

THREE-DIMENSIONAL COMPUTED TOMOGRAPHIC ANALYSIS FOR PLACEMENT OF MAXILLOFACIAL IMPLANTS AFTER MAXILLECTOMY

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ABSTRACT

Three-dimensional computed tomography scanning was used to examine six patients who had undergone maxillectomy and who were being considered for endosseous dental implants in the residual maxillary bone. This technique allowed three-dimensional visualization of the precise structures of the deformed maxilla, which facilitated the operation procedure by indicating optimal sites for fixture installation.

Key Words: Three-dimensional computed tomography, Osseointegrated implant, Maxillary tumor

INTRODUCTION

An osseointegrated implant system utilizing pure titanium fixtures applied to the jaw bone was introduced by Brånemark et al. in 1977,¹⁾ and they have reported many long-term results of this implant system during the past ten years.²⁾ The success rate of the implant procedure is reported to be more than 90% in the mandible and 80% in the maxilla.³⁾ Maxillary implantation has been more difficult than that of the mandible because of the complex structures and limited thickness of the cortical bone of the maxilla. Optimal positioning of the titanium fixtures requires detailed knowledge of the anatomy of the alveolar ridges in the edentulous region along the entire curvature of the maxillary bone. Especially after maxillectomy, the shape of the maxillary bone changes drastically. Conventional radiograms and computed tomography (CT) scan views, although useful, do not provide precise information about the deformed maxilla. The three-dimensional computed tomography (3D-CT) scan is a well-established diagnostic tool for maxillofacial surgery. Recently, conventional CT scans have been used for the preoperative examination of dental implants.⁴⁾ However, the 3D-CT scanning examination of the maxilla has a greater advantage compared with conventional CT scanning because it can visualize the three-dimensional structure of the bone, allowing the surgeon to observe the anatomical structures precisely from any direction desired. Moreover, the surgeon can image the exact sites and direction of fixture installation, which helps him decide the appropriate size of the fixture.

The purpose of this study is to describe the preliminary clinical results of 3D-CT scanning in the preoperative examination of maxillary tumor patients being planned for implant surgery in the maxilla.

MATERIALS AND METHODS

Six patients who had undergone maxillectomy because of maxillary tumor were the subjects

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in this study. There were four men and two women and their ages ranged from 40 to 78 years (Table 1). Three of the six patients had received radiotherapy before surgery. All patients had used removable maxillary prostheses after maxillary surgery, but were not satisfied with their dentures because of lack of retention and stability. Therefore, the patients strongly hoped to be treated with bone-anchored prostheses. Before implant surgery, all patients in this study underwent routine radiograms and 3D-CT scanning.

High resolution CT scans of facial structures were obtained using unmodified commercially available units (Somatom DRH). All scans were obtained on a Somatom DRH (Siemens Co., Ltd.) with 2-mm slice at 1-mm intervals. A 256×256 reconstruction matrix was used. To delineate the maxillary structures better, often only the frontal half of the subject's skull was included in the original transverse transaxial CT images.

The original CT scan data were archived on to floppy discs, and surface reconstructions were obtained subsequently using the CT scanner console, or after being transferred to an independent CT scan-viewing console. The image data were ultimately copied on to a moderate capacity cartridge disk unit integrated into the viewing console. Routine planar reconstructions in the sagittal, coronal, and oblique orientations were obtained as needed.

Computer programs for three-dimensional surface reconstruction from sequences of high resolution CT scans were designed and implemented. These programs were written in Fortran and assembler languages to operate on a minicomputer incorporated in the CT viewing console. These programs operate without modification of the CT scanners. The programs accept the original transaxial high resolution CT scan sequence as input and produce a set of three-dimensional surface-reconstruction images as output. Any view from any projection may be obtained, but we routinely produce only those views that have clinical significance.

