ASSESSMENT OF THREE-DIMENSIONAL X-RAY IMAGES: RECONSTRUCTION FROM CONVENTIONAL TOMOGRAMS, COMPACT COMPUTERIZED TOMOGRAPHY IMAGES, AND MULTISLICE HELICAL COMPUTERIZED TOMOGRAPHY IMAGES

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KEY WORDS

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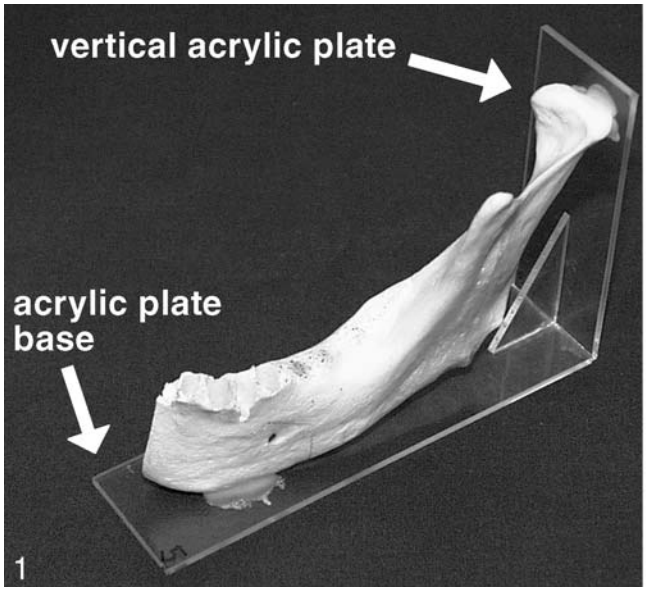
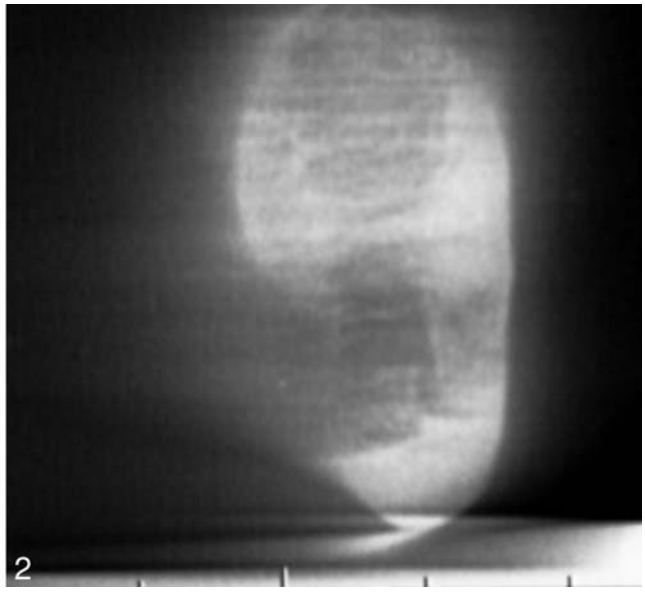
Three-dimensional X-ray images (3D images) were used for imaging diagnosis in the oral and maxillofacial region. These images could be fundamentally reconstructed from various tomograms, though clinical 3D images were mainly reconstructed from computerized tomography (CT) images. In this investigation, 3D images were reconstructed from conventional tomograms with a panoramic unit, compact CT images, and multislice helical CT images, and the usefulness of each system was subjectively assessed for dental implant treatment. Three hemilateral dried human mandibles were used and were examined by linear tomography with a panoramic unit, compact CT, and multislice helical CT, and 3D images were reconstructed by using the rendering software for each system. The 3D images were visually evaluated on a 5-point scale covering the alveolar ridge, buccal and lingual bone surface, mental foramen, and tooth sockets. As a result, 3D images reconstructed from conventional tomograms with the panoramic unit were assessed as fair to unsure, compact CT 3D images were assessed as unsure to good, and multislice helical CT 3D images were assessed as good to excellent. It was concluded that compact CT 3D images and multislice helical CT 3D images were useful in dental implant treatment.

