CHAPTER 7


Ali Tahmaseb, Renaat De Clerck, Daniel Wismeijer
Abstract

**Aim:** The purpose of this study was to evaluate the performance of a computer-aided three-dimensional planning protocol in combination with previously inserted reference mini-implants and CAD/CAM technology to restore completely edentulous patients. The study evaluated implant and superstructure survival in a prospective clinical trial. **Materials and Methods:** The plan protocol called for treatment of 35 patients who were edentulous in either jaw. Mini-implants were used to establish a platform for computerized tomography and the fixation of the surgical template. The planning software based on 3D simulation was used to plan ideal implant placement, digitally integrating the future prosthetic and anatomic situations to design the final superstructure. **Results:** A total of 34 patients, 20 with edentulous maxillae, 10 with edentulous mandibles and 5 patients with edentulism in both arches, were treated. All patients received definitive prostheses on the day of surgery. The majority of patients treated in maxilla underwent a sinus graft procedure to achieve sufficient bone to place implants. A total of 40 final superstructures were inserted and immediately loaded. Of the 240 inserted implants 229 survived (95.4%), with 146 (93.6% survival) and 83 (98.8% survival) implants in the maxillary and mandibular jaws, respectively. Of the 11 implants that failed in the maxilla, 10 occurred in the patients with augmented sinus. All the final restorations demonstrated clinically acceptable fit. **Conclusions:** When using implant and superstructure survival, reference based guided surgery seems to be a reliable treatment option for treatment of edentulous patients. The CAD/CAM superstructure, inserted and loaded immediately after guided implant insertion, demonstrated acceptable fit to the underlying implants.
Introduction

Computerized tomography (CT)-guided dental implant surgery is a treatment modality that may offer several advantages for both patients and clinicians. Specifically, the introduction of cone beam CT (CBCT) provides an affordable method for the application of computerized tomography to the dental environment. With this technology, three-dimensional imaging of the jaws is possible. The data derived from these images allows the simulation of a virtual patient. 1-5 This virtual information could also be used in computer-aided design and computer-aided manufacturing (CAD/CAM) to create a surgical guide that directs flapless implant placement according to a predetermined planning protocol that was established with the ultimate prosthetic design as the treatment objective. For example, using a limited patient population suggested that even flapless implant placement is useful when it is based on accurate and reliable 3D CT imaging data and dedicated implant-planning software. 6 The information obtained from the predetermined implant location could be used to prefabricate the dental prosthesis and achieve immediate loading of dental implants. Also the new technologies on the surface modification of the dental implants suggest predictable outcome in early or immediate loading procedures.7

The literature describes two main fabrication modalities of the drill guides used in these systems: rapid prototyping (stereolithography) and model-based drill guide. Rapid prototyping or stereolithography is a technique in which a 3D image of the jaw and the planned implants are used to create a drill guide, slice by slice from bottom to top, in a vessel of liquid polymer that hardens when struck by a computer-driven laser beam. 8-11 Model-based drill guides are fabricated by using an acrylic part that fits on the cast recorded from the patient. The computer matches the scan images and the cast according to different types of references and a computer-driven device drills the implant positions in the acrylic part according the implant–planning protocol. 12,13

Although the reports on these techniques emphasize high implant survival rates, a systematic review 14 questioned the precision and reliability of the commercially available techniques. In essence, the technique provides a reliable approach for implant survival however the
adaptation of the prefabricated prosthesis is not sufficiently accurate to allow this to be a definitive prosthesis.

In the present study the results of a new technique used to increase the precision of guided surgery are reported. The aim of this study is to evaluate the use of a computer-aided three-dimensional planning protocol in combination with previously inserted reference mini-implants and CAD/CAM technology to restore completely edentulous patients in a prospective clinical trial.

**Material and Methods**

This was a prospective study designed to evaluate the performance of implants placed in immediate function to support full arch fixed restorations that were fabricated prior to surgery using CAD/CAM technology. The ethical committee of VU University (Amsterdam, Netherlands) approved the study. All patients were informed about the treatment protocol and its risks and provided written informed consent.

