Cross-Sectional Imaging of the Jaws for Dental Implant Treatment: Accuracy of Linear Tomography Using a Panoramic Machine in Comparison with Reformatted Computed Tomography

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Purpose: *Although various panoramic X-ray machines with linear tomographic functions are now frequently applied to diagnosis related to dental implant treatment, the angles of the tomographic objective planes are automatically determined and cannot be adjusted for individual patients. To resolve this problem, a direct laser positioning (DLP) system was developed. In this investigation, the measurement accuracy of images obtained by the DLP system in comparison with those from reformatted computed tomography (CT) was assessed.* ***Materials and Methods:*** *A rectangular parallel piped phantom was scanned with the system and the height and width were measured on linear tomograms. Ten sites in 3 dried mandibles and 21 mandibular molar sites in 15 patients were examined both with the DLP system and the reformatted CT to compare the measured values on both images.* ***Results:*** *The phantom experiment showed that the difference between the actual and measured heights and widths of the phantom were within 1 mm.* ***Discussion:*** *The difference between the values obtained by the DLP system and CT was slightly larger in the patients than those in the dried mandibles.* ***Conclusion:*** *The DLP measurement accuracy was deemed sufficient for clinical use.* (INT J ORAL MAXILLOFAC IMPLANTS 2002;17:107–112)

Key words: *computed tomography, dental implant, panoramic machine*

Cross-sectional jaw images in the buccolingual direction may provide additional information for improved implant placement before surgery.[1] These images can usually be obtained by computed tomography (CT),[1–4] or conventional X-ray tomography.[5–7] These modalities, however, are usually available only at medical hospitals, where access for dental use may not be a priority.[8] Under these circumstances, various panoramic X-ray machines have been developed for use in dental offices and clinics and have been frequently used to obtain cross-sectional jaw images using the tomographic function.[9–11] The cross-sectional angles in these tomographies are fundamentally important for the accurate visualization of the jaw structures, especially for the mandible, because the images differ considerably in magnification and distortion according to the angles.[11] However, the angles of the objective planes are automatically determined in most machines and cannot be adjusted for individual patients.

To resolve this problem, the direct laser positioning system (DLP system, Asahi Roentgen, Kyoto, Japan) was developed using a panoramic X-ray machine with a linear tomographic function. The tomographic objective angles of this system can be manually set in accordance with the optimal tomographic plane for the individual patient.[12] The accuracy of the linear and rotational movements of the objective planes has already been confirmed to be sufficient for clinical use.[13] In this report, the measurement accuracy of the images obtained by the DLP system in comparison with those from reformatted CT was assessed.

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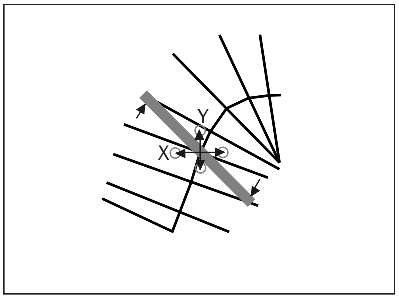

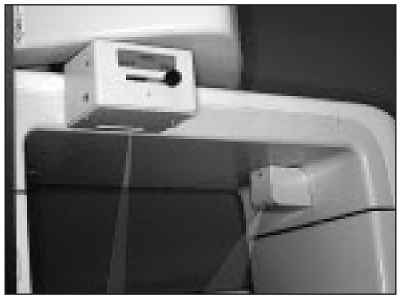

Fig 1a *(Left)* The position and angle of the tomographic objective plane was moved along the X- and Y-axes and rotated through use of the computer software for the DLP system.

Fig 1b *(Right)* The laser beams cross each other at right angles. They indicate the location and angle of the tomographic objective plane.

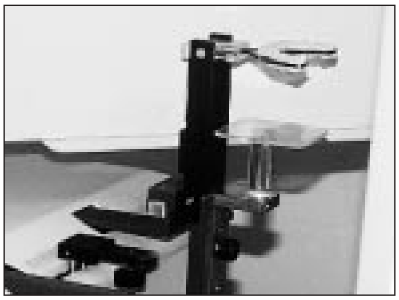

Fig 2a Accessory tools for the DLP system give a high reproducibility of accurate positioning during the examination.

