Validation procedures in computerized dentistry
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Citation for published version (APA):

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CHAPTER 3

Approach for valuating the influence of laboratory simulation of implant placement

Keywords: chewing simulation, thermal cycling and mechanical loading, zirconia, veneering, CAD/CAM
3.1 Abstract

Introduction: new digital techniques can be used to improve localization and targeting of implant placement and reduce the inherent invasiveness of surgery. However, further studies are needed for these techniques before they can widely accepted by implantologists. The aim of this study was to compare the orientation differences between planned and placed implants by manual drilling and by drilling with the help of computer planning and guidance.

Material and methods: a partial dentate patient was selected for the study. Between the 44 and 46 a diastema was present. Impressions of both maxilla and mandible were made, where after twenty-six gypsum casts (one maxilla and twenty-five mandibles) of Moldano Blue were produced. The mandible gypsum casts were divided at random into three groups (T,A &B). Group T contained five casts which were used for training. Group A and B had both ten casts. Drilling of the casts in group A was with a drill guide. Group B was the control group and the casts were manual drilled. The drill guide was made during the planning phase in which a scannographic guide with three glass balls as reference markers, a CT-scan and an optical laser scan were used. A special drill guide was produced for the pilot drill (diameter 2.0 mm), because of the high difference of diameter between that drill and the rest, namely two intermediate drills (diameter 3.6mm and 3.8 mm) and one final drill (diameter 4.0 mm). Also a registration bite was made, so that the occlusion was taken in consideration during the planning. Twenty Helix® implants with a length of 10 mm and a diameter of 4.2 mm were placed in the twenty drilled holes of group A and B. The position and direction of the placed implants in the casts were optically scanned by the optical laser scan. Difference between planned and placed implants was determined by matching.

Results: two variables were calculated: ‘XY’ and ‘Angle’. The XY was defined as the distance between the planned and placed implant in a two-dimensional geometry. The Angle was defined as the direction of the placed implant as reference to the three glass balls. The mean XY of group A was 0.198 mm (± 0.0950). Group B had a higher mean XY, namely 1.20 mm (± 0.681). The difference of XY between group A and B was statistically significant (p < 0.05). Also the difference of Angle between group A and B was statistically significant (p < 0.05). Group A had a mean Angle of 2.45° (± 1.55), whereas the mean Angle of group B was 7.05° (± 3.92).

Conclusion: In comparison with manual drilling the use of drill guides lead to a more accurate and predictable implant placement.
3.2 Introduction

In the last years, dental implants faced an increasing growth of popularity. The great aesthetic rehabilitee and the tooth-saving advantages of the neighbouring teeth unlike bridges gave implants a growing demand. However, according to Massey et al. [1] only 17.8% of the implants placed by implantologists could be classified as ‘ideal’ with regard to orientation. This brings a need of a technique or a method for precise surgical planning and accurate placing of implants. New digital techniques could be used to improve localization and targeting of implant placement and reduce the inherent invasiveness of surgery. Verstreken et al. [2] described a planning system for oral implant surgery based on a true three-dimensional approach which allows the interactive placement and adjustment of axial-symmetric models representing implants in the jawbone structures visible on computerized tomographic volume data and largely outperforms the manual planning practice based on two-dimensional dental computerized tomographic images printed or on film. Sarment et al. [3] compared the accuracy of a conventional surgical guide to the of a stereolithographic surgical guide. The stereolithographical technique built surgical guides in an attempt to improve precision of implant placement. This improvement was proved. However, further studies were necessary to validate its clinical use. Tardieu et al. [4] presented a case of immediate loading of mandibular implants using a five-step procedure. The first step consisted of building a scannographic template, the second step consisted of taking a computerized tomographic (CT) scan and the third step consisted of implant planning using SurgiCase software. The final two steps consisted of implant placement using a drill guide created by stereolithography and placement of the prosthesis. Using a CT scan-based planning system, the surgeon was able to select the optimal locations for implant placement. By incorporating the prosthetic planning using a scannographic template, the treatment was optimized from a prosthetic point of view. Furthermore, the use of a stereolithographic drill guide allowed a physical transfer of the implant planning to the patient's mouth. The scannographic template was designed so that it could be transformed into a temporary fixed prosthesis for immediate loading and the definitive restoration was placed 3 months later. Di Giacomo et. al. [5] evaluated the match between the positions and axes of the planned and placed implants when a stereolithographic surgical guide was employed. Clinical data suggested that computer-aided rapid prototyping of surgical guides might be useful in implant placement. However, the technique required improvement to provide better stability of the guide during the surgery, in cases of unilateral
bone-supported and non-tooth-supported guides. Van der Zel (6) described a newly developed implant procedure CADDIMA (Computer Diagnosis and Design of Implant Abutments) to be used to virtually place dental implants and construct a precise guide splint and temporary prosthesis for delivery at the time of implant placement. The therapy is developed to improve surgical and restorative accuracy, allowing for predictable placement of implant prosthetics taking account of loading of implants through use of CT imaging, laser optical imaging, stereolithographic guides and individualized prosthetic restoration design.

