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Fully Digital Workflow with Magnetically Connected Guides for Full-Arch Implant Rehabilitation Following Guided Alveolar Ridge Reduction

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Abstract

This technique report describes a fully digital workflow in which two surgical guides (i.e. one for alveolar bone reduction and the other for implant placement) are magnetically connected to ensure stability during full-arch implant surgery following guided bone reduction. Digital prosthesis design as well as virtual bone reduction and implant planning are developed from the superimposition of facial, intraoral and CBCT scans. With this technique, different surgical guides and interim poly(methylmethacrylate) (PMMA) fixed prosthesis are precisely connected with magnets after being digitally designed and 3D-printed. As a result, such magnetic connection allows for satisfactory stability of the implant surgical guide, as well as of the interim fixed PMMA fixed prosthesis during capture of screw-retained abutments.

With the advent of digital workflows, a three-dimensional (3D) virtual patient can be created for planning implant surgeries and prosthodontics noninvasively. In addition, digital workflows allow for sharing treatment plan data immediately with a network of other professionals, enhancing communication among patients, dentists and dental technicians.[1]

In the field of oral rehabilitation, digital 3D and two-dimensional (2D) facial analyses have been found to be significantly beneficial in predicting the final aesthetic result. In this context, several methodologies of working with facial images of the patient during virtual treatment planning have been described in the literature.[2-4] Combination and integration of "Digital Communication in Medicine" (DICOM) files from cone-beam computed tomography (CBCT) and "Standard Triangle Language" (STL) files from intraoral scans (IOS) enable the concomitant use of data from hard and soft tissues during virtual surgical and prosthetic planning.[5] Among the advantages of the aforementioned methodology are virtual wax-up tools for adjusting teeth shape, size and positions during prosthetically driven virtual implant planning.[2,4]

Despite the above-mentioned evidences, little is known on advantages of superimposing object (OBJ) files from facial scan, STL files from IOS and DICOM files from CBCT for planning cases requiring image-guided alveolar bone reduction followed by implant placement. Furthermore, despite the sequential use of multiple surgical guides (e.g., for grafting and implant placement) has been recently described,[6-8] it was not possible to find any article in the literature describing the use of magnets to connect two different surgical guides, or to connect a surgical guide with an immediate temporary implant-supported prosthesis.

Thus, the aim of this technique report is to introduce a fully digital workflow using facial, IOS, and CBCT scans for full-arch implant rehabilitation following guided alveolar ridge reduction.

Technique

1. In the first clinical appointment, take frontal and profile facial photographs of the patient. Check conditions of the soft tissues (e.g. amount of keratinized tissue,

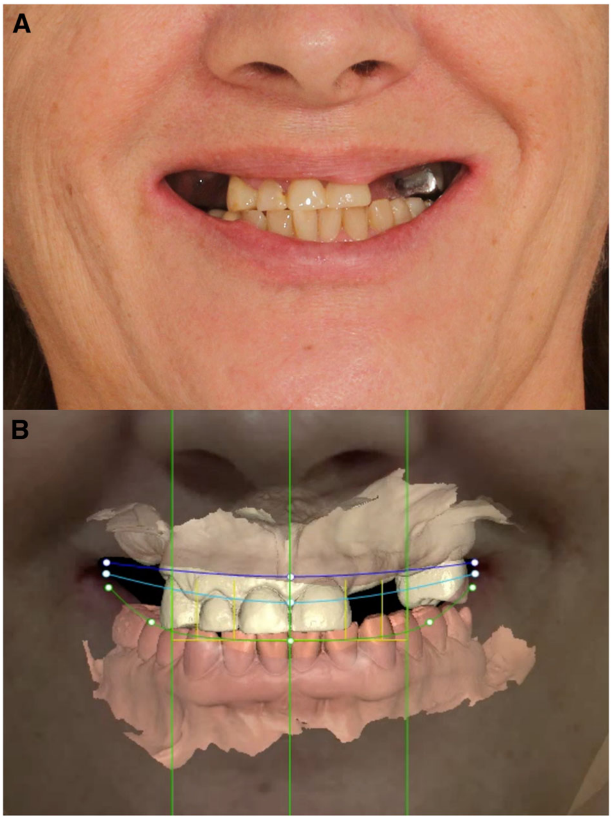

Figure 1 Initial clinical situation. (A) Initial patient smile. (B) Superimposed scans of the initial clinical situation of the patient.