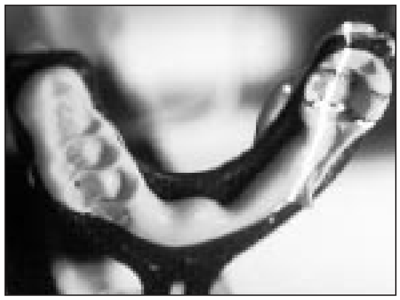

Fig 2b Adjusting the tomographic objective plane. The laser beams directly indicate the tomographic objective plane on the occlusal surface impression.

Fig 2c Setting the patient using accessory tools. The patient occludes on the plate, leaving an impression, and tomography is performed.

Two experiments and 1 clinical study were conducted. First, the net measurement accuracy was investigated by scanning a bone mineral chart. Second, 3 dried mandibles were scanned both with the DLP system and CT to assess any measurement errors, including blurs based on specific mandibular shapes. Finally, images obtained from patients using the DLP system were compared with those from reformatted CT images to establish clinical use.

MATERIALS AND METHODS

Direct Laser Positioning (DLP) System

A panoramic machine with linear tomographic function, AZ3000 (Asahi Roentgen, Kyoto, Japan) was used to develop the DLP system. This system consists of 3 parts: computer software, laser beam units, and accessory tools. Using computer software, movements of the machine can be controlled to obtain accurate locations and angles of the tomographic objective plane. The objective planes can be adjusted along the X- and Y-axes and can be rotated around the center of the plane (Fig 1a). The laser beams, which cross each other at right angles, indicate the location and angle of the tomographic objective planes (Fig 1b).

The accessory tools are fabricated to give high reproducibility of accurate positioning during the examination (Fig 2a). The occlusal surfaces of the patients are impressed using bite plates and silicone rubber impression material. Each bite plane with an impression is then set on the base of the accessory tool. The bite plate can be tilted superior-inferiorly within a range of ± 15 degreees since the tomographic objective planes must be adjusted parallel to the designed angulations of the implant. This function is especially effective for the posterior portion of the mandible. The laser beams directly indicate the tomographic objective planes on the occlusal surface impression. The location and angle of the objective planes are then correctly adjusted to the position of the designed placement (Fig 2b).

Movements along the X- and Y-axes can be adjusted within a range of ± 20 mm at intervals of 1 mm and the rotation is within the range of ± 30 degrees at intervals of 1 degree. The patient occludes on the plate, leaving an impression, and tomography is performed (Fig 2c).

CT Scans

Axial CT images were obtained using a CT unit, Somatom ART (Siemens, Erlangen, Germany). The CT unit was set at 110 kV, 70 mA, 3.0 seconds and 2-mm-thick slices with 2-mm intervals. The thinnest slice width in this CT unit was 2 mm. Cross-sectional images were reconstructed using the Dental CT[R] software package (Sirex, Dental Equipment, Walsall, UK) and were printed on films. The observational conditions for the images were set at 250 HU for the window level and 3,000 HU for the window width.

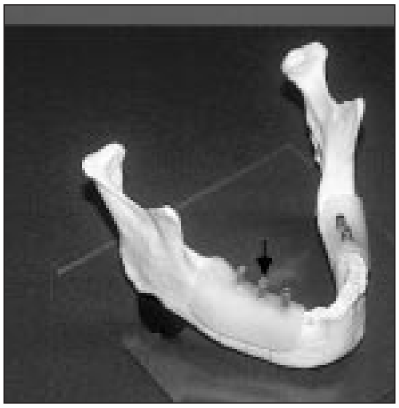

Fig 3 The diagnostic template contained aluminum tubes which were 4 mm in diameter.

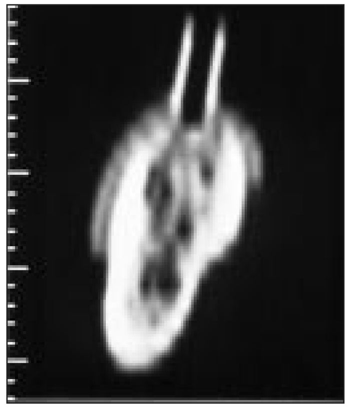

Fig 4a Dental CT^R image of a dried mandible.

Fig 4b Tomogram of a dried mandible. The tomographic objective plane is adjusted to the cross-sectional plane in Dental CT^R images.