Table 1. Type of defect and implant treatment.

| TYPE OF DEFECT AND IMPLANT TREATMENT | | | | |
|--------------------------------------|----------|---------------|---|-----------------|
| Case | Location | Diagnosis | Type of Defect | Site of Implant |
| 60. F | Max. (L) | S.C.C.* |  | Max. |
| 78. M | Max. (L) | S.C.C.* |  | Max. |
| 40. F | Max. (R) | Ameloblastoma |  | Max. |
| 67. M | Max. (L) | S.C.C.* |  | Max.+Orbit |
| 42. M | Max. (R) | S.C.C.* |  | Orbit |
| 68. M | Max. (R) | S.C.C.* |  | Orbit |

* S.C.C. : Squamous Cell Carcinoma.

The surface reconstruction computer program reads each of the original high resolution CT scans in order from the cartridge disc and loads the image into the 256×256 pixel display memory of the evaluation console. The soft tissue contour is extracted by comparing each value of CT density in the column from top to bottom of the image with a preset threshold that represents the CT attenuation that distinguishes air from soft tissue.

Each column of the CT scan section is then examined from top to bottom in comparison with a bone threshold. The soft tissue to bone density transition detected in this manner forms the bone contour in the frontal projection. This bone contour vector is written on to a separate file on the cartridge disc. During the contour extraction process, the frontal contours are displayed on the evaluation console TV monitor as a quality control measure. Each succeeding CT scan is read from the disc, loaded into the display memory, bone and soft tissue contours are extracted, and results are written on to the cartridge disc to complete the surface reconstructions. The images output by these software are copied on to a TV monitor and films for preoperative evaluations.

Implant surgery was performed using the Brånemark implant system on all patients. Fixtures used in this study were usual dental fixtures (3.75 mm in diameter, 7–15 mm in length) and flange fixtures (3.75 mm in diameter, 4 mm in length) for maxillofacial prostheses. Fixture installation was done in the usual manner described by Lekholm.⁵⁾ Before the implantation, hyperbaric oxygen therapy⁶⁾ (2 ata* or 3 ata*, 90 min., 20 times) was carried out on three patients to promote bone healing; in addition, hyperbaric oxygen therapy was performed 10 times under the same conditions after the operation. (* ata: atmosphere's absolute pressure)

PREOPERATIVE ANALYSIS BY THREE-DIMENSIONAL COMPUTED TOMOGRAPHY

We have used three-dimensional computed tomographic analysis and conventional radiographic examination in all patients. Maxillectomy in the usual manner⁷⁾ was performed on dry skull, and the exact structure of the residual maxillary bone was examined (Fig. 1). The structural details of the maxillary bone could be viewed from any perspective unit. According to the results of 3D-CT examination of the maxillary bone after usual maxillectomy in six patients and one dry skull, the following anatomical structures were interpreted as optimal sites for fixture installation (Fig. 2):

- 1) Body of the zygomatic bone
- 2) Root of the maxillary frontal process
(Lateral wall of the nasal cavity)
- 3) Maxillary tuberosity

Although the major part of the maxillary bone was gone after maxillectomy, the above sites still remained. Suitable bone quality and quantity to install the fixture were thought to exist. According to this preoperative information about the maxillary bone, 26 fixtures were installed in six patients. Nine of the 26 fixtures were flange fixtures installed into the upper rim of the orbit in two patients. Seventeen of the 26 fixtures were usual dental implants seated into the residual maxillary bone. Abutment connection to the fixtures was performed sometime between nine and 12 months after surgery. As a result, all flange fixtures were integrated successfully in the orbital region; however, in the maxillary region, one fixture failed to integrate. Using these fixtures as anchors, maxillary or orbital prostheses were placed for the six patients.

