Dental implantology—An evolving treatment modality

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Over the past 30 years implant dentistry has evolved into a predictable, even conventional, treatment alternative for patients who are missing teeth. In fact, the art and science of implant dentistry has expanded to include many ancillary supporting modalities such as bone grafting, ridge splitting, sinus augmentation, soft-tissue grafting, biologic modifiers, 3-dimensional (3-D) imaging technologies, CAD/CAM technologies, guided surgery applications, and enhanced restorative materials.

Diagnosis and treatment planning for dental implants has dramatically improved with the advent of computed tomography (CT), followed by a proliferation of lower dosage cone beam CT (CBCT) devices. Two-dimensional (2-D) periapical radiographs and panoramic radiography are inherently deficient in their ability to provide accurate diagnostic information for dental implant placement and related surgical procedures due to potential distortion and ability to communicate three-dimensional information related to the maxillo-mandibular anatomy. Prior to the scalpel touching the patient, the ability to assess the individual patient-specific anatomy is now a clinical reality with advanced imaging technologies and interactive treatment planning software (Fig. 1). The quantity and quality of bone can be determined, aiding clinicians in making educated decisions regarding treatment. Implant receptor sites can be evaluated with ever-increasing accuracy, based upon complete visualization of the buccal and lingual cortical plates and intermedullary bone.

However, it has been stated that “the goal of implant dentistry is not the implant, it is the tooth that we replace.” Therefore if clinicians wish to achieve restoratively or prosthetically-driven implant reconstruction there needs to be a complete
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The special evolution of dental implantology underlines the understanding of the relationship between the tooth and the underlying bone.

The ideal pre-surgical workflow should require conventional impressions and mounted articulated study casts. A diagnostic wax-up, or duplicate of the patient’s denture representing the desired tooth position can then be utilized to fabricate a radiopaque scanning appliance to be worn by the patient during the scan acquisition. Depending on the interactive treatment planning software, protocols can differ requiring fiducial markers that act to register the digital information to the CBCT scan data. Additionally, the proliferation of optical scanning devices at dental laboratories, or intra-oral optical scanners can play a role in acquiring this digital information that will be merged with the data from the CBCT scan enhancing the accuracy of the planning software (Figs. 2a & b). Utilization of a scanning appliance provides the clinician an unparalleled ability to visualize the relationship between the tooth and the underlying bone. Using an interactive treatment planning software such as SimPlant (Materialise Dental), NobelClinician (Nobel Biocare), Treatment Studio/Invivo5 (Anatomage), BlueSkyBio (Blue Sky Bio) the virtual implant can then be positioned within the receptor site to fit within the envelope of the desired restoration. However, it needs to be noted that the link between the implant and the tooth is the abutment. Therefore it is essential to place a virtual abutment or an abutment “projection” with an appropriate vertical height to visualize the spatial positioning of the abutment as it relates to the tooth to achieve restoratively driven outcomes (Figs. 3a & b).

**Utilizing the data**

The utilization of CBCT imaging and interactive treatment planning software has been increasing in its adoption for planning both the surgical and prosthetic phases of treatment.

Once the scan in taken regardless of whether a scanning appliance is used, the clinician has several options in utilizing data:

- diagnostic-freehand;
- template-assisted;
- and full template guidance.

Each CBCT device has its own native software which can provide valuable three-dimensional information about the patient’s anatomical presentation.

The concept of diagnostic-freehand can be divided into two applications:

- the surgeon can visualize this data, make measurements, plan the implant positions, communicate with the restorative dentist and then perform the surgical placement free-hand based on his/her personal level of experience;
- or the CBCT data (DICOM—digital communication in medicine) can be imported into an interactive treatment planning software where there are additional diagnostic and implant planning tools to enhance the process (Fig. 4). The surgeon can then perform the surgery free hand based upon the information gleaned from the virtual plan.

Template-assisted protocol can be described where the information from the interactive treatment planning software can be utilized to fabricate a surgical guide. Surgical guides come in several types including bone borne, tooth borne, or soft tissue/mucosal borne and contain guide cylinders that correspond to the drilling sequence for osteotomy creation (Fig. 5). Surgical guides can be used in flapless/minimally invasive, or flapped surgical procedures helping to increase accuracy, minimize surgical time, and potential patient morbidity.

**Full template guidance** encompasses perhaps the most important innovation where there is a link between the surgical guide and the implant manufacturers’ components. The development of implant specific hardware allows for full template guidance—when it is possible to deliver the implants through the guide with specially designed carriers that provide for the most precise place-
Bone volume preservation

3-D imaging technologies can identify areas with great clarity areas that have insufficient bone volume for implant placement. It is well documented that atrophy of the bone can occur once teeth have been removed from the jawbone. When a tooth needs to be extracted, preservation of the alveolar ridge has become a significant and practical procedure to prevent resorption and to provide enough bone volume for future dental implant placement. If there is not enough bone volume within a designated receptor site to place an implant, many options are now available to replace missing anatomy to create a sound foundation for future implant placement. The area of biologics has greatly expanded the choices for clinicians to determine the appropriate method and materials to rebuild lost soft- and hard-tissue anatomy. Demineralized bone, mineralized bone, bone putties, allografts (human cadaver bone), and xenografts (bovine bone), as well as combinations of particulate and block graft materials, are available as scaffolds to increase volume and promote new bone growth. There are also a variety of different resorbable and nonresorbable membranes of various materials that can be used in conjunction with grafting procedures with and without tenting screws to preserve space as an aid to the remodeling process. The most popular membranes are made from different configurations of collagen matrices, and can be short-acting or long-acting depending on the desired usage.

