Integrating three-dimensional digital technologies for comprehensive implant dentistry

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ABSTRACT

Background. The increase in the popularity of and the demand for the use of dental implants to replace teeth has encouraged advancement in clinical technology and materials to improve patients' acceptance and clinical outcomes. Recent advances such as three-dimensional dental radiography with cone-beam computed tomography (CBCT), precision dental implant planning software and clinical execution with guided surgery all play a role in the success of implant dentistry.

Methods. The author illustrates the technique of comprehensive implant dentistry planning through integration of computer-aided design/computer-aided manufacturing (CAD/CAM) and CBCT data. The technique includes clinical treatment with guided surgery, including the creation of a final restoration with a high-strength ceramic (IPS e.max CAD, Ivoclar Vivadent, Amherst, N.Y.). The author also introduces a technique involving CAD/CAM for fabricating custom implant abutments.

Results. The release of software integrating CEREC Acquisition Center with Bluecam (Sirona Dental Systems, Charlotte, N.C.) chairside CAD/CAM and Galileos CBCT imaging (Sirona Dental Systems) allows dentists to plan implant placement, perform implant dentistry with increased precision and provide predictable restorative results by using chairside IPS e.max CAD.

Conclusions. The precision of clinical treatment provided by the integration of CAD/CAM and CBCT allows dentists to plan for ideal surgical placement and the appropriate thickness of restorative modalities before placing implants.

Key Words. CAD/CAM; cone-beam computed tomography; implants; restorative dentistry; fixed prosthetics; guided implant surgery.

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Dental computer-aided design/computer-aided manufacturing (CAD/CAM) technology is used in both dental laboratories and dental offices for multiple restorative applications. Chairside CAD/CAM systems for dental offices offer dentists the opportunity to design, mill and place ceramic restorations in a single appointment. As implants become the treatment of choice for fixed tooth replacement, dentists also are considering using chairside CAD/CAM systems as a restorative solution for implant prosthetics. A predictable CAD/CAM technique for dental implantology could satisfy patients' preference for convenience and dentists' desire for predictable, long-term restorations. Clinical research provides documentation of the success of ceramic restorations created using the CEREC system (Sirona Dental Systems, Charlotte, N.C.).[1-4] As the technology has evolved, it also has been used to restore dental implants.[5,6]

CAD/CAM TECHNOLOGY FOR DENTAL IMPLANTS

Initial attempts to fabricate implant restorations chairside with the CEREC system included the use of feldspathic and leucite-reinforced ceramic CAD/CAM blocks. These ceramics require adhesive bonding to be successful in restoring natural teeth. Adhesive bonding to implant abutments remains unpredictable and reduces the reliability of conventional all-ceramic materials. Reports of increasing the occlusal thickness of the restoration beyond the 1.5 millimeters recommended for conventional tooth preparations does not offset the fracture risk of adhesive glass ceramic CAD/CAM blocks used on implant abutments.[6,7] The results of the study by Wolf and colleagues[6] suggest that increasing the thickness of the crown to an unusual 5.5 mm in combination with shortening the abutment does not result in greater crown strength. To date, there have been no published clinical studies in which this type of ceramic material was used to restore dental implants. Despite this lack of published data, the introduction of a lithium disilicate glass ceramic with 360 megapascals of biaxial flexural strength (IPS e.max CAD, Ivoclar Vivadent, Amherst, N.Y.) provides dentists with the option to use either cementation or an adhesive bonding protocol. This material has the potential to be used for definitive implant restorations. The higher flexural strength of the

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material reduces the risk of fracture under normal masticatory load compared with that of conventional glass ceramic CAD blocks.[7-9] The results of the study by Wolf and colleagues[6] suggest that the interaction between abutment material and mode of cementation plays an important role in the viability of conventional glass ceramic CAD/CAM materials. They noted that the use of adhesive resin cement increased the overall fracture load of conventional CAD/CAM ceramic restorations compared with that of nonadhesive cements. With the recent availability of a high-strength ceramic material, a more favorable outcome for implant-supported restorations may occur.