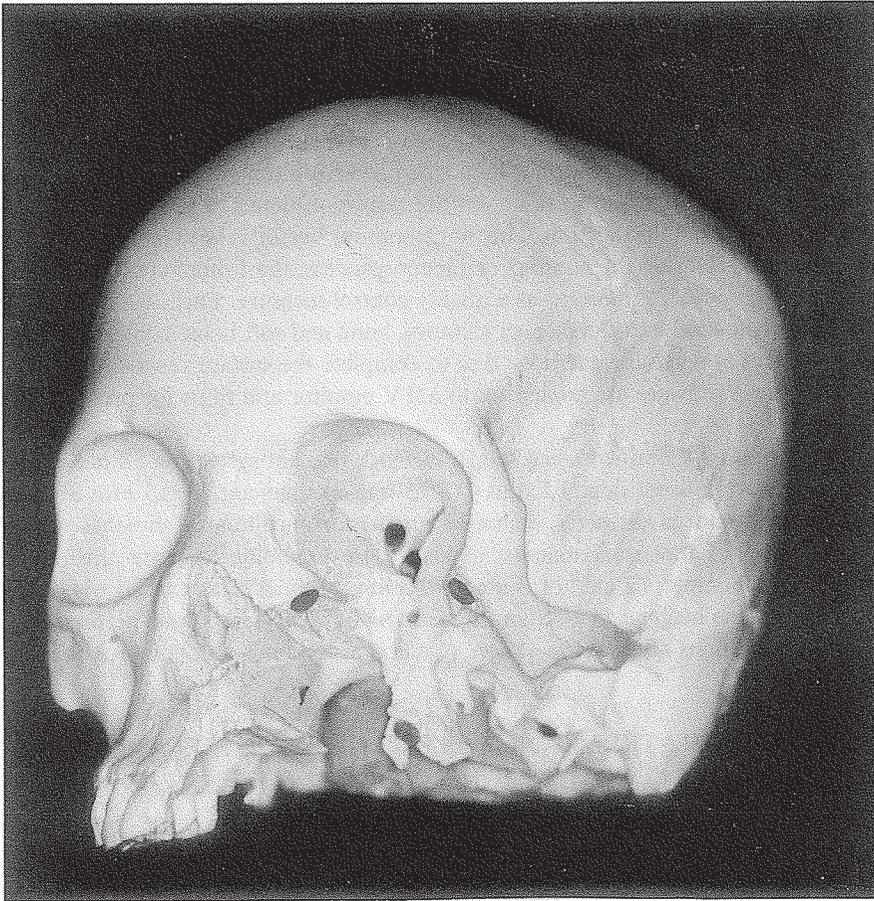


Fig. 1. Maxillectomy performed on dry skull following the usual procedure (Black dots show the suitable site for fixture installation).

3DCT FOR MAXILLOFACIAL IMPLANT

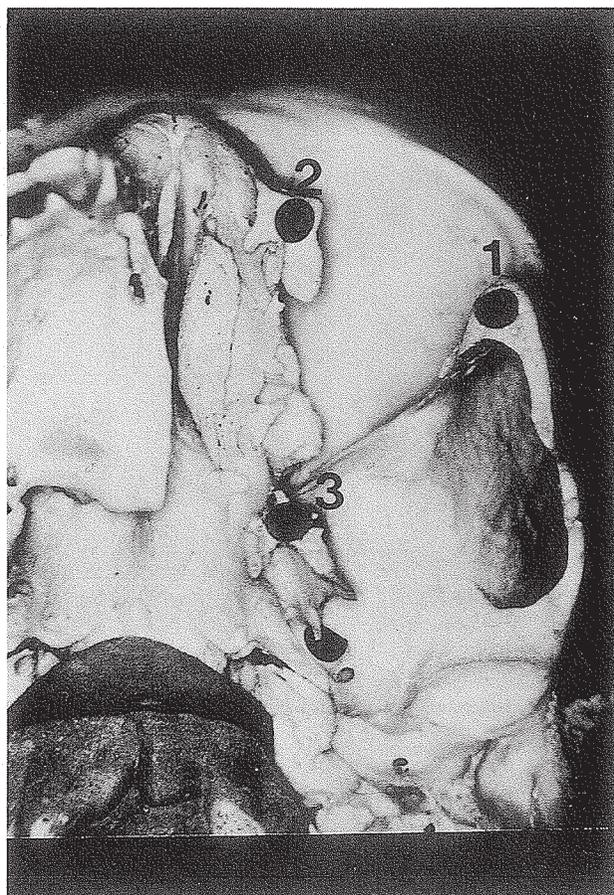


Fig. 2. Three useful sites for fixture installation after maxillectomy (Basal view of dry skull).