**Inclusion criteria**

- Patients referred to a university-based dental clinic for implant placement between April 2006 and May 2007 were selected to participate in this study if they met inclusion and exclusion criteria (tables 1). In general the inclusion criteria demanded patience that were not growing, had sufficient bone for implant placement and were generally healthy. Exclusion criteria consisted of systemic disease, localized mucosal lesions, radiation therapy, para-functional activity, and inadequate bone quantity or quality.
- Patients referred to a university-based dental clinic (University of Amsterdam, ACTA, Department of Implantology and Fixed Prosthesis) for implants between April 2006 and May 2007 were selected according to the following criteria:
  - Individuals of either gender, older than 25 years, with full craniofacial growth;
  - Dentate patients with failing maxillary and/or mandibular teeth;
  - Sufficient osseous structure to place 4–8 dental implants with a minimum length of 13 mm at the time of surgery;
  - Negative pregnancy test for women of childbearing age;
  - At least a 3-month period between extraction or loss of teeth at the implant site and the date of surgery;
patients willing to provide written informed consent and willing to comply with the study requirements.

The patients were selected after clinical and radiographic (panoramic) evaluation. The existing dentures were also evaluated and shortcomings were detected and noted. Alginate impressions of both jaws were made and stone casts (Model 1) as well as impression trays for the use of open impression copings were fabricated in the dental laboratory.

<table>
<thead>
<tr>
<th>Exclusion criteria</th>
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<tr>
<td><strong>Systemic exclusion criteria</strong></td>
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<tr>
<td>Conditions requiring chronic routine prophylactic use of antibiotics (e.g. rheumatic heart disease, bacterial endocarditis, cardiac valvular anomalies, prosthetic joint replacements);</td>
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<td>Conditions requiring prolonged use of steroids;</td>
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<td>History of leucocyte dysfunction and deficiencies;</td>
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<td>History of bleeding disorders;</td>
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<td>History of neoplastic disease requiring the use of radiation or chemotherapy;</td>
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<td>History of renal failure;</td>
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<td>History of metabolic bone disorders;</td>
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<td>History of uncontrolled endocrine disorders;</td>
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<tr>
<td>Physical handicaps that would interfere with the ability to perform adequate oral hygiene;</td>
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<td>Use of any investigational drug or device within the 30-day period immediately before implant surgery (study day 0);</td>
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<td>Alcoholism or drug abuse;</td>
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<td>Conditions or circumstances, in the opinion of the investigator, that would prevent complete participation or interfere with analysis of the results, such as history of non-compliance and unreliability.</td>
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<tr>
<td><strong>Local exclusion criteria</strong></td>
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<td>Mucosal diseases;</td>
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<td>History of local irradiation therapy;</td>
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<tr>
<td>Presence of osseous lesions;</td>
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<td>Severe smoking (&gt;10 cigarettes/day);</td>
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<td>Unhealed extraction sites (&lt;4 months after extraction of teeth);</td>
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<td>Bone surgery at the implant site(s) (bone grafts, guided tissue regeneration techniques for bone enhancement) before implant placement, unless performed more than 6 months before implant placement;</td>
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<td>Surgical sites requiring bone grafting at the time of surgery;</td>
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<td>Visible bruxism or clenching habits;</td>
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<td>Persistent intra-oral infection;</td>
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<td>Lack of primary stability of 2 (or more) implants at the time of surgery (the patient must be withdrawn and treated accordingly);</td>
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<td>Inadequate oral hygiene or lack of motivation for adequate home care.</td>
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*Table 1: Exclusion criteria*
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Preparation phase

Reference implants were inserted at predetermined locations, which were chosen on the cast (model 1). Three reference implants of 3-mm diameter and 4–6 mm length (Straumann, Basel, Switzerland) were inserted. These implants were designed on the basis of the existing architecture of Straumann Standard Implants (soft Tissue Implants, Straumann, Basel, Switzerland). The implant was placed using a pilot drill even when soft bone was encountered. These implants were inserted in a triangular pattern at least three weeks prior to the final implant surgery (Fig. 1) at positions chosen to avoid interference with the anticipated locations of the prosthesis supporting implants: the maxillary reference Implants were thereby inserted in the midline and bilateral tuberosities, and the mandibular implants were inserted in the midline and bilateral dorsal regions. The reference mini implants were inserted under local anaesthesia after performing a minor flap for secure insertion.

Impressions of the reference Implants were recorded immediately after insertion by using the open impression trays and polyether impression material (Impregum, 3M ESPE, Seefeld, Germany). Specially designed impression copings (Straumann, Basel, Switzerland) were used. A master stone-cast (Model 2) was fabricated by using mini-implant analogues (Straumann, Basel, Switzerland), as illustrated in Figure 1. If patients required a sinus graft, the patients underwent the sinus graft procedure and the reference Implants were simultaneously inserted and left submerged for healing over a period of 6 months. The impressions were recorded after uncovering the reference mini-implants in the second-stage surgery. Thereafter, the patients of all groups were treated according to the conventional prosthetic procedure, followed by bite registration and fabrication of a wax-up (Fig. 2).

After approval of the wax-up, function, aesthetic and phonetics, a plaster matrix was prepared to duplicate the final wax-up. A CT template was fabricated by using barium sulphate-containing resin (Vivotac/Orthotak, Ivoclar Vivadent, Schaan, Liechtenstein) for CT scanning (Fig. 2). This template formed the basis for manufacturing the final dental superstructure and permitted full diagnostic evaluation of aesthetics, function, and occlusion.

The CT template was affixed to the reference Implants with a specially designed screw complex before imaging (Fig. 3). The screw complex not only stabilized the CT template but
**Figure 1:** Insertion of RMI, 3 per jaw. An impression has been taken and stone cast 1 has been fabricated.

**Figure 2:** The prosthetic preparation. Bite registration and wax-up.

**Figure 3:** Left, Plaster key (PK) to duplicate the final wax up. Right, the affixed to Reference implants barium sulphate CT-template together with the screw complex.

also compensated for scanning error. A sphere-shaped radiopaque-percha point of 1 mm was positioned on the top of the screw complex. As such, the gutta-percha marker was always visible on cross-sections (range, 0.5–1 mm) on CT images without any distortion.

CBCT device Morita, Japan) was used to scan the jaw and fixed CT template were recorded to enable pre-operative implant planning. The CT data were processed to generate multiple cross-sections and 3D images by using the planning software (Exeplan, Brussels, Belgium) as illustrated in Figure 4. The implant positions were planned according to the bone anatomy.
and future prosthetic situation and were represented by the barium sulphate-enhanced image of the diagnostic template affixed to the reference Implants.

After approval of the plan, the data were exported to the CAD program. The surgical template and framework of the future dental superstructure were designed by using the same digital data. In the design software, the imported CT data and planned implants were represented as dots denoting the apex and top of the implants, and thus, their orientation, and length. The design of the template and titanium bar of the future superstructure was simplified by the clarity of the barium sulphate-enhanced image of the diagnostic template. The design software permitted cross sectioning in different segments of the diagnostic template, which facilitated delineation of the titanium bar that accords with the available volume of the future prosthesis. The design data were then imported back into the planning to virtually check the fit of the planned implants. In this way, errors in design within the virtual environment were eliminated before fabrication. Figure 5 illustrates the CAD phase.

After the plan and design of the dental superstructure were approved, the data were sent to a milling company (Es-Healthcare, Beringen, Belgium). A simultaneous 5-axis milling device was used for fabrication of the surgical template and titanium frameworks. The frameworks were then sent to a dental laboratory (Van de Bijl TTL, Tilburg, The Netherlands; Ceulemans Dental Laboratory, Kessel, Belgium; Kint-de Jong, Harlem, The Netherlands, Kies Tandtechnick, Amsterdam, The Netherlands) to prepare the full dental prosthesis (Fig. 6) by using Model 2 and the Plaster Key.

Surgical phase

The patients received local anaesthesia. The surgical template was then connected to the mini-implants with a narrow-neck occlusal screw (Straumann, Basel, Switzerland). Stability of the drilling guide was established. An open structure drill guide was used to ensure visualization of the operative site. Further, additional, external, cooling was utilized the osteotomy as required (Fig. 7).

The guiding segment of each drill was of standard diameter and the stop dictated the depth of osteotomy, which was pre-determined during the computer-aided planning stage. No additional instruments were used adjust the diameter of each drill (Fig. 8). During the drilling sequence, drills of three different diameters (2.2 mm in three lengths as the pilot drill; 2.8 and 3.2 mm for 3.3 and 4.1 mm length implants, respectively) were used (Fig. 9).
The pre-planned implants (Straumann Standard Implants, Soft Tissue Implant, which were pre-packed with special for this study designed implant mount, Basel, Switzerland) of 4.1- or 3.3-mm diameter and 8, 10, or 12 mm length were then inserted by using an implant mount (Straumann, Basel, Switzerland) modified with a stop and the guiding segment fitting the drill guide (Fig. 9). These implants were specially pre-packed including the modified guided implant mount. The Precision pin concept was used to determine the correct vertical position of the implants as planned on the computer software. To determine whether the implant reached the desired vertical position in the template, the Precision pin concept was used. The precision pin is placed in the implant guide via the groove, which is situated in the surgical template. When inserting the implant, a small amount of force is exerted on it, moves into the groove and blocks deeper insertion of the implant (Fig. 10). The procedure was repeated for each implant in the treated jaw (Fig. 11).

After placing the last implant, the surgical template was removed by unscrewing the connections to the Reference implants and implants (Fig. 12). The reference Implants were removed by reverse torquing. Immediately thereafter, the dental superstructure was connected to the implants without using abutments (Fig. 13) and torqued with 30 Ncm using Straumann Torque wrench (Straumann, Basel, Switzerland). The schematic view of the complete procedure is shown in Figure 14. The passive fit was evaluated clinically and by panoramic radiography after tightening the connection screws (Fig. 15). The occlusion was checked and minor corrections were made. Any other complications than minor occlusal adjustments were considered as prosthetic complication and were registered.

The patients received post-surgical medication (ibuprofen, 600 mg) and were asked to rinse thrice a day for at least seven days with chlorhexidine solution. Patients were also asked to be cautious and avoid extreme chewing activity.

Follow-up

Patients returned for follow-up at one week, 2 months, 6 months and 12 months following surgery. They were assessed using clinical and radiographic (panoramic X-rays) means (figs. 15-16). In addition resonance frequency was assessed using an Osstell device (Osstell A.B, Gothenburg, Sweden). The occlusal screws were checked and torqued again (30 Ncm) when it was necessary.
Figure 4: the determination of the reference points on the CT using implant placement-planning software.

Figure 5: CAD stage:
Upper left: The dots, digital coordinates, which represent the most coronal and the most apical points on the planned implants.
Upper middle: CAD image of the planned implants and prosthetic setup
Upper right: CAD image of the designed drill guide
Lower left: STL file of a designed framework
Lower middle: Designed framework in situ
Lower left: A cross section through all structures

Radiographic analysis
The pre- and post-surgical panoramic x-rays were analysed by three different individuals. Any implants with possible bone lost were recorded as the demarcation line between the rough and polished surface of Implants was considered as initial bone level. Any bone loss below this level was registered.
Statistical analysis

The per-patient proportion and jaw-wise proportion of failed implants were calculated. These proportions were compared across groups using a Kruskal–Wallis test, Mann–Whitney U-tests and a $\chi^2$–test.

![Image of the finished superstructure](image)

**Figure 6: The finished superstructure**

![Image of the drill guide](image)

**Figure 7: Left: The drill guide affixed to the reference mini implants (RMI) in a stable fashion. Middle and right: The open drill guide provides a good vision and accessibility of the operation site.**
Figure 8: Left: Schematic view of the drill sequence, Right: The guided drills: The guiding segment of 9mm has an identical diameter in all drills.

Figure 9: Guided osteotomy

Figure 10: The schematic illustration of the precision pin concept, from left to right:
- Groove situated on the drill guide
- Corresponding recess on the implant-mount.
Figure 11: Guided implant placement with vertical control using the precision pin concept

Figure 12: Clinical view after removal of the drill guide

Figure 13: The superstructures were connected immediately after the surgery.
Results

Thirty-four patients (17 men and 18 women) with 40 edentulous jaws were treated and completed the study.

The patients were divided into different groups according to the treated jaw and the amount of residual bone volume (table 2):

**Group Edentulous Mandible**: 10 Patients with adequate amount of bone volume in the edentulous mandibular arch to insert implants

**Group Edentulous Maxilla**: 5 Patients with adequate bone volume in the edentulous maxilla to insert implants

**Group Edentulous Augmented Maxilla**: 10 Patients with insufficient bone volume in the posterior maxilla who required sinus graft augmentation as a pre-implant treatment 6 months prior to the implant surgery.

**Group both jaws**: 5 patients with adequate bone volume in both jaws to insert implants.
In total, 240 implants (84 in 15 mandibles and 156 in 20 maxillas) were inserted. All the patients completed at least one year of evaluation (12–36 months). Sixty implants were inserted in five patients (Group both jaws) with combined, upper and lower, jaws.