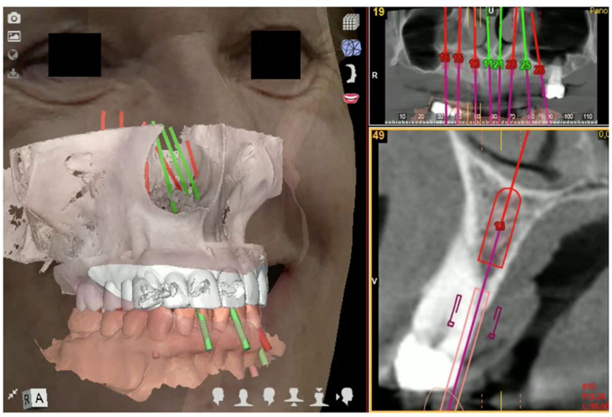

Figure 2 Virtual wax-up and implant planning. Since there was adequate bone volume according to the CBCT images in all implant sites, no bone grafting technique was required.

inflammation) and determine whether or not occlusal vertical dimension needs to be adjusted.

2. Scan primary and antagonist arches, as well as the occlusion of the patient using an intraoral scanner (Trios II, 3Shape, Copenhagen, Denmark). Scan the patient in occlusion and smiling with a facial scanner (Cloner II, Done3D, Ribeirao Preto, Brazil). Take a second facial scan with the patient in occlusion using a bite fork with addition silicone (Scan Putty, Yller, Pelotas, Brazil). Then, scan the bite fork with the same IOS device (Trios II, 3Shape). Finally, take a CBCT scan (OP 300, Instrumentarium, Tuusula, Finland) of the patient using a lip retractor.

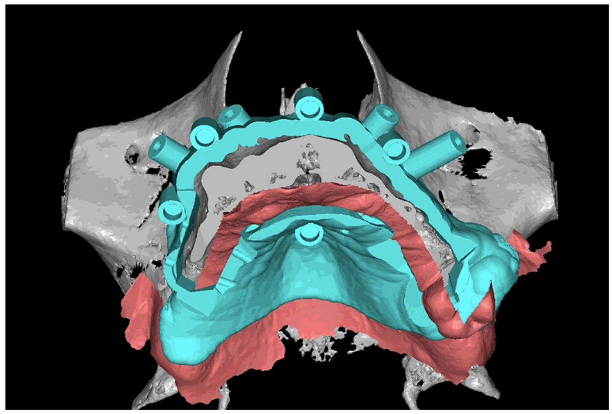

Figure 3 Alveolar bone reduction surgical guide.

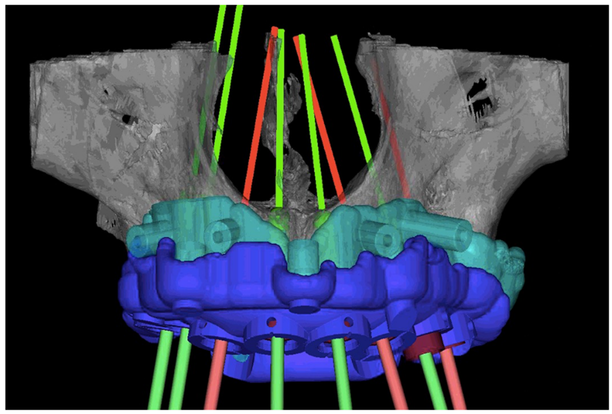

Figure 4 Implant surgical guide (blue) planned to be magnetically connected to the alveolar bone reduction guide (green).

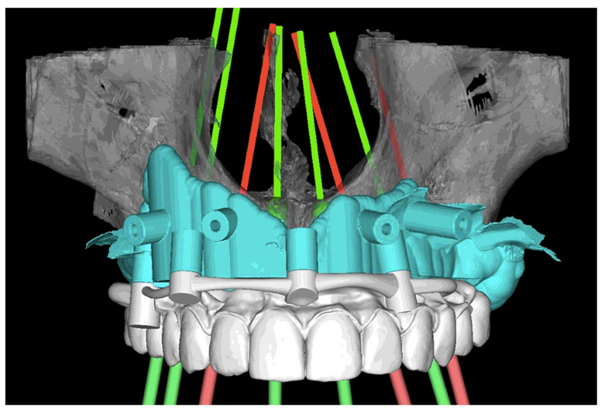

Figure 5 Implant-supported interim PMMA fixed prosthesis (white), also planned to be magnetically connected to the alveolar bone reduction surgical guide (green).

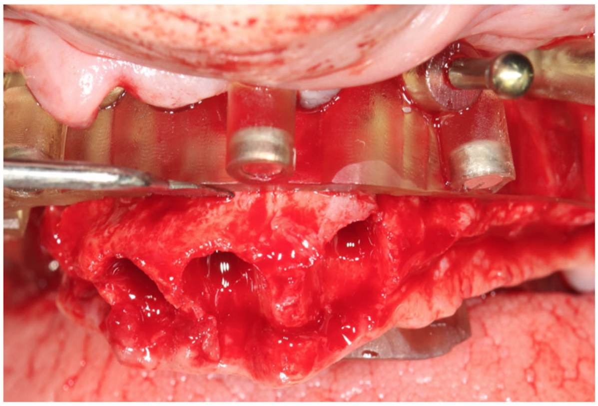

Figure 6 Alveolar bone reduction procedure with surgical guide in position.

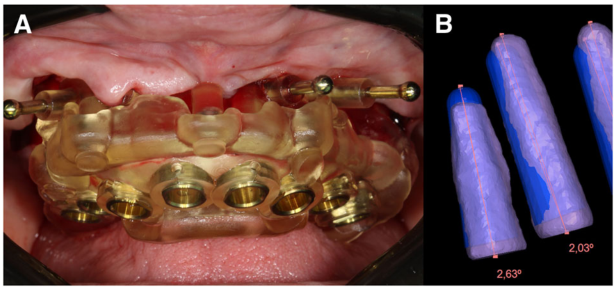

Figure 7 Dental implant placement. (A) Implant surgical guide magnetically connected to the alveolar bone reduction guide for performing immediate implant placement. (B) Planned and placed STL superimposition to calculate deviations. Mean deviation at the apex was 1.21 mm, mean deviation at the entry point was 0.44 mm, and mean angle deviation was 3.01°.

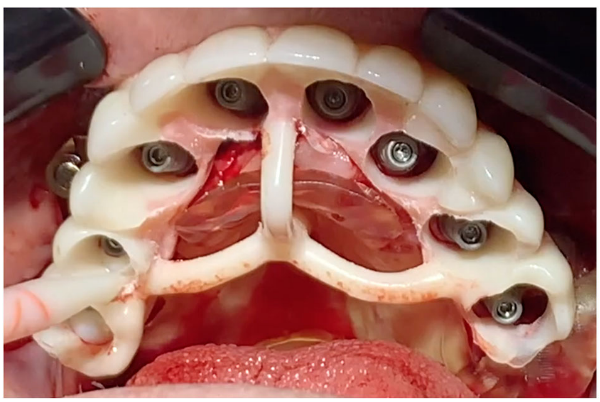

Figure 8 Interim PMMA fixed prosthesis magnetically connected to the alveolar bone reduction guide to capture the screw-retained abutments. All implants presented peak insertion torque greater than 45 Ncm, which enables immediate loading with the present implant system.

Figure 9 Prosthetic result 2 weeks after immediate installation of the interim PMMA fixed prosthesis.

Figure 10 Smile of the patient 2 weeks after immediate installation of the interim PMMA fixed prosthesis.

3. Import all patient photographs, CBCT DICOM, IOS STL, and facial scan OBJ files (Fig 1) to the same computer-aided design (CAD) software (NemoStudio®, Nemotec SL, Madrid, Spain). Perform virtual wax-up by selecting and importing maxillary teeth from a library, followed by edition of each tooth shape and position according to the patient's occlusion and smile, which can be analyzed by means of digital smile design (DSD) methodology.[9] Then, virtually plan eight implants in optimal positions with the implant planning tool of the NemoStudio software (Fig 2). If implant placements require alveolar bone reduction, perform virtual surgical planning of alveolar ridge reduction and design a surgical guide fixed with anchor pins to orientate direction and depth of bone reduction (Fig 3). Finally, design an implant placement surgical guide with a shape to be connected to the bone reduction guide, and export both guides as STL files (Fig 4). For the aforementioned

purpose, individual magnetic attachments should be digitally designed in another CAD software (Autodesk Meshmixer 3.5, Autodesk Inc., San Rafael, CA, USA) as separate 3D meshes and save as STL files. Such files, in turn, should be imported to the implant planning software (NemoStudio®, Nemotec SL, Madrid, Spain), and adjusted to fit in the digital shape of both surgical guides.
4. Print three-dimensionally (Hunter printer, Flashforge, Zhejiang, China) both ridge bone reduction and implant surgical guides with polymethylmethacrylate (PMMA, Makertech Labs, Tatuí, Brazil). Post-process both resulting guides by cleaning, UV curing and polishing it before applying magnets to the planned locations. For this purpose, use a system of magnetic guides (BDS magnetic guides-TIMMES, Beyond Digital Solutions, Curitiba, Brazil). Such system includes magnet discs measuring 3 mm in diameter that fit tightly in the attachments that are digitally designed according to the dimensions and offsets recommended by the manufacturer. The use of magnet discs enables precise attachment of one guide to the other with satisfactory stability.
5. Before any surgeries, digitally design (NemoStudio®, Nemotec SL) as an STL file (Fig 5) and fabricate an interim temporary PMMA (Trilux Multilayer, RuthiBras, Pirassununga, Brazil) prosthesis with magnetic attachments by using a milling machine (Ceramill, Amann Girrbach AG, Curitiba, Brazil; Fig 5). The shape of the aforementioned temporary prosthesis should enable connection with the bone reduction guide, and should have spaces on each implant site for capturing screw-retained abutments into the prosthesis.
6. In the first surgery, perform osteotomy to reduce alveolar ridge using a piezoelectric surgical device (DentSurg Pro, Cvdentus - Clorovale Diamantes Ind. Com. Ltda. Epp, Jardim Torrão de Ouro, Brazil) with the ridge bone reduction surgical guide in position (Fig 6). Then, attach the implant placement surgical guide to the ridge bone reduction guide (Fig 7A), and perform image-guided implant surgery (eight implants with 4.1mm in diameter; Cone Morse, Neodent, Curitiba, Brazil). Implant scan bodies can be used for taking another intraoral scan to confirm implant placement accuracy, as compared with the respective planned positions by means of superimposition of STL files (Fig 7B).
7. Immediately after implant placement, detach the implant surgical guide while keeping the alveolar bone reduction guide in position, and connect screw-retained abutments to the implants (Mini pilar, 4.1 mm in diameter, Neodent). Then, attach the temporary PMMA prosthesis, and capture the screw retained abutments into the prosthesis with bis-acryl composite resin (Protemp 4, 3M Espe, Seefeld, Germany; Fig 8). Finally, unscrew the abutments and detach the temporary prosthesis. Remove the alveolar bone reduction surgical guide, perform vicryl sutures (Ethicon, Somerville, NJ, USA). Considering that satisfactory primary stability was achieved for immediate loading, install and adjust the temporary prosthesis (Figs 9 and 10).

Discussion

The technique presented herein is an alternative to achieve satisfactory aesthetic outcomes for patients with failing teeth requiring full-arch implant rehabilitation with an implant digital workflow. As shown in the present report, superimposing facial, intraoral and CBCT scans of both patients in the CAD software allows the professional to digitally plan and edit the desired ridge bone shape, implant positions, teeth shape, color and occlusion to match the clinical situation of the patient receiving implant rehabilitation. This is in agreement with a previous systematic review suggesting that the use of digital technology might offer advantages as compared with conventional procedures, such as fewer patient visits, better results of marginal fit and reproducibility of the prosthesis.[10]

As shown in the present technique report, virtually guided alveolar ridge reduction has been recently described as a safe and precise procedure to overcome insufficient crown height space.[11] Object (OBJ) files from facial scans can also be superimposed with STL files from intraoral scans during virtual wax-up, revealing whether alveolar ridge reduction is actually required to achieve proper crown heights with a satisfactory aesthetic outcome.

This report also supports previous evidence suggesting that face scans are significantly beneficial and clinically relevant for decision-making in implant rehabilitations using digital workflows, especially when choosing teeth shape from digital libraries or performing virtual wax-up.[12] Furthermore, this is the first report of a case using two surgical guides attached by magnets. As observed herein, magnetic attachment led to easy positioning (due to the force of attraction field between magnets) and enhanced stability of the implant surgical guide, which is desirable and clinically relevant to achieve success in full-arch image-guided implant surgeries.[13]

One drawback of the present approach is the slightly increased cost of treatment, due to application of magnets. Moreover, since magnetic attachments must be digitally designed, CAD knowledge and more time are required for treatment planning. Finally, because this is a technique report, future prospective studies would be recommended to address the impact of using magnetic connection between surgical guides and interim implant-supported fixed prosthesis on outcomes of image-guided implant surgeries.

In conclusion, the present technique allows for a fully digital workflow with immediate loading for maxillary full-arch implant rehabilitation following alveolar bone reduction with enhanced stability of the implant surgical guide and of a digitally designed interim PMMA fixed prosthesis during capture of screw-retained abutments.

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