิด โดยใช้โคนบีมคอมพิวเตดโทโมกราฟฟี

# Palatal Cortical Bone Thickness in Thai Patients with Open Vertical Skeletal Configuration, Using Cone-beam Computed Tomography

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## บทคัดย่อ

**วัตถุประสงค์:** เพื่อประเมินความหนาของกระดูกทึบเพดานปากในผู้ป่วยไทยที่สบฟันเปิดบริเวณฟันหน้าและมีโครงขากรรไกรแนวดิ่งแบบสบเปิดโดยใช้โคนบีมคอมพิวเตดโทโมกราฟฟี

**วัสดุและวิธีการ:** ภาพรังสีโคนบีมคอมพิวเตดโทโมกราฟฟีของผู้ป่วยไทย (อายุ 15-30 ปี) ที่มีการสบฟันผิดปกติแบบที่หนึ่งร่วมกับสบฟันเปิดบริเวณฟันหน้าและมีโครงขากรรไกรแนวดิ่งแบบสบเปิด จำนวน 15 ราย ถูกนำมาวัดความหนาของกระดูกทึบเพดานปากบริเวณตำแหน่งซึ่งห่างจากจุดกึ่งกลางขอบกระดูกด้านท้ายของรู

## Abstract

**Objective:** To assess the palatal cortical bone thickness in Thai patients exhibiting anterior open bite and open vertical skeletal configuration, using cone-beam computed tomography (CBCT).

**Materials and Methods:** Fifteen CBCT images of Thai orthodontic patients (aged from 15 to 30 years) exhibiting Class I malocclusion with anterior open bite and open vertical skeletal configuration were recruited. The palatal cortical bone thickness was measured at 3.0-mm anteroposterior intervals

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หลังฟันตัดไปทางด้านหลังในระยะทุก ๆ 3 มิลลิเมตร และห่างจากระนาบแบ่งครึ่งซ้ายขวาไปทางด้านซ้ายและขวาในระยะทุก ๆ 3 มิลลิเมตร

**ผลการศึกษา:** กระดูกทึบเพดานปากมีความหนาตั้งแต่ 1.27±0.40 ถึง 2.90±0.63 มิลลิเมตร โดยทุกตำแหน่งมีความหนาเท่ากับหรือมากกว่า 1 มิลลิเมตร

**บทสรุป:** การศึกษาโดยใช้โคนบีมคอมพิวเตดโทโมกราฟฟี พบว่าความหนาของกระดูกทึบเพดานปากมีความแปรปรวน และกระดูกทึบเพดานปากในทุกตำแหน่งของผู้ป่วยที่สบฟันเปิดบริเวณฟันหน้าและมีโครงขากรรไกรแนวดิ่งแบบสบเปิดมีความหนาเพียงพอต่อเสถียรภาพปฐมภูมิในการฝังวัสดุฝังเกลียวขนาดเล็กบริเวณเพดานปาก

**คำสำคัญ:** กระดูกทึบ เพดานปาก สบฟันเปิด โคนบีมคอมพิวเตดโทโมกราฟฟี

from the middle of the distal bony margin of the incisive foramen, and at 3.0-mm mediolateral intervals from the midsagittal plane on both right and left sides.

**Results:** The palatal cortical bone thickness ranged from 1.27±0.40 to 2.90±0.63 mm. The cortical bone thickness measurements at all sites were equal to or greater than 1.0 mm.

**Conclusions:** CBCT-based investigation showed variations in palatal cortical bone thickness, and suggested the palatal cortical bone thickness at all sites of patients exhibiting anterior open bite and open vertical skeletal configuration is sufficient for primary stability in miniscrew implant placement.

