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Evaluation of the difference in accuracy between implant placement by virtual planning data and surgical guide templates versus the conventional free-hand method – a combined in vivo – in vitro technique using cone-beam CT (Part II)

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SUMMARY. Purpose: **The purpose of this study was to assess the accuracy of implant placement after virtual planning of implant positions using cone-beam CT data and surgical guide templates, and to match the results with those achieved with the conventional free-hand method.** Materials and methods: **Twenty-three implants were placed in 10 patients with a Kennedy Class II with 3-dimensional (3-D) planned surgical guide template. Manual implantation was performed in anatomical casts of the same patients by a prosthodontist and a maxillo-facial surgeon. Postoperative images of casts were superimposed onto the preoperative image of virtual planned ideal position of the implant.** Results: **The 3-D surgical guide template produced significantly smaller variation between the planned and actual implant positions at the implant shoulder (0.9 mm (0–4.5)) and apex (0.6–0.9 mm (0.0–3.4)) compared with the free-hand implantation (2.4–3.5 mm (0.0–7.0); $p = 0.000$ and 2.0–2.5 mm (0.0–7.7); $p = 0.002$). Accuracy of axis was also significantly improved.** Conclusions: **Accuracy of implant placement after virtual planning of implant position using cone-beam CT data and surgical templates is high and significantly more accurate than free-hand insertion. The demonstrated method of superimposing radiographic images of postoperative casts and virtual planning images is a useful method, which allows reduced patient radiation exposure.** © **2009 European Association for Cranio-Maxillo-Facial Surgery**

Keywords: **dental implantation, image processing, computer-assisted, three-dimensional, patient care planning**

INTRODUCTION

The use of computer-aided surgical systems for dental implant bed preparation and implant placement results in an average precision within 1 mm of implant position and within 5° of deviation for implant inclination (*Besimo* et al., 2000; *Sarment* et al., 2003; *Schneider* et al., 2004; *Widmann* et al., 2005; *Van Assche* et al., 2007; *Ersoy* et al., 2008). Recently published in vitro and in vivo studies indicate no significant differences between the different computer-aided surgery systems in dental implantology (*Wittwer* et al., 2007). Additionally, there is no significant difference in accuracy between the use of surgical templates or intraoperative navigation using optical tracking (*Ruppin* et al., 2008).

Precision and accuracy of computer-based or –supported implant placement is valuable only if an exact transfer to the intraoral anatomy is possible. The use of surgical templates requires good intraoperative stability of the guide. Fixed intraoral reference points can effectively improve precision in cases of unilateral bone-supported and non-tooth-supported guides (*Di Giacomo* et al., 2005; *Holst* et al., 2007).

Most currently published studies have evaluated the accuracy of computer-aided surgical systems. Only a few consider the clinical effectiveness of these systems in comparison with the conventional free-hand method. It has been reported that the accuracy of free-hand implantation is sufficient for most clinical situations (*Brief* et al., 2005); it is also reported that computer-aided surgical systems reduce the risk of damage to adjacent structures (*Fortin* et al., 2003; *Suzuki* and *Suzuki*, 2008). Accurate presurgical planning also permits implementation of restorative goals (*Lal* et al., 2006; *Nickenig* and *Eitner*, 2007; *Katsoulis* et al., 2008).

The purpose of this study was to assess the difference in accuracy between implant placement after virtual planning using cone-beam CT data and surgical guide templates versus the conventional free-hand method.

The applied method of evaluating planned and achieved implant position, with elimination of postoperative radiation exposure, was described by *Nickenig* and *Eitner* (submission part I). It was hypothesized that this new evaluation technique provided results similar to those provided by comparison of pre- and postoperative CT imagine, i.e. confirming a high rate of precision for

computer-aided surgical techniques and a explicit reduction of precision with the free-hand method (*Fortin* et al., 2003; *Brief* et al., 2005; *Suzuki* and *Suzuki*, 2008).

MATERIALS AND METHODS

Patient selection

Ten patients with a Kennedy Class II defect in the mandible were randomly selected from all patients who had undergone implant placement using cone-beam CT data for a virtual planning of implant positions and surgical guide templates in a three-month interval.

All patients got an integer ID-number which based on the data of their appearance in the clinic. Out of the group of patients who fulfilled the inclusion criteria the first ten patients with an impair ID were selected for the study.

Inclusion criteria were unilateral free-end gap in the lower jaw, the need for preoperative cone-beam CT, and no clinical requirement of augmentation procedures. Further inclusion criteria defined by the initial anatomical situation were a minimum distance of 2 mm to adjacent anatomical structures (mandibular canal, mental foramen, adjacent teeth) and a minimum length of 10 mm and a minimum diameter of 4 mm of the planned implants. If possible a virtual implant position central to the restorative goal (radiopaque simulation of the fixed partial denture in the template; Fig. 1).

Implant placement with surgical guide system
A surgical template was built for each patient according to the protocol of *Nickenig* and *Eitner* (submission part I):

1. First, a wax-up with optimized tooth position was created.
2. Based on this wax-up a scanning template was fabricated out of a radiopaque acrylic resin.
3. Axial images were obtained by cone-beam CT with a DVT NT3 G machine (New Tom Company, Verona, Italy).
4. The CT data were transferred in DICOM-size to the planning software (coDiagnostiX®, IVS-Solutions, Chemnitz, Germany) that provides real 3-dimensional (3-D) information for planning implant positions.
5. The dental technician remounted the scanning template into a special laboratory appliance, inputting the coordinates of each virtually calculated implant position.
6. The scanning template was prepared with small tube-in-tube system with varied channel diameter dimensions (2 mm, 2.5 mm, or 3 mm) to accomodate different drill sizes used during oral surgery. The scanning template thus becomes a drill template/drill guide.
7. The surgical guide template was placed on existing teeth; an additional anchor pin was not necessary. In all cases the implant bed could be prepared by transmucosal drilling with mucosal punching using the 3-D planned surgical guide.

Twenty-three rough-surfaced microthreaded implants (Replace Select Straight Groovy, Nobel Biocare AB, Gothenburg, Sweden) were placed in the lower jaws of ten patients according to the manual for the Replace Select Straight System.

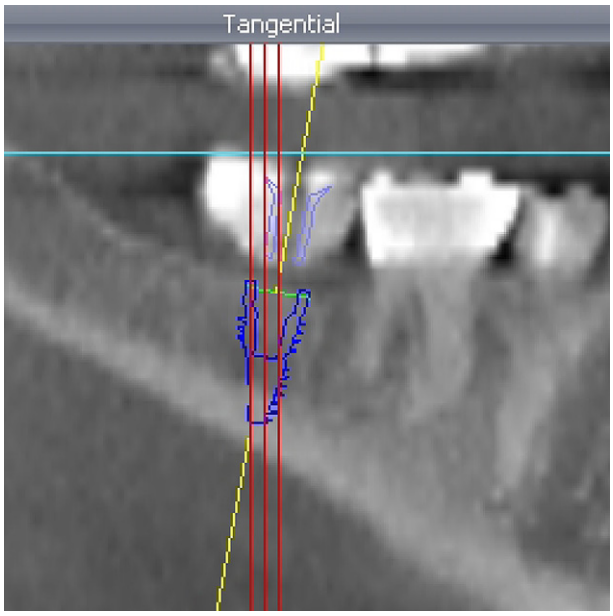

Fig. 1 – Criteria for virtual planning of implant positions: sagittal view of image showing minimum distance of the implant to linea mylohyoidea and mandibular canal and positioning of the implant central to the restorative goal (yellow line).

The same dentist performed all implant sugeries clinically.

Implant placement with conventional free-hand method
Manual implantation was performed in anatomical casts of lower jaws (contents: 90% dental plaster (fuji rock®, GC Europe, Belgium-Leuven); 7% pumice stone powder; 3% barium sulfate) of the same ten patients who had undergone real implantation.

Both a prosthodontist and a maxillofacial surgeon (not the same dentist who performed implant placement with guided surgery) conducted the free-hand insertion. They were instructed to insert identical sizes and numbers of implants as performed in the corresponding operations into the anatomical casts of the patients' lower jaws. The surgeons had access to the panoramic X-ray and an articulated model of the upper jaw; they were instructed to place the implants in an ideal surgical and prosthetic position. The surgical technique used for fixture placement followed the manual for the Replace Select Straight System and was performed with an original drilling machine and new drills.

A cone-beam CT with a DVT NT3 G machine (New Tom Company, Verona, Italy) was subsequently performed for the radiopaque casts with the implants.

Matching of the 3-D images

(1) Evaluation of implant placement with surgical guide system: To compare the planned and achieved positions of the implants, a postoperative cone-beam CT was taken of the master cast model with implant