Digital Technologies for Dental Implant Treatment Planning and Guided Surgery

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KEYWORDS

• Cone beam CT • Dental implant • Oral and maxillofacial surgery • Dental implant surgery

KEY POINTS

- Oral and maxillofacial surgeons now have extraordinary imaging, software planning, and guide fabrication technologies at their disposal to aid in their case selection, clinical decision making, and surgical procedures for dental implant placement.
- Cone beam CT (CBCT) has opened a new era of office-based diagnostic capability and responsibility.
- Improved clinical experiences and evidence-based superior outcomes can be provided with confidence to patients when CT-guided dental implant surgery is used.

New digital technologies have greatly benefited modern dental treatment. The development of dental CBCT scanners from medical helical CT scanners for use in dental offices has given oral and maxillofacial surgeons and their dental colleagues powerful imaging capabilities and software applications. Dental CBCT now allows the implementation of a software-based treatment plan into clinical use through patient-specific, computer-generated, CT-guided drill templates. From a historical perspective, when CT scans were first used to plan dental implant surgery, the first surgical drill guides were handmade by dentists or laboratory technicians from cold cure or processed acrylic, with radiopaque occlusal markers placed prior to the scan and metal drill sleeves placed after the scan. These early surgical drill guides did not have the integration of the CT data into the surgical plan. Klein and colleagues[1,2] and other investigators developed computer planning methods to use fiducial markers to relate the CT scan data to the prosthetic plan and had dental implant drill guides with the placement of planned trajectories based on a technician adjusting a drill press according to the fiducial markers position in 3-D space from the CT scan. This allowed implant trajectories to be placed into the handmade radiographic guide, converting it into a surgical drill guide. Columbia Scientific developed software known as SimPlant, which made planning these cases possible. After the acquisition of Columbia Scientific by Materialise (Leuven, Belgium), which had a process to use the rapid manufactured output from the software-planned dental implant trajectories into the bone made it possible to initially create bone-borne and later tooth-borne surgical drill guides.[3] The use of fan beam CT for the planning of dental implants and the use of

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surgical guides for CT-guided dental implant placement had become possible. Use of the dual-scan process was first described for the completely edentulous by Jacobs and colleagues[4] and Van Steenberghe and colleagues,[5] who first recognized the potential for CT rapid prototyped surgical guides for complete denture patients.[6,7] After the CT scan of a patient with a barium-impregnated radiographic guide, bone-borne surgical drill guides were fabricated to fit stereolithographic jaw models that required the opening of a flap for placement of dental implants. Materialise then developed the next generation of surgical drill guides that had bone trajectories merged by surface-to-surface matching with an optical scan of a dental model.[8] The surgical drill guide could then be created by rapid prototyping, which was then tooth-borne. Feldman[9] with iDent Imaging (New York, New York) furthered the development of dual-scan process for the partially edentulous with an artifact-corrected image to create a postsegmentation surgical guide that could be tooth- or mucosal-borne. Instead of using barium, the dual-scan surgical guide process uses the registration of radiodense fiducial radiographic markers, such as metal beads or guttapercha, from the scan of the radiographic guide in a patient's mouth (**Fig. 1**) and from a separate scan of the radiographic guide in a Styrofoam box or stand aligned in the same orientation (**Fig. 2**). These 2 data sets that that can be merged through the registration of the fiducial markers and permits the creation of an artifact-corrected image. The 2 data sets of digitized images are uploaded to the company for file conversion and are merged in the planning software, with registration and superimposition of the radiographic template to the bone images. iDent Imaging, Nobel Biocare (Yorba Linda, California), and other companies developed the first commercial dual-scan tooth-borne surgical drill guides with virtual

Fig. 1. Radiographic guide in a patient's mouth for CBCT scan. (*Courtesy of* Dr. Mark Hamburger, London, UK.)

Fig. 2. Radiographic guide on Styrofoam for CBCT scan.

insertion of drill trajectories manufactured by rapid prototyping manufacturing. When using these software programs, it may be necessary to modify the voxel settings of the CBCT so that the data are obtained in the right DICOM format that needs to be used by the planning software. The planning software vendor should be checked carefully to obtain their scanning protocol. These 2 DICOM data sets are then exported from the CBCT scanner by a custom export plug-in and transferred as data files for uploading to the vendor. The data are uploaded to the master site software, or the software may need to be converted by third-party service vendors or the software vendor itself, which may require the payment of a fee for conversion and can include set-up of the case for review by a clinician, who ultimately must make the final approval regarding the case and the production of the surgical drill guide.

Materialise's software SimPlant has a barium-impregnated scan appliance created and scanned as the first data set; then a model is sent to Materialise for optical scanning so that an artifact-free image of the teeth can be created as a second data set. After the merger of the data sets, a surgical drill guide is made according to the planned implant position(s) in the treatment planning software.

There are many treatment planning software programs and providers of surgical guides, with some closed systems associated with particular implant systems, whereas others are open platforms for use with all dental implants. Some software programs, such as Cybermed (Irvine, California) and Blue Sky Bio (Grayslake, Illinois), may not require a radiographic scan appliance and can surface-to-surface merge either from a CBCT scan of a dental model or an optical scan of a patient's dentition for the fabrication of a surgical drill guide. In the case of Blue Sky Bio, this process is via a rapid printed model on which a