EVALUATION OF BONE HEIGHT AND BONE DENSITY BY COMPUTED TOMOGRAPHY AND PANORAMIC RADIOGRAPHY FOR IMPLANT RECIPIENT SITES

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The objective was to compare the bone height and bone density measurements of implant recipient sites by panoramic radiography and computed tomography. Thirty-seven sites of 21 patients were evaluated using both panoramic radiography and computed tomography. The bone height was measured as the vertical distance from the alveolar crest to the closest anatomical landmark. Density was compared by means of densitometric measurements. Data was evaluated using paired t-test and Pearson's correlation coefficient analysis. Although bone heights measured with the two imaging modalities differed significantly \( p < 0.05 \), there was a significant correlation between bone density measurements \( r = 0.93, p = 0.0 \). Measurements of bone height as well as bone density was found to be comparable using either radiographic method.

INTRODUCTION

The goal of presurgical treatment planning in dental implantology is to enable the placement of implants of optimum number and size in the most favorable position in order to provide adequate masticatory, phonetic, and esthetic function. Therefore, the ability to determine the quality and quantity of available bone in the potential implant site is of paramount importan. Regardless of the type of endosseous implant system, preoperative assessment requires various radiographic examinations, including basic plain radiography as well as advanced methods such as computed tomography (CT).

CT has been widely advocated for implant site assessment and is regarded as the most useful method because of its capacity to evaluate trabecular and cortical bone separately. CT may improve pretreatment diagnosis and treatment planning for implants, allowing clinicians to place the longest implant with confidence. Moreover, the fact that CT identifies various anatomical structures three-dimensionally is of great value to the diagnostician.
FIGURE 1. Axial CT scan showing the circular ROI set in the trabecular bone of the mandible.

be inserted safely, panoramic radiographs have also proved to be accurate. Panoramic radiographs are most desirable because it is an inexpensive and widely used technique, whereas the availability of CT to dental practitioners may be limited, particularly in developing countries.

The purpose of this study was to compare the bone height and bone density measurements of implant sites by panoramic radiography and CT.

MATERIALS AND METHODS

Twenty-one patients who were candidates for endosseous implant therapy and who did not have any systemic illnesses were included in this study. Patients were selected from those who sought treatment at the clinic of the Department of Oral Diagnosis and Radiology, School of Dentistry, Ege University, Izmir, Turkey. They had been referred for the insertion of one or more cylindrical implants in the mandible or maxilla. Prior to any radiological examination, a transparent polymethyl methacrylate (Dentaurum Orthocryl, Germany) 2-mm thick template was prepared on the preliminary study cast of the patient. Drill guide holes 5 mm in diameter were created on the templates corresponding to the location of the intended implant sites. Steel or composite (Isopast, Vivadent, Liechtenstein, Germany) spheres were placed in these holes with cold cure acrylic resin. All panoramic radiographs and CT scans were made with the template positioned supracrestally in the mouth. During CT scanning, steel spheres were replaced with the composite ones in order to avoid scattering. Thirty-seven sites in all patients were imaged with both panoramic radiography and CT.

Panoramic radiography

Panoramic radiographs were taken with an orthopantomography (IMA-GO, Archograph Zeus Rf, Italy) machine with total filtration equivalent to 2.5 mm of the aluminum thickness. An aluminum step-wedge ranging in thickness from 1 to 8 mm was attached horizontally at the inferior right corner of the panoramic cassette corresponding to a point below the lower border of the mandible and was free of any overlying shadows. Satisfactory density and contrast of the film was obtained by using a machine setting between 68 and 80 kV and 165 mAs. Kodak Lanex medium screen and Trimax 3M films were used. The radiographs were processed with an automatic processor (Protec, Germany) using Kodak solution (Kodak RP X-Omat Lo, France) mixed fresh according to the manufacturer's instructions and developed at 33°C for 2 minutes.