- 1) Body of zygomatic bone
- 2) Root of maxillary frontal process
- 3) Maxillary tuberosity

REPRESENTATIVE CASES

Case 2: A 78-year-old-man had received chemotherapy (Peplomycin 40 mg, Cisplatin 80 mg) and radiotherapy (Co^{60} , 40Gy) before partial maxillectomy (Fig. 3a). After the operation, the prognosis of primary disease was very good. However, the patient's maxillary denture was

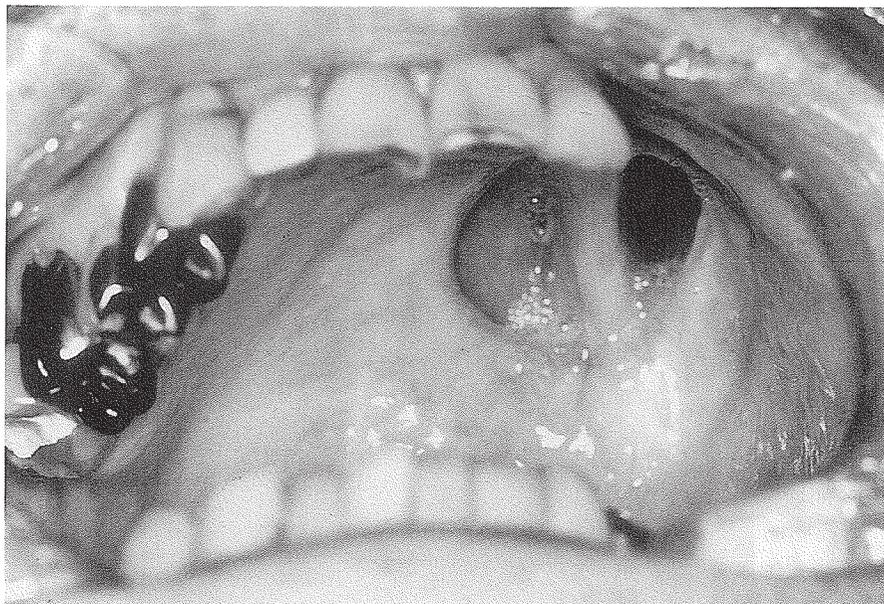


Fig. 3a. Intraoral findings of Case 2.
Partial maxillectomy was performed after chemotherapy and radiotherapy.

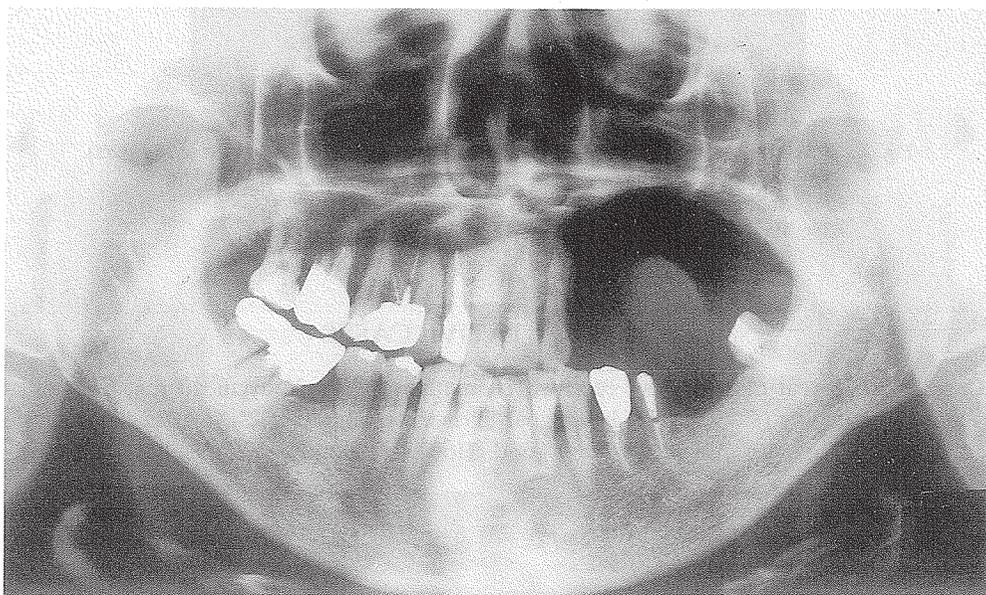


Fig. 3b. Panoramic radiogram of Case 2.

3DCT FOR MAXILLOFACIAL IMPLANT

remade seven times during five years because of lack of retention and stability of the denture. The patient hoped to have a bone-anchored prosthesis instead of the conventional removable denture. Preoperative radiographic examination with Waters or panoramic radiogram failed to indicate the morphological details of the maxilla (Fig. 3b). However, 3D-CT scanning radiograms showed the exact structures of the maxilla after maxillectomy (Fig. 3c). In this case, a 13-mm fixture was inserted in the body of the zygomatic bone, and a 15-mm fixture into the root of the maxillary frontal process. A fixture of 10-mm was inserted into the maxillary tuberosity and a 7-mm fixture was able to be seated in to the residual alveolar bone. All fixtures survived completely at 9 months post surgery (Fig. 3d).

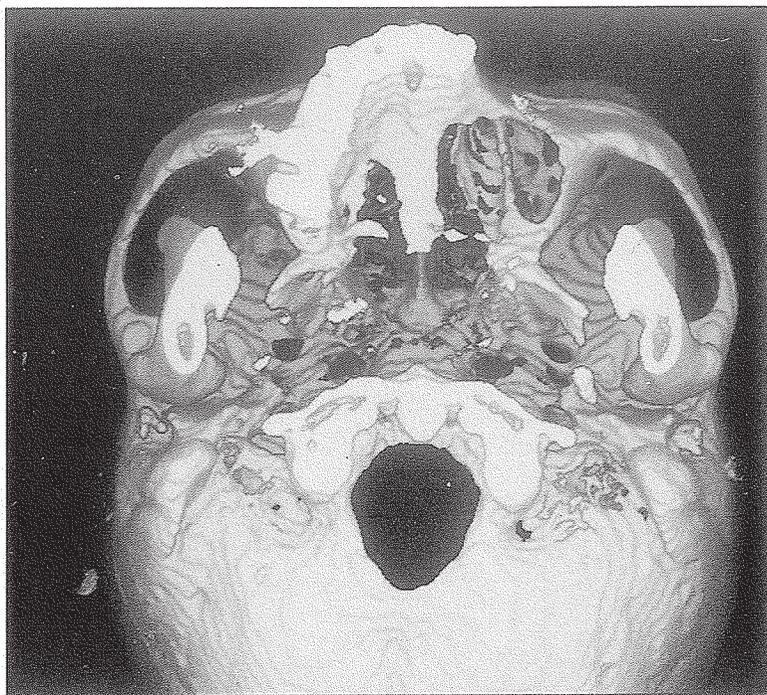


Fig. 3c. Three-dimensional computed tomography of Case 2 shows the exact structures of deformed maxilla.



Fig. 3d. Postoperative radiogram of Case 2.

Four fixtures were installed into the maxillary region.

A 13-mm fixture was inserted in the body of the zygomatic bone, a 15-mm fixture into the root of the maxillary frontal process, a 10-mm fixture into the maxillary tuberosity, and a 7-mm fixture into the residual alveolar bone.

3DCT FOR MAXILLOFACIAL IMPLANT

Case 4: A 67-year-old man had undergone radiotherapy (Co^{60} , 50Gy) and hemimaxillectomy with orbital exenteration and removal of the orbital floor. The defects were larger than those in Case 1 and sites for fixture installation were extremely limited. Three-dimensional computed tomographic examination indicated that the upper orbital margin was completely intact. However, the root of the maxillary frontal process and the body of the zygomatic bone were completely absent (Fig. 4a). Three flange fixtures were installed into the upper orbital rim, and one 10-mm fixture was inserted into the maxillary tuberosity. Also, four fixtures (10-mm, 10-mm, 13-mm, 15-mm) were installed into the contralateral alveolar bone (Fig. 4b). All fixtures were found to be integrated 12 months after surgery.

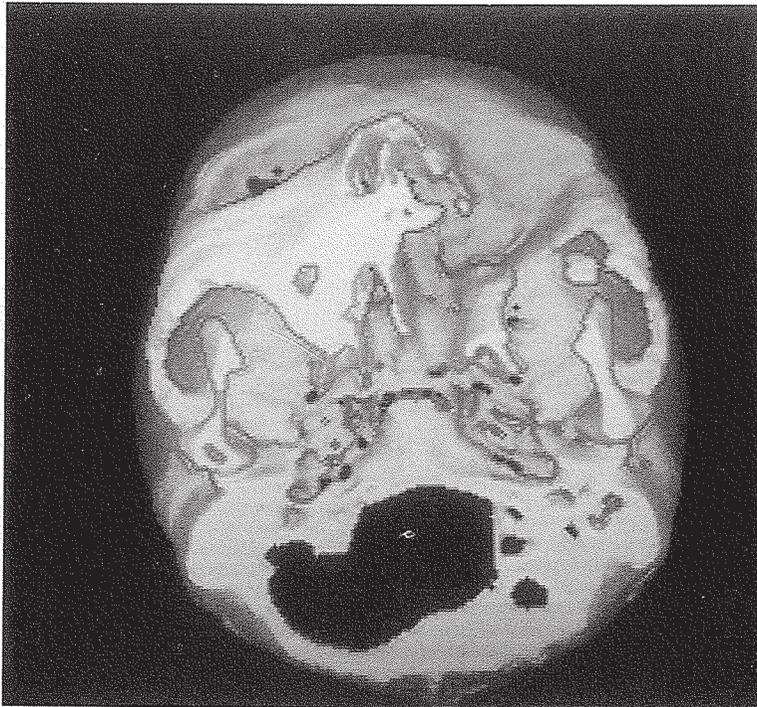


Fig. 4a. Three-dimensional computed tomographic views of Case 4. 3D-CT image indicating installation sites. The root of the maxillary frontal process and the body of the zygomatic bone were lost because of wide resection of the maxilla.

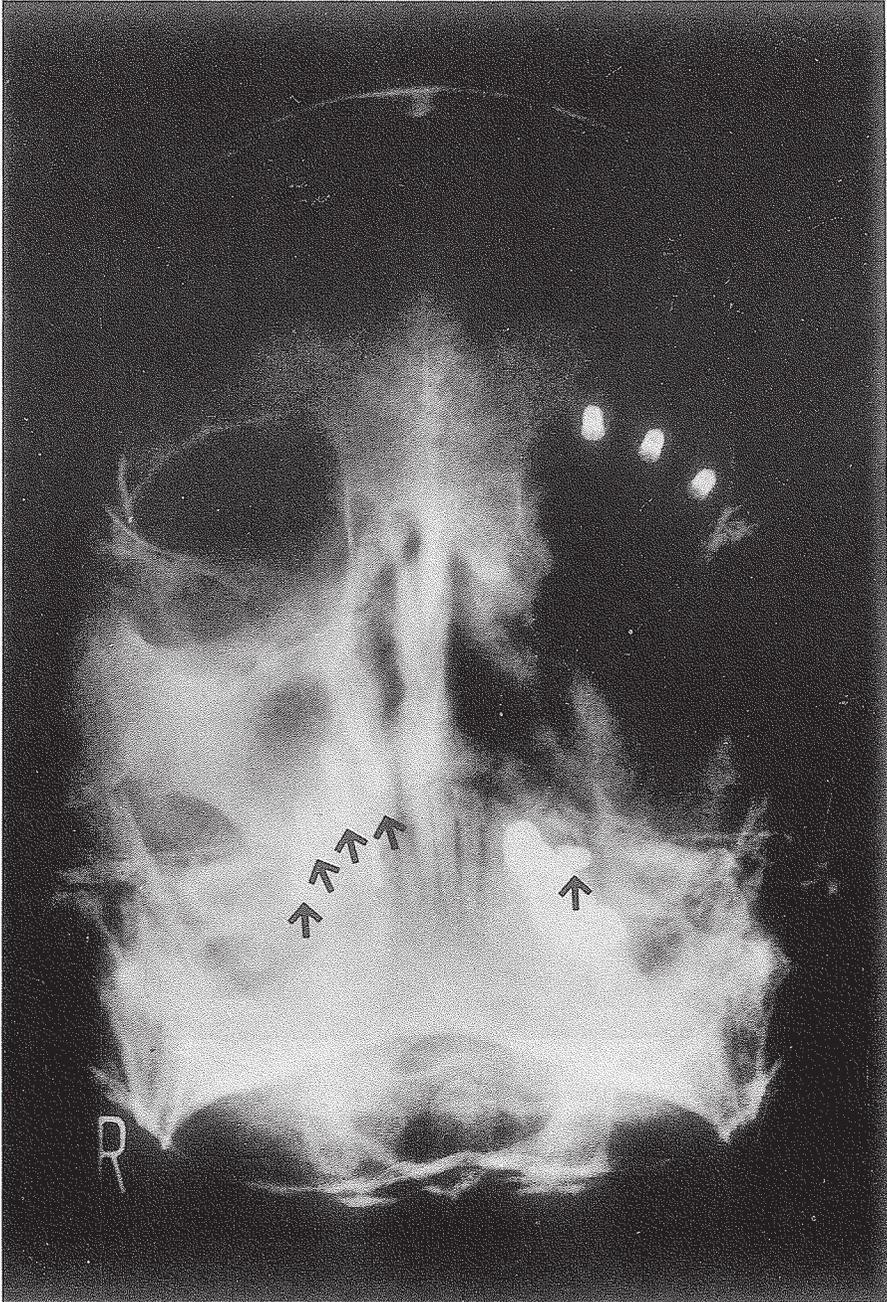


Fig. 4b. Postoperative radiogram of Case 4.
One 10-mm fixture was able to be installed into the maxillary tuberosity.
Four fixtures were inserted into the contralateral alveolar bone. (Arrows show inserted fixture.)

DISCUSSION AND CONCLUSION

Implantation of fixtures into the maxilla presents a significant challenge to the oral surgeon who is charged with the responsibility of placing them in the optimal position. The surgeon is limited by lack of information on the precise size and shape of the maxilla as well as by the location of both the cortical bone and anatomic structures. Preoperative planning with 3D-CT is preferable for having to make strategic decisions concerning the patient being planned for treatment with implant therapy in the maxilla. Especially in the deformed maxilla due to maxillectomy, 3D-CT scans have the advantage of visualizing the precise structures of the residual bone. The optimal placement of the fixtures can usually be attained when the surgeon and prosthodontist work together. The 3D-CT scan provides an opportunity for both members of the team to confer in the best interest of the patient. Assessment of the shape and contour of the maxilla is best done with the 3D-CT scan. From our study with these 3D-CT examinations, three sites were identified as the optimal sites for fixture installation after maxillectomy:

- 1) Root of the maxillary frontal process
- 2) Body of the zygomatic bone
- 3) Maxillary tuberosity

In these sites, suitable bone quality and quantity for fixture installation remained even after maxillectomy. However, the entire thickness of the bone as well as the available cortical bone can only be understood clearly in the conventional CT scan views. Cross-sectional scans assist the surgeon in locating cortical bone in the maxilla and in predetermining the optimal fixture lengths required to engage the cortical bone;⁸⁾ at the same time, whole anatomical features such as the incisive canal can be visualized and thus avoided during surgery. In the future, moreover, such improvements in software will be necessary for 3D-CT as will clearly indicate bone density, just like a geograph, by differences in contrast of the image. If this is realized, appropriate positioning of fixtures will be facilitated. The availability of bone can be predetermined with either 3D-CT or cross-sectional scanning. It is extremely important to evaluate both the exact shape and quality of the maxilla to succeed in the implant surgery.

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