RESEARCH

Transtomography for implant placement guidance in non-invasive surgical procedures

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Objectives: To illustrate the use of transtomography for the placement of implants using a radiopaque radiographic guide and to evaluate the accuracy of transtomography.

Methods: The study included 11 implants inserted with minimally invasive procedures. Pre-, intra- and post-operative examinations were performed with a ProMax panoramic unit implemented with transtomographic technique (Planmeca Oy, Helsinki, Finland). At each implant site, cross-sectional and longitudinal intraoperative transtomograms were taken through a radiopaque reference guide to control and adjust the drilling axis. The effective axis on post-operative tomograms was compared with the planned axis correction estimated on intraoperative images. Radiopaque guides, used as the gold standard, were measured on intraoperative cross-sectional slices to evaluate image distortion.

Results: Intraoperative transtomograms, with the reference guide inserted in the bone, gave clear images of the cortical plates and accurate information of drilling length and axis which allowed the surgeon to adjust pilot drilling axis in 6/11 (54.5%) sites, including sites with narrow bone ridges. The implant axis on the post-operative tomogram compared with the planned axis correction showed an angle difference ranging from 0.8° to 3.4°. The image distortion on cross-sectional slices ranged from 0.03 mm to 0.52 mm, resulting in a distortion ratio ranging from 0% to 6% when expressed in percentages.

Conclusions: Transtomographic examination performed with a radiographic reference guide during implant surgery can provide the necessary and accurate information for implant placement. Transtomography distortion appears to be less important than in other conventional tomographic systems and comparable with CT scan distortion.

Keywords: dental implants, tomography, distortion, mandible

Introduction

Various imaging techniques, including conventional radiography and CT, are used for the pre-surgical planning of implant placement. Conventional tomography is the method of choice to obtain cross-sectional information of small regions of interest for implant planning.1 Tomograms before dental implant placement will help determine the height, width, inclination and undercut of the alveolar bone, as well as the location of anatomical structures such as the mandibular canal, the submandibular gland fossa, the maxillary sinus and the nasal fossa.2,3 Cross-sectional images, using films or photostimulable phosphor (PSP) plates obtained with panoramic radiographic units, showed similar image performance and are acceptable for dental implant placement planning.4 In a study on phantom heads, Welander et al5 tested transtomography, which employs the narrow beam of an advanced direct digital panoramic machine. They showed that this new tomographic scanning technique, which cannot be used in other panoramic units with a sensor technique, gave images with properties comparable with those of conventional tomography. In conventional implant placement surgery, a large full-thickness periosteal flap is reflected to visualize the bone contour before drilling, whereas flapless and minimally invasive procedures maintain a better blood supply to the site by leaving the peristeum intact on the buccal and lingual aspects of the ridge.6-7 However, these “blind” procedures make it more difficult to evaluate the shape of the alveolar bone; as the risk of cortical plate perforation is increased, flapless surgery is limited to straightforward cases with a favourable bone crest.8–10
The aim of this article is to illustrate how transtomography, when used with a radiopaque radiographic guide, can assist the surgeon during implant placement. The protocol developed in the present study allowed to evaluate the accuracy of transtomography.

**Methods**

Between January and October 2005, nine partially edentulous patients (six females and three male patients), age ranging from 31 to 76 years (mean age 53 years), were treated using flapless surgery or a minimally invasive procedure. The implants were inserted in 11 sites (in one incisor site in the maxilla, in seven molar and three premolar sites in the mandible).

Pre-operative planning included clinical and radiographic examination. All patients were examined using a ProMax panoramic unit implemented with transtomographic technique (Planmeca Oy, Helsinki, Finland). This digital panoramic unit can make image layer thickness ranging from 1 mm to 36 mm and combines a longitudinal and cross-sectional transtomograms in one composite image. An image layer thickness of 3 mm was chosen for this study. The exposure values were 66 kV, 1 mA and 8 s. Implant position and length were estimated by measuring the crestal width and the distance from the top of the ridge to the critical anatomic structures (cortical plates, undercutts, concavities or mandibular canal) on the panoramic image (1.2 magnification factor) and on a composite image (1.4 magnification factor; Figure 1).