**Keywords:** cortical bone, palate, open bite, cone-beam computed tomography

## Introduction

The miniscrew implant is a common temporary anchorage device, providing absolute anchorage during orthodontic treatment. It has many advantages, including small size, low cost, easy placement, and the absence of trauma during placement. Miniscrew implant placement sites are classified into tooth-bearing and non-tooth-bearing areas. Miniscrew implant placement in tooth-bearing areas increases the risk of dental root contact, leading to damage to dental roots and failure of miniscrew implant placement. Therefore, miniscrew implant placement in non-tooth-bearing areas, such as infrazygomatic, retromolar, and palatal areas, is an alternative in order to avoid dental root contact during miniscrew implant placement.[1,2]

The palatal area provides effective miniscrew implant placement sites due to its dense and sufficiently thick cortical bone, few vital anatomical structures, and thin keratinized palatal mucosa. Several studies[3,4] have reported good stability and high success in palatal miniscrew implant placement. Palatal miniscrew implants have been used as skeletal anchorage for intrusion of posterior teeth in anterior open bite treatment, for distalization of maxillary molars, and for retraction of anterior teeth.[2,5-10]

The stability of miniscrew implants depends on several factors. Several studies[11-13] have revealed that the cortical bone thickness is a crucial factor affecting primary stability and success in miniscrew implant placement. Primary stability prevents movement of the miniscrew implant, and allows an appropriate environment for healing. Finite element analysis has shown that most of the force applied to miniscrew implants was concentrated in the cortical bone.[14,15] Motoyoshi et al.[13] suggested that the cortical bone thickness should be at least 1.0 mm for adequate primary stability and clinical success.

Skeletal open bite is related to an unfavorable craniofacial growth pattern. Orthodontic tooth movement can camouflage the vertical skeletal

discrepancy in mild skeletal open bite cases. Posterior tooth intrusion in conventional orthodontic treatment is aimed to cause counter-clockwise rotation of mandible. The miniscrew implant plays an important role as a skeletal anchorage for posterior tooth intrusion in mild skeletal open bite cases.[16] Moon et al.[17] has reported significant reduction in success rate during interradicular miniscrew implant placement in open vertical skeletal configuration cases, especially miniscrew implant placement at the buccal maxillary region. They also have reported that the cortical bone in dento-alveolar areas in patients with open vertical skeletal configurations was thinner than in those with deep vertical skeletal configurations.[18,19] The thinner and less dense alveolar cortical bone in patients with open vertical skeletal configurations is affected by low masticatory force.[20] Therefore, palatal miniscrew implant placement has been used as skeletal anchorage for posterior tooth intrusion in mild skeletal open bite cases.[2,8,10] However, no study has examined the palatal cortical bone thickness in patients with open vertical skeletal configurations.

The purpose of this study was to assess the palatal cortical bone thickness in Thai patients exhibiting anterior open bite and open vertical skeletal configuration, using cone-beam computed tomography (CBCT).

## Materials and Methods

### Subjects and image acquisition

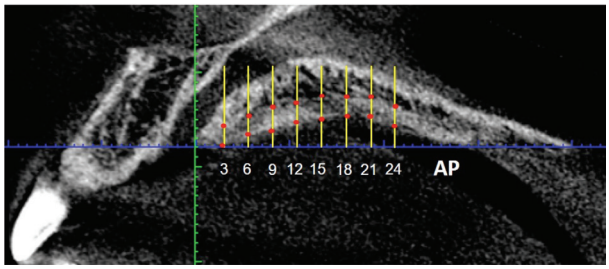
This study was approved by the Human Experimentation Committee, Faculty of Dentistry, Chiang Mai University (NO.39/2559). In this retrospective study, the subjects were Thai orthodontic patients, who required pretreatment CBCT images and had met the following inclusion criteria: 1) age from 15.0 to 30.0 years; 2) a Class I malocclusion with anterior open bite (overbite < 0 mm; 3) Class I sagittal skeletal relationship (ANB angle = 2°±2°; 4) an open vertical skeletal configuration; 5) full eruption of permanent dentition (except for the third molars; 6) no history of previous orthodontic treatment; 7) no evidence of craniofacial malformations; 8) no history of bone-altering medication or disease; and 9) absence of torus palatinus.

The subjects were categorized into open vertical skeletal configuration according to the following six cephalometric measurements: 1) SN-GoGn angle; 2) SN-PP angle; 3) PP-GoGn angle; 4) gonial angle; 5) ratio of upper to lower face height; 6) ratio of posterior to anterior face height. The open vertical skeletal configuration was chosen when the configuration was confirmed by three or more of those cephalometric measurements. Fifteen CBCT images of the patients were produced using a ProMax 3D (Planmeca OY, Helsinki, Finland) machine at 84 kVp, 10 mA, an 8 cm×8 cm field of view, and a voxel size of 0.16 mm. Each patient was positioned with the occlusal plane horizontal.

### Measurement of the palatal bone thickness

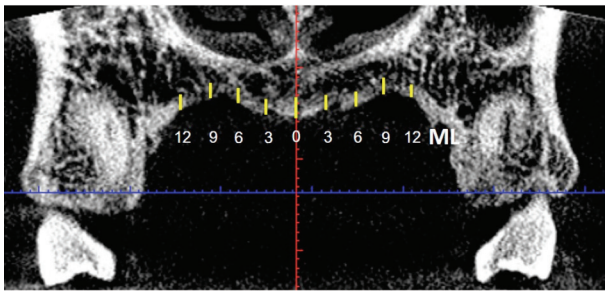
Using the Romexis viewer program, a line joining the middle of the distal bony margin of the incisive foramen and posterior nasal spine (PNS) was oriented to the midsagittal plane. In the midsagittal view, the horizontal reference plane was oriented to pass through the middle of those distal bony margins (Figure 1).[4,5,21-25] The cortical bone thickness of the palate was measured perpendicular to this horizontal reference plane from the outer to the inner border of the cortical bone of the palate. In the sagittal view, the palatal cortical bone thickness was measured at 3.0-mm intervals posteriorly from the middle of the distal bony margin of the incisive foramen to PNS (Figure 1). In each frontal view, the palatal cortical bone thickness was measured at 3.0-mm intervals laterally from the midsagittal reference plane (inclusive) on both right and left sides (Figure 2), eventually producing a grid pattern of measurements (Figure 3). To test the intra-examiner reliability, ten randomly-selected CBCT images were re-measured by the same examiner after a four-week interval. In addition, ten randomly-selected CBCT images were re-measured by the oral and maxillofacial radiologist. Each measurement site was named according to the anteroposterior (AP) intervals posteriorly from the

middle of the distal bony margin of the incisive foramen, and mediolateral (ML) intervals laterally from the midsagittal plane on both right and left sides. For example, the measurement site marked "x" in Figure 3 would be named Left AP6/ML3.



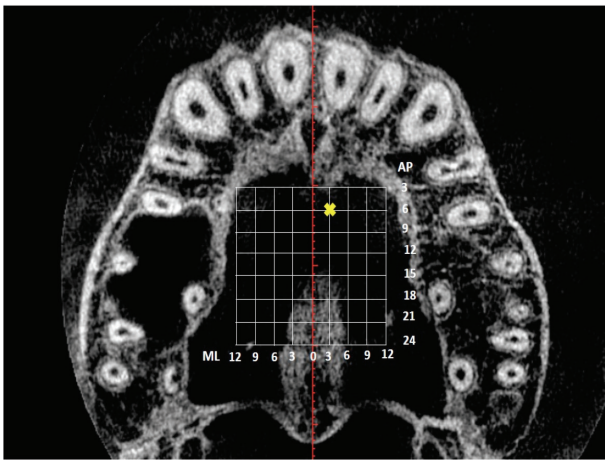

**รูปที่ 1** *ในแต่ละภาพแบ่งซ้ายขวา กระดูกทึบเพดานปากถูกวัดตั้งฉากกับระนาบอ้างอิงแนวนอน (เส้นสีน้ำเงิน) ที่ตำแหน่งทุก ๆ 3 มิลลิเมตรหลังจุดกึ่งกลางขอบกระดูกด้านท้ายของรูหลังฟันตัดไปยังเยื่องกระดูกจมูกส่วนหลัง*

***Figure 1*** *In each sagittal view, the palatal cortical bone thickness was measured perpendicular to the horizontal reference plane (blue line) at 3.0-mm intervals posteriorly from the middle of the distal bony margin of the incisive foramen to PNS.*




**รูปที่ 2** *ในแต่ละภาพแบ่งหน้าหลัง กระดูกทึบเพดานปากถูกวัดที่ตำแหน่งทุก ๆ 3 มิลลิเมตรจากระนาบแบ่งครึ่งซ้ายขวาไปทางด้านซ้ายและขวา*

***Figure 2*** *In each frontal view, the palatal cortical bone thickness was measured at 3.0-mm intervals laterally from the midsagittal reference plane on both right and left sides.*




**รูปที่ 3** *ตำแหน่งที่วัดมีรูปแบบคล้ายตาราง โดยวัดทุก ๆ ระยะ 3 มิลลิเมตรในแนวหน้าหลังหลังต่อจุดกึ่งกลางขอบกระดูกด้านท้ายของรูหลังฟันตัด (ส่วนตัดแนวหน้าหลังที่ 3, 6, 9, 12, 15, 18, 21, 24 มิลลิเมตร) และทุก ๆ ระยะ 3 มิลลิเมตรแนวใกล้กลางไกลกลางจากระนาบแบ่งครึ่งซ้ายขวาไปทางด้านซ้ายและขวา (ส่วนตัดแนวใกล้กลางไกลกลางที่ 0, 3, 6, 9, 12 มิลลิเมตร) โดยเรียกตำแหน่งที่มีเครื่องหมาย "x" ว่า AP6/ML3 ซ้าย*

***Figure 3*** *Measurement sites in a grid pattern at 3.0-mm anteroposterior intervals posteriorly from the middle of the distal bony margin of the incisive foramen (AP 3, 6, 9, 12, 15, 18, 21, 24 mm-sections), and at 3.0-mm mediolateral intervals laterally from the midsagittal plane on both right and left sides (ML 0, 3, 6, 9, and 12 mm-sections). The measurement site marked "x" was named Left AP6/ML3.*

**Statistical analysis**

Data were analyzed using SPSS 17.0 (SPSS Inc., Chicago, Ill., USA). Means and standard deviations of the cortical bone thickness of palate were measured.

## Results

The intra-examiner and inter-examiner reliability test for measurement of the cortical bone thickness of the palate showed high intraclass correlation (r = 0.994 for intra-examiner reliability test, r = 0.802 for inter-examiner reliability test) and suggested high reliability in measurement. The palatal cortical bone thickness

***ตารางที่ 1*** *แสดงค่าเฉลี่ยและส่วนเบี่ยงเบนมาตรฐานของความหนาของกระดูกทึบเพดานปากที่ตำแหน่งต่าง ๆ*

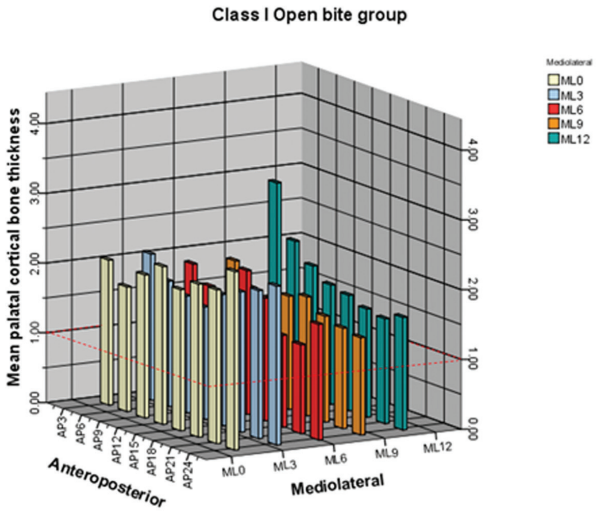
***Table 1*** *Means and standard deviations of the cortical bone thickness of the palate (mm) at each anteroposterior (AP) and mediolateral (ML) sites*

| Cortical bone thickness of the palate (mm) | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AP/ML site | ML0 [c] | | | | ML3 [b] | | | | ML6 [a] | | | | ML9 [a] | | | | ML12 [b] | | | |
| | Mean | SD | Min | Max | Mean | SD | Min | Max | Mean | SD | Min | Max | Mean | SD | Min | Max | Mean | SD | Min | Max |
| AP3 [b] | 2.08 | 0.78 | 0.56 | 3.22 | 2.09 | 0.54 | 0.49 | 3.22 | 1.88 | 0.52 | 1.10 | 3.17 | 1.85 | 0.34 | 1.24 | 2.83 | 2.90 | 0.63 | 1.54 | 4.37 |
| AP6 [a] | 1.79 | 0.64 | 0.76 | 2.98 | 1.80 | 0.51 | 0.62 | 3.09 | 1.65 | 0.54 | 0.49 | 2.48 | 1.55 | 0.32 | 0.65 | 2.26 | 2.15 | 0.73 | 0.80 | 3.80 |
| AP9 [a] | 2.05 | 0.81 | 1.13 | 3.84 | 1.67 | 0.50 | 0.72 | 2.90 | 1.48 | 0.52 | 0.48 | 2.49 | 1.49 | 0.44 | 0.44 | 2.68 | 1.89 | 0.63 | 0.76 | 3.42 |
| AP12 [a] | 2.26 | 0.84 | 0.79 | 3.90 | 1.61 | 0.60 | 0.85 | 3.54 | 2.06 | 1.49 | 0.82 | 9.00 | 1.62 | 0.72 | 0.44 | 3.28 | 1.71 | 0.63 | 0.69 | 4.08 |
| AP15 [a] | 2.02 | 0.72 | 1.05 | 3.55 | 1.88 | 0.88 | 0.79 | 4.47 | 1.76 | 0.91 | 0.72 | 3.82 | 1.70 | 0.78 | 0.53 | 3.05 | 1.65 | 0.63 | 0.41 | 2.93 |
| AP18 [a] | 2.19 | 0.94 | 0.85 | 3.64 | 2.01 | 0.90 | 0.39 | 3.65 | 1.32 | 0.61 | 0.48 | 2.53 | 1.52 | 0.65 | 0.52 | 2.75 | 1.55 | 0.62 | 0.92 | 3.16 |
| AP21 [a] | 2.20 | 1.10 | 0.59 | 4.30 | 2.12 | 0.92 | 0.57 | 3.93 | 1.27 | 0.40 | 0.51 | 1.99 | 1.44 | 0.43 | 0.79 | 2.32 | 1.50 | 0.44 | 0.66 | 2.6 |
| AP24 [a] | 2.56 | 1.41 | 0.79 | 5.37 | 2.28 | 1.10 | 0.62 | 4.27 | 1.66 | 0.59 | 0.86 | 3.09 | 1.40 | 0.52 | 0.60 | 3.43 | 1.62 | 0.66 | 0.70 | 2.85 |

**AP** (Anteroposterior) sites represent posterior distances of 3, 6, 9, 12, 15, 18, 21, and 24 mm from the distal bony margin of the incisive foramen along the incisive foramen-PNS reference line; **ML** (Mediolateral) sites represent lateral distances of 0, 3, 6, 9, 12 mm from the midsagittal plane; different superscripts indicate significant differences ($P<0.05$), and identical superscripts indicate no significant differences in the designated groups.

measurements were normally distributed, and had no statistical difference between the left and right sides. Therefore, the measurements from both sides were pooled for statistical analysis.

The means and standard deviations of the palatal cortical bone thickness measurements are shown in Table 1. Combined plots of the palatal cortical bone thickness are shown in Figure 4. The palatal cortical bone thickness ranged from 1.27±0.40 (at the AP21/ML6 site) to 2.90±0.63 mm (at the AP3/ML12 site). The measurements at all sites were equal to or greater than 1.0 mm.




***รูปที่ 4*** *แผนผังแสดงค่าเฉลี่ยความหนาของกระดูกทึบเพดานปากที่ตำแหน่งต่าง ๆ เส้นประสีแดงที่ระดับ 1 มิลลิเมตรแสดงตำแหน่งที่มีความหนาของกระดูกทึบเพดานปากเท่ากับหรือมากกว่า 1 มิลลิเมตร*

***Figure 4*** *Combined plots of average palatal cortical bone thickness at various sites. The red dash lines are inserted at the 1.0 mm level of cortical bone thickness, revealing the sites where the average was equal to or greater than 1.0 mm.*

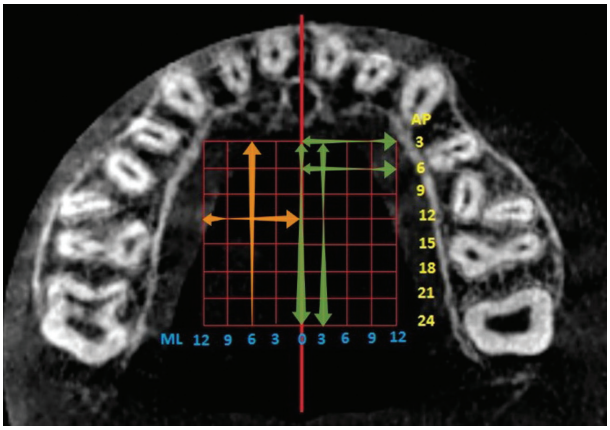
## Discussion

Cortical bone thickness has a strong effect on the primary stability of miniscrew implants.[1,26] It is correlated with placement torque value. Placement torque values outside the 5 to 10 Ncm range lead to failure of miniscrew implant placement.[27] Motoyoshi et al.[13] have demonstrated that the cortical bone thickness should be at least 1.0 mm for adequate primary stability and clinical success. Baumgaertel et al.[28] confirmed that this thickness was also adequate

in patients with open vertical skeletal configurations. In our study, the palatal cortical bone thickness at all sites in subjects exhibiting anterior open bite and open vertical skeletal configurations was equal to or greater than 1.0 mm, confirming that the palatal cortical bone thickness was sufficient for the stability of miniscrew implant placement. However, Nakahara et al.[4] have reported that the palatal cortical bone thickness in the posterior paramedian areas was less than 1.0 mm, a thickness which is not sufficient for the stability of miniscrew implants. The discrepancy in results between this and Nakahara's studies may be due to variations in palatal cortical bone thickness, differences in vertical skeletal configurations, ethnicity, or measurement methods.

Measuring the palatal cortical bone thickness perpendicular to the palatal bone surface cannot provide accurate or reproducible measurement intervals, because the palatal bone surface is not a straight line. In our study, the cortical bone thickness of the palate was measured perpendicular to the horizontal reference plane, as recommended by several studies.[4,5,21-25] The horizontal reference plane was parallel to the palatal bone surface, except for the posterior and transverse end points. The horizontal reference plane permitted reproducible and accurate measurements in the palatal cortical bone thickness.[4,5,21-25] It should be noted that the amount or thickness of cortical bone through which the miniscrew penetrates depends on the angle of measurement and the angle of miniscrew placement. Moreover, previous studies have shown various measurement sites and methods.[4,28] Therefore, miniscrew implant placement in controversial areas, such as posterior paramedian areas, should be considered carefully.

Our CBCT-based investigation has shown the pattern of palatal cortical bone thickness in subjects exhibiting anterior open bite and open vertical skeletal configurations. The palatal cortical bone thickness was greatest at all AP sites along the ML0 section, or midsagittal plane (Figure 5). This finding agreed with the findings of Nakahara et al.[4] and Baumgaertel et al.[28] Within the ML sections, the palatal cortical bone thickness decreased toward the lateral region and increased at the ML12 sections. The lowest palatal cortical bone thickness measurements were found along the ML6 and ML9 sections. But some studies have suggested that there was no significant difference in measurements from the ML3 to ML12 sections.[4,28] Within the AP sections, the palatal cortical bone thickness decreased toward the posterior region, similarly to the findings of other studies.[4,28] However, our study has shown the palatal cortical bone thickness increased toward the posterior region along the ML0 and ML3 sections.




**รูปที่ 5** *แผนภาพแสดงรูปแบบความหนาของกระดูกทึบเพดานปากที่ตำแหน่งต่าง ๆ หัวลูกศรแสดงการทิศทางการเพิ่มขึ้นของความหนาของกระดูกทึบเพดานปาก ลูกศรสีเขียวแสดงรูปแบบความหนาของกระดูกทึบเพดานปากที่ด้านตัด ML0, ML3, AP3, AP6 ลูกศรสีส้มแสดงรูปแบบความหนาของกระดูกทึบเพดานปากในบริเวณอื่น*

***Figure 5*** *The palatal map shows the pattern of the cortical bone thickness of the palate at various sites. The arrowheads represent the direction of the increase in cortical bone thickness. The green arrows show the pattern of the palatal cortical bone thickness along the ML0, ML3, AP3, AP6 sections. The orange arrows show the pattern of the palatal cortical bone thickness in the other remaining areas.*

The pattern of the cortical bone thickness of the palate, shown in our study, is different from the patterns in other studies due to our specific investigation in patients exhibiting anterior open bite and open vertical skeletal configurations. The anterior open bite with open vertical skeletal configuration is related to the alteration of masticatory muscle function, bite force, tongue position and soft tissue function.[29,30] According to the mechanostat hypothesis of Frost,[31,32] the form and mass of bone is influenced by the range of strains. Therefore, bite force and soft tissue function influence skeletal morphology. Several studies[19,20] have reported different cortical bone thicknesses in different types of vertical skeletal configuration. Therefore, miniscrew implant placement in patients exhibiting anterior open bite and open vertical skeletal configurations should be considered prudently.

Several previous studies[4,28,33] have attempted to investigate the palatal cortical bone thickness in order to identify miniscrew implant placement sites with sufficient available cortical bone. Methods for measuring the palatal cortical bone thickness are classified into direct and indirect (or radiological) measurements. Direct measurement, including craniometry, is limited only to autopsy specimens.[27] Indirect (or radiological) measurement can be performed in both cadavers and living humans. In addition, specimen preparation for direct measurement is more complicated than for radiological measurement. According to our study, three-dimensional imaging with either high-resolution computed tomography or CBCT provides precise and reliable information on the osseous, especially the cortical bone thickness. Information about the cortical bone thickness is helpful during orthodontic treatment for the selection of miniscrew implant placement sites, especially in the palatal areas.[4]

Additionally, other factors should be considered concomitantly for the selection of palatal miniscrew implant placement sites, including the quantity and quality of the palatal bone, palatal soft tissue thickness, surrounding vital anatomical structures and the appliance design.[34] Although the palatal cortical bone thickness at all sites was sufficient for the stability of miniscrew implant placement, the anterior and median areas of the palate have been suggested to be suitable miniscrew implant placement sites.[35,36] For further study, the total palatal bone thickness of patients exhibiting anterior open bite and open vertical skeletal configurations should be investigated.

## Conclusions

This CBCT-based investigation showed variations in the palatal cortical bone thickness, and suggested the palatal cortical bone thickness at all sites of patients exhibiting anterior open bite and open vertical skeletal configurations might be sufficient for providing primary stability of miniscrew implants if other contributing factors were within the normal range.

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