Use of autologous biomaterials has also been expanded since the development of platelet-rich plasma (PRP) many years ago. Natural bioactive membranes can be fabricated from the patient's own blood for the purpose of enhancing hard- and soft-tissue healing. PRP protocols are basically enhanced fibrin glues. Recent advances with platelet-rich fibrin (PRF) create a true fibrin-based biomaterial that can function as a membrane with its improved properties and incorporation of significant growth factors. As a completely autogenous material developed from the patient's own blood, the membranes derived from this process are easy to handle and inexpensive to produce. These membranes can be used to cover surgical sites, mixed with bone grafting materials, acting as optimized blood clot (Fig. 7).

Other biologics that have evolved include recombinant human bone morphogenetic proteins which have shown clinical efficacy, although they remain quite expensive, and thus have limited applications.

Sinus grafting

Sinus augmentation procedures were introduced years ago to provide a new foundation for the placement of dental implants in the severely resorbed posterior maxilla. CBCT imaging allow for total inspection of the sinus to evaluate potential pathology as well as to plan the grafting procedure (Figs. 8a & b). New surgical techniques and instruments have significantly simplified maxillary sinus surgery, by decreasing the potential of perforating the Schneiderian membrane through the selective cutting action of hard tissue and not soft tissue. Creating a piezoelectric bony window osteotomy can be accomplished without damaging the soft tissue, followed by
piezoelectric sinus membrane elevation to separates the membrane without causing perforations (Fig. 9). The concept of piezoelectric surgery has now been utilized for ridge-splitting, introral bone harvesting from the ramus and chin, orthodontic procedures, impactions, distraction osteogenesis and much more.

Other innovations for sinus grafting include the development of new surgical kits that include a variety of specially designed large and small diamond-coated drills for crestal and lateral approaches to adding bone into the sinus without perforation (Fig 10). These instruments are available from a variety of different companies that include predefined stoppers, sinus elevation instruments, osteotome inserts allowing clinicians to perform a well-controlled maxillary sinus augmentation.

_Restorative enhancements_

The restorative phase of implant reconstruction has seen significant evolution in components, manufacturing processes, impression methodologies, and materials. Perhaps the most important technological change has been the increased use of CAD/CAM technologies for custom abutments, bar and prosthesis fabrication. Due to the fact that most implants may not be placed ideally, and that round implants are not true representations of natural tooth morphology, custom abutments are a necessity for the restoration phase. The lost-wax casting method has many issues including the labor intensive method to fabricate custom abutments. CAD/CAM technology allows a higher degree of accuracy, consistency, improved emergence design and morphology, avoiding the porosities and distortion that can occur with analogue casting methods. In addition, custom abutments can be fabricated from titanium or more aesthetic materials like zirconia. CAD/CAM bars for overdenture applications or as a base for fixed-detachable hybrid restorations have also benefitted from advances in computer design and highly accurate machining to create a significantly improved end-product. CAD/CAM technology has been now utilized to fabricate full arch restorations from monolithic zirconia providing enhanced strength without compromising aesthetics (Fig. 11).

The evolution of dental implants will continue as the industry progresses in combining both the art and science of replacing lost intraoral anatomy and as dentistry remains committed to developing improved methods and materials to treat patients who require these services.

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**Fig. 9** A lateral window approach facilitated by piezo-electric surgery can be accomplished without damaging the soft tissue membrane.

**Fig. 10** Large and small diameter diamond-coated drills offer new solutions to lateral window and trans-crestal sinus grafting procedures.

**Fig. 11** A CAD/CAM designed implant-supported full arch monolithic zirconia restoration is planned on the computer screen.

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**Dr Scott D. Ganz** currently maintains a private practice for Prosthodontics, Maxillofacial Prosthetics, and Implant Dentistry in Fort Lee, New Jersey, USA. Dr Ganz has been voted one of the “Best Dentists in America,” “Top Dentists in New Jersey,” and served as Past President of the NJ Section of the American College of Prosthodontists, and the Computer Aided Implantology Academy (CAI).

Dr Ganz delivers presentations worldwide on both the Surgical and Restorative phases of Implant Dentistry and has published extensively on these topics. He is considered one of America’s leading experts in the evolution of computer utilization and interactive software for diagnostic and treatment planning applications using CT and newer generation Cone Beam CT imaging modalities.