Before new digital techniques and methods get success in the world of implantology further studies and information about not only the advantages and the disadvantages, but also the indications and the contra-indications are needed. However, no study about the (possible) difference in accuracy between implant placement by manual drilling without any digital planning and guidance and implant placement by drilling with computer planning and a surgical guide (CADDIMA) had been done before.

The aim of this study was to compare the orientation differences between planned and placed implants by manual drilling and by drilling with computer planning and guidance.

### 3.3 Material and Methods

A fifty years old healthy male patient, who was partial dentate, was presented in this study. The maxilla was fully dentate without any diastema, as in the mandible the 45 was missing. The jaw bone at the place of the lost 45 was slightly reduced.

The treatment procedure consisted six phases:

1. Gypsum casts phase: generating impressions and gypsum casts
2. Scanning phase I: scannographic guide in the optical scan and CT-scan
3. Planning phase: planning of implant by using Cyrtina guide software
4. Surgical phase: drilling the implant holes
5. Restorative phase: placement of the implants and its abutments on top.
6. Scanning phase II: comparing of the optically scanned position and direction of the placed implant with those of the planned implant
Gypsum casts phase

Two impressions of silicones were made from the patient: one of the maxilla and one of the mandible. Twenty-five gypsum casts were produced from the mandible impression and one from the maxilla impression. The material of the gypsum cast was Moldano Blue.

The twenty-five mandible gypsum casts were divided into three groups: group T (training), group A and group B. Silicones impressions could be used as many times as needed without any information loss. However, to make sure the distribution happened randomly.

Group T contained five casts. The purpose of those casts was surgeon training: handling the drill and getting used of drilling gypsum. The gypsum casts in group T were used before any drilling of casts in group A and B. The remaining twenty casts were divided between group A and group B: each group got ten casts. Casts of group A were used for drilling with the help of computer planning and guidance. Group B was the control group and the casts were used for manual drilling without any computer planning and guidance.

Scanning phase I

Before any planning could be done, a scan of the region of interest (ROI) had to be made. In the first scanning phase three parts can be divided:

1. Scannographic guide
2. CT-scan
3. Optical laser scan

Ad 1

A scannographic guide was produced over a mandible gypsum cast. By that the guide could only fit in one way in the mandible cast. Three glass balls of 4 mm diameters were adhesively fixed to the guide after drilling three small holes spread out over the guide with an excavation drill (Figure 1 and 2). The glass balls were used as reference markers.
Figure 3.1: Drilling of three small holes in fixed the scannographic guide.

Figure 3.2: Three glass balls adhesively to the scannographic guide.

Ad 2.

