Density of the alveolar and basal bones of the maxilla and the mandible

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Introduction: The purpose of this investigation was to quantitatively evaluate density of the alveolar and basal bones of the maxilla and the mandible. Methods: Sixty-three sets of computed tomographic (CT) images were selected, and bone density was measured with V-Works imaging software (Cybermed, Seoul, Korea). The sample consisted of 23 men (ages, 29 ± 10.9 years) and 40 women (ages, 25.6 ± 7.6 years). Cortical and cancellous bone densities at the alveolar and basal bones at the incisor, canine, premolar, molar, and maxillary tuberosity/retromolar areas were measured. Results: The cortical bone density of the maxilla ranged approximately between 810 and 940 Hounsfield units (HU) at the alveolar bone except for the maxillary tuberosity (443 HU at the buccal and 615 HU at the palatal alveolar bone), and between 835 and 1113 HU at the basal cortical bone except for tuberosity (542 HU). The cortical bone density of the mandible ranged between 800 and 1580 HU at the alveolar bone and 1320 and 1560 HU at the basal bone. The highest bone density in the maxilla was observed in the canine and premolar areas, and maxillary tuberosity showed the lowest bone density. Density of the cortical bone was greater in the mandible than in the maxilla and showed a progressive increase from the incisor to the retromolar area. Conclusions: These data might provide valuable information when selecting sites and placement methods for miniscrew or microscrew implants in the dental arch. (Am J Orthod Dentofacial Orthop 2008;133:30-7)

Many attempts have been made to develop suitable anchorage for orthodontic treatment. However, none of the previously developed intraoral devices provided sufficient anchorage, and extraoral appliances are not reliable unless the patient is compliant.

To overcome problems associated with anchorage loss, skeletal anchorage methods such as dental implants, miniplates, and miniscrew or microscrew implants have been developed and are now increasingly used. Microscrew implants have many benefits, including easy placement and removal, immediate loading, minimal anatomical limitations thanks to their small size, and low cost, as compared with other skeletal options. With their increase in popularity, many reports have dealt with various clinical situations, such as en-masse retraction of the anterior or posterior teeth, retraction of the whole dentition, molar distalization, molar uprighting, protraction of molars, and forced eruption of the canines.

Several sites have been proposed for the placement of miniscrew or microscrew implants. Most frequently recommended sites were the midpalatine area, the alveolar bone between the maxillary second premolars and first molars, and the mandibular first and second molars. Other possible locations for microscrew implants are the retromolar area, the chin, the inferior ridge of the piriform aperture, the inferior ridge of the zygomatic arch, the maxillary tuberosity, and the mandibular body. However, there is insufficient information concerning the thickness of cortical bone, bone density, and characteristics of the overlying soft tissues, which might influence the success of miniscrew or microscrew implants.

Three main factors affect the success of dental implants: host, implant, and surgical method. A close relationship was shown between bone density and the success of dental implants. Microscrew implants can be placed in the alveolar bone in both edentulous and dentulous areas. Therefore, data concerning density of the alveolar bone are essential for selecting sites for microscrew implant placement and predicting success. Buck and Wheeler measured the density of alveolar and retromolar bones from human cadavers. Miller et al studied bone density using computed tomography (CT) in monkeys. However, there are not enough data,
especially dealing with density of the alveolar bone in the dentulous areas in patients.

In this study, we evaluated quantitatively the density of the alveolar and basal bones of the maxilla and the mandible to provide guidelines for placement sites or methods for microscrew implants.

**MATERIAL AND METHODS**

The sample consisted of 63 sets of CT scans (Ipro; GE, Waukesha, Wis) from patients who had visited the Kyungpook National University Hospital in Daegu, Korea, for orthognathic surgery and reduction of a fractured jaw bone. The research protocol was approved by the institutional research board for ethical issues. Patients with general diseases or pathologic lesions in the jaws or who were on medication that affected bone density were excluded. The sample consisted of 23 men (ages, 29 ± 10.4 years) and 40 women (ages, 25.4 ± 7.8 years).

The V-Works (version 3.5, Cybermed, Seoul, Korea) program was used to measure bone density. After storing CT images with slice thicknesses of 3 mm into a personal computer, a CT section of 5 to 7 mm from the alveolar crest was selected to measure the density of the alveolar bone. Another section, 3 to 5 mm above the root apex, was selected to measure the density of the basal bone (Fig 1). The densities of these bones were measured in Hounsfield units (HU) for the incisor, canine, premolar, and molar areas, and tuberosity in the maxilla and the retromolar area in the mandible anteroposteriorly (Fig 2). At each site, density of the buccal cortical bone, cancellous bone, and palatal or lingual cortical bone for the alveolar bone and buccal cortical and cancellous bone for the basal bone was measured. At the retromolar area of the mandible, bone density at the buccal and lingual sides of the crest of ridge was measured. When measuring the density of the cortical bone, its center point was chosen. The density of the cancellous bone was measured at the trabeculae, located halfway buccolingually between the buccal and palatal or lingual cortical plates. Bone density in the paramedian area of the midpalatine suture, where midpalatine implants are frequently placed, was also measured. If it was impossible to measure 1 side, measurements of the opposite side were used.

**Statistical analysis**

SAS software (version 8.01; SAS, Cary, NC) was used for statistical analysis. There were no differences between men and women, so the combined sample was used for the statistical analysis between sites. To analyze differences of bone density at the incisor, canine, premolar, molar, and retromolar or tuberosity areas in the maxilla and the mandible, the 1-way analysis of variance (ANOVA) was performed, and the Tukey multiple range test was used for multiple comparisons. The Student t test was used to evaluate differences between the alveolar and the basal bones, and between the maxilla and the mandible. The 1-way ANOVA was performed to analyze differences between the cortical bone at the paramedian area and the basal and alveolar bones of the maxilla. The Tukey test was used to analyze differences between sites.

To calculate the errors of measurement, 69 randomly selected measurement sites were measured 1 month later. The measurement error was calculated based on the differences between the first and second measured values with the paired t test. There was no
significant difference between the 2 measurements. The method error according to Dahlberg’s formula was 88.2.

RESULTS

The overall bone density was approximately between 810 and 940 HU for the maxillary alveolar bone except for the maxillary tuberosity (443 HU in the buccal and 615 HU in the palatal cortical bone), and between 835 and 1113 HU at the basal cortical bone except for tuberosity (542 HU) (Table I). The density of the cancellous bone of the maxilla ranged approximately between 280 and 500 HU except for the lowest density of the tuberosity area (151 HU).

For the mandible, cortical bone densities were approximately between 810 and 1580 HU for alveolar bone and between 1320 and 1560 HU for basal bone. These numbers increased progressively from the incisor area to the retromolar area. Cancellous bone in the mandible had densities of 300 to 500 HU for alveolar bone and 170 to 440 HU for basal bone.

In the maxilla, buccal cortical bone density of the alveolar bone at the premolar area was the highest of all measurements of the alveolar bone. Bone density at the maxillary tuberosity was the lowest. Regarding the palatal cortical bone, tuberosity showed the lowest bone density, and there was no statistically significant difference between the other areas. In the maxillary basal cortical bone, the highest bone density was evident at the canine and premolar areas, whereas the tuberosity area had the lowest density. There was no statistically significant difference in density of the alveolar cancellous bone between the incisor, canine, and premolar areas, but the maxillary tuberosity showed statistically significant low density. For the basal cancellous bone, the density at the maxillary tuberosity was lower than other sites (Table I).

In the mandible, the buccal cortical bone at the incisor area was the weakest, and there was a progressive increase in bone density from the incisor to the retromolar areas. The density at the retromolar area was the highest. The lingual cortical bone showed a similar trend as the buccal cortical bone. There was no statistical difference between sites in the cancellous bone of the mandibular alveolar bone. For the basal cancellous bone, the incisor and canine areas showed higher bone densities than the retromolar area (Table I).

Bone density measurements are given according to Misch’s classification (Table II). With this method, the alveolar cortical bone in the maxilla was type 2 or 3, which is similar to basal cortical bone. For the mandible, the basal cortical bone was type 1, whereas the alveolar cortical bone was type 2 or 3 at the incisor, canine, and premolar areas. The molar and retromolar areas had type 1 bone (Table II).

For the maxilla, the buccal cortical bones of the basal bone at the canine, premolar, and tuberosity areas were denser than the alveolar bone. The density of alveolar bone at the incisor and molar areas was similar to that of basal bone. The density of the cancellous bone of the alveolar bone at the incisor and canine areas was higher than that of the basal bone (Fig 3).

