The Combination of Digital Surface Scanners and Cone Beam Computed Tomography Technology for Guided Implant Surgery Using 3Shape Implant Studio Software: A Case History Report

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The incorporation of virtual engineering into dentistry and the digitization of information are providing new perspectives and innovative alternatives for dental treatment modalities. The use of digital surface scanners with surgical planning software allows for the combination of the radiographic, prosthetic, surgical, and laboratory fields under a common virtual scenario, permitting complete digital treatment planning. In this article, the authors present a clinical case in which a guided implant surgery was performed based on a complete digital surgical plan combining the information from a cone beam computed tomography scan and the virtual simulation obtained from the 3Shape TRIOS intraoral surface scanner. The information was imported to and combined in the 3Shape Implant Studio software for guided implant surgery planning. A surgical guide was obtained by a 3D printer, and the surgical procedure was done using the Biohorizons Guided Surgery Kit and its protocol. Int J Prosthodont 2015;28:169–178. doi: 10.11607/ijp.4148

Thorough case evaluation and precise diagnosis are two of the most important factors for appropriate treatment selection and a predictable outcome. Efforts to incorporate innovative technological advances into daily clinical practice are resulting in optimized and personalized oral health care delivery. Even though clinical evaluation, conventional radiographic measurements, and cast model analysis are still the most common resources of clinical data for practitioners, new tools and technologies are emerging to achieve more precise and personalized patient information.1,2 Virtual engineering and digitization of clinical information have given new perspectives and innovative alternatives for dental purposes. Availability and accessibility of these technologies also have greatly improved. In the past, only a few manufacturers were thinking of the future of digital dentistry. During the last decade, however, this kind of technology has evolved into a large, profitable market for dental and technology enterprises.3 Companies such as Nobel Biocare and its NobelGuide, Materialise Dental and the SimPlant digital alternatives, Dental Wings and the development of CoDiagnostiX software, Sirona with CEREC solutions, Align Technology with its iTero scanner, and the 3Shape Dental System are some of the most renowned names in the development of digital impressions and virtual surgical solutions.

Digital technology in the oral surgical field also is expanding the options for the development of personalized oral reconstructive treatments.4 Computer-guided implant surgery was developed to overcome the limitations related to conventional surgical templates5,6 and to improve the accuracy of surgical implant placement with a less-invasive surgical approach.7,8 The use of noninvasive surgical techniques such as flapless implant placement may offer several clinical advantages while maintaining similar survival rates to conventional implant placement procedures.5,10 When indicated, avoidance of unnecessary flap release allows for the maintenance of the periosseal vascular bed, which helps ensure optimized blood supply. It is also well documented that patients treated with this approach may experience faster tissue healing and a better postsurgical course.11–13
Virtual surgical simulation permits a complete analysis of three-dimensional (3D) implant position and its relation to vital maxillofacial structures. More importantly, the computer-generated surgical guide provides a link between the virtual treatment plan and the actual surgery by transferring the simulated intervention accurately to the surgical site.14 Until recently, most of the digital surgical planning software available needed a radiographic template and used a double scanning protocol. Thus, it was necessary to enlist a laboratory technician to fabricate an appropriate radiographic template. The double scanning protocol has been reported by several authors in the past and is still the key point for an ideal prosthetically driven surgical plan for most digital solutions.15-20 These data become the basis for surgical guide fabrication.

The surgical template is fabricated using 3D printing technology and is custom manufactured for each patient.21 The final result is a digital restorative and surgical plan that gives the clinician the opportunity to perform a predictable, personalized, and noninvasive implant intervention.

The introduction of digital surface scanners to the dental field and the simplicity of the information transference are closing the gap in the creation of a completely "virtual patient" and the optimization of the digital treatment workflow.22 Digital impression devices are an alternative to conventional impression techniques and materials. The combination of the radiographic, prosthetic, surgical, and laboratory worlds under a common virtual scenario is becoming possible through the capacity to import the information obtained from digital surface scanners and the Digital Imaging and Communications in Medicine (DICOM) files produced by a cone beam computed tomography (CBCT) scan to a surgical and prosthetic planning software.23-25 In other words, the digitization of all patient information and the possibility of combining it in one specific platform gives clinicians several advantages and changes the way patients perceive dental treatments. For all clinicians involved in patient treatment, the speed of file transference simplifies communication, optimizing treatment planning with an efficient time-cost workflow.26 Eliminating
unnecessary radiographic templates for a double scanning protocol also helps to reduce expensive laboratory work and time.\textsuperscript{27,28} Furthermore, 3D printing technologies enable clinicians to obtain the surgical guides within a few minutes, which minimizes preoperative preparation.\textsuperscript{29} As a result, treatment time is reduced by decreasing the number of necessary dental appointments while also shortening the duration of surgical procedures.

The aim of this article is to describe a computer-aided implant placement procedure in which a combination of CBCT technology and digital surface scans were utilized using a new guided implant planning software.

Case Report

A 55-year-old healthy woman came to the authors' clinic for treatment. She presented with a missing mandibular left first molar due to an extraction performed several years ago resulting from endodontic treatment failure. She had no history of known disease and was not taking any medication. After a complete diagnostic evaluation, including clinical and photographic analysis, a CBCT of the quadrant of interest was performed (Planmeca, ProMax 3D s; Fig 1a). At the same appointment, a digital surface scan of the left maxilla, left mandible, and the maxillary intercuspal relation of both arches was done with a 3Shape TRIOS digital scanner (3Shape TRIOS Cart Solution; Figs 1b to 1d). Finally, a conventional alginate mandibular impression (Tropicalgin, Zhermack) was done for a study cast fabrication (Elite Rock Fast, Zhermack). After the evaluation of the scanned zones and their occlusal relations (Fig 2c), the files were exported to the 3Shape Implant Studio software (3Shape). When all diagnostic information was gathered, the patient was dismissed and a treatment appointment was made for the next day.

After the DICOM files obtained from the CBCT were initially processed, they were imported to the 3Shape Implant Studio software to combine both scans and create a 3D superimposition of the real intraoral situation and the CBCT images (Fig 2). A restorative
designing tool, included with the 3Shape Implant Studio software, was utilized to create a functional and esthetic virtual crown with an ideal prosthetic position on the superficial reconstructed image (Fig 3). After the final evaluation of the virtual crown position, the 3D digital implant location was defined to obtain the most convenient implant-prosthetic relation, respecting vital structures such as the inferior alveolar nerve and vascularity, as well as the minimal safety measurements of bone surrounding the implant (Fig 4). The planning was performed using a superficial intraoral scanned image and was checked with the
Definitive implant position and axis based on the virtual crown design in a three-dimensional reconstructed virtual model.

Final implant position based on the virtual crown design in the cone beam three-dimensional reconstruction model. Note the relationship between the implant and bony architecture and the inferior alveolar nerve.

Design of the virtual surgical guide. (a) Lateral view of the guide design. The green line shows the future guide margin. (b) The orange cylinder shows the screw exit for the future restoration. (c) Virtual three-dimensional reconstruction of the surgical guide shows the screw exit of the future restoration. (d) Angled view of the final surgical guide design and the insertion axis of the implant.

CBCT 3D reconstruction at the same time, ensuring an optimum implant position and avoiding any bone fenestration or dehiscence or a vital structure lesion (Figs 5 and 6).

The implant selected was a BioHorizons Tapered Internal (BioHorizons) of 4.6-mm platform width and 10.5-mm body length. Once the implant position was approved, a dental-supported virtual surgical guide was designed considering a vertical insertion axis to facilitate the clinical placement during the surgical procedure (Fig 7). The final guide design was sent as an .stl file to the 3D printer, where fabrication of
the surgical guide was completed in 2 hours (Objet Eden260V, Stratasys). A final try-in was performed on the study cast to assess any fit inaccuracies or surgical access inconveniences before sterilizing the guide and the BioHorizons Guided Surgical Kit (BioHorizons; Fig 8a).

The next day, the patient returned to the authors’ practice for the surgical procedure. After a mouth-rinse with chlorhexidine (0.12%, Oralgene) for 2 minutes and the disinfection and preparation of the surgical field, local anesthesia was delivered to the edentulous area (mandibular left first molar region) by buccal, crestal, and lingual infiltrations (lidocaine HCL 2% and epinephrine 1:100,000, Henry Schein). After a few minutes, the surgical guide was placed in position and the 4.6-mm-diameter guided tissue punch was utilized through the guide’s master cylinder at 1,200 rpm. The guide was then removed, and the sectioned soft tissue was taken out using a tissue elevator and kept in saline solution (Figs 8b to 8d).

The surgical guide was repositioned and a 2.0-mm-diameter guided key was engaged on the master cylinder. A 21-mm-length, 2.0-mm-diameter pilot guided drill was utilized to start the osteotomy at 1,200 rpm through the guided key cylinder. The surgical guide system compensates for 10 mm of the real drill length so the final osteotomy in this situation was performed at 11-mm depth (Figs 9a and 9b). The procedure was sequentially repeated with the 2.5-mm guided key and a 21-mm-length/2.5-mm tapered drill, the 3.2-mm guided key and the 21-mm-length/3.2-mm tapered drill, the 3.7-mm guided key and the 21-mm-length/3.7-mm tapered drill, and, finally, the 4.1-mm guided key and the 21-mm-length/4.1-mm guided tapered drill (Fig 9c).

The surgical guide was then removed to check the osteotomy site (Fig 9d). After the guide was repositioned, a 4.6-mm-platform, 10.5-mm-length BioHorizons Tapered Internal implant was mounted in the 4.6-mm guided implant driver (Fig 9e). The implant was placed through the master cylinder at 15 rpm, reaching more than 50-Ncm torque (Fig 9f). Once the implant was at the final depth position, the guided implant driver was removed (Fig 10a) and a 4.6-mm-diameter, 3-mm-length healing abutment (BioHorizons) was positioned over the implant (Fig 10b). A small connective tissue graft taken from the soft tissue removed by the tissue punch was then placed in a buccal wedge to gain soft tissue volume and thickness of the remaining keratinized tissue (Fig 10c). No sutures were indicated. A postsurgical periapical radiograph was then taken (Fig 11).
Fig 9  Surgical procedure. (a) The 2.0-mm guided key is in position, engaged on the master cylinder of the surgical guide. (b) The 2.0-mm pilot guided drill is used to begin the osteotomy. (c) The 4.2-mm tapered guided drill is used to widen the osteotomy. (d) Surgical site without the surgical guide showing the osteotomy. (e) Guided implant driver and drill stop key with a 4.6-mm BioHorizons Tapered Internal implant. (f) Guided implant placement.

Fig 10  Surgical procedure. (a) BioHorizons 4.6-mm Tapered Internal implant is inserted. (b) A 3-mm healing abutment is placed. (c) A small connective tissue graft is placed under a buccal wedge to create denser and thicker keratinized tissue around the implant.

Fig 11  Comparison between the (a) virtual implant position plan and (b) postsurgical radiograph.
Discussion

Flapless surgery appears to be a safe treatment modality for implant placement, demonstrating clinical efficacy. However, this technique is dependent on advanced imaging, technologic appliances, clinical training, and surgical judgment. The development of new digital impressions, such as superficial digital scanning, allows for a fast and accurate information transference between clinicians, lab technicians, and patients that is decreasing the incidence of potential errors in every step of the conventional surgical-restorative process.

Vieira et al\(^3\) reported a study in which 62 implants were placed in edentulous arches under a virtual planning approach using stereolithographic surgical guides in 14 patients. Through a postsurgical CBCT analysis, they compared the real implant position with the virtually planned implant location. They found a mean and SD of linear measurements at the cervical, middle, and apical implant portions of 2.17 ± 0.87, 2.32 ± 1.52, and 2.66 ± 2.17 mm for the maxilla and 1.42 ± 0.76, 1.42 ± 0.76, and 1.42 ± 0.76 mm for the mandible, respectively. This deviation and inaccuracy could be explained by the differences in bone density between the CBCT measurement (estimated in Hounsfield units) and the actual bone density and in the flexibility of the surgical guides.\(^3\) However, the most probable explanation is that the surgical guides were designed and fabricated based on a CBCT 3D reconstruction that could have minor distortion and scatter from existing restorations or because it simply is not as accurate in measuring superficial anatomical topography of the dentition and surrounding soft tissue.\(^3\) The information acquired by the digital surface scanners provides precise topographic information of intraoral structures, thereby eliminating the previous shortcomings, which may improve the accuracy of the final implant position based on the digital planning.

Furthermore, a second surface scan can be performed after implant placement with an appropriate scanning abutment. The orientation and position of the implant can be virtually recreated to confirm its final location. One could then assess the postsurgical implant position and compare it with the original virtual surgical plan without taking an additional CBCT, minimizing patient exposure to radiation. This option would help to check every single guided implant placement position to ensure the software and technique calibration.\(^3\)

One of the technique’s limitations is that this approach cannot be precisely applied to fully edentulous patients. As reported by different authors, the double scanned protocol of the radiographic templates allows for a virtual superposition of a dental set-up onto the 3D CBCT reconstruction.\(^3\) This feature provides the necessary reference points for restoratively driven surgical implant planning.\(^2\) As the 3Shape Implant Studio software needs dental reference points for the virtual crown designing and alignment, lack of teeth in fully edentulous patients makes the implant planning inaccurate and, therefore, not advisable. Future digital innovations will probably solve this inconvenience.

One of the most interesting features of the Beta version of the Implant Studio software was that it has a versatile virtual restoration-designing tool. This property eliminates the need for radiographic templates and double scanning protocols for partially edentulous patients, saving time and laboratory work.\(^4\)

A common problem in the 3D cone beam reconstruction is the interference of metallic restorations with the quality of the resulting image. This is because the metallic structures absorb and reflect the radiation differently from the oral hard tissues, creating a phenomenon known as scatter or “noise.”\(^4\) Because 3Shape Implant Studio software still requires a CBCT reconstruction, minimization of the radiographic distortion is recommended. For that purpose, it is important to follow each guided surgery software recommendation regarding the tomographic equipment setting.\(^4\) Moreover, because the implant planning is generally done in the maxilla or the mandible in separate stages, a convenient recommendation is to place an object between the superior and inferior teeth that is not detected by the CBCT (eg, cotton rolls) to allow a separation between both jaws. This simple procedure will help to avoid distortion resulting from metallic restorations in an opposing arch. The outcome is a more defined final image.

One of the major advantages of the 3Shape Implant Studio software is that it is a universal system; surgical planning can be made based on different implant systems. Furthermore, it allows for the use of different 3D printers and distinct types of computer-aided design/computer-assisted manufacture systems for abutments and restoration fabrication. The versatility of the whole system and the easy communication workflow provide the clinician with enough tools to perform simple, fast, and precise surgical planning and clinical procedures.

Conclusions

This case history report described how the combination of digital surface scans and CBCT files for virtual planning can be used for noninvasive computer-guided implant placement and subsequent prosthetic replacement for the described specific clinical situation. It must be acknowledged, however, that the routine
use of this technology demands more outcome studies to confirm their reported merits. The digital prosthetic designing tool included with the reported software makes radiographic templates for a double scanning protocol unnecessary, thereby reducing laboratory work and treatment times for both patient and dentist. It is expected that the combined advantages of both systems will become a fundamental component of future diagnosis, planning, and treatment for noninvasive guided implant placement.45

Acknowledgments

The authors received funding support from the International Team for Implantology through the ITI Scholarship Program (AL). The authors want to thank Drs Miguel Padiel-Molina, Andrew Barnett, and Eboné Jordan from the Department of Periodontics and Oral Medicine at the University of Michigan for their collaboration in the revision of this manuscript. The authors also want to thank Protoaco for its collaboration in the surgical guide fabrication. The authors do not have any financial interests, either directly or indirectly, in any of the products listed in this article. The authors reported no conflicts of interest related to this study.

References

Defective wound healing in aging gingival tissue

The physiologic process of aging can affect cell function negatively; senescence is known to be associated with a reduction in regenerative ability and collagen synthesis in periodontal tissues. This study aimed to investigate the differences in cellular responses between young and old human gingival fibroblastic tissue cultures and also the differences in gingival wound healing between young and old rats. Human gingival fibroblasts were harvested from five younger (15 to 25 years old) and five older (50 to 70 years old) healthy patients at third molar or crown lengthening sites and cultured for cell analysis. The younger human gingival fibroblasts showed increased cell proliferation and viability, faster migration times, and better collagen gel remodeling capacity. The older human gingival fibroblasts stimulated with rat TGF-β1 showed altered myofibroblastic differentiation. With regard to gingival wound healing in rats, there was significant delay in wound healing in older rats (18 months old) compared to younger rats (2 months old) at the seventh day of wound healing. This article provides some insight into the differences in healing processes between younger and older periodontal tissue, and results are consistent with the current understanding of the physiologic effects of senescence.