A ‘NewTom® 3G’ cone beam computer tomogram scanner (QR s.r.l., Verona, Italy) was used for three-dimensional imaging of the bone structures. During CT-scanning of the patient the scannographic guide was placed in the patient (Figure 3). Axial slices of 300 micrometers were made in the 3D jaw bone structure. A CT-scan was also made of a mandible gypsum cast with the same scannographic guide, where after axial slices of the same distance were generated (Figure 4). The CT data were stored on a CD-ROM in DICOM3 format. Clarity and distortion were adjusted which allow determination and delineation of critical anatomic structures

Figure 3.3: Patient with scannographic guide in CT-scan

Figure 3.4: Mandible gypsum cast with scannographic guide in CT-scan
Ad 3.
One gypsum cast of group A was optically scanned by a modified laser triangulation scanner ‘D200c’ (3Shape A/S, Copenhagen, Denmark) with an accuracy within 10 micrometers. To higher up the visibility of the three glass balls in the scan, the scannographic guide and the glass balls were sprayed white (Figure 5). A part of the cast was also painted black for a better view of the ROI in the scan.

A registration bite with the impression of antagonists was made (Figure 6). Together with a maxilla and mandible gypsum cast the registration bite was optically scanned. By that the occlusion was taken in consideration in the next phase where the position and the direction of the implant would be planned.

![Figure 3.5: Optically scanning of this mandible with the cast scannographic guide.](image)

![Figure 3.6: Optically scanning of the registration bite between a white maxilla and mandible gypsum cast.](image)

Planning phase
A virtual implant was chosen from a wide range of implant options varying in lengths, diameters and manufacturer. The implant would be planned in the optimal position by Cyrtina guide software according to the critical information defined by occlusion relations, critical anatomical structures and the three-dimensional and cross-sectional views (Figure 7, 8, 9 and 10).
Figure 3.7: Laser scan data of the mucosa and remaining dentition.

Figure 3.8: Laser scan data of the surface and reference markers in position.

Figure 3.9: Laser scan data of the drill guide with the planned implant position

Figure 3.10: Laser scan data of the surface of the mucosa and remaining dentition with an implant and its abutment on top.

Figure 3.11: Sectional view with abutment in place on the planned implant with drill guide, antagonist, mucosa and bone.
The surgeon could see the antagonists, mucosa and bone at the implantation site in one sectional view. The implant could be planned in line with the direction of loading by chewing forces which made occlusal loading predictable (Figure 11).

**Surgical phase**

With the outcome of the planning phase the drilling could begin by one surgeon (22 years old student dentistry with three years of drilling experience). Four different drills were used for creating the implant holes: a pilot drill with a diameter of 2.0 mm, two intermediate drills with a diameter of 3.0 mm and 3.8 mm and a final drill with a diameter of 4.0 mm (Figure 12). For the pilot drill a special drill guide was produced, because of the high difference of diameter between that drill and the rest. For the intermediate drills and the final drill one drill guide was created.

All the implant holes were made with three thousand rotations per minute.

![Figure 3.12: The final drill.](image1)

![Figure 3.13: Drilling of group B casts.](image2)

The five gypsum casts in group T were getting drilled in the hiaat between 44 and 46 for training. The five holes were drilled till a depth that was thought to be ‘correct’. Also the position and angle were guessed.

Then drilling in group B was started. With the experience of the drilling during the group T phase the ten holes were getting drilled. No computer guidance and planning were used (Figure 13).

Drilling in the casts of the last group (group A) was with the help of a drill guide planned by the CT-scan and the optical laser scan. The drill guide gave the position and the angle that have to be drilled. A hole in the drill guide leaded the drill in the gypsum cast making an implant hole until the drill touched the guide (Figure 14).
Restorative phase

After the holes were drilled, the implants were placed. Twenty Helix® implants (Dyna Dental Engineering B.V., Bergen op Zoom, The Netherlands) with a length of 10 mm and a diameter of 4.2 mm were used (Figure 15).

After the implants were placed in the twenty holes of the gypsum casts of group A and B the second scanning phase could begin.