Computed tomography

CT examinations were performed with a GE Hilight Advantage 18200 (Wisc) machine facilitated with a noninteractive software allowed to perform multiple electronic measurements on reformatted sagittal and coronal images. 512 × 512 matrix and bone detail algorithms were used. The exposures were made at 120 kV and 140 mA with an exposure time of 3 seconds. Scanning was accomplished with a fixed slice spacing of 1 mm and a slice thickness of 1.5 mm. For scans of the maxilla, the scan plane was parallel to the hard palate. The first slice was placed at the alveolar crest, and the final slice was just above the hard palate. For the axial scans of the mandible, the first slice was at the lower border of the mandible, the last slice at the alveolar crest, and the scan plane was parallel to the inferior border of the mandible. Reformatted sagittal and coronal images were obtained using the CT software.

MEASUREMENTS

Bone height

Height of bone on panoramic radiographs was measured as the vertical distance along an axis parallel to the midsagittal plane from the alveolar crest to the closest anatomical landmark. Bone height measurements were made under standard conditions of illumination by one examiner (G.A.) to the nearest 0.05 mm using a caliper (VIS, Poland) and corrected for distortion by reference to the metal spheres on the template.

To test the precision, measurements were repeated 10 times on different
EVALUATION OF BONE BY CT AND PANORAMIC RADIOGRAPHY

FIGURE 2. Bone height values measured by panoramic radiography and CT.

FIGURE 3. Correlation between bone density values obtained by panoramic radiography and CT.

days with no reference to the original data. The measurements were compared with the analysis of variance and no difference was found between replicate readings.

Bone height on CT images was measured electronically on both coronal and sagittal reformatted images in which the composite spheres were depicted. The measurements were corrected for distortion by reference to the CT scale.

Bone density

An optical transmission densitometer (Macbeth TD-932, Newburg, NY) was used to determine the density of bone on panoramic radiographs. Initially, the optical densities of each step of the step-wedge was measured using the 2-mm circular aperture of the densitometer. For each step of the step-wedge, an average of five densitometric measurements was determined on one horizontal line in the middle of the penterometer image, a mean was calculated, and the result was expressed as optical density units (ODU). In order to determine the density of available bone of the selected site, five consecutive measurements were made on the panoramic radiographs from the alveolar crest to the closest anatomical location along an axis parallel to the midsagittal plane. The mean value of all measurements was calculated to obtain the overall density of available bone at the selected implant site. For correction of the variations of exposure and processing, the mean value obtained from the step-wedge was divided by the mean value of bone measured on the radiograph, and the end result was expressed as ODU.

Density of bone on CT images was assessed only on axial scans. Images were displayed with a window width of 3500 HU and window level of 500 HU. Data analysis regarding density measurements were completed with region of interest (ROI) analysis software. Circular ROIs of 5–9 mm in diameter were set on the image of the bone from the first slice beginning at the alveolar crest to the last slice and the CT number measured (Fig 1). The same circular ROI was used throughout the study, and the localization of the ROI was determined as accurately as possible by relating it to the composite spheres used on the template. Caution was taken to measure the CT number of cortical bone for the purpose of measuring the overall CT number of the available bone at that particular selected site in an attempt to correlate with the measurements made on panoramic radiographs. Results were obtained by calculating the mean CT number of all measured slices.

Student's paired t-test was used to compare the differences between mean bone height measurements made on the panoramic radiographs and CT images. The correlation between bone density measurements were calculated.
as the Pearson’s correlation coefficient ($p < 0.05$ was accepted as significant).

**RESULTS**

Figure 2 illustrates the corrected values of bone height measurements performed on panoramic radiographs and reformatted CT images. In most cases, mean bone height measurements derived from panoramic radiographs were higher than those obtained with CT images. The difference between mean bone heights obtained by two distinct radiographic methods was statistically significant ($p < 0.05$; Table 1).

The correlation of bone density measurements determined on panoramic radiographs and CT numbers is shown in Fig 3. The values of bone density on panoramic radiographs ranged between 0.98 and 4.8 ODU, whereas CT values were between 123.4 and 664.7 HU. Pearson’s correlation coefficient analysis revealed significant correlation between the bone density values of panoramic radiography and CT ($r = 0.93$, $p = 0.00$).

