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Clinical Paper
Dental Implants

An accuracy study of computer-planned implant placement in the augmented maxilla using osteosynthesis screws

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Abstract. Previous research on the accuracy of flapless implant placement of virtually planned implants in the augmented maxilla revealed unfavourable discrepancies between implant planning and placement. By using the osteosynthesis screws placed during the augmentation procedure, the surgical template could be optimally stabilized. The purpose of this study was to validate this method by evaluating its clinically relevant accuracy. Twelve consecutive fully edentulous patients with extreme resorption of the maxilla were treated with a bone augmentation procedure. Virtual implant planning was performed and a surgical template was manufactured. Subsequently, six implants were installed using the surgical template, which was only supported by the osteosynthesis screws. Implant deviations between planning and placement were calculated. A total of 72 implants were installed. Mean deviations found in the mesiodistal direction were 0.817 mm at the implant tip and 0.528 mm at the implant shoulder. The angular deviation was 2.924°. In the buccolingual direction, a deviation of 1.038 mm was registered at the implant tip and 0.633 mm at the implant shoulder. The angular deviation was 3.440°. This study showed that implant placement in the augmented maxilla using a surgical template supported by osteosynthesis screws is accurate.

Key words: implant planning; CAD/CAM technology; surgical guides; sinus floor elevation; flapless implant surgery; edentulous maxilla; cone beam computed tomography; computer-assisted; atrophic maxilla; accuracy; osteosynthesis screws.

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Previous research on the accuracy of flapless implant placement of virtually planned implants in the augmented maxilla revealed unfavourable discrepancies between implant planning and placement. These inaccuracies occurred mainly due to translations and rotations of the surgical template, which is corroborated by the relatively flat alveolar process. A previously published study by Verhamme et al. proposed a new method to eliminate these rotations and translations through use of the osteosynthesis screws already placed during the first stage augmentation procedure; these act as a support for the surgical template during implant placement.[1]

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The aim of this study was to evaluate the accuracy of this new approach in a larger patient population.

Materials and methods

Augmentation procedure

Twelve consecutive fully edentulous patients were enrolled prospectively in this study. These patients showed extreme atrophy of the edentulous upper jaw. All patients underwent a maxillary augmentation procedure using iliac crest bone grafts. After performing a sinus floor elevation procedure, autologous bone particles were applied. Subsequently, corticocancellous bone blocks were fixed onto the maxillary alveolar process. For this procedure, six to eight osteosynthesis screws were used (2.0 mm; Champy System, KLS Martin, Tüttlingen, Germany). These were placed perpendicular to the original alveolar process in the buccolingual direction (Fig. 1).

The study protocol was approved by the Research Ethics Committee of Radboud University Nijmegen Medical Centre, The Netherlands.

Image acquisition and implant planning

Cone beam computed tomography (CBCT) scans were obtained to determine the relationships between the denture and osseous structures and to locate the osteosynthesis screws; scanning was performed with the i-CAT 3D Imaging System (Imaging Sciences International Inc., Hatfield, PA, USA) using a setting of 120 kV peak, pulses of 3–8 mA, 8 cm scan height, and an exposure time of 20 s. A first scan was made of only the relined denture containing the markers; this was followed by a second scan of the patient wearing this denture. Subsequently, three-dimensional (3D) models were created using Maxilim software (Medicim NV, Mechelen, Belgium). By registering the two models to each other according to the double-scan procedure, the relationship between the denture and osseous structures was obtained.[2] Six Nobel Replace Straight Groovy implants (Nobel Biocare, Zürich, Switzerland) were virtually planned at the best achievable position for bone and prosthetic demands, using Maxilim software.

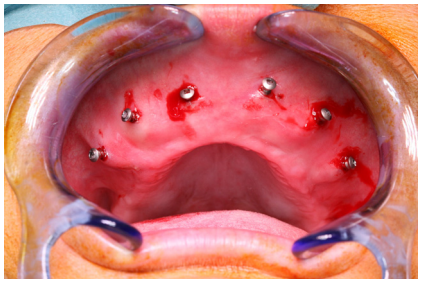

Fig. 1. The partly unscrewed osteosynthesis screws during the implant installation procedure. Screws were placed perpendicular to the alveolar process during the augmentation procedure.

Surgical template creation

A surgical template was created according to the technique described by Verhamme et al.[1] In addition to the conventional way of supporting the surgical template on the alveolar process and palate, this technique uses the osteosynthesis screws, already introduced in the augmentation procedure, as additional support for the surgical template to reduce its rotations and translations during implant placement.

First, the osteosynthesis screws were segmented and reconstructed from the scan. To obtain the exact location of the screw central axis and screw head, 3D computer-aided design (CAD) models of these screws were registered to the segmented screws. Based on these central axes of the screws, a conventional surgical template with additional support structures to rest the template on the screws was virtually created (Fig. 2). This template was 3D printed from biocompatible resin. Finally, a plan was made indicating both the screw and implant locations to prevent interference between screws and implants. In the event that such an interference was unavoidable, the surgeon could choose to first install the non-interfering implants, thereby ensuring that the patient specific template was still stable before loosening that specific screw to allow implant placement.

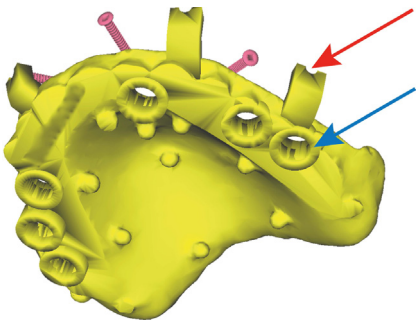

Fig. 2. Virtual model of the surgical template with the drill guide sleeves (blue arrow) at the implant positions and half tube structures (red arrow) at the osteosynthesis screw locations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

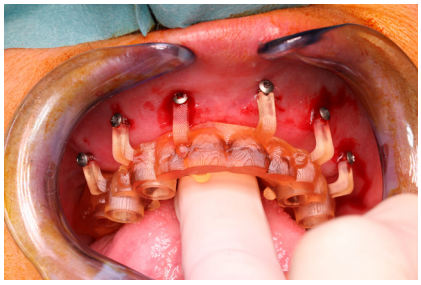

Fig. 3. Surgical template during surgery with five of the six extensions properly resting on the osteosynthesis screws.

Surgical procedure

All patients received general nasotracheal anaesthesia without local anaesthesia. By holding the surgical template in place, the supports of the template showed the locations where the osteosynthesis screws were present. These were unscrewed by only 2–3 mm and as their central axis was known, this allowed optimal support of the patient-specific surgical template which was designed based on the central axis of the screw (Fig. 3).

In a next step, six implants were installed according to the NobelGuide procedure,[3] and the predetermined installation plan. After implant installation, the surgical template was removed together with the remaining osteosynthesis screws.

Validation

A postoperative CBCT scan was acquired 1 week after surgery using the same settings as for the preoperative scan. This scan was registered to the preoperative scan that was used for virtual implant planning using voxel-based registration.[4] Next, the IPOP validation method was used (implant position orthogonal projection).[5] In brief, the postoperative implants are first segmented. The postoperative position of each implant is then compared to the planned implant position. Resulting deviations are calculated as 3D measurements, which are subsequently divided into the clinically relevant buccolingual (BL) and mesiodistal (MD) directions. This validation method was performed for the variables ‘implant tip’, ‘implant shoulder’, ‘angulation’, and ‘depth’. Finally, the rotations in terms of pitch, roll, and yaw (Fig. 4) and translations of the surgical template between the planned and postoperative situations were calculated in

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