First Experiment with a Rectangular Parallel-Piped Phantom

A bone mineral density chart (hydroxyapatite content: 400 mg/cm^3, Kyoto Kagaku, Kyoto, Japan) was used as a rectangular parallel-piped phantom. The phantom was placed in water and tomography was performed using the DLP system at the exposure conditions of 60 kV and 5 mA with a 40 degree tomographic projection angle. The same position, which was approximately at the center of the phantom, was exposed 5 times. Linear tomographic images were processed and printed using the CR system (HQ9000, CR-LPD, Fuji Medical, Tokyo, Japan) and the linear gradation process. The height and width of the phantom on the obtained images was measured with a digital caliper (CD-S15, Mitutoyo, Tokyo, Japan). One of the authors (M.N.) measured all images in this study. The measured value was divided by the tomographic magnification rate (1.34) and averaged. In addition, the phantom was directly measured 5 times for the height and width corresponding to the images, and the average value was defined as the real value. The net dimensional accuracy was evaluated by comparing the measured value with the real value.

Second Experiment with 3 Dried Mandibles

Three dried mandibles with diagnostic templates were scanned both with the DLP system and CT scans. The diagnostic templates, which were originally designed for the CT examinations, contained aluminum tubes indicating the simulated position of the implants (Fig 3).[1] The length of the aluminum tubes was 10 mm and the diameter was 4 mm. The templates were used to correctly identify the angle of the cross-sectional images in the reformatted CT as well as in the tomographic objective planes. A total of 10 selected sites where bone healing after extraction was detectable in the mandibular molar region were examined. Initially, axial CT images were obtained and then Dental CT^R images were reconstructed (Fig 4a). Each angle between the cross-sectional plane (line) and the central line, which was the midsagittal plane running through the contact point of the central incisiors, was measured on the axial CT image setting Dental CT^R program. The angles of the tomographic objective planes were adjusted to these angles using the laser beam on the dried mandibles with the templates. Tomography was performed at an exposure of 65 kV and 6 mA with a 0.5-mm copper filter and 40 degree tomographic projection angle (Fig 4b).

The bone height and width were measured 5 times both on the CT and tomographic images. The definition of height and width was as follows: Height A was defined as the length from the alveolar crest to the inferior border of the mandible along the designed implant direction, which was indicated by the aluminum tubes on the images (Fig 5). Height B was defined as the length from the crest to the superior border of the mandibular canal. Widths A and B were defined as the lengths between the outer surfaces of the cortical plates at a level 5 mm below the crest and the superior border of the mandibular canal, respectively. Taking the magnification factor into account, width A was actually measured at a level 6.7 mm below the crest on the tomograms. The dimensional accuracy of tomography was determined as the difference of the heights and widths between the measured values from the CT and tomography.

A Clinical Study in Pretreatment Imaging

Twenty-one predetermined implant sites in the mandibular molar region were evaluated in 15 patients (6 males and 9 females) with a mean age of 53.2 years. All patients were sufficiently informed of

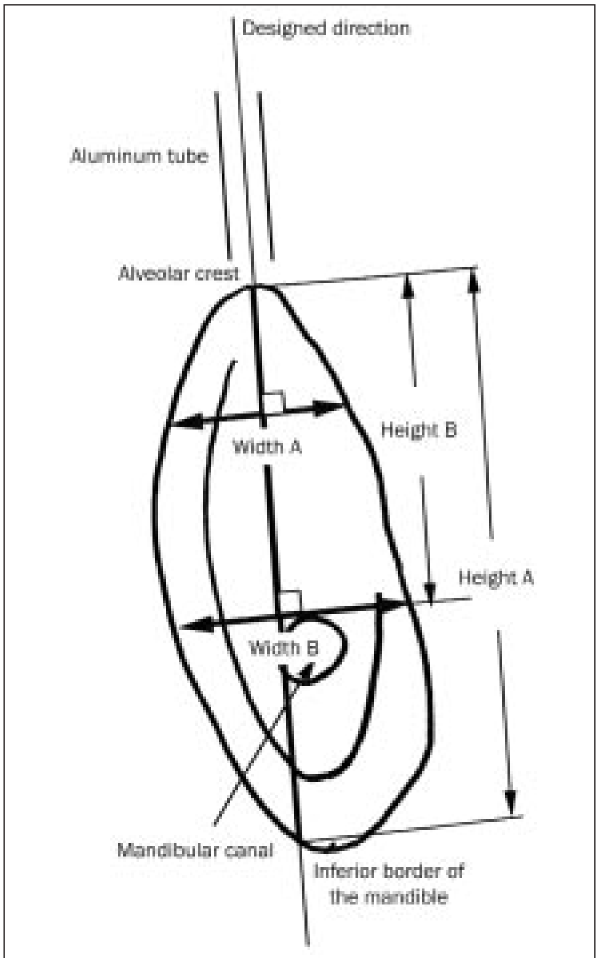

Fig 5 Measurement parameters. Height A: length from the alveolar crest to the inferior border of the mandible. Height B: length from the alveolar crest to the superior border of the mandiblar canal. Width A: distance between the outer surface of the cortical plate at the level 5 mm below the crest. Width B: distance between the outer surface of the cortical plate at the level of the mandibular canal.

the aim of this study and gave their consent to participate. The Dental CT[R] images were obtained in the same way as for the dried mandible. Although the angle of the objective planes in the DLP system (which was directly indicated on the impression by the laser beam) could be set equal to the cross-sectional angle on the CT image, the position of the objective plane in the DLP system could not completely be identified with that in the CT image. Therefore, the positions of cross-sectional images obtained by the 2 modalities were set as equal as possible with reference to the shape of the mandible on the impression and the axial CT image. The tomographic projection angle was set at 40 degrees and the exposure conditions varied for individual patients ranging from 64 to 68 kV at 6 mA. The morphology measurements and dimensional accuracy were investigated in the same way as for the dried mandibles.

Statistical Analysis

The difference between the measured values from CT and tomography were evaluated using the Student *t* test. The testing was considered significant if $P < .05$.

RESULTS

The means and standard deviations of the height and width of the phantom on the tomographic images were 30.5 ± 0.5 mm and 10.2 ± 0.2 mm, respectively, while those of the real values were 30.0 ± 0.1 mm and 10.0 ± 0.1 mm. The differences were less than 1 mm for both the height and width.

For the dried mandibles, the mean of the difference in the heights A and B was 0.8 mm and 0.7 mm, respectively (Table 1). The mean of the difference was 0.4 mm in both widths A and B. Only 2 of 10 selected sites showed differences of over 1 mm in both the A and B heights. There was only 1 site with a difference of more than 1 mm in both widths A and B. The maximum difference was 1.9 and 1.4 mm in the height and width, respectively.

For the clinical study in pretreatment imaging, the mean of the differences was 1.5 and 0.8 mm in the heights A and B, while the mean of the differences in the widths A and B was 0.7 and 0.9 mm, respectively (Table 2). Differences of less than 1 mm were observed in 43% (7 sites) and 71% (15 sites) of the 21 examined sites for the heights A and B, respectively. For the widths A and B, the differences were less than 1 mm in 76% (16 sites) and 71% (15 sites) of the 21 examined sites, respectively. The maximum differences were 2.6 and 1.5 mm in the heights A and B, respectively. The maximum differences were 1.8 and 2.7 mm in the widths A and B, respectively.

DISCUSSION

At present, conventional cross-sectional tomography is recommended by the American Academy of Oral and Maxillofacial Radiology for most patients receiving implants.[13] However, the measurement accuracy of conventional tomography is affected by the moving tube system, the tomographic projection angle, or the angle of the tomographic objective plane. Consequently, the measurement accuracy of images obtained by the DLP system with a linear tomographic function was assessed. The measurement accuracy of the jaw images obtained by CT and conventional tomography have been investigated using dried skulls and cadavers.[10,14–19] Reported errors associated with measurements on CT scans ranged from 0.5 to 2 mm.[8] However, the measurement error was generally required to

Table 1 Measured Values on the Dried Mandible Images Obtained by the DLP System and by Reformatted CT (Mean ± SD)

	DLP system	CT	Differences
Height A	25.6 ± 2.5	24.9 ± 2.6	0.8 ± 0.5
Height B	13.5 ± 1.3	13.3 ± 1.5	0.7 ± 0.4
Width A	12.3 ± 2.4	12.0 ± 2.4	0.4 ± 0.4
Width B	11.9 ± 1.3	11.6 ± 1.1	0.4 ± 0.3

Heights A and B and Widths A and B are shown in Fig 5.
Units = mm.
SD = standard deviation.

Table 2 Measured Values on the Patient Mandible Images Obtained by the DLP System and by Reformatted CT (Mean ± SD)

	DLP system	CT	Differences
Height A	29.2 ± 4.2	29.2 ± 4.3	1.5 ± 0.6
Height B	17.0 ± 3.7	17.0 ± 3.7	0.8 ± 0.5
Width A	9.6 ± 2.5	9.5 ± 2.2	0.7 ± .06
Width B	12.1 ± 1.4	12.1 ± 1.6	0.9 ± 0.5

Heights A and B and Widths A and B are shown in Fig 5.
Units = mm.
SD = standard deviation.

be less than 1 mm on images for implant treatment.[8] In another study using cadaver mandibles, the difference was less than 1 mm in 94% between the actual length and measured values in CT images, while the difference in conventional tomograms was 39%.[14] The accuracy of tomography is generally considered to be lower than that of CT. However, in the present phantom investigation the differences were less than 1 mm, both in the height and width, in tomographic images.

The measured height and width was 30.5 ± 0.5 mm and 10.2 ± 0.2 mm. The accuracy of reformatted CT was evaluated using the same phantom as in a previous study,[20] and it was reported that the measured values were 30.4 ± 0.3 mm and 10.1 ± 0.1 mm for the height and width, respectively. No significant difference was found between the 2 modalities (P = .5263 for the height and P = .075 for the width). These results indicated that the lower accuracy of tomography in other reports was mainly the result of difficulties in the adjustment of the objective planes, but not to the quality of the image. This hypothesis was also supported by Petrikowski and associates.[19] In their report, the mean differences between the actual and measured values of the mandible were relatively low (0.49 mm for the height and 0.35 mm for the width) and equivalent to the CT results.[15,16]

In the present study, the measurement accuracy of the DLP system was evaluated by comparing it with that of CT, because the accuracy of CT was verified to be adequate for clinical use.[15,16] The mean differences between the DLP and CT images were within 1 mm, with the exception of height A in the patients' mandibles. This relatively larger difference was probably related to the variation in the estimated line of implant angulation. The difference in this angulation strongly influences the point of the inferior border of the mandible. However, height B is more essential to implantation than height A. Therefore, these measurements could be sufficient for clinical use. The differences in the patients were slightly larger than those in the dried mandibles. In the patients, the error may have been enhanced because of difficulties in the identification of the image planes in both modalities. Implant sites showed that the maximum differences in heights and widths were in the third molar regions. The images obtained by the linear tomography in third molar regions included the obstructive shadows from the ramus of the mandible. Generally, it suggested that the tomographic objective planes should be adjusted optimally for the jaws as shown in previous reports.[11,20]

Tomography using a panoramic machine has some major advantages compared to reformatted CT. First, the radiation exposure of the patients is relatively low in tomography.[21–23] The use of tomography is recommended for the evaluation of separate implant sites, especially if the sites are situated in both the maxilla and the mandible. Conversely, CT can be applied to the evaluation of multiple adjacent implant sites.[23] Second, a panoramic machine can be used effectively in a dental clinic, but the availability of CT is usually limited to hospitals, where access for dental use may not be a priority.[8]

The authors have routinely used CT for pretreatment evaluation and also for patients with abnormal findings in the postoperative state to assess peri-implant conditions. It is possible to reduce the total radiation dose with conventional tomography because it permits examination of the region of interest. Furthermore, with the DLP system, the measurement accuracy is improved compared to other tomographic machines and the reformatted CT. With the exception of the large and expensive CommCAT IS-2000 Imaging System (Imaging Sciences, Roebling, NJ),[24] all tomographic X-ray machines do not have the capability for adjusting the tomographic angles to the optimal tomographic plane for individual patients. Using presently-available software for dental implants, reformatted images are reconstructed by continuously piled-up axial CT images which are always perpendicular to the axial images. However, the angles of designed implants vary and frequently differ from the angles perpendicular to the axial CT plane. In such cases, CT should be performed for each implant site to obtain an accurate diagnosis, which significantly increases the radiation dose. The DLP system allows the adjustment of the angle of the objective plane to the angulation of each designed implant site by tilting the occlusal plate with the accessory tool. The DLP system is considered useful, especially for patients with a small number of implant sites.

CONCLUSION

Within the limitations of this investigation, the accuracy of the DLP system was deemed to be high enough for clinical use. Thus, with the DLP system, quality diagnosis may be achieved for dental implant treatment with a reduction in radiation exposure compared to CT.

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