All measurements were taken with the computed Planmeca measurement program which allows the calibration of the image on the screen. The ProMax panoramic with transtomographic digital unit offers three picture grabbing modes. The three resolution modes are: normal resolution (one picture pixel equals four physical pixels), enhanced resolution (one picture pixel equals three physical pixels) and high resolution (one picture pixel equals two physical pixels). The size of the physical pixel is 33 \( \mu m \). After picture calibration for panoramic or transtomographic images (1.2 or 1.4 magnification factor, respectively), measurements were carried out in normal resolution mode (i.e. 132 \( \mu m \) representing the size of four physical pixels), leading to values precised to two decimals. Angle measurements were carried out with the Dimaxis computerized compass program joined to the ProMax panoramic unit, which gave degree values precised to one decimal. Consequently, to ensure accuracy of the measurement system, results were not rounded off.

An individualized silicon occlusal registration key was used for patient positioning during pre-, intra- and post-operative transtomography. Throughout surgery, to avoid injury to the inferior alveolar nerve and other critical anatomic zones, the drilling length through the mucosa and the bone before transtomographic control was maintained 2 mm shorter than the estimated distance to these zones. The first drilling, performed with the pilot drill, respected the axis corresponding to the planned implant axis.

A custom-made radiopaque radiographic reference guide made of titanium alloy (Ti6Al4V) was inserted in the bone after the first drilling. The reference guide consists of a 2 mm diameter intrabony part, either 5.50 mm or 9.60 mm long. The intrabony part of the 9.60 mm long guides has notches which make it easier to take measurements on the images (Figure 2). The extrabony part of the radiographic guide is 1.5 mm high, 4 mm in diameter and protrudes out of the mucosa. At each implant site, cross-sectional and longitudinal intraoperative transtomograms were taken with the radiopaque reference guide securely sutured to the adjacent teeth or to the surrounding mucosa. The position of the reference guide on the transtomographic images allowed three-dimensional control of the planned surgical drilling trajectory (Figure 3), so the drill’s axis could be adjusted as necessary.

After full drilling and enlargement, implants were inserted. Ten implants were Branemark Tiunite Mk3 (Nobelbiocare France, Paris, France) and one was a Replace Select Tapered (Nobelbiocare France). 5/11 (45.4%) implants were 13 mm long, 3/11 (27.3%) implants were 11.5 mm long and 3/11 (27.3%) implants were 10 mm long.

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**Figure 1** Pre-operative longitudinal and cross-sectional transtomograms. The horizontal lines are drawn with the Planmeca program to improve the assessment of critical anatomic structures. The distance from the top of alveolar crest to the lingual undercut is 10 mm. The distance from the top of the alveolar crest to the superior border of the mandibular canal is 13 mm. The occlusal registration key, used to position the patient, is also visible.

**Figure 2** Three radiographic reference guides. The intrabony part, with or without notches, measures 9.60 mm for the long guides and 5.50 mm for the short one. The extrabony part may be sutured to the mucosa.
For the purposes of this study, post-operative transtomography (Figure 4) was used to evaluate the inserted implant; the effective axis of the implant on the post-operative images was compared with the planned axis rectification estimated on intraoperative images.

The radiopaque guide, used as the gold standard in this study, was measured on the intraoperative cross-sectional slices to evaluate the image distortion. The measurements were carried out thrice on the screen using the Planmeca program after calibration of the image; the recorded value was the measure having the biggest difference with the gold standard. Measurements of the intrabony part of the reference guide on the slices were compared with the real intrabony length of the guide.

Results

Comparison of the pre-, intra- and post-operative transtomograms showed no artefact produced by either the titanium guide or the dental implant. Composite images (cross-sectional and longitudinal slices), with optional alignment of the different zones on the two images, improved the visualization of the bone contours and anatomic limits at each site (Figure 1). In 7/11 (63.6%) sites, the crest width was less than 7 mm (ranging from 5.2 mm to 6.5 mm) and a lingual undercut or a buccal concavity was obvious on pre-operative tomograms in 8/11 (72.7%) sites.