In general, 229 of the 240 inserted implants survived (95.4%), with 146 (93.6%) and 83 (98.8%) implants in the maxillary and mandibular jaws, respectively. When looking at the individual groups, 1 (out of 60) implant failed in Group Edentulous Mandible (98.4% survival rate), 1 (out of 30) implant failed in Group Edentulous Maxilla (96.7 survival rate), 9 (out of 90) implants failed in Group Edentulous Augmented Maxilla (90% survival rate) and finally none (out of 60) implants failed in Group both jaws (100% survival rate).

Four implants in one patient were failed 6 months post surgical; this patient was considered to have a cluster failure. Was this in the augmentation group? It would prove be best to describe this was in, my assumption is that it would be in the augmentation and if this is the case it might be nice to point that out. The remaining failures were limited to one failed implant per patient. Most of the failures were diagnosed and removed during the last appointment, at twelve months post-operatively. Figure 17 shows the result on the implant level.

All surgical procedures were performed with a flapless protocol. However, in one case, a mini-flap was raised to correct an extensive knife-edge ridge diagnosed during the treatment-planning phase.

One patient reported some post-operative pain, which lasted for three days. The other patients experienced no pain to minor pain limited to the surgery day.

All the metal frames (n=40) were produced in the first production run, avoiding the need to remake the individual frameworks before the surgery and showed a clinically passive fit at the time of surgery. No adjustments of the metal-to-implant fit were needed. 39 (out of 40) finished superstructures (97.5%) showed satisfactory occlusion and no major adjustments were necessary.

The frameworks were placed and torqued with 30 Ncm using Straumann torque wrench immediately after the implant insertion. During the first recall appointment, one week post-op, all occlusal screws were checked and it was found that in almost all patients some minor screw loosening was occurred, although these findings were not recorded during the following recall appointments.

One patient (both maxillary and mandibular jaws treated in one surgery) experienced
occlusion failure. Although the framework fitted well on the implants, the occlusion differed from that established during the preparation phase. The occlusion of the prosthesis in the mandible was corrected extensively for the new FDP to function. The mandibular superstructure was adjusted with new teeth arranged appropriately six months post-operatively.

Patient with the cluster failure, (from Group Edentulous Augmented Maxilla) the superstructure was obviously lost as well. In this case, patient was retreated following the conventional implant approach and restored according to delayed protocol.

In two cases where an implant was lost, the superstructures were adjusted in cooperation with the dental laboratory. The respective implant connection was cut, filled with acrylic, and re-attached onto the remaining implants. However, in one case of implant failure in the mandible, the lost implant was replaced three months later. The original drilling guide was used during the implant surgery and the same superstructure was re-attached with a passive fit.

The radiographic analysis 229 remaining implants showed bone lost on two implants, both in posterior augmented maxilla, up to second implant threads. 15 implants were not measurable due to the quality of the panoramic images. Resonance frequency analysis (RFA) was recorded during the last appointment and showed that the ISQ (Implant Stability Quotient) of the remaining implants was above 65.

A Kruskal–Wallis test indicated that there was no statistically significant difference among the patients with only maxillary implants, only mandibular implants and implants in both jaws with respect to the mean proportion of failed implants (p = 0.308). Further, no significant difference was found between the patients with maxillary implants and those with mandibular ones (Mann–Whitney U-test, p = 0.298).

A Mann–Whitney U-test showed no statistically significant difference in the proportion of failed implants in the maxillary jaw (p = 0.313) between the patients with and without bone augmentation. In addition, smoking did not influence the results (p = 0.424 for the maxillary jaw and p = 0.546 for the total proportion of failed implants).

The total number of failed implants in the maxillary jaw was significantly different between the patients with and without bone augmentation ($\chi^2 = 4.57$, df = 1, p = 0.033): a relatively higher number of implants failed in the patients with bone augmentation. However, when this
analysis was repeated without including the patient with the cluster failure, no difference was noted ($\chi^2 = 1.90$, df = 1, $p = 0.169$). There was no statistically significant difference between the patients with and without bone augmentation having at least one failed implant ($\chi^2 = 1.04$, df = 1, $p = 0.307$).

<table>
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<th>Groups</th>
<th>Patients</th>
<th>Implants</th>
<th>Failed implants</th>
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<tr>
<td>Group Edentulous Mandible</td>
<td>10</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>Group Edentulous Maxilla</td>
<td>5</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Group Edentulous Augmented Maxilla</td>
<td>15</td>
<td>90</td>
<td>9</td>
</tr>
<tr>
<td>Group both jaws</td>
<td>5</td>
<td>60</td>
<td>0</td>
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*Table 2* Study groups and patient distribution

Next, 120 Reference implants were inserted in the maxillary and mandibular jaws (75 and 45 Reference implants, respectively). Fourteen Reference implants (8 maxillary [9.4%] and 6 mandibular [13.3%]) were lost prematurely. All the premature loss of Reference implants occurred before the CT-scan procedure and during the prosthetic fase. One patient lost two Reference implants and needed re-treatment by repeating the procedure to insert Reference implants. In fifteen patients of Group B, the insertion of Reference implants and sinus graft procedure were performed at the same time; only three of these Reference implants (6.6%) were lost and were replaced (Fig. 17). There was no statistically significant difference in the success or failure of the mini-implants between the maxillary and the mandibular jaws ($\chi^2 = 0.194$, df = 1, $p = 0.660$) or between the augmented and the non-augmented maxillary jaws ($\chi^2 = 1.889$, df = 1, $p = 0.169$). When this analysis was repeated at the patient level, there was no difference in the survival or failure of the mini-implants among the maxillary, mandibular, and augmented maxillary jaws.

![Post-op panoramic X-rays](image-url)

*Figure 15: Post-op panoramic X-rays*
and both jaws ($\chi^2 = 1.377, df = 2, p = 0.502$) and between the augmented and the non-augmented maxillary jaws ($\chi^2 = 2.482, df = 1, p = 0.115$).

**Discussion**

The present clinical trial demonstrates the possibility to digitally design and fabricate surgical guides and superstructure and their reliability to integrate this technique in immediate loading of dental implants in fully edentulous patients. In this protocol, Reference implants were inserted before the actual implant insertion at the beginning of the procedure; they remained during the procedure and were used to place the drill guide during the surgery. They were removed after the insertion of the last implant and removal of the drill guide. Thus, unlike in the other concepts of guided surgery, there are clear references from the beginning of the procedure to the end of the treatment period. However, the insertion procedure of these mini implants is an extra, minor surgery for the patients.

![Figure 16: 12 months post-op panoramic x-rays:
-Panoramic, patient: Fully integrated implants,
Panoramic, patient: one failed implant, upper right most posterior.](image)

A total of 13 patients lost 14 Reference implants prematurely, before the CT scan- and thus final procedure; these failures may be attributed to their design, which is similar to that of Straumann standard implants. Straumann standard implants have a passive, not self-tapping, feature; thus, a drill is required to insert these implants. Most of the patients treated during this study had a compromised bone condition because of edentulousness for many years. The compromised bone condition and use of the drill might have caused poor primary stability of some of these Reference implants, leading to their premature loss. A self-tapping implant (an
implant that cuts its own path into bone) feature would be a better and more reliable choice. because of edentulousness for many years. The premature lost of Reference implants resulted in compromised reference situation. Although there was only slightly occlusion inaccuracies occurred when one RMI was lost, the loss of multiple Reference implants resulted (in one patient) in extended treatment time where the Reference implants were reinserted.

The exact position of titanium Reference implants is difficult to define on reconstructed images because of CT-specific image artefacts, including scatter radiation, limited dynamic range of the x-ray area detectors, truncated-view artefacts and beam hardening.\textsuperscript{1,3} These artefacts have a significant influence on the image quality (5). Also CT images introduce a transfer error of 0.6 mm (standard deviation of 0.4 mm) in the maxilla and 0.3 mm (standard deviation of 0.4 mm) in the mandible.\textsuperscript{2,15} The positions of the screws were defined, and visualized, in CT images by means of a gutta-percha marker (Fig. 5). A ball-shaped radiopaque gutta-percha point of 1 mm was positioned on the top of the screw complex. As such, the gutta-percha marker was always visible on cross-sections (range, 0.5–1 mm) on CT images without any distortion. (Fig. 18). This information on the measurements is crucial for the subsequent implant planning and superstructure design in a CAD system.

Further to minimize the errors during the surgery, the osteotomy procedure was modified. The guiding segment of each drill was of the same diameter, which fit the drilling guide in a precise manner. The stop on each drill dictated the depth of osteotomy, as pre-determined during the computer-aided planning of the case. Consequently, no additional instruments

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure17.png}
\caption{Reference Implants (RMI) distribution and results}
\end{figure}
were required to adjust the diameter of each drill, minimizing errors during treatment. During
the drilling sequence, drills of three different diameters were used. Each drill was used to
bore through about +/- 2 mm length of bone. This strategy avoids extreme movements during
the osteotomy, which can occur even during complete guided surgery using full-length drills,
and ensures continuous guidance of the drills. The same principles were used when inserting
the implants. The implant mount had the same guiding segment as the drills, which fits into
the drill guide. The stop on the mount determined the implant depth, which was additionally
controlled by using the precision pin. The precision pin gives the implant driver extra
precision to position the implant in the correct vertical dimension determined during the
computerized planning, decreasing the possibility of misfit. Also by utilizing the same data
for planning, surgery, and designing of the surgical guide and superstructure, we excluded
transition error, which may occur when the data has to be translated or scanned.
Furthermore, nine of eleven implant failures occurred in the patients with sinus graft
augmentation before implant insertion. Although the sinus grafts were allowed to heal for at
least six months, the implants were loaded immediately after insertion. In these cases,
therefore, a delayed protocol should be applied. The overall survival rate, 95.4%, is in the
range of previously reported numbers published in ITI Consensus meeting in 2008 16.
Further research on the loading protocol is required to draw any final conclusions. The
patient with the cluster failure received a new treatment where a conventional implant-
retained over-denture was implemented.
In the current study, all the patients were restored according to an immediate loading
protocol. The frameworks were placed and torqued with 30 Ncm using Straumann torque
wrench immediately after the implant insertion. During the first recall appointment, one week
post-op, all occlusal screws were checked and it was found that in almost all patients some
minor screw loosening was occurred, although these findings were not recorded during the
following recall appointments. This might emphasise that the immediate loaded implants had
moved towards the framework during the early post-loading period, due to tension induced
by limited amount of misfit in implant/framework interface. Duyck et al. reported similar
findings in their animal study that prosthesis misfit leaded to topographically adaptation of
immediately loaded implants to the prosthesis, thereby minimizing the existing misfit.17 Still
there are more studies required to determine the clinically acceptable maximum misfit, as
well as the misfit induced micro-movement of dental implants.
Also the lack of an exact information of the condition of the soft tissue around the planned implants during the computer planning faze can effect the long term success of the placed implants. 18-20 More innovation and research in this field may improve the guided procedure. Accuracy of component fit may be evaluated through visual or microscopic inspection, tactile assessment or displacement when single screws are tightened 21-23 and Strain gauge assessments may provide more objective analysis however this approach is more difficult and may not lend itself to routine quality control. Unfortunately all these technique could be used in laboratory environment and not in clinical situation. Post-surgical radiographs taken in this study might indicate the passive fit but it is not a scientifically objective method. Still, it is a fact that an objective fit evaluation in case of patient treated in this study, following a fully digital approach where no master model has been fabricated, might be extremely difficult.

The implant/bone contact analysis was not one of the objectives in this study. For this reason no standardize peri-apical radiographs were taken. However, panoramic radiographs were taken on, 6 and 12 months of post-op evaluation, to monitor any unexpected complication. The panoramic radiographs have been previously described in literature to evaluate the implant/bone contact in atrophic jaws. 24

Figure 18: Right, Clearly visible Gutta Percha point on the CT cross-section.
Left, the exported data of the entire screw complex image.
Conclusions

On the basis of the results, high survival rate of inserted implants and superstructures, in limited number of treated patients, it is concluded that immediate loading of dental implants after reference-based guided surgery is a successful surgical and prosthetic treatment option for fully edentulous patients. Despite that the evidence is weak for a difference between augmentation- and non-augmentation cases, it is proposed to apply the loading protocol with caution in patients with augmentation. The findings emphasise the importance of communication and collaboration between all the involved parties.

Acknowledgments

We would like to thank all the referring colleagues, the dental laboratories Van de Bijl (Tilburg, the Netherlands), Corpix (Antwerp, Belgium), Kint-de Jong (Haarlem, the Netherlands) and Kies Tandtechniek (Amsterdam, the Netherlands) and Erik Schildermans and Stijn Hanssen from ES Healthcare, Hasselt, Belgium, for their clinical support and technical cooperation.

We are also grateful for tremendous support of Straumann Company, Basel Switzerland in general and Dr Rene Willi, Dr A. Haverhals and Mr Wim van Dam in particular.
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