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Implant Planning and Placement Using Optical Scanning and Cone Beam CT Technology

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This technique was used as part of a study that was presented at the joint meeting of the Continental European Division (CED) and the Scandinavian Division (NOF) of the IADR on 15th September 2005 at the RAI Congress Centre Amsterdam, The Netherlands, Abstract No. 0159.

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Abstract

There is a growing interest in minimally invasive implant therapy as a standard prosthodontic treatment, providing complete restoration of occlusal function. A new treatment method (CADDIMA), which combines both computerized tomographic (CT) and optical laser-scan data for planning and design of surgical guides, implant abutments, and prosthetic devices, is described. Imaging using a "NewTom 3G" cone beam CT scanner and a modified laser triangulation scanner "D200c" is discussed, as are impression and surgical guide fabrication, which allow for flapless, precise implant placement and an accurate provisional prosthesis. The new approach gives the operator full control over the design of the implant prosthesis for planning of proper occlusal relations and shows promise for further evaluation.

Dental implants, which may allow for optimal esthetic and functional restoration, have been available for many years, but have not always been as convenient and accessible as at this moment. In recent years, dental implant rehabilitation has faced demands from prosthetic and esthetic arenas calling for increasingly ideal outcomes, which require precise surgical planning and placement.

Verstreken et al[1] recognized that a planning system for oral implant surgery based on a true 3D approach allows the interactive placement and adjustment of implants in jawbone structures visible on computerized tomographic (CT) volume data and outperforms the manual planning practice based on printed or film 2D dental CT images. Verstreken et al[2] then developed a preoperative planning system, which takes CTs of the jaws as input, for oral implant surgery. A technique was developed for scanning and visualizing an eventual existing removable prosthesis together with the bone structures. The benefits of a 3D approach are evident in cases where a prosthesis is involved in the planning.

Massey and Alder[3] analyzed implant placement in the posterior maxilla and concluded that only 20% of implants placed could be classified as "ideal" with regard to orientation. Sarment et al[4] described a computer-aided design and manufacturing (CAD/CAM) method that makes it possible to use data from CT to not only plan implant rehabilitation, but also to transfer this information to the surgery. The technique uses stereolithography, a laser-driven polymerization process that fabricates surgical guides. Tardieu et al[5] presented a case of immediate loading of mandibular implants using a five-step procedure. First, a scannographic template is constructed, followed by performing a CT scan. The third step consists of implant planning using SurgiCase software (Materialise Dental, Leuven, Belgium). The final two steps consist of implant placement. Using a CT scan-based planning system, the surgeon is able to select the optimal locations for implant placement. Furthermore, the use of a stereolithographic drill guide allows a physical transfer of the implant planning to the patient's mouth.

Figure 1 D200c laser-optical scanner.

Figure 2 Gypsum cast of mandible.

Figure 3 Check bite of antagonists.

Figure 4 Scannographic guide in patient's mouth.

Figure 5 Scannographic guide on cast.

Figure 6 NewTom® 3G Cone Beam CT scanner.

This paper describes an alternative implant procedure, computer diagnosis and design of implant abutments (CADDIMA), to be used to virtually place dental implants and construct a precise guide splint and provisional prosthesis for delivery at the time of implant placement. The technique was developed to improve surgical and restorative accuracy; it provides for predictable placement of implant prosthetics while taking into account implant loading, through use of CT imaging, laser optical imaging, stereolithographic guides, and individualized prosthetic restoration design. The software allows precise planning for implant placement after which the planned case is sent to a manufacturing facility for splint and prosthesis construction. The surgical template and final prosthesis are returned,

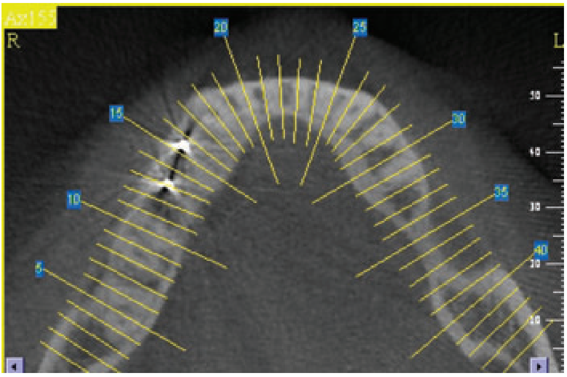

Figure 7 Axial view sliced.

together with the implants and drills used in the planning, to the clinical site for implant placement.

This technique, as illustrated by a clinical case study, is used to demonstrate the possibilities of the new computer-aided implant planning and placement therapy and to explain the new procedure, showing diagnostic and design features of the "Cyrtina®CAD" software package (Oratio B.V., Zwaag, The Netherlands).

Technique

1. An impression is made of the implant jaw along with an occlusal registration of the antagonistic arch. A heavy body silicone (Zetalabor, Zhermack, Badia Polisine, Italy) is used as registration material. A scannographic guide is made by thermal vacuum forming (Erkoform-3d, Erkodent GmbH, Pfalzgrafenweiler, Germany) of 2-mm transparent, polyvinylacetate plate (Erkoflex, Erkodent GmbH) over the gypsum cast of the implant jaw, and 4-mm alumina ball markers (Hoover, Cumming, GA) are fixed with cyanoacrylate adhesive to the guide.
2. A modified laser triangulation scanner "D200c" (3Shape A/S, Copenhagen, Denmark) is used for high accuracy optical scanning (Fig 1) of the gypsum surface, the reference markers on the scannographic guide, the gypsum cast of the implant jaw, and the occusal registration. The optical scan technique, as described by Olthoff et al[6] is used. The accuracy of the modified laser optical scanner is within 12 μm. Using optical scan data of the mucosa and remaining dentition instead of CT scan data enables a more precise reconstruction of the supporting side of the drill guide, resulting in a stable seating of the surgical guide during transmucosal drilling of the implant osteotomy. The gypsum cast is scanned with and without the occlusal registration in place (Fig 2). The mucosal surface with remaining dentition and occlusal registration with an impression of the opposing arch are optically scanned. Black–white contrast is used for convenience (Fig 3).
3. The scannographic guide with three markers is placed in the patient's mouth during CT scanning and on the gypsum model during optical scanning to obtain a combined 3D view of the region of interest (ROI) (Fig 4). The scannographic guide is reproducibly fitted in a position on the cast (Fig 5). A "NewTom® 3G" cone beam CT scanner (QR s.r.l., Verona, Italy) is used for imaging of the bone (Fig 6). Axial slices, with a slice distance of 300 μm, are generated in the 3D jawbone structure (Fig 7). The CT data are stored on a CD-ROM or may be uploaded by e-mail to a secure FTP server in DICOM3 format.
4. The program then generates a 3D view of the mandible showing the ROI and position of nervus alveolar inferior (Fig 8). The thick mucosal tissue layer at the ROI is clearly visible for implant placement.
5. A virtual implant is chosen from a range of implant options varying in lengths and diameters. The virtual implant is then placed in the optimal position according to the critical information defined by designated critical structures, and the 3D and cross-sectional views (Fig 9). Because the operator will see the bone scan and the antagonist and mucosal surface combined in one 3D view, the implant can be placed in line with the direction of loading by chewing forces. This unique feature makes planning of a specified implant a reassuring activity, knowing that the prosthetic device on the implant that occludes with the antagonist

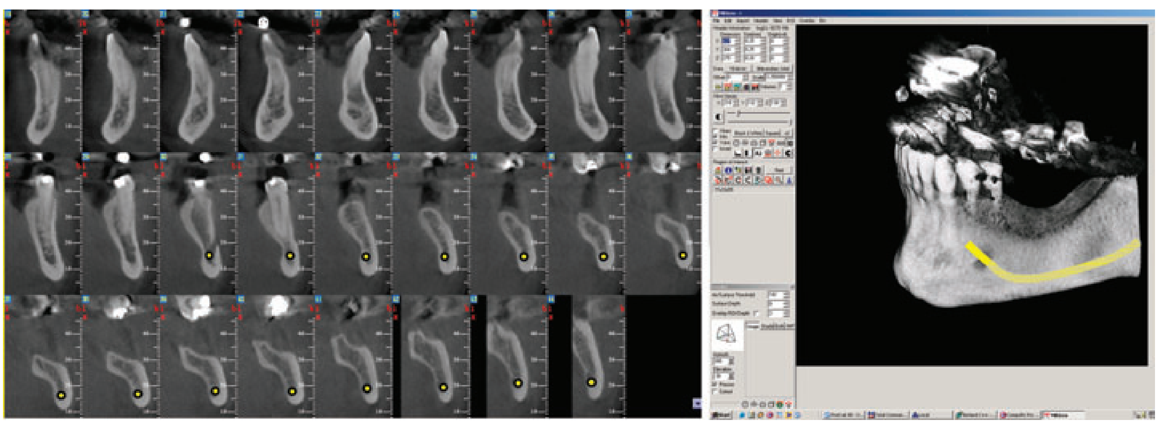

Figure 8 An overview of the sections of the mandible (l) and a 3D view of the nervus alveolar inferior.

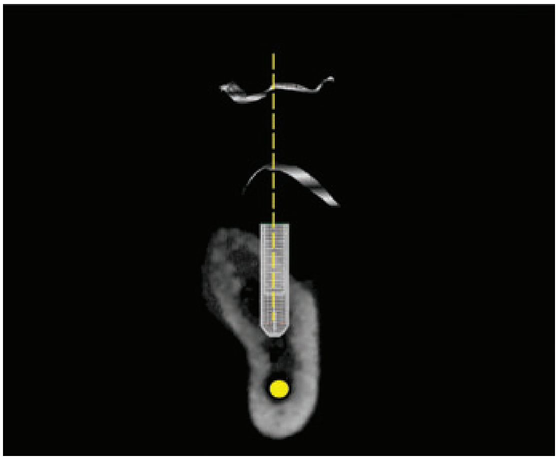

Figure 9 CADDIMA planning stage.

will have a predictable occlusal loading. It also enables the design of a prosthetic device in occlusion, which can be placed as a provisional restoration first and after a healing period be replaced by a definitive restoration.

6. Based on the drilling sequence of the "Helix®" implant (Dyna Dental Engineering B.V., Bergen op Zoom, The Netherlands), two customized surgical guides are designed to accommodate a pilot drill and an end drill. For this purpose an appropriate pilot and final drill with regard to diameter and length are introduced into the dataset. Based on the image and implant planning data, the software generates a virtual surgical guide (Fig 10, left) on the jaw with the planned implant in position. Also shown is the inside of the surgical guide obtained by optical scan of the gypsum model (Fig 10, right). A combination of high accuracy optical surface digitization of the implant jaw with a controlled design of the cervical and mucosal boundaries is designed to give maximum stability during drilling.
7. The surgical guides are produced by stereolithography and fit perfectly on the work model (Fig 11). The surgical guide can be positioned in the patient's mouth (Fig 12) in a unique and stable position with a snap-fit, to transfer the preoperative treatment plan. No drilling cylinders are used, because the drills only cut at the tip of the drill.
8. An abutment is then fixed to the implant with a fixing screw (Fig 13), and a temporary restoration in functional contact using CAD/CAM techniques[7–9] with the antagonist is cemented with temporary cement (Fig 14). After a healing period, the temporary restoration can be replaced by a definitive restoration.

Discussion

The combination of accurate optical scanning geometrically matched with CT scan data provides a more accurate surgical guide with a better fit than when CT scan data only are used. In recent literature, procedures for guided implantation are described whereby the surgical guide is fixed to the jawbone. Nkenke[9] described the Nobelguide™ (NobelBiocare, Goteborg, Sweden) procedure, whereby small diameter holes are drilled in the bone, after which pins are placed through the guide into the holes, to keep the surgical guide in place. Gabert[10] describes the SurgiGuide™ (Materialise Dental) procedure, whereby for the same reason the guide is fixed to the bone with screws. The present procedure gives a snap fit, which makes a fixing mechanism of the surgical guide to the bone unnecessary. For edentulous patients, the procedure and the Cyrtina®CAD software can design and produce a precise "full denture" type seating of the drill guide. It also enables the production of a stereolithographic guide for each drill diameter instead of using a complicated telescopic system of sleeves for drill guidance for different diameter drills used in the two other systems.

The radiation effective dose for a full-head Cone Beam NewTom®3G image is the equivalent of about four to six panoramic radiographs, depending on whether the salivary

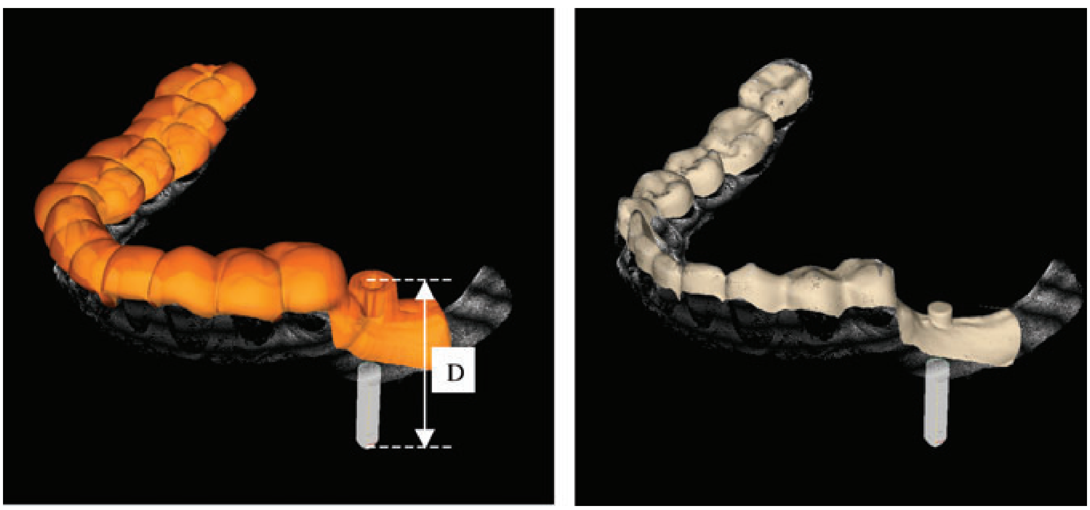

Figure 10 Virtual surgical guide on model (D = drill depth). Drill guide inside optically scanned surface (right).

Figure 11 Surgical guide on model with final 3.6-mm drill.

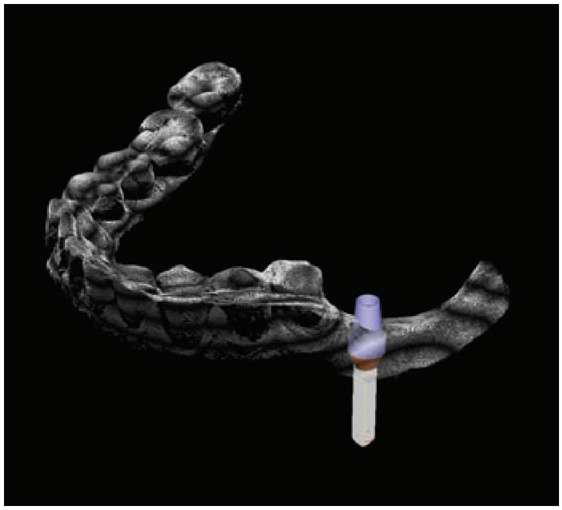

Figure 13 Abutment on implant.

glands are counted separately.[6] As comparison, the cone beam CT requires 30 to 90 times less radiation than the conventional CT scanner used in the present systems.

Conclusion

In the new procedure, image data from a simple cone beam head CT scan are combined with accurate laser scan data to obtain a virtual cross-section of the bone with a view of the antagonist jaw and the mucosal surface. This results in optimized implant positioning with regard to chewing loads and the planning of prosthetics with occlusal contacts. The presurgical planning procedure allows fabrication of a provisional fixed prosthesis before the implant surgery for immediate postoperative loading. This innovative protocol can enhance prosthodontic-driven placement of implants in a fully monitored flapless surgery. This technique can be expected to flourish as dental implant therapy develops, to meet the highest demands of comfort, precision, and safety.

Figure 14 Crown (provisional/definitive) in occlusion.

Figure 12 Surgical guide seated in patient's mouth.

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