Scanning phase II

Some of the gypsum casts of group B were not drilled till the right depth. The consequence was that some of the implants were placed at a depth that was not deep enough for placing the scannographic guide from the first scanning phase on the mandible cast. A new scannographic guide had to be made. Three glass balls were adhesively fixed on top of it in order to make a standard for the measurement of the location of the placed implant with regard to those of the planned implant and ultimately the calculation of the difference in angle between the planned and placed implant. The used material was putty (Figure 16).
Each gypsum model was scanned with the reference bite and the scannographic guide. From each ball the centre was calculated (refP1, refP2, refP3). In the next stage the reference bite was removed and a cylindrical implant dummy was placed on the implant for optically scanning of the position and the direction (Figure 17). The plane top surface of the dummy was optically scanned by the same scanner as in the first scanning phase (Figure 18).
The outcomes of each gypsum model were obtained by CyrtinaCAD20 software and put in a data record (Table 2.1 and Fig. 2.9).

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Table 3.1. The outcomes of each gypsum model.
3.4 Results

In group A and B the amount of gypsum casts were both ten. The position and direction of the placed implants in all the casts were optically scanned by the laser optical scan in the second scanning phase. Difference between planned and placed implants was determined by matching.

After scanning two variables were calculated: ‘XY’ and ‘Angle’. The XY was defined as the distance between the planned and placed implant in a two-dimensional geometry. In figure 19 the geometry could be seen as one determined by the three glass balls placed at the scannographic guide. The Angle was defined as the direction of the placed implant as reference to the three glass balls.

Figure 3.19. Example of a calculation of the direction and the position of the placed implant with regard to those of the planned implant.
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<th>Max XY (mm)</th>
<th>Mean Angle (°)</th>
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<td>Group A (Drill Guide)</td>
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<td>0.366</td>
<td>2.45 (± 1.55)</td>
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<td>Group B (Manual)</td>
<td>1.20 (± 0.681)</td>
<td>2.32</td>
<td>7.05 (± 3.92)</td>
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<td>(N=10)</td>
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Table 3.2: Mean and maximum of XY and Angle for Group A and B.

In table 3.2 the mean and maximum of XY are given. Also the mean and maximum of the Angle. The mean XY of group A was 0.198 mm (± 0.0950). Group B had a higher mean XY, namely 1.20 mm (± 0.681). The difference of XY between group A and B was statistically significant (p < 0.05).

Also the difference of Angle between group A and B was statistically significant (p < 0.05). Group A had a mean Angle of 2.45° (± 1.55), whereas the mean Angle of group B was 7.05° (± 3.92).

3.5 Discussion

Using a CT scan-based planning system the surgeon is able to select the perfect location for implant placement, taking into account important anatomic structures and using the optimal bone densities. Research has been done to select the optimal position and to compare the outcome with the planning.

According to Sarment et. al. (3) surgical guidance for implant placement relieves the clinician from multiple perioperative decisions. He scanned edentulous mandibles using cone beam CT-scanner with high isotropic spatial resolution planning five implants on each side of the jaw. With respect to measurement of the angle formed between the planned implant and the actual implant preparation, the standard technique allowed for an accuracy of 8° ± 4.5 and the test method achieved an accuracy of 4.5° ± 2. This difference was statistically significant (p < 0.001).

Di Giacomo et. al. (5) conducted a test in which six surgical guides were used in four patients (age from 23 to 65 years old). Twenty-one implants were placed with the help of a radiographic template and computer-assisted tomography. The virtual implants were placed in
the resulting three-dimensional image. With the use of a stereolithographic machine three surgical guides were made. After surgery a new CT scan was taken and the images of planned and placed implants with their location and axes were compared. On average, the match between the planned and placed implant axes was within 7.25° ± 2.67; the differences in distance between the planned and placed positions at the implant shoulder were 1.45 mm ± 1.42, and 2.99 mm ± 1.77 at the implant apex. In all patients, a greater distance was found between the planned and placed positions at the implant apex than at the implant head. In our study a statically significant improvement was found in all measurements when the drill guides were used and most importantly, variations from the mean were significantly reduced in comparison with manual drilling. The significance of this study could for instance be relevant in situations when multiple parallel distant implants were placed and when the angle of accuracy was critical for obtaining a single prosthetic path of insertion.
3.6 References


4. Tardieu PB, Vrielinck L, Escolano E. Computer-assisted implant placement. A case report:

