PREDICTABLE COMPUTER GUIDED FLAPLESS SURGERY FOR DENTAL IMPLANTS INSERTION

CONSUELA GHIUȚĂ[1], CORINA MARILENA CRISTACHE[2], AUGUSTIN MIHAI[3], GABRIELA TĂNASE[4], MIHAI DAVID[5], TRAIAN BODNAR[6], ANCA TEMELCEA[7], DANA CRISTINA BODNAR[8]

[1,2,3,4,5,6,7,8] *"Carol Davila" University of Medicine and Pharmacy Bucharest*

Keywords: *flapless surgery, cone beam computed tomography (CBCT), computer-aided design/ computer aided manufacturing (CAD/CAM) stereolitographic template*

Abstract: *Computer aided implant planning and placement has been developed in the past years allowing for more efficient preoperative patient evaluation and safe restorative driven implant insertion. The use of a computer based surgical template allows to use the advantages of state-of-the-art flapless surgery including reduced postoperative pain and swelling, reduced intraoperative bleeding, preservation of soft and hard tissue and maintenance of periosteal blood supply. The aim of this prospective study was to present a predictable protocol for dental implants insertion with the use of a stereolitographic guide for flapless surgery and immediate or conventional loading based on a bone quality assessment. Material and methods: Four consecutive patients partially dentate and fully edentulous were planned and operated using a computer-aided treatment concept (R2GATE) and flapless surgery. Results: Ten implants were successfully inserted with no accidents or complications during surgery. Four implants placed at one fully mandibular edentulous patient, in type 1 and 2 bone, were immediate loaded. The six other implants were inserted in the anterior and lateral maxilla in type 2, 3 and 4 bone and were conventionally loaded for a predictable treatment outcome. All implants reached primary stability after insertion. As assessed with postoperative panoramic radiograph, all implants were placed according to the planned position, established in a prosthetic driven manner. Conclusions: Within the limitations of this pilot study, it can be stated that three-dimensional guided implant surgery improves the quality of the surgical procedure and the restorative results, enabling a very safe and predictable rehabilitation.*

INTRODUCTION

During the past years, dental implant insertion has developed mostly due to achievements in radiographic three-dimensional (3D) imaging technique and computer technology (1,2), providing 3D digital information with respect to anatomical structures - cone beam computed tomography (CBCT) - and prosthetic parameters - 3D implant planning software.

Together with the advances in Computer-Aided Design/Computer-Assisted Manufacturing (CAD/CAM) technique, digital data from the surgical plan can be transferred to the actual clinical settings with the aid of stereolitographic surgical guides (additive process) or computer-milled templates (subtractive process).

Virtual 3D planning allows a better visualisation of the underlying bone before any surgery for reverse designing implant treatment according to a "prosthetic driven" concept and it also opens the possibility of a proper communication among the patient, the surgeon and the prosthodontist.(3)

This technique primary aimed at improving diagnosis, surgical and prosthetic precision can be used for flapless surgical procedures due to the fact that mucosal flap elevation for inspection of bone anatomy is not necessary.(4)

Furthermore, the exact position of the implant can be transferred to the laboratory before surgery and a prefabricated prosthesis can be manufactured for immediate loading.(3)

For an adequate implant placement and the correct decision regarding immediate or conventional loading, it is mandatory to evaluate bone quality at treatment planning.

Bone quality depends on the thickness of cortical bone, the abundance of trabecular bone, and the overall degree of mineralization being a key factor that influences successful osseointegration.(5) The Lekholm and Zarb (6) classification of bone quality, commonly used (7,8), is based on the subjective perception during drilling prior to implant placement. In this classification, bone quality is categorized into four types: predominantly cortical bone (type 1), a central core of dense trabecular bone surrounded by a thick layer of cortical bone (type 2), a thin layer of cortical bone surrounding dense trabecular bone of favourable strength (type 3), and a thin layer of cortical bone that surrounds low density trabecular bone (type 4).(6)

CBCT assesses the degree of mineralization of an osseous site under examination by the attenuation of the x-ray beam, in gray values, also referred to as voxel values or computed tomography (CT) numbers.

In medical CT scanners (these gray values are presented as Hounsfield units (HU), which are based on a standard scaling of the x-ray attenuation coefficients relative to water.

Due to many advantages over medical CT including lower radiation dose to the patient, shorter acquisition times, reasonable price and submillimeter resolution, dental CBCT units are widely used.(9)

CBCT do not use the same standard scaling system (HU) as CT scanners but many studies showed a strong linear relationship (8-10) between the CBCT gray value and HU and also a direct correlation with bone density at implant surgery

[2]Corresponding author: Corina Marilena Cristache, B-dul. Eroii Sanitari, Nr. 8, Cod 050474, București, România, E-mail: trili_poli@yahoo.com, Phone: +40723 472632
Article received on 28.01.2015 and accepted for publication on 09.02.2015
ACTA MEDICA TRANSILVANICA June 2015;20(2):119-122

measured according to Lekholm and Zarb classification (11,12) and insertion resistance torque.(12)

PURPOSE

The aim of this paper is to present a predictable protocol for dental implants insertion based on CBCT evaluation with the use of a stereolitographic guide for flapless surgery and immediate or conventional loading based on a bone quality assessment.

MATERIALS AND METHODS

Four consecutive patients were enrolled in this pilot study conducted in accordance with the ethical principles, including the World Medical Association Declaration of Helsinki and the written consent of each subject was also obtained. Patients were partially or fully edentulous with no diseases affecting bone density or previous bone graft at the plan implant insertion sites.

Patient data collection

Initial examination, panoramic radiograph was performed and impression for stone models was taken to all patients. For diagnosis accuracy, impression of the surgical site and the opposite arch is mandatory.

For the fully edentulous and extensive edentulous subjects - Class III and IV according to the American College of Prosthodontists – ACP (13) – a visible light cure record bases with occlusal rims were manufactured for bite registration (figure no. 1).

CBCT was taken with a datum tray filled with impression material or with record basis in centric relation (CR).

Four dental larger volumes CBCT were performed, one for each patient, using ProMax 3D (Planmeca, Finland) with a rotation of 360 degrees, for data acquisition (figure no. 2). All CBCT were with the following characteristics: height and diameter were 160 mm and 160 mm, voxel size was 0.2 mm and the exposure factors were 90 kV, 14.0 mA, 13.779 s exposure time.

Figure no. 1. Centric relation (CR) registration with the use of occlusal rims

Figure no. 2. CBCT was performed in CR with the occlusal rims in place. The light cure acrylic base is visible on the CBCT scan and it is used to match scanned models with CBCT data

A series of axially sliced image data were obtained and exported to a personal computer in Digital Imaging and Communications in Medicine (DICOM) format.

Models, occlusal rims and datum trays were scanned using a D 700 3D scanner (3Shape, Denmark) and imported as Stereo Lithography (STL) files (figure no. 3). On the scan models, a virtual wax-up was designed with the use of 3Shape CAD software and saved as STL file (figure no. 4).

Figure no. 3. Scanned models mounted in CR with the aid of the occlusal rims

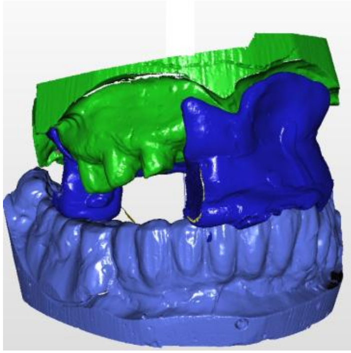
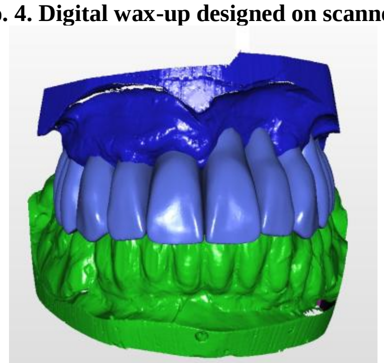


Figure no. 4. Digital wax-up designed on scanned models



Matching CT and models scan data

DICOM files obtained from CBCT and STL files were imported in a treatment plan software R2GATE version 1.0.3 (Megagen Implant, Korea) and implant insertion was planned according to the final restoration and bone anatomy.

Treatment planning

To facilitate bone density assessment, the specific diagnostic and treatment planning software R2GATE provides an option, "Digital Eye", allowing the conversion of CBCT gray scale in 5 basic colours, corresponding to bone density: green 40% - type 1 bone, yellow 26% - type 2 bone, blue 16% - type 3 bone, red 14% - type 4 bone and black 4% - air. Type 1 to 4 are classified according to Lekholm and Zarb.(14)

In figures no. 5 to 8, treatment plan on R2GATE software 1.0.3 is illustrated.

Manufacturing of the stereolitographic guide and abutments/temporary dentures for immediate loading cases.

For the four patients, surgical guide was printed according to the established position of the implants, which was simulated in alveolar bone by the R2GATE software based on the obtained CBCT data, bone density and digital wax-up of the future prosthetic reconstruction.

Surgery

Surgery was performed flapless, by one experienced surgeon, under local anesthesia, using a minimum invasive technique.

Prosthetic reconstruction

Implants were immediately or conventionally loaded, depending of the bone density and volume to increase treatment predictability.

Figure no. 5. Treatment planning for case no. 1 using R2GATE software and digital wax-up on CBCT: three implants were inserted - 11, 23 and 24

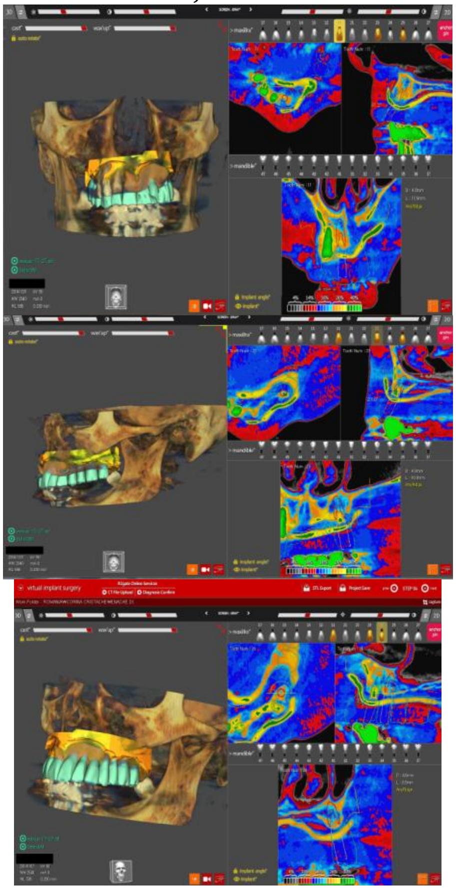


Figure no. 6. Treatment planning for case no. 2: two implants were inserted – 24 and 26

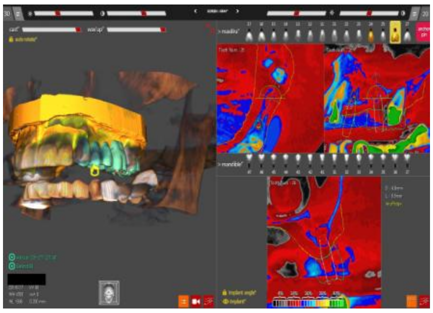


Figure no. 7. Treatment planning for case no. 3: four implants in the anterior mandible – 34, 32, 42 and 44 and immediate loading with an overdenture retained with a bar

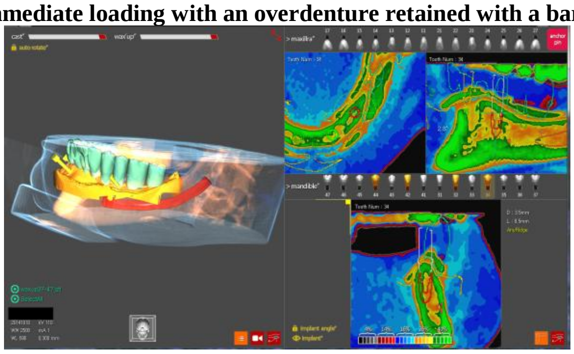
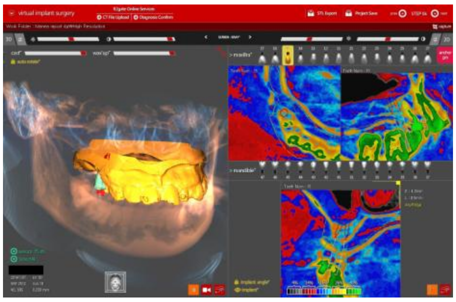


Figure no. 8. Treatment planning for case no. 4: one implant at 15 is inserted



RESULTS

All four patients included in the present prospective study were women aged from 58 to 69 years old. A total of 10 implants, 6 in maxilla and 4 in the mandible were inserted.

Implant insertion was performed flapless, with a use of a stereolitographic template printed according to the planned position of the implants.

Neither accidents nor complications occurred during surgery. All implants reached primary stability after insertion.

Postoperative assessment of the patients showed the absence of pain, bleeding and swelling, regardless the surgical site, mandible/maxilla, anterior/lateral.

After bone density assessment with the aid of R2DATA software, only the four mandibular implants were suitable for immediate loading (case no. 3, figure no. 7). At implant insertion in case no. 3, type 1 and type 2 bone at drilling, according to Lekholm and Zarb classification (6), were found in the anterior region of the mandible in accordance to the CBCB evaluation.

The four implants inserted in the fully mandibular edentulous patient (case no. 3) - type 1 and 2 bone - were immediate loaded and the prosthetic procedure was described in a previous published paper.(15)

Type 4 bone was found at drilling in case no. 2 (figure no. 6) – in red according to CBCT (colour code of grey scale - R2GATE software) and conventional loading was decided.

For case no. 1, a fixed bridge 11-24 was planned. Bone density on CBCT and drilling was type 2 for 11, type 2 and mostly type 3 for 23 and type 3 for 24, therefore conventional loading was decided.

Case no. 4 with mostly type 3 bone (figure no. 8) required sinus lift using Summers (16) technique and, consequently a conventional loading was performed.

As assessed with postoperative panoramic radiograph, all implants were placed according to the planned position, established in a prosthetic driven manner.

DISCUSSIONS

The computer-guided implant concept in combination with immediate or conventional loading is proved to be safe and predictable.(3) Nowadays, different computer-assisted implant placement procedures with a high success rate are available, using different software, template manufacturing, guiding device, stabilization and fixation.(17) Several factors influencing the accuracy of the computer-guided approach in a negative way such as: bone-supported guides, the use of multiple templates and the lack of guide fixation are reported.(17)

Flapless surgery based on stereolitographic template, proposed in our protocol has multiple advantages, including: reduction of complications at patient level, i.e., swelling and pain, reduction of intraoperative bleeding, reduction of surgical time and need for suturing, preservation of soft and hard tissues, and maintenance of blood supply.(18)

The flapless guided implant placement techniques allow the surgeon to install the implants with minimal surgical trauma to the bone and associated soft tissues and maximize patient discomfort. As such, these techniques may be particularly attractive to use in frail patient groups.(3)

Evaluation of bone quality during treatment planning is mandatory especially when immediate loading is intended.

To evaluate bone quality, CBCT performed at high resolution and dedicated software (R2DATA version 1.0.3) was used in treatment planning.

After the CBCT scan, the resultant image set data are subjected to a reconstruction process that results in the production of a digital volume composed of volume elements called “voxels” that can be visualized with specialized software.

CBCT voxels generally are isotropic (that is, X, Y and Z dimensions are equal) and range in size from approximately 0.07 to 0.40 millimetres per side.(19)

Each voxel is assigned a gray-scale value that approximates the attenuation value of the represented tissue or space. For example, the latest generation of CBCT units produces 12- or 14-bit images in which 12 bits are 2^{12} (4.096) shades of gray and 14 bits are 2^{14} (16.384) shades of gray.(19) But computer monitors used to visualize the 12- or 14-bit digital or voxel volume can display only eight bits (256 shades) of gray at a time.(19) Important details, for example bone density cannot be assessed easily with naked eye on the computer monitors. Therefore, R2 DATA software, with the option of providing five different colour groups for the gray scale, is a useful diagnosis tool, facilitating bone structure evaluation and deciding the loading protocol for a predictable treatment outcome.

The promising results of this pilot study leads to the necessity for developing a larger clinical trial to assess long term success rate of this treatment protocol.

CONCLUSIONS

Within the limitations of this pilot study, it can be stated that three-dimensional guided implant surgery improves quality of the surgical procedure and the restorative results, enabling a very safe and predictable rehabilitation.

Evaluating bone density during treatment planning is mandatory to establish implants loading protocol.

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