CHAPTER 5

Discussion

Several previous studies (10, 40, 37, 69-71) have attempted to investigate both total palatal bone and palatal cortical bone thickness in order to identify miniscrew implant placement sites with sufficient available bone for implant success. Methods for measuring the palatal bone thickness are classified into direct and indirect (or radiological) measurements. Direct measurement, including craniometry, is limited only to autopsy specimens (39). 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. Two-dimensional imaging cannot provide accurate information about the palatal bone thickness (43, 44). Several studies (10, 29, 37, 69-71) have investigated both total palatal bone and cortical bone thickness, using CT or CBCT. According to this study, three-dimensional imaging with CBCT provides precise and reliable information on the osseous, both total bone and cortical bone, thickness. Gahleitner *et al*. (72) have reported that CBCT assesses the palatal bone volume accurately. Information about the bone thickness is helpful during orthodontic treatment for the selection of miniscrew implant lengths and placement sites, especially in the palatal areas.

Information pertaining to the palatal bone thickness supports the selection of ideal miniscrew implant placement sites and miniscrew implant lengths to secure adequate retention and to avoid damage to vital structures. Winsauer *et al* .(38) have suggested bony support of at least 5.0 mm to resist rotational forces and dynamic loads, contributing to the stability of miniscrew implants. For palatal bone thickness measurement, this study determined that the end points of measurement at the outer borders of the cortical bone of surrounding vital structures were located at the nasal floor, maxillary sinus floor, or incisive canal wall. The palatal bone thickness was measured perpendicular to the reference plane, as recommended by several studies (29, 37, 69, 70). The horizontal reference plane permitted reproducible measurement intervals, and was parallel to the palatal bone surface, except for the posterior and transverse end points. Measurement, perpendicular to the palatal bone surface, could not provide accurate or reproducible intervals, because the palatal arc is not a straight line (10, 29, 70). Miniscrew implant placement, perpendicular to the reference plane according to our investigation, might be limited in some areas due to clinical inaccessibility.

This study reveals that the palatal bone thickness in the Class I normal bite and the Class I open bite groups had similar patterns, though they were not equal (Figure 5.1). Along the midpalatal plane or the ML0 section, the palatal bone thickness was lowest in the anterior region and increased toward the posterior region. This finding agreed with the findings of Kang *et al*. (37). The palatal bone thickness at the AP3 to AP6 sites along the midpalatal plane or 1.0-mm lateral distance is affected by the incisive canal that generally extends superiorly and posteriorly in the anterior region of the palate. On the contrary, Gracco *et al*. (69) found that the palatal bone thickness decreased toward the posterior region, because the incisive canal was included in the palatal bone thickness measurement along the ML0 section in their study. However, the palatal bone thicknesses at all AP sites along the ML0 section below the incisive canal were greater than 5.0 mm, especially in the posterior region. The additional bone height is provided by the nasal crest (29, 44, 73, 74). Kim *et al.* (40) have reported that the midpalatal area within 1.0 mm is the thickest part of the palatal bone. In addition, the midpalatal area is covered by thick palatal mucosa in the anterior region, and from 4.0-mm posteriorly to the incisive papilla a constant 1.0-mm-thick palatal mucosa. Because of the quantity of bone and soft tissue, the midpalatal area is suggested by Kim *et al.* (40), supported by this study, as a suitable miniscrew implant placement site, except for the anterior region of the palate. However, Asscherickx *et al.* (75) recommended not placing miniscrew implants in the midpalatal area in children or adolescents, in whom the midpalatal suture is not fully ossified because such placement increases the risk of disturbing maxillary growth. In addition, the limited vertical bone volume and the degree of obliteration of the midpalatal suture are crucial factors for the stability of miniscrew implants.

Paramedian areas of the palate are alternative miniscrew implant placement sites. In this study, along the ML3 section, the palatal bone thickness was greatest in the anterior region, decreased in the middle region, and slightly increased in the posterior region. In the Class I normal bite group, the palatal bone thicknesses were greater than 5.0 mm at all AP sites along the ML3 section (Figure 4.1). Therefore, the palatal areas along the ML3 sections are recommended as miniscrew implant placement site in the Class I normal bite group. However, the palatal bone thicknesses in the Class I open bite group were greater than 5.0 mm at only the AP3, AP6 and AP24 sites along the ML3 section (Figure 4.2). Along the ML6 to ML12 sections, the palatal bone thicknesses decreased toward the posterior region.

Within the ML section, in the anterior region of the palate (at the AP3 to AP6 sections), the palatal bone thickness increased toward the lateral region. In the middle and posterior region of the palate (at the AP9 to AP24 sections), the palatal bone thickness was greatest at the ML0 site, decreased at the ML6 and ML9 sites, and increased at the ML12 sites. The additional bone height along the ML12 section was supported from the lateral wall of the nasal cavity. This finding agrees with the findings of Nakahara *et al*. (29) and Baumgaertel *et al*. (10), reporting that the palatal bone thickness increased in the extremely lateral region.

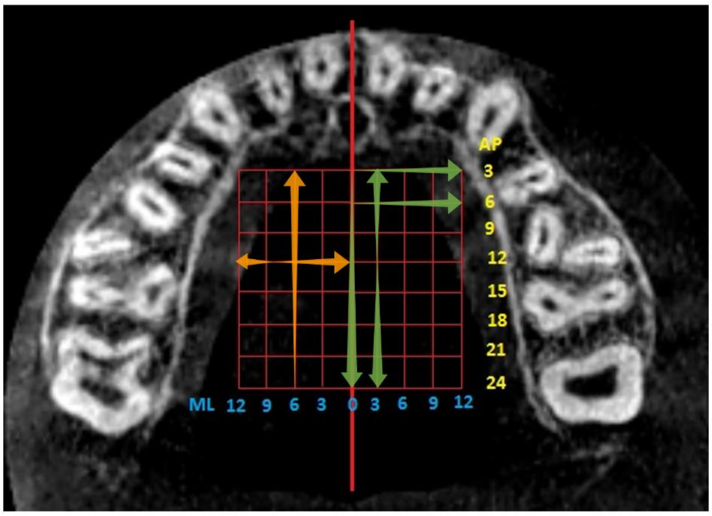

Figure 5.1 The palatal map shows the pattern of the bone thickness of the palate at various sites in the Class I normal bite and the Class I open bite groups. The heads of the arrows represent the direction of the increase in bone thickness. The green arrows show the pattern of the palatal bone thickness along the ML0, ML3, AP3 and AP6 sections. The orange arrows show the pattern of the palatal bone thickness in the other remaining areas.

Information about the palatal cortical bone thickness is beneficial for miniscrew implant placement site selection, because the cortical bone thickness has a strong impact on the primary stability of miniscrew implants (4, 5). Motoyoshi *et al.* (48) have demonstrated that the cortical bone thickness should be at least 1.0 mm for adequate primary stability and clinical success. In our study, the palatal cortical bone thicknesses at all sites in both groups were equal to or greater than 1.0 mm, confirming that the palatal bone thicknesses were sufficient for the stability of miniscrew implant placement (Figures 4.3 and 4.4). This finding agrees with the findings of Baumgaertel *et al.* (10). However, Nakahara *et al.* (29) 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.

This study reveals that the palatal cortical bone thickness in the Class I normal bite and the Class I open bite groups had similar patterns, though they were not equal (Figure 5.2). The palatal cortical bone thickness was greatest at all AP sites along the ML0 section, or midsagittal plane. This finding agrees with the findings of Nakahara *et* *al.* (29) and Baumgaertel *et al.* (10). 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 (10, 29) have suggested that there was no significant difference in measurements from the ML3 to ML12 sections. Within the AP sections, the palatal cortical bone thickness decreased toward the posterior region, a finding similar to the findings of other studies (10, 29). However, in this study the palatal cortical bone thickness increased toward the posterior region along the ML0 and ML3 sections.

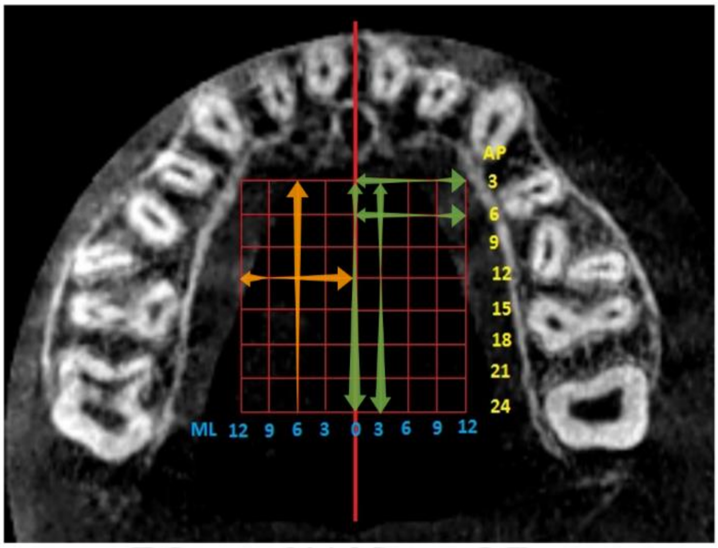

Figure 5.2 The palatal map shows the pattern of the cortical bone thickness of the palate at various sites in the Class I normal bite and the Class I open bite groups. The heads of the arrows represent the direction of the increase in bone thickness. The green arrows show the pattern of the palatal bone thickness along the ML0, ML3, AP3 and AP6 sections. The orange arrows show the pattern of the palatal bone thickness in the other remaining areas.

Miniscrew implants provide skeletal anchorage for posterior tooth intrusion in anterior open bite treatment. Moon *et al.* (6) have reported a significant reduction in interradicular miniscrew implant success in the buccal maxillary region with open vertical skeletal configurations, and suggested that the reduction was associated with high Frankfort-mandibular plane and low upper gonial angles. Therefore, the palate is an alternative miniscrew implant placement site for orthodontic treatment in patients with anterior open bite and open vertical skeletal configuration. Our study found that the Class I normal bite and open bite groups had similar patterns of both total palatal bone and palatal cortical bone thickness. But the palatal bone thickness measurements at almost all AP/ML sites in the Class I open bite group were lower than those in the Class I normal bite group, and there were significant differences at almost all AP sites along the ML3, ML6 and ML9 sections. Significant differences in palatal bone thickness between the two groups were rarely found along the ML0 and ML12 sections. This finding may be the result of high variation of the palatal bone thicknesses and of surrounding anatomical structures in this area, such as the maxillary sinus, and nasal cavity.

Differences in the total palatal bone and palatal cortical bone thickness between the two groups might be explained by masticatory muscle function, bite force and soft tissue function, which influence skeletal morphology. The mechanostat hypothesis of Frost (53) suggests that the form and mass of bone is influenced by a range of strains. Some studies (56, 58) have shown the association between increased facial divergence and decreased muscle function. Furthermore, other studies (7, 8, 59) have reported relationships between open vertical skeletal configurations and reduced thickness and density of alveolar bone and of alveolar cortical bone due to lower masticatory function and bite force. However, bony adaptation has been found not only in alveolar bone, but also in other facial bones, to which force is dissipated (76). In animal experiments, relationships between high strain from masticatory force and a thickened palate have been reported (77, 78). However, the relationships between masticatory function and bite force and palatal bone thickness in humans are still controversial (79, 80). Further study should focus on the association between the palatal bone thickness and both the masticatory muscle function and bite force in the hyperdivergent facial type. In addition, the differences in the total palatal bone and palatal cortical bone thickness between the two groups might be attributed by variations in soft tissue function, such as tongue's position and function during swallowing. Most patients with anterior open bite have tongue tip protrusion during swallowing (81). However, Proffit (11) demonstrated that the intermittent force of short duration, including swallowing, does not have an effect on the skeletal morphology.

A decrease in the palatal bone thickness in the Class I open bite group is affected by a decrease in either cortical bone thickness, or trabecular bone thickness. In this study, the palatal cortical bone thickness measurements in the Class I open bite group were significantly lower than those in the Class I normal bite group at some AP/ML sites, including the AP6/ML6, AP18/ML6, AP21/ML6, AP6/ML9 and AP6/ML12 sites. The decrease in palatal bone thickness measurements at the other sites may be the result of a decrease in the trabecular bone thickness. Previous studies (8, 59) have found reduced cortical bone thickness and density with constant trabecular bone thickness in open vertical skeletal configuration cases due to low masticatory muscle force and bite force. Johari et al. (82) have reported that the palatal cortical bone thickness in some areas in patients with long faces was less than those with short faces. However, the masticatory force and bite force can cause remarkable changes in the trabecular bone thickness and pattern (76, 79). In this study, there was thin palatal bone in some paramedian areas, where the palatal trabecular bonewas absent. The palatal and nasal cortical layers of the palatal bone were fused together and could not be individually measured. However, the palate provided sufficient cortical bone thickness for the stability of miniscrew implants at all AP/ML sites in both the Class I normal bite and the Class I open bite groups (Figures 4.3 and 4.4).

In the Class I normal bite group, when palatal miniscrew implant placement was required in the anterior region of the palate (3.0-9.0 mm posteriorly from the incisive foramen), the suggested site was the paramedian area (Figure 5.3). This finding agrees with those of other studies that found sufficient palatal bone thickness in the anterior paramedian palate (10,37, 69). When palatal miniscrew implant placement was required in the middle and posterior regions of the palate (12.0-24.0 mm posteriorly from the incisive foramen), the suggested sites were along the ML0 or ML3 sections. However, miniscrew implants longer than 6.0 mm are not recommended at the AP3 to AP6 sites along the ML0 section (or the midpalatal plane) to avoid nasopalatine nerve injury (29, 37, 69, 70). This study suggests that the paramedian areas more than 3.0 mm laterally from the midpalatal plane and 9.0 mm posteriorly from the incisive foramen should be avoided due to the potential for poor miniscrew implant retention and risk of nasal perforation. Contrastingly, other CBCT-based investigations (10, 29, 37, 69) have recommended not placing miniscrew implants in paramedian areas of the middle or posterior palate more than 1 mm laterally to the midpalatal plane, due to the lack of sufficient palatal bone. The discrepancy in results between this and other studies may be due to variations in palatal bone thickness, differences in measurement methods or ethnicity. Moreover, in the open bite group, the suggested miniscrew implant placement sites in our study were at all AP sites along the midpalatal plane or 3.0-6.0 mm posteriorly from the incisive foramen along the other ML sections (Figure 5.4).

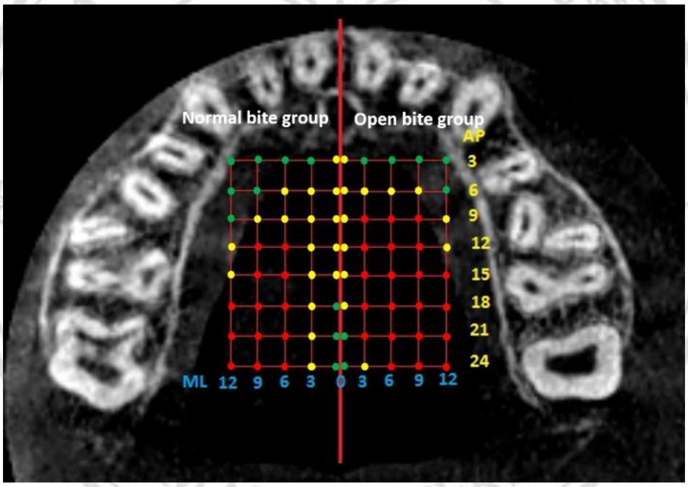

Figure 5.3 The palatal map shows the average palatal bone thickness measurements at various sites in the Class I normal bite (Left side) and the Class I open bite groups (Right side). The green dots indicate the sites where the average palatal bone thicknesses were equal to or greater than 8 mm. The yellow dots indicate the sites where the average palatal bone thicknesses were equal to or greater than 5 mm. The red dots indicate the sites where the average palatal bone thicknesses were less than 5 mm.

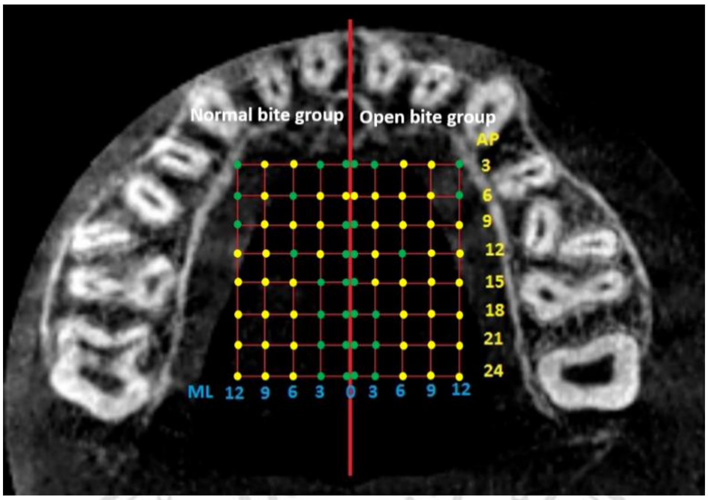

Figure 5.4 The palatal map shows the average palatal cortical bone thickness measurement at various sites in the Class I normal bite (Left side) and the Class I open bite groups (Right side). The green dots indicate the sites where the average cortical bone thicknesses were equal to or greater than 2 mm. The yellow dots indicate the sites where the average palatal cortical bone thicknesses were equal to or greater than 1 mm. The red dots indicate the sites where the average palatal cortical bone thicknesses were less than 1 mm.

However, the determination of palatal miniscrew implant placement sites depends on several factors. Not only the quantity of bone, but also other factors, should be concomitantly considered, including the quality of bone, soft tissue, and biomechanical demand. Although the palatal bone thickness was the greatest at the AP3/ML12 site in both groups, it is not a favorable miniscrew implant placement site because of poor biomechanics and the mucosa-covered slope to the alveolar process (83). In addition, the definitive miniscrew implant length also depends on the angle of miniscrew implant placement and palatal soft tissue thickness.

In this study, there was high variation in bone thickness measurements. A larger number of subjects should be recruited in future studies. In addition, the discrepancy in results between this and other studies may be due to variations in palatal bone thickness, differences in measurement methods, measurement sites, or ethnicity. For further study, the total palatal bone thickness and palatal cortical bone thickness of patients with anterior deep bite exhibiting deep vertical skeletal configuration, or different sagittal skeletal relationships should be investigated. The information should be beneficial for palatal miniscrew implant placement site selection when palatal miniscrew implants are required.