**DISCUSSION**

This study attempted to test the usefulness of panoramic radiography in assessing bone height and density for implant recipient sites. Panoramic radiography has previously been utilized for evaluation of bone tissue. With the aid of sensitive screen-film combinations and rare earth-filtering techniques, panoramic radiography has been found to be reliable in the establishment of bone density. In the present study, densitometric evaluation of bone by panoramic radiographs is highly correlated with the bone density measured by CT. Although panoramic radiography measures the sum of cortical and trabecular bone whereas CT measures them separately, the high correlation of the results is attributed to the fact that measurements of cortical and trabecular bone were both included during the determination of bone density using CT.

As long as a standardized examination technique is provided to minimize artifact formation, CT is proven to supply uniform images and is accepted to be reliable for performing analytic measurements. Whenever reproducible films are needed, particularly for densitometric analysis, similar ob- ligations regarding standardization of exposition and patient position are required for panoramic radiography. In order to quantify the radiographic analysis on panoramic radiographs, use of an aluminum step-wedge as a gauge is recommended. Hence in the present study proximity of the density measurements using two different imaging techniques may be related to the use of step-wedge and acrylic stents with spheres, as well as to the well-standardized technique that was performed during both imaging applications. Therefore, it is possible to suggest that as long as the technique is meticulously performed, panoramic radiography may possibly serve as an adjunct for quantitative densitometric evaluations.

The present study demonstrates that bone height values measured with two radiographic methods are significantly different. The data indicated that panoramic radiography significantly underestimated the bone height compared with CT, which is similar to the findings of Reddy et al. Although the use of panoramic radiography for linear measurements is limited because of distortion of the radiographic image, many quantitative measurements such as tooth length, alveolar ridge height, and temporomandibular joint dimension measurements have been performed thoroughly. There are many studies providing the reproducibility of vertical and angular measurements, provided that the technical errors are eliminated by attention to detail. In spite of the use of acrylic stents with metal markers and meticulous precautions taken during exposure, the significant variation in the bone height measurements in this study may be because the distance selected on the reformatted images can be varied by the operator. Another reason for the significant difference in bone height measurements may also be related to the errors in tracing caused by the blurring of the reformatted images. Nevertheless, because differences of less than 1 mm are of insufficient clinical significance for implant treatment, measurements of bone height determined with two distinct radiographic methods may be described as comparable.

The criteria for selecting a particular imaging system includes whether the benefit achieved from the diagnostic information outweighs the risk to the patient. In this respect, the advantages of CT are numerous for maximal use of available bone. Preoperative CT evaluation, particularly with the patient wearing a stent containing radiopaque markers in the proposed tooth location, can help clinicians avoid many pitfalls. However, besides its numerous advantages, the CT system has many technical limitations including artifacts, as well as the major disadvantage of delivering the highest ionizing radiation dose to the patient. Furthermore, the cost of a CT scan is much higher than any other imaging system, and scanners are located mainly in large medical centers. When the influence of all these factors (cost, dose, and accessibility) are considered, conventional methods that are of equal utility may be preferred in order to minimize risks and uncertainty in the evaluation of an implant recipient site.

As many advances in imaging tech-

### Table 1

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Mean bone height (mm) ± SD</th>
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<tbody>
<tr>
<td>Computed tomography</td>
<td>18.86 ± 0.78</td>
</tr>
<tr>
<td>Panoramic radiography</td>
<td>19.31 ± 0.67</td>
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nologies and radiographic systems, along with interactive software for CT, begin to penetrate dental offices, dentists will be able to offer a better service to their patients. However, when weighing risk and cost against the benefit, excessive utilization of newer techniques should be avoided, especially when conventional methods are similarly efficient and adequate.

REFERENCES


30. Rothman SLG, Chaftez N, Rhodes ML, Schwartz MS. CT in the preoperative assessment of the mandible and