INTRODUCTION

In the oral and maxillofacial region, three-dimensional X-ray images (3D images) have been used in imaging diagnosis of impacted teeth,[1] dental implant treatment,[2,3] fractures,[4,5] and prognathism.[6] In dental implant treatment, the condition of edentulous bone and designed site and angulation are evaluated by using 3D images. Moreover, 3D images were the essential image display technique for an image navigation system and fabrication of a stereolithographic surgical guide, which can be





FIGURES 1 AND 2. FIGURE 1. Dried human mandible mounted on imaging apparatus. FIGURE 2. Cross-sectional tomogram with a panoramic unit with linear tomography.

useful in surgical planning.[7–9] Three-dimensional images can be fundamentally reconstructed from various tomograms, such as conventional tomography, computerized tomography (CT), and compact CT; however, these images were mainly reconstructed from medical CT images in dental implant treatment.[10]

For patients receiving implants, the American Academy of Oral and Maxillofacial Radiology and the European Association for Osseointegration recommend conventional cross-sectional tomography.[11–13] Recently, a compact CT was developed with differences in mandibular measurements similar to those of conventional tomography and CT.[14–16] In addition, the effective dose values were lower in comparison with those of CT or panoramic radiography.[17] Only a few reports have considered 3D images reconstructed from conventional tomograms and compact CT images, and the accuracy of the 3D images has not been compared with real objects or subjects.[1,9,18]

Therefore, in this investigation 3D images were reconstructed from conventional tomograms with a panoramic unit, compact CT images, and multislice helical CT images, and the usefulness of each system was subjectively assessed for dental implant treatment.

MATERIALS AND METHODS

Dried human mandibles

Three edentulous hemilateral dried human mandibles were used in this investigation. Two pieces of acrylic resin plate were fixed at a right angle, and then the mandibles were set on an acrylic plate base. An imaginary occlusal plane was set parallel to the acrylic plate base, and the posterior buccal surface was set parallel to the long axis of the acrylic plate base (Figure 1).

Tomograms with a panoramic unit

Cross-sectional tomograms in the premolar and molar regions were obtained with a panoramic machine with a linear tomographic function (AZ3000 DLP, Asahi Roentgen Ind Co, Kyoto, Japan) using a stainless steel wire set along the long axis of the acrylic plate base as a marker to reconstruct 3D images. Tomography was performed with the acrylic plate base set parallel to the floor base plane of the panoramic machine at exposure conditions of 60 kV and 4 mA with a 0.5-mm copper filter. The tomographic projection angle was set at 60° with nominally 1.0-mm thick slices at 1.0-mm intervals. Linear tomographic images were processed with linear gradation and frequency processes and were printed by a computed radiographic system with an imaging plate (FCR9000HQ, HI-654, CR-LPD, Fuji Medical System Co, Tokyo, Japan). The printed images were converted to digital images with a CCD video camera (KY-F55MD, Olympus, Tokyo, Japan) and a color image analyzer (SP500F, Olympus). The images were saved on magnetic

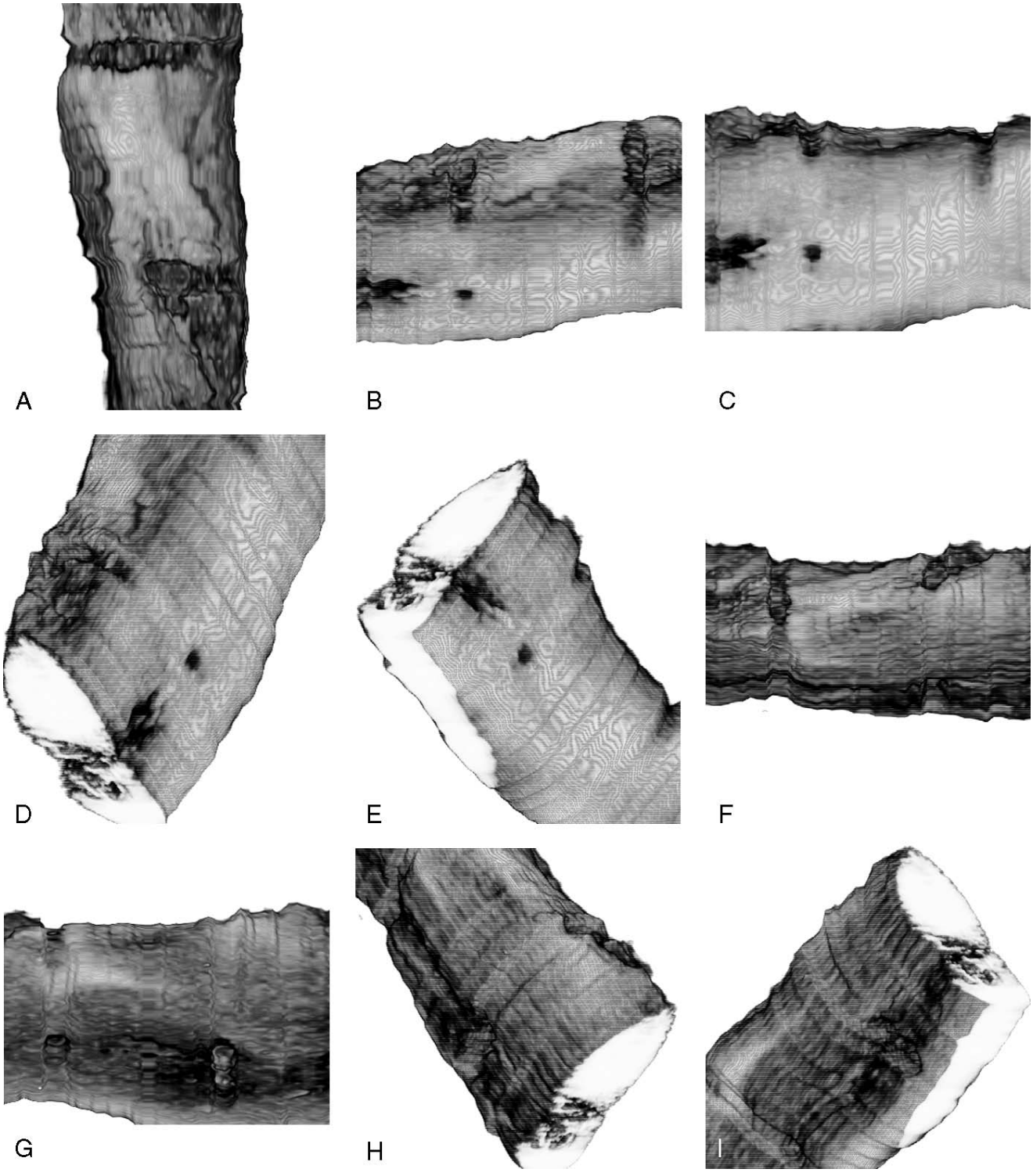
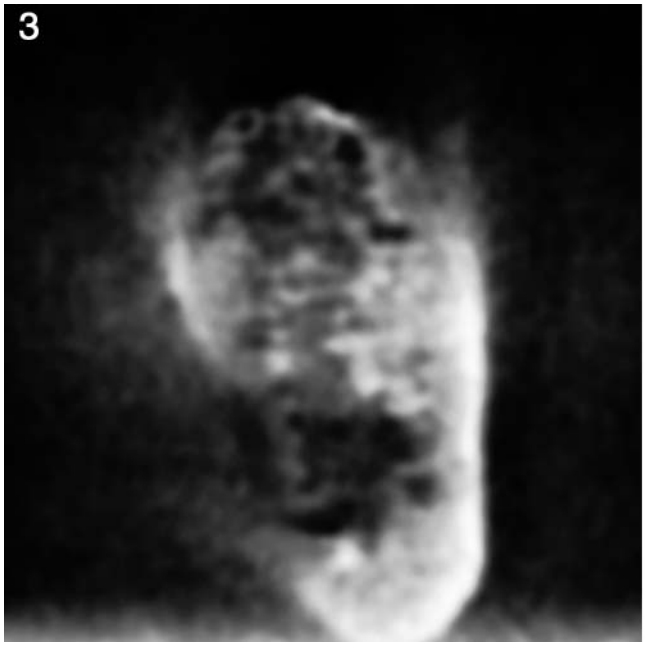
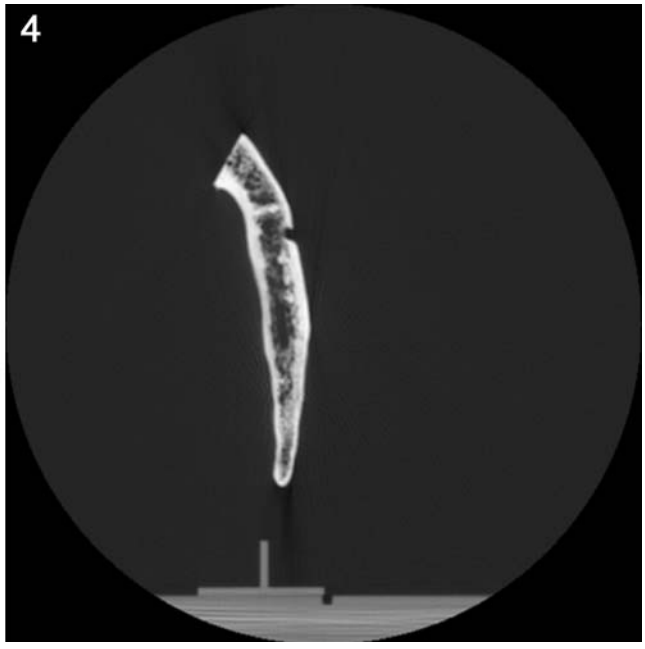


PLATE 1. Three-dimensional images reconstructed from cross-sectional tomograms with the panoramic unit. (A) View from above right. (B) Buccal view from above at 45°. (C) Buccal view. (D) Buccal view from 45° anterior and 45° above. (E) Buccal view from 45° anterior and 45° below. (F) Lingual view from 45° above. (G) Lingual view. (H) Lingual view from 45° anterior and 45° above. (I) Lingual view from 45° anterior and 45° below.





FIGURES 3 and 4. FIGURE 4. Compact computerized tomography image. FIGURE 4. Multislice helical computerized tomography image.

optical (MO) disks as 8-bit TIFF files and 512 × 512 matrix data (1 pixel = 0.1 × 0.1 mm). Cross-sectional tomographic images were processed for density and gradation by image-editing software (Photoshop version 5.5, Adobe Systems, San Jose, Calif) on a personal computer (Macintosh G3 266, Apple Computer Inc, Cupertino, Calif). Then, after the x and y coordinates were standardized, 3D images were produced by 3D reconstruction software (Vox Blast version 2.2, VayTec Inc, Fairfield, Iowa) (Figure 2 and Plate 1).

Compact CT

A series of images in the premolar and molar regions were obtained with a compact CT unit (3DX, Morita Co, Kyoto, Japan). The acrylic plate base was set parallel to the floor base plane. The exposure conditions were 80 kV and 3 mA with a 0.5-mm copper filter. The images were reconstructed as 0.125-mm thick slices at 0.125-mm intervals. The information from all coronal slices was saved on MO disks as 8-bit TIFF files and 240 × 320 matrix data (1 pixel = 0.125 × 0.125 mm). Three-dimensional images were reconstructed from the compact CT images with density, gradation, and unsharpness processing by 3D reconstruction software (Vox Blast version 2.2) on a personal computer (Macintosh G3) (Figure 3 and Plate 2).

Multislice helical CT

A multislice helical CT unit (Hi-Speed NX/i Pro, GE Yokogawa Medical Systems, Tokyo, Japan) was used. The acrylic plate base was set perpendicular to the floor

TABLE

Visual evaluation of three-dimensional (3D) images*

3D Images	Alveolar Crest	Buccal Bone Surface	Lingual Bone Surface	Mental Foramen	Tooth Socket	Total
Cross-sectional tomography	2.7**†	3.0†	2.3†	2.5†	1.3†	2.5**‖
Compact CT	3.6‡	4.1†	2.4§	4.0§	2.8‡	3.4§
Multislice helical CT	4.4	5.0	4.6	4.8	4.3	4.6

*CT indicates computerized tomography.

**P < .05, between cross-sectional tomography and compact CT.

†P < .01, between cross-sectional tomography and multislice helical CT.

‡P < .01, between compact CT and multislice helical CT.

§P < .05, between compact CT and multislice helical CT.

‖P < .01, between cross-sectional tomography and compact CT.

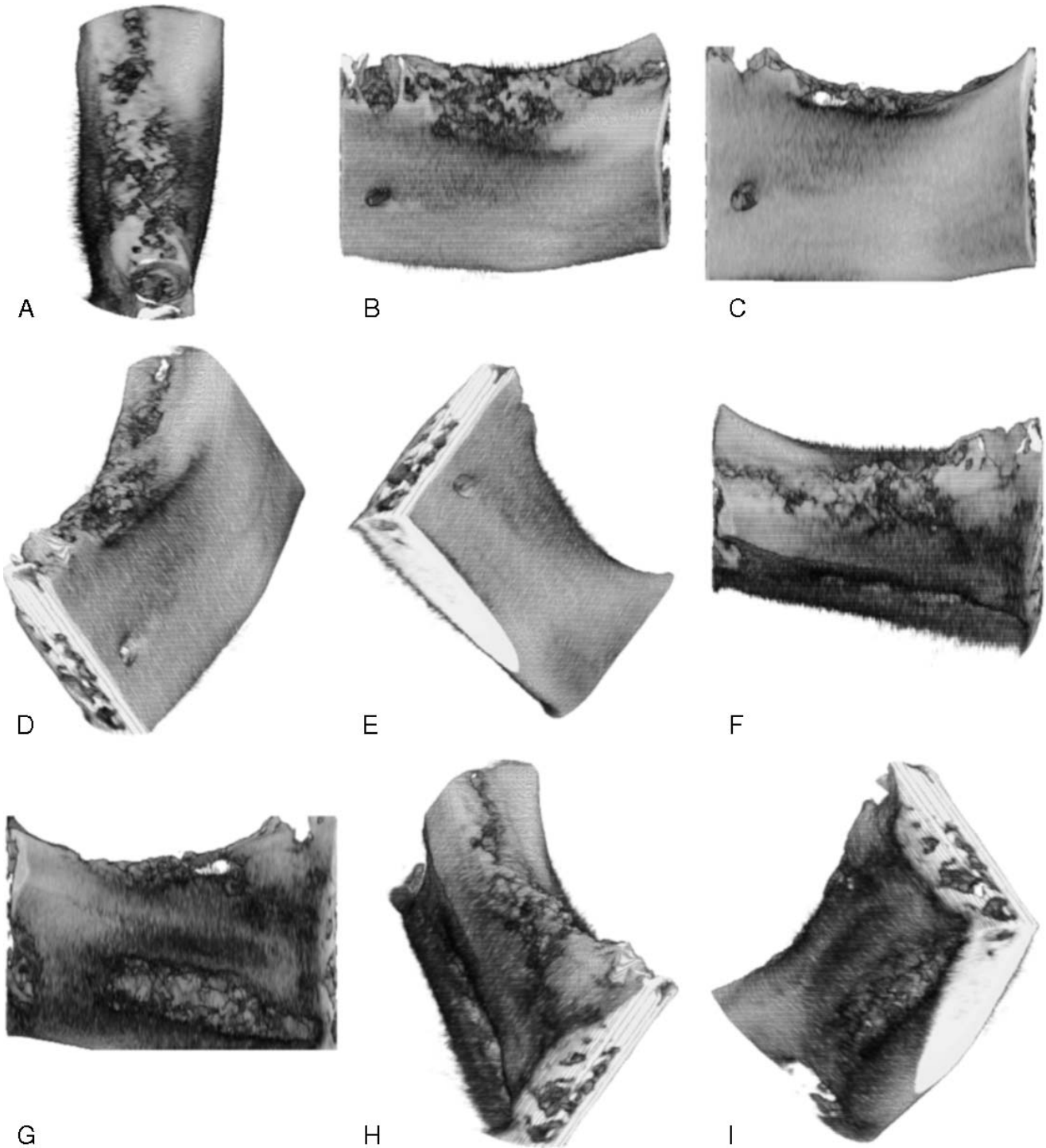


PLATE 2. Three-dimensional images reconstructed from compact computerized tomography images. (A) View from above right. (B) Buccal view from above at 45°. (C) Buccal view. (D) Buccal view from 45° anterior and 45° above. (E) Buccal view from 45° anterior and 45° below. (F) Lingual view from 45° above. (G) Lingual view. (H) Lingual view from 45° anterior and 45° above. (I) Lingual view from 45° anterior and 45° below.

base plane. The axial scan was set at 120 kV, 200 mA, and 0.5-mm thick slices with a 1.5 table pitch by the helical technique. The axial images were obtained from 0.5-mm thick slices at 0.25-mm intervals, and the images of DICOM files were saved on MO disks by medical display software (Vox-base, J-mac system, Sapporo, Japan). Three-dimensional images were produced from the axial CT images by 3D reconstruction software (Vox Blast version 2.2) on a personal computer (Macintosh G3) (Figure 4 and Plate 3).

Visual evaluation

Three-dimensional images reconstructed from tomographic images, compact CT images, and helical CT images were visually compared with real mandibles. In each mandible, nine 3D images were reconstructed as shown in Plates 1, 2, and 3. The observation was performed for 5 anatomical structures: alveolar crest, buccal cortical bone, lingual cortical bone, mental foramen, and tooth sockets. Three oral radiologists independently scored the evaluations on a 5-point scale: 1 = bad, 2 = fair, 3 = unsure, 4 = good, 5 = excellent. Mean values were then calculated.

Statistical analysis

The differences between the obtained values were evaluated by using the Wilcoxon t test. The values were considered significant if $P < .05$.

Results

Visual evaluation of 3D images reconstructed from tomograms with the panoramic unit, compact CT images, and multislice helical CT images are shown in the Table. Overall, 3D images reconstructed from conventional tomograms with the panoramic unit were assessed as fair to unsure, compact CT 3D images were assessed as unsure to good, and multislice helical CT 3D images were assessed as good to excellent.

Discussion

The diagnosis of an anatomical location and continuity is easily achieved with 3D images reconstructed from CT images in comparison with 2-dimensional images.[1] In dental implant treatment, the information obtained from 3D images reveals the form of the alveolar bone, location of the mental foramen, and location and form of the maxillary sinus. In the diagnosis of jaw fractures, bone displacement and the course of the fracture line were revealed to be excellent; however, diagnosis of small bone fragments can be unclear.[4]

In this study, the 5 objects of the observation were considered to be comparatively large structures. However, the evaluations of the 3D images reconstructed from multislice helical CT images could have revealed even more detailed information.

In the 3D images reconstructed from conventional tomograms and compact CT images, the evaluation was fair in lingual cortical bone and unsure to good in buccal cortical bone. Therefore, we considered that these results might be influenced by mandibular forms, because the bone mineral density would not be largely different between lingual and buccal cortical bones. In the 3D images reconstructed from tomograms with the panoramic unit, the evaluation of tooth sockets was bad. We considered that the result was influenced by the superimposition of blurred images, which arose from anterior or posterior neighboring structures in the tomographic plane, although the nominal slice thickness of each tomogram was 1.0 mm.

Because compact CT images and multislice CT images were direct digital images with x and y coordinates, it was easy to reconstruct 3D images from them. However, in tomograms the films were converted to digital images with a CCD video camera and a color image analyzer, and then the image coordinates were standardized. In this study, tomography was repeated more than 40 times to obtain over 40 mm mesiodistally. Therefore, 3D images were not clinically reconstructed at this level.

Compact CT has some advantages compared with multislice helical CT. In compact CT, the radiation exposure of patients is relatively low[19] and the machine can be used effectively in dental clinics.[14] Although compact CT 3D images were assessed overall as unsure to good, the evaluation of lingual cortical bone and tooth sockets was fair to unsure. Further studies are needed to improve the quality of 3D images for utilization of dental implant treatment.

Conclusion

Three-dimensional images were reconstructed from tomograms with a panoramic unit, compact CT images, and multislice helical CT images, and the usefulness of each system was subjectively assessed for dental implant treatment. Three-dimensional images reconstructed from tomograms with the panoramic unit were assessed as fair to unsure overall, whereas compact CT 3D images were assessed as unsure to good

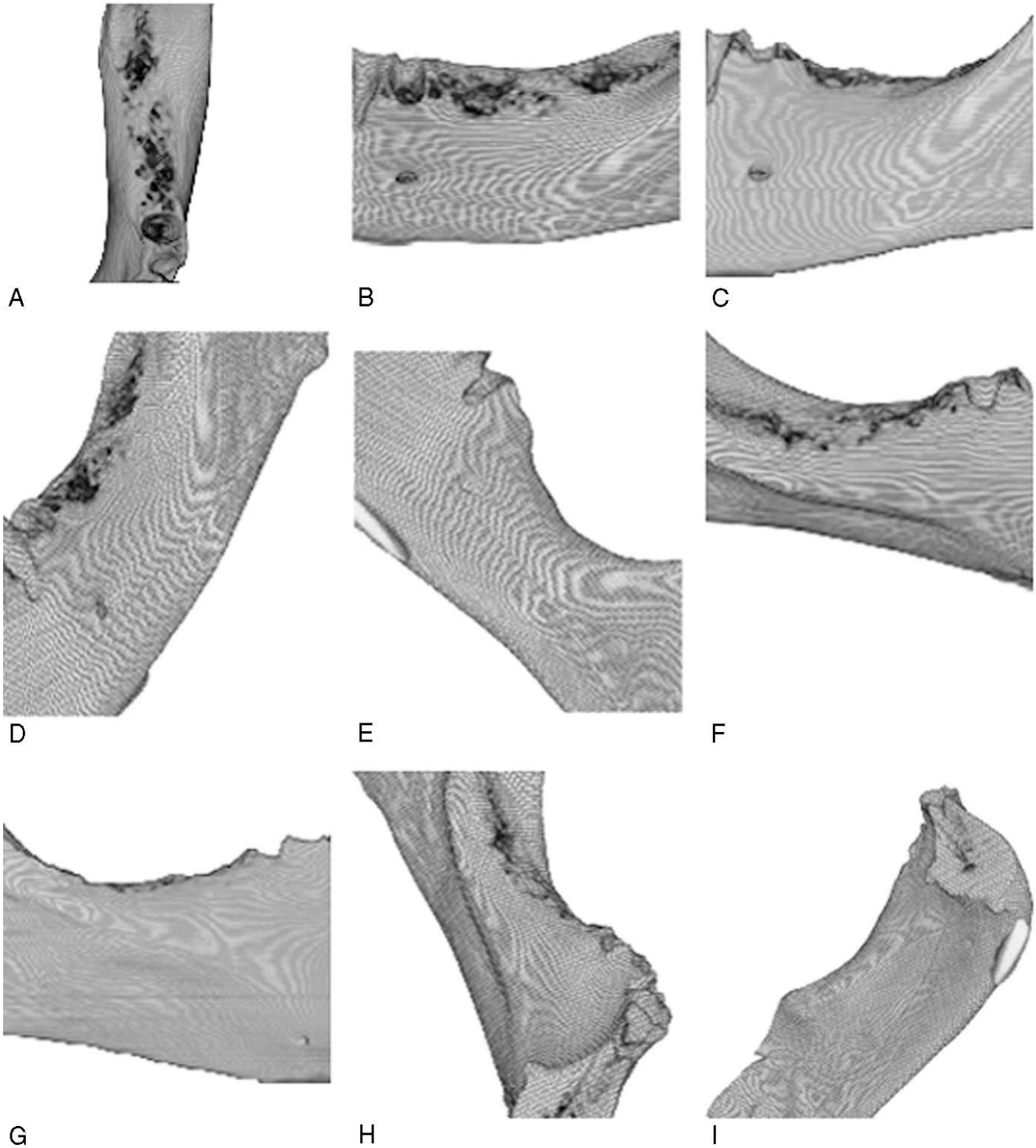


PLATE 3. Three-dimensional images reconstructed from multislice helical computerized tomography image. (A) View from above right. (B) Buccal view from above at 45°. (C) Buccal view. (D) Buccal view from 45° anterior and 45° above. (E) Buccal view from 45° anterior and 45° below. (F) Lingual view from 45° above. (G) Lingual view. (H) Lingual view from 45° anterior and 45° above. (I) Lingual view from 45° anterior and 45° below.

and multislice helical CT 3D images were assessed as good to excellent. It was concluded that compact CT 3D images and multislice helical CT 3D images would be useful in dental implant treatment.

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