Postoperative Assessment of Incisor Dental Implants Using Cone-Beam Computed Tomography

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The bone configuration surrounding anterior dental implants was postoperatively assessed using cone-beam computed tomography (CBCT). In 21 patients with a mean age of 41.5 years, 36 implants placed in the incisor region were postoperatively evaluated using CBCT. The rate of bone-to-implant contact (%) was calculated. The mean rate of bone-to-implant contact on the labial side was 78.3% with and 65.3% without bone grafts. The postoperative findings of incisor implants could be assessed using CBCT.

Key Words: dental implant, bone graft, incisor region, cone-beam computed tomography, postoperative findings

INTRODUCTION

Presently, dental implant treatment is considered to be one prosthodontic procedure to treat an edentulous jaw.[1] Also, the application of dental implant treatment has been expanded using various augmentation procedures, such as veneer and onlay bone grafting for severely resorbed residual ridges, and the maxillary sinus floor lift procedure for alveolar crests close to the maxillary sinus floor.[2–4] Critical reviews of the findings demonstrated variations in the anterior implant survival rates.[4–7] Implant survival was reported to be 90.4% for implants placed into onlay/veneer grafts. Further, alveolar augmentation techniques are not supported by detailed documentation or long-term follow-up studies, with the exception of guided bone regeneration.[4]

Maxillary sinus lift procedures were previously evaluated using computerized tomography (CT), and it was found that grafted bone surrounding the implants showed the marked progression of resorption, particularly at the implant apex.[8–11] Veneer bone grafting with implant treatment was evaluated using conventional tomography, and it was reported that the rate of bone-to-implant contact was low, and the area of bone was small on the labial sides of maxillary anterior implants with and without bone grafting.[12]

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Recently, a new cone-beam computed tomography (CBCT) device has been equipped with a flat panel detector to replace the image intensifier and charge-coupled device systems.[13] A bifid mandibular canal in the mandibular ramus region was observed in 65% of the subjects, and the CBCT images in the retromolar region were less influenced by metal artifacts caused by a metal restoration and/or crown in comparison with multislice CT images.[14]

However, the postoperative imaging of dental implant treatment has not been evaluated using CBCT images. Therefore, the bone configuration surrounding anterior dental implants with or without bone grafting was assessed using CBCT images in the present study.

Materials and Methods

In 21 patients (9 male and 12 female) with a mean age of 41.5 years (19 to 74 years), 32 implants were placed in the maxillary incisor region and 4 implants in the mandibular incisor region, and examined postoperatively using CBCT. Tooth loss was due to apical or marginal periodontal disease in 13 of 21 patients, traumatic injury in 5, and congenitally missing with alveolar bone cleft in 3 patients. Twelve implants without bone grafting (8 in the central incisor and 4 in the lateral incisor regions) and 24 implants with autogenous bone grafting (14 in the central incisor and 10 in the lateral incisor regions) were placed. All implants were clinically stable without complaints or mobility at the time of follow-up.

Bone grafts and implant placement

In the preoperative diagnostic imaging of planned implant sites without an alveolar bone cleft, when the thickness of labial bone was less than 1 mm at the sites, bone grafts were planned. Autogenous veneer bone grafting was performed using corticocancellous bone-blocks harvested from the chin or retromolar region a few months prior to implant placement. At planned implant sites with an alveolar bone cleft, autogenous bone grafting was performed using particulate cancellous bone and marrow (PCBM) harvested from the tibia. No membrane technique was used in any case.

Implant placement was performed in accordance with the surgical methods reported by Naitoh et al.[12] Five implants were from the Branemark implant system (Nobel Biocare, Goteborg, Sweden), and 31 were from the Replace tapered implant system (Nobel Biocare). No perforation of the implant on the labial or palatal side of the nasal floor was observed during implant placement. The mean period between bone grafting and implant placement was 4.1 months (SD 1.0), and that between implant placement and abutment connection was 4.5 months (SD 2.0).

CBCT

CBCT using Alphard VEGA (Asahi Roentgen Ind, Kyoto, Japan) was performed after abutment. All implants were clinically stable without complaint or mobility at the time of CBCT. The mean period between implant placement and CBCT was 30.4 months (SD 23.2) without and 28.5 months (SD 24.4) with bone grafting. The exposure volume was set at 51 mm in diameter and 51 mm in height (D-mode), or 102 mm in diameter and 102 mm in height (I-mode). The voxel size was $0.1 \times 0.1 \times 0.1$ and $0.2 \times 0.2 \times 0.2$ mm, respectively. The voltage and current were set as recommended by the manufacturer. The DICOM files of the axial images were saved to a portable hard disk.

Measurements of CBCT images

Cross-sectional and longitudinal 2-dimensional images of each dental implant were reconstructed on a computer (Macintosh G4, Apple Computer Inc, Cupertino, Calif) using

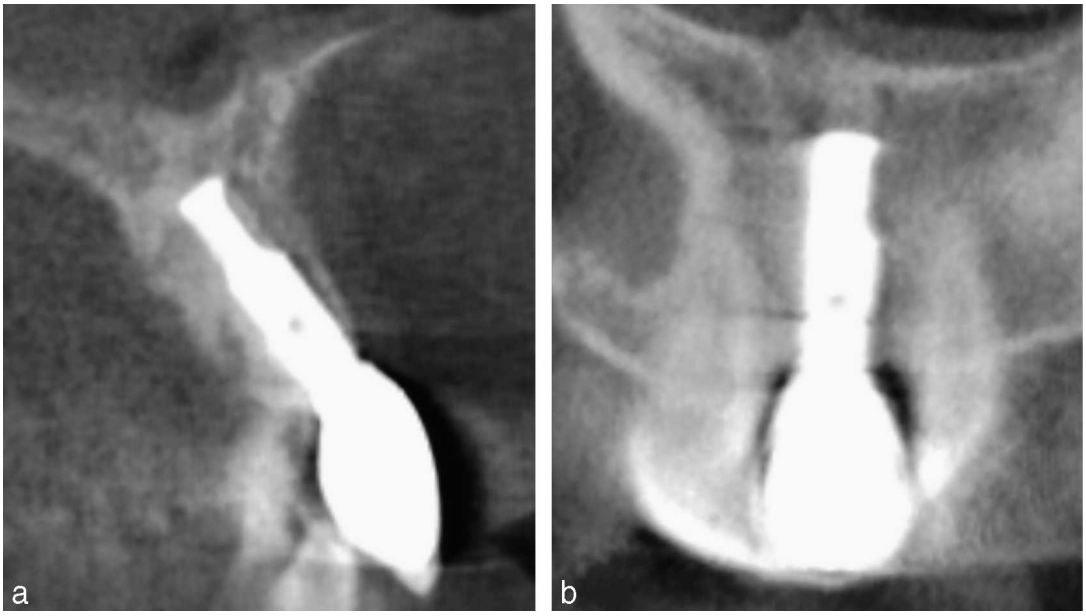

Figure 1. Reconstructed 2-dimensional cone-beam computed tomography (CBCT) images of a maxillary incisor implant. Two-dimensional images of the dental implant were reconstructed using OsiriX imaging software. (a) Narrow alveolar bone on the labial side was noted, and the labial bone thickness at the central superoinferior level of the implant was 1.7 mm. (b) An alveolar bone crest on the mesiodistal side of the dental implant was identified at the level of the implant neck.

3-dimensional visualization and measurement software (OsiriX imaging software, The OsiriX Foundation, Geneva, Switzerland, http://www.osirix-viewer.com[15]) (Figure 1). At first, the length of the implant covered by labial bone was recorded using cross-sectional images (Figure 2). The site of bone contact on the cervical side of dental implants was visually decided on referring to black and white binary images (Figure 3). The binary threshold value was set at the mean voxel value of the labial cortical bone. Also, the covered mesial and distal lengths were measured using longitudinal images in the same way. The rate of bone-to-implant contact (%) was calculated as the length of the implant covered by bone / the actual length of the implant $\times$ 100. The mesial and distal values were averaged. Subsequently, the condition of labial covered bone was classified into 3 types: thin, thick, and hollow, when the rate of bone-to-implant on the labial side was 60% or more (Figure 4). The thick type was recorded when the labial bone thickness of the central superoinferior level of each implant was 2 mm or more. The thin type was recorded when the labial bone thickness was less than 2 mm. The hollow type was defined as the labial bone configuration with a hollow. One oral and maxillofacial radiologist with experience of 25 years (M.N.) reconstructed and measured the images.

Statistical analysis

The differences between the obtained values of labial and mesiodistal sides, and between the obtained values with and without bone grafts were evaluated using the Mann-Whitney *U* test. Values were considered significant if $P < .01$.

Results

The rate of bone-to-implant contact

The rate of bone-to-implant contact on the labial side without bone grafting ranged from 20.0% to 100.0%, with an average of 65.3% (SD 23.5), and the rate on the mesiodistal side ranged from 51.8% to

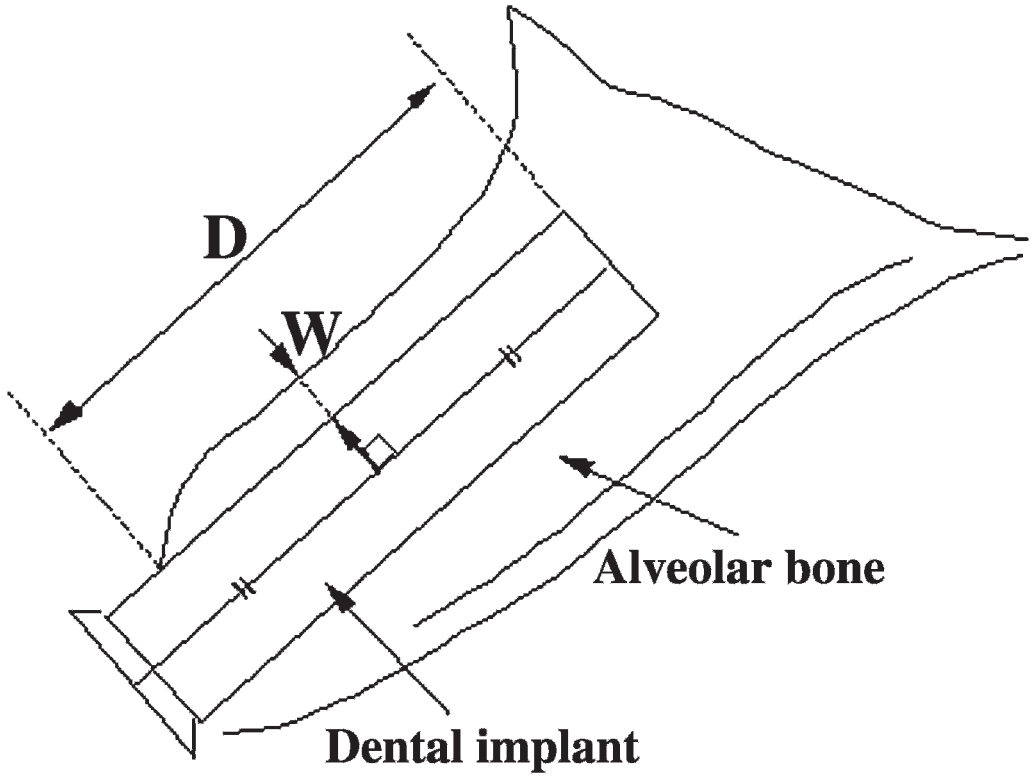

Figure 2. Schematic drawing of measurements of cone-beam computed tomography (CBCT) images. The length of the dental implant covered by labial bone (D) and the labial bone thickness at the central superoinferior level of the dental implant (W) were measured.

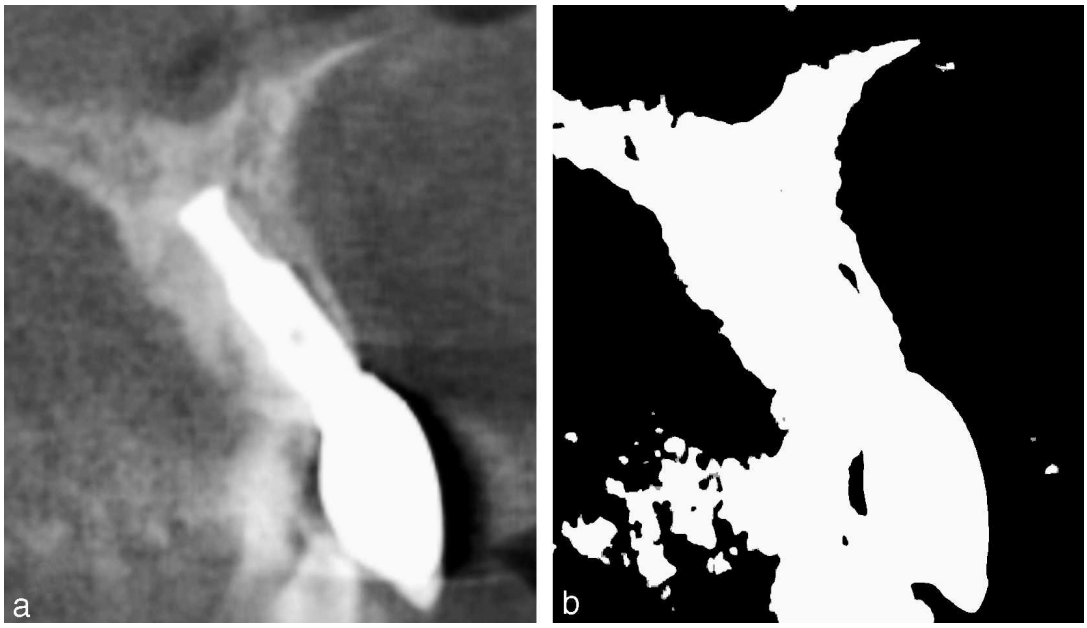

Figure 3. Cross-sectional cone-beam computed tomography (CBCT) images with conventional contrast (gray-scale) and binary threshold values. (a) Conventional contrast (gray-scale) image. (b) Black and white binary image.

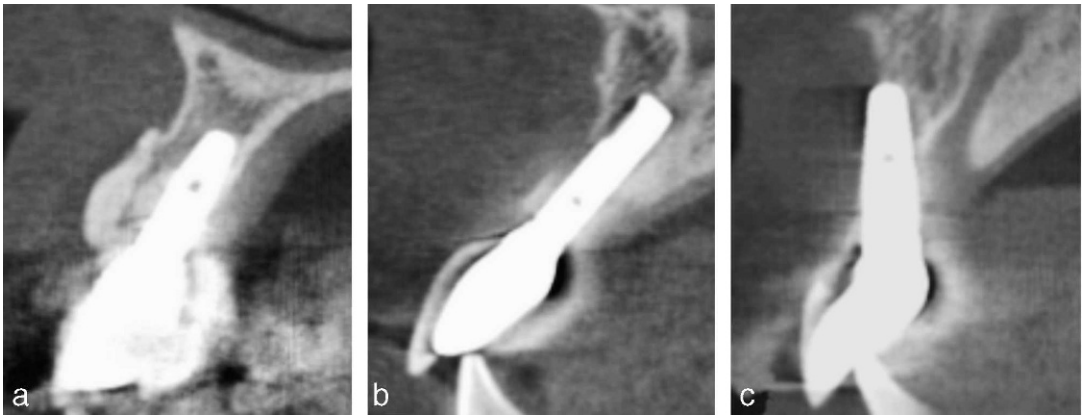

Figure 4. Cross-sectional cone-beam computed tomography (CBCT) images of the maxillary anterior implant. (a) Thick type: the labial bone thickness at the central superoinferior level of the dental implant was 2 mm or more. (b) Hollow type: the labial bone configuration of the central incisor implant was observed as a hollow shape. (c) Resorbed type: the labial bone between the neck and apex of the incisor implant was unclear.

100%, with an average of 87.3% (SD 16.8) (Table). A significant difference in the rate of bone-to-implant contact was noted between the labial and mesiodistal sides. Also, the rate of bone-to-implant contact on the labial side with bone grafting ranged from 0.0% to 100.0%, with an average of 78.3% (SD 23.1), and the rate on the mesiodistal side ranged from 59.6% to 100%, with an average of 86.9% (SD 8.0). No significant difference in the ratio of bone-to-implant contact was identified between the labial and mesiodistal sides ($P = .27$). No significant differences in the rate of bone-to-implant contact on the labial ($P = .09$) and mesiodistal ($P = .13$) sides were noted between implants with and without bone grafts. Moreover, the average rate of bone-to-implant contact of 20 implants with bone grafts using corticocancellous bone-blocks was 74.9% (SD 28.0) on the labial side, and 85.9% (SD 9.72) on the mesiodistal side. The average rate of bone-to-implant contact of 4 implants with bone grafts using PCBM was 80.3% (SD 17.3) and 81.8% (SD 5.42), respectively. Significant differences in the rates of bone-to-implant contact on the labial and mesiodistal sides were not noted between corticocancellous bone blocks and PCBM.

Type of labial bone configuration

Without bone grafts, at 4 sites (33.3%) the rate of bone-to-implant contact on the labial side was less than 60%. The thin type of labial covered bone was observed at 5 sites (41.7%), thick type at 2 sites (16.7%), and hollow type at 1 site (8.3%). The labial bone thickness of the central superoinferior level at 1 site showed a hollow type of less than 1 mm.

With bone grafts, at 4 sites (16.7%), the rate of bone-to-implant contact on the labial side was less than 60%. The thin type of labial covered bone was observed at 4 sites

Table
The rate of bone-to-implant contact

Bone Graft	Side	Range, %	Average, % (SD)
Without bone graft	Labial side	20.0–100.0	65.3 (23.5)
	Mesiodistal side	51.8–100.0	87.3 (16.8)
With bone graft	Labial side	0.0–100.0	78.3 (23.1)
	Mesiodistal side	59.6–100.0	86.9 (8.0)

(16.7%), thick type at 10 sites (41.7%), and hollow type at 6 sites (25%). The labial bone thickness of the central superoinferior level at 3 of 6 sites showed a hollow type of less than 1 mm.

Discussion

The implant survival rate was reportedly high for anterior implants irrespective of the presence of veneer grafting.[4–7] Bone loss on the mesial and distal sides of inserted implants was postoperatively measured using an intra-oral radiograph with paralleling technique.[16] The radiographic criterion of success is that the mean vertical bone loss is less than 0.2 mm annually following the first year of function.[17] However, Jemt and Lekholm[18] reported that all patients showed buccal crest volume resorption during the first year after buccal bone grafting using study casts and an optical 3-dimensional scanner. Further, all patients showed a reduction of the buccal crest volume during the first year after abutment or crown placement, reaching a significant level in the apical part of the crest. Also, grafted bone surrounding the implants using veneer bone grafting and sinus floor lift showed the marked progression of resorption using postoperative imaging in some previous studies.[8–12,19] Widmark et al[19] reported that bone resorption in the buccal/palatal direction of the anterior maxilla was 25% at 4 months and 60% at 10 months after bone grafting, when a bone graft from the symphyseal region of the mandible was used in the maxillary central incisor region. Moreover, Naitoh et al[12] reported, on using conventional tomography, that the mean rate of labial bone-to-implant contact without bone grafting was 81.8% (SD 18.8), and that with bone grafting it was 63.6% (SD 24.0).

Since pixel or voxel values obtained from CBCT images were not absolute values, like CT values (Hounsfield units: HU) obtained by medical CT, it was difficult to quantitatively decide on the site of bone contact on the cervical side of dental implants using voxel values in CBCT images. In the study, the site of bone contact on the cervical side of dental implants was visually decided on referring to black and white binary images. In a study using CBCT, the mean rate of labial bone-to-implant contact without bone grafting was 65.3% (SD 23.5), and that with bone grafting was 78.3% (SD 23.1). No significant difference in the rate of labial bone-to-implant contact was found between the implants with and without bone grafts in the present ($P = .09$) and previous ($P = .16$) studies. As the cortical bone thickness of bone blocks harvested from the retromolar region in 11 of 15 patients with bone grafts was thicker than that from the chin, the labial bone of anterior implants with bone grafts might have been clearer in CBCT images. Also, a significant difference in the rate of bone-to-implant contact without bone grafting was noted between the labial and mesiodistal sides. Thin labial bone of anterior implants appears unclear in CBCT images, and similar conditions were shown in a previous study using conventional tomograms. Moreover, metal artifacts, revealed as band-like radiolucent areas, were observed in alveolar bone between dental implants using CBCT images (Figure 5). The rate of bone-to-implant contact on the mesiodistal sides might be influenced by metal artifacts. Even if bone of labial, mesial, and distal sites appears unclear in CBCT images, the surrounding area of the implant would be covered by thinner bone. All implants were clinically stable without complaints or mobility at the time of CBCT. Significant differences in the rates of bone-to-implant contact on the labial and mesiodistal sides were not noted between corticocancellous bone blocks and PCBM.

Stable esthetic restoration was required for anterior implants over long-term follow-

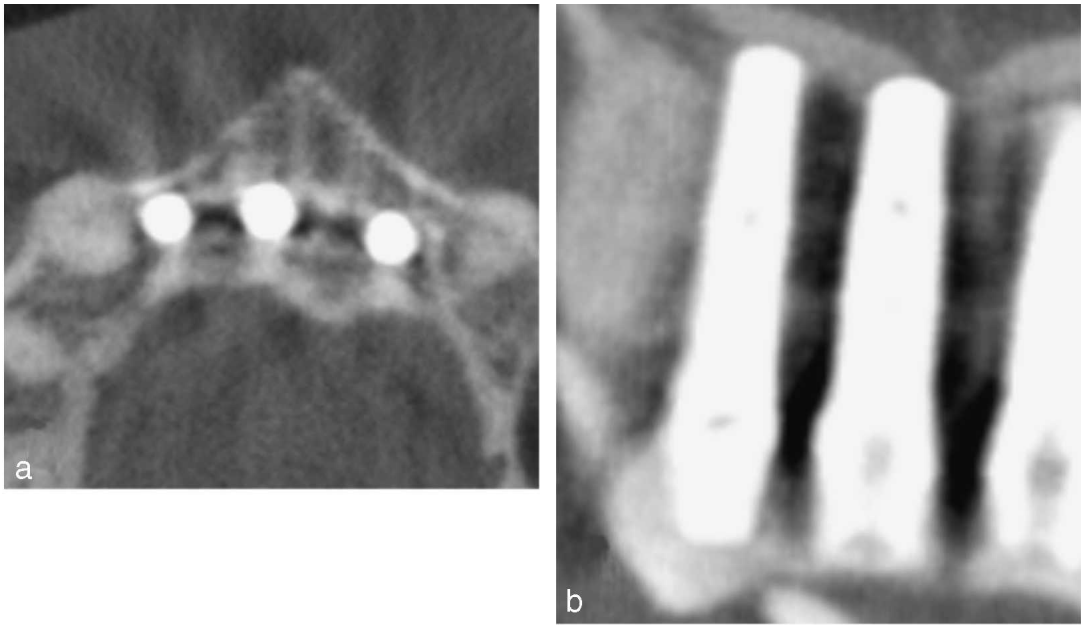

Figure 5. Metal artifacts between dental implants. (a) An axial image. (b) A longitudinal image.

up. The labial crest volume of soft tissue could be evaluated using study casts; however, the bone configuration could not be evaluated. CBCT images were considered useful to assess the buccolingual condition of alveolar bone.

The minimum bone thickness surrounding dental implants detected using CBCT images should be clarified in further in vitro studies. Also, future studies should assess the bone configuration surrounding posterior dental implants using CBCT images, and evaluate the relationship between the labial/buccal crest volume of soft tissue and bone, and between the measured bone volume and prognosis. Moreover, we should clarify the relationship between voxel values and the bone configuration surrounding dental implants in CBCT images, as well as histologic findings and turnover in the grafted and host bones using a bone marker.

Conclusion

The postoperative findings with and without bone grafting in incisor implant treatment were assessed using CBCT images. The mean rate of bone-to-implant contact on the labial side was 78.3% with and 65.3% without bone grafts, with no significant difference noted between them. A significant difference in the rate of bone-to-implant contact was identified between the labial and mesiodistal (mean 87.3%) sides without bone grafting.

Abbreviations

CBCT: cone-beam computed tomography
CT: computerized tomography
PCBM: particulate cancellous bone and marrow

Acknowledgments

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