For the mandible, all density measurements of the cortical basal bone were statistically higher than those of the alveolar bone, except for the retromolar area. Bone density at the retromolar area was measured at the

### Table I. Bone density measured at each site of the maxilla and the mandible (in HU)

<table>
<thead>
<tr>
<th>Maxilla</th>
<th>Incisor</th>
<th>Canine</th>
<th>Premolar</th>
<th>Molar</th>
<th>Tuberosity/retromolar</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alveolar bone</td>
<td>Buccal cortical</td>
<td>812.68 ± 172.94A</td>
<td>914.27 ± 185.63BC</td>
<td>940.85 ± 223.87BC</td>
<td>884.48 ± 183.48AB</td>
<td>443.23 ± 211.26D</td>
</tr>
<tr>
<td>Cancellous</td>
<td>498.44 ± 187.53A</td>
<td>395.83 ± 159.67AB</td>
<td>404.11 ± 182.75A</td>
<td>323.53 ± 171.86B</td>
<td>151.80 ± 105.79C</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Palatal cortical</td>
<td>866.46 ± 136.45A</td>
<td>913.12 ± 166.91A</td>
<td>925.16 ± 176.85A</td>
<td>924.53 ± 210.42A</td>
<td>615.04 ± 291.41B</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Basal bone</td>
<td>Buccal cortical</td>
<td>835.48 ± 179.86A</td>
<td>1113.65 ± 248.19B</td>
<td>1106.97 ± 298.56B</td>
<td>887.11 ± 282.59A</td>
<td>542.68 ± 231.04C</td>
</tr>
<tr>
<td>Cancellous</td>
<td>365.83 ± 165.42A</td>
<td>279.80 ± 143.50AB</td>
<td>326.61 ± 226.27A</td>
<td>399.72 ± 339.05A</td>
<td>156.24 ± 128.05B</td>
<td>.0004</td>
</tr>
<tr>
<td>Mandible</td>
<td>Alveolar bone</td>
<td>Buccal cortical</td>
<td>802.75 ± 240.69A</td>
<td>1004.43 ± 232.87B</td>
<td>1136.54 ± 266.96C</td>
<td>1319.06 ± 238.33D</td>
</tr>
<tr>
<td>Cancellous</td>
<td>507.40 ± 221.88</td>
<td>527.73 ± 276.56</td>
<td>447.98 ± 546.08</td>
<td>358.23 ± 340.88</td>
<td>325.18 ± 441.45</td>
<td>.1684</td>
</tr>
<tr>
<td>Lingual cortical</td>
<td>775.13 ± 200.24A</td>
<td>1157.77 ± 253.15B</td>
<td>1153.20 ± 198.95B</td>
<td>1281.21 ± 149.77C</td>
<td>1233.20 ± 230.68BC</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Basal bone</td>
<td>Buccal cortical</td>
<td>1327.56 ± 369.91A</td>
<td>1438.44 ± 233.32B</td>
<td>1506.64 ± 201.95BC</td>
<td>1568.96 ± 204.38C</td>
<td>1482.07 ± 157.32BC</td>
</tr>
<tr>
<td>Cancellous</td>
<td>427.53 ± 264.84AB</td>
<td>443.65 ± 354.23A</td>
<td>263.09 ± 237.70BC</td>
<td>232.13 ± 293.39BC</td>
<td>173.96 ± 287.57C</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

Same letters are not statistically significant at P = 0.05 by the Tukey multiple range test.
ridge of the crest, which had denser bone than the basal bone. For the cancellous bone, all density measurements of the alveolar bone were higher than those of the basal bone, with statistical significance at the premolar, molar, and retromolar areas (Fig 4).

When comparing alveolar cortical bone density of the maxilla with the mandible, the mandibular measurements were statistically higher than those of the maxilla, except for the incisor measurements. For cancellous bone, the canine and retromolar areas of the mandible were statistically higher than the maxilla (Fig 5).

In comparing basal bone density between the maxilla and the mandible, all measurements of the cortical bone in the mandible were higher than those in the maxilla (\( P < .05 \)). At the cancellous bone, there was no statistically significant difference at the incisor, premolar, and retromolar areas. However, the mandible had a statistically significant higher density at the canine area, whereas the maxilla had a higher density at the molar area (\( P < .05 \)) (Table I).

In the canine area, the highest bone density was evident at the basal bone, the alveolar bone had the second highest density, and the paramedian bone showed the lowest bone density. There was no statistical difference at the molar area (Fig 6).

**DISCUSSION**

Regarding the failure rate of dental implants, Jaffin and Berman\(^\text{12}\) reported that it was 3% for types 1, 2, and 3 bone, but 35% for type 4 bone, according to bone quality as defined by Lekholm and Zarb.\(^\text{17}\) Truhlar et al\(^\text{18}\) concluded that the Q1 (dense cortical bone with minimal trabecular bone) bone experienced a failure rate greater than the Q2 (dense cortical bone with dense trabecular bone) and Q3 (thin cortical bone with dense trabecular bone) bones. Factors affecting the success of dental and microscrew implants might be multifactorial. However, these researchers suggested the importance of bone density for the success of dental implants. The success of microscrew implants can also be affected by bone quality, just as the success of dental implants is influenced by bone quality.

CT images in DICOM format contain data of bone density so that the software program V-Works can measure it. Maki et al\(^\text{19}\) showed a high correlation between the average CT number and the level of hydroxyapatite concentration in an in-vitro study. Norton and Gamble\(^\text{20}\) and Shahlaie et al\(^\text{21}\) examined implant sites with quantitative CT in Hounsfield units and compared them with subjective quality scores defined by Lekholm and Zarb.\(^\text{17}\) They concluded that quantitative CT was a valuable supplement to subjective bone density in the region of implant placement. They hypothesized that CT scanning is a viable and accurate method to measure bone density. Therefore, we used CT scans to measure bone density. Misch\(^\text{16}\) classified bones into 5 categories according to density: D1 bone had density \( >1250 \) HU; D2, 850-1250 HU; D3, 350-850 HU; D4, 150-350; and D5, \( <150 \) HU. Misch\(^\text{16}\) stated that the bone density measurements using CT provided more accurate results than radiographic...
assessment. A subjective bone density assessment had reported a wide range of density values.\(^{20,21}\) Therefore, bone density with this measurement can provide more valuable information than other methods.

Previous investigations dealing with the success of screw implants showed high failure rates in the posterior mandible.\(^{22-24}\) Cheng et al\(^{23}\) speculated that movable soft oral mucosa was the cause. However, Park\(^{22}\) thought that failures might be caused by movable oral mucosa, excessive heat generated during placement because of thick and dense cortical bone, or irritation from food. The thick cortical bone in the posterior mandible\(^{25-27}\) and the high bone density (D1 bone) we observed in this study might show that bone damage is possible from overheating during drilling. Placement of implants in D1 bone was less successful than D2 and D3 bones.\(^{18}\) Heat generated at 47°C is known to cause bone necrosis and can adversely affect the success of dental implants.\(^{28}\) Bone necrosis becomes extensive with increases in temperature and exposure time to heat. Tehemar\(^{29}\) stated that heat generation increases during drilling in dense bone. Therefore, when placing the microscrew implants into the retromolar and posterior areas in the mandible, clinicians must be careful not to generate heat. Heat generation can be prevented by irrigating abundantly with saline solution, not applying too much pressure on the bone, and not using a worn drill.\(^{30}\) When considering the assumption that less heat is produced with a large-diameter drill than a small-diameter drill,\(^{29}\) the placement of microscrew implants requires more caution than dental implants to minimize the amount of heat generated. The high rate of failure in
the posterior mandible can be explained by various factors, which should be elucidated in further studies.

Cortical bone is known to increase in thickness from the anterior mandible to the posterior mandible.\textsuperscript{26,27} In our study, bone density showed the same increase from the anterior to the posterior. In the maxilla, the highest bone density was observed in the canine and premolar areas. This result combined with enough space between roots\textsuperscript{26} might support the selection of the bone between the maxillary second premolar and the first molar as the site for microscrew implants to retract maxillary anterior teeth.\textsuperscript{6,7,9}

Cancellous bone did not show much difference between the maxilla and the mandible, but the cortical bone in the maxilla is much thinner\textsuperscript{26,27} and less dense than in the mandible. In the comparatively weak cortical bone area, the stress is known to be distributed to the cancellous bone and the cortical bone, whereas the stress is centered on the cortical bone where it is thick and dense. When considering this with Hedia’s study\textsuperscript{31} showing that stress can be concentrated at the cortical bone with weak or no cancellous bone, the cancellous bone in the maxilla might have a greater influence for success than that of the mandible. For these reasons, when selecting screw implants, a clinician should choose longer screw implants in the maxilla. But in the mandible, the most support for screw implants originates from the cortical bone because it is thick and dense. Therefore, longer screw implants in the mandible might not enhance stability as in the maxilla, but the diameter might affect stability.

The area of the midpalatine suture is known to have sufficient bone of good quality and was considered a good site for dental implants\textsuperscript{32} and miniscrew implants.\textsuperscript{8} However, the paramedian area of the midpalatine area is recommended as a site for orthodontic dental implants\textsuperscript{33} because there might be connective tissue at the midpalatine suture even after the completion of growth.\textsuperscript{34} Bone density of the paramedian area of the palate at the canine was less dense than cortical alveolar bone and cortical basal bone. The paramedian bone at the first molar showed similar density as the buccal alveolar cortical bone. Therefore, in considering the ease of placement and accessibility, the paramedian bone might not be superior to the buccal alveolar bone, as some believe.

In our study, bone density at the maxillary tuberosity was approximately 450 HU and comparatively weak. Therefore, when placing microscrew implants in the maxillary tuberosity, longer implants were recommended. In a previous report, a long microscrew implant provided anchorage for molar uprighting successfully in the maxillary tuberosity.\textsuperscript{35}

For lingual orthodontics, a good site for the placement of microscrew implants is the palatal alveolar bone between the first and second molars.\textsuperscript{36} This site has enough space between roots because of the single palatal root of the first and second molars.\textsuperscript{26,27} Density of the palatal alveolar cortical bone is similar to that of the buccal alveolar cortical bone. Additionally, the palatal mucosa is firm, thick, and resistant to inflammation. However, the thickness of the palatal mucosa varies from patient to patient, and from site to site,\textsuperscript{37} and it sometimes reaches 4 to 5 mm. Therefore, long microscrew implants should be used to compensate for the thick palatal mucosa.\textsuperscript{36} A thick, firm palatal mucosa might have a positive influence on the success of microscrew implants. A previous investigation had a 100% success rate for microscrew implants in the palatal mucosa.\textsuperscript{22,24}

The 2 most frequently used ways of placing screws into the bone are predrilling and the drill-free or self-drilling method.\textsuperscript{38} Drill-free screws have more bone contact than predrilling screws.\textsuperscript{39} However, in thick, dense cortical bone, drill-free screws can cause fracture of the screw implants and more bone damage. It has also been suggested that screws should be placed with a predrilling method in the thick and dense cortical bone area.\textsuperscript{40} This information, with the results of our study, indicates that drill-free screws might be a better system in the maxilla and the anterior region of the mandible, which comparatively has less dense bone. The dense and thick bone in the retromolar and molar...
areas of the mandible could require a predrilling method when placing screw implants.

The rate of tooth movement seems to depend on the density of the bone. Animal experiments inducing decreased bone density and altered bone metabolism after nutritional hyperparathyroidism and acute and chronic corticosteroid treatment showed rapid tooth movement. The rate of tooth movement in dense compact bone was slower than in weak spongy bone. Our data indicate that greater anchorage loss can be expected in the maxillary posterior teeth that have less dense cortical bone and similar density of cancellous bone than the mandibular posterior teeth.

In this study, all patients were adults. Further study evaluating bone density in various age groups including young adolescents might provide more information about the placement of microscrew implants for patients of all ages.

CONCLUSIONS

Descriptive bone density measurements were illustrated. Cortical density of the maxillary alveolar bone was between 810 and 940 HU, except for the tuberosity, which was approximately 443 HU in the buccal and 615 HU in the palatal alveolar bone. Cortical density of the mandible was between 810 and 1580 HU at the alveolar bone and between 1320 and 1560 HU at the basal bone. Cortical bone of the mandible was denser than that of the maxilla, whereas cancellous bone had similar densities between the mandible and the maxilla with some exceptions. Basal bone generally showed higher density that alveolar bone. These data could provide valuable information when selecting sites and choosing placement methods for miniscrew and microscrew implants.

REFERENCES

29. Tehemar SH. Factors affecting heat generation during implant site preparation: a review of biologic observations and
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