All intraoperative transtomograms gave clear images of the cortical plates and information of drilling length and axis which allowed the surgeon to adjust pilot drilling axis in 6/11 (54.5%) sites, including sites with narrow bone ridges. The effective axis of the implant on the post-operative transtomogram, compared with the estimated axis rectification planned when necessary on the intraoperative transtomography, showed an angle difference ranging from 0.8° to 3.4°. Post-operative transtomograms confirmed that all implants had been placed as planned and that the implants did not intrude on critical anatomic structures.

Measurements of the guide on cross-sectional slices compared with the gold standard showed a distortion ranging from 0.03 mm to 0.52 mm (maximum overestimation 0.03 mm, maximum underestimation 0.52 mm), resulting in a distortion ratio ranging from 0% to 6% when expressed in percentages.

Discussion

Welander et al described how advanced panoramic machines that combine a translational movement with a pendular movement of the beam and detector make direct digital transtomographic images and can be utilized for the same purposes as conventional tomography. Transtomography produces almost instant results and allows quick measurements on the screen with a computed program. This made transtomography more appropriate in our study than conventional tomography using films or PSP plates. In addition, the panoramic machine’s compact size allowed it to be installed in the operating room. The surgeon rapidly and conveniently performed intraoperative investigations in the shortest time (with no discomfort to the patient) as the panoramic machine was within a few paces of the operating table. Positioning of the patient was facilitated by means of the individualized silicon key.

The present image distortion (maximum overestimation 0.03 mm, maximum underestimation 0.52 mm) can be compared with other previous studies on distortion using different tomographic systems. In a conventional spiral tomography study on human cadavers, Serhal et al used a digital calliper for the measurements and reported a maximum overestimation of measured distances of 1.05 mm and a maximum underestimation of 1.36 mm. The 0%–6% distortion reported with CT scan and the 0%–5.2% distortion reported with limited cone-beam CT are similar to our results with transtomography (distortion ranging from 0% to 6%).

As the distortion with transtomography, using a ProMax panoramic unit implemented with transtomographic technique, and the CT scan distortion are similar, transtomography may be considered as an imaging tool providing accurate information for implant planning.

In this study, the radiographs were produced with 66 kV, 1 mA, during 8 s and the emitted dose was 51 mGy cm². Absorbed dose for a composite image (one longitudinal slice and one transversal slice) was 6 μSv–8 μSv and 3 μSv–4 μSv for a single slice (information given by the manufacturer, Planmeca Oy). These absorbed doses are comparable with results reported by Lecomber.
The absorbed dose was 2 μSv for one linear cross-sectional tomogram slice and 314 μSv for a CT scan examination. Other previous works showed absorbed doses ranging from 4 μSv to 6.1 μSv for a conventional spiral cross-sectional tomography\(^1\) and 3 μSv for one slice of conventional tomography.\(^2\)

Intraoperative transtomography using a radiographic guide may be considered as a form of navigation surgery; three-dimensional information allows the surgeon to rectify the drill’s axis when needed. We believe it is more flexible than reported navigation surgeries for dental implants needing a CT scan, a computer software and a template for implant guidance.\(^3\)\(^-\)\(^5\) Navigation surgical procedures requiring a CT scan appear to be better suited for large edentulous zones or full arch rehabilitations, whereas a transtomographic navigation protocol, resulting in a reduced absorbed dose, may be considered a safe procedure for implant placement in small edentulous zones.

This transtomographic navigation protocol may also improve flapless surgical procedures; currently reported, limitations with these blind procedures are a narrow alveolar ridge and the presence of anatomical undercuts.\(^8\)\(^-\)\(^10\) When an undercut of more than 15° is detected radiologically, or when the width of the ridge is less than 7 mm, flapless procedures are no longer possible; a traditional flap reflection is then recommended to allow better visibility.\(^3\)\(^-\)\(^10\) With a radiographic guide and transtomography, the risks of critical anatomical zones injury and of cortical plate perforation were minimized, allowing implant placement in all cases, including sites presenting a narrow ridge, a buccal concavity or a lingual undercut.

In conclusion, transtomographic examination performed with a radiographic reference guide during implant surgery can provide the necessary and accurate information for implant placement. This protocol may be especially valuable during blind surgical procedures as cortical plates or critical anatomical structures may be approached when needed without increasing the risk of damaging them. Distortion of the images appears to be less important than with other conventional tomographic systems and comparable with CT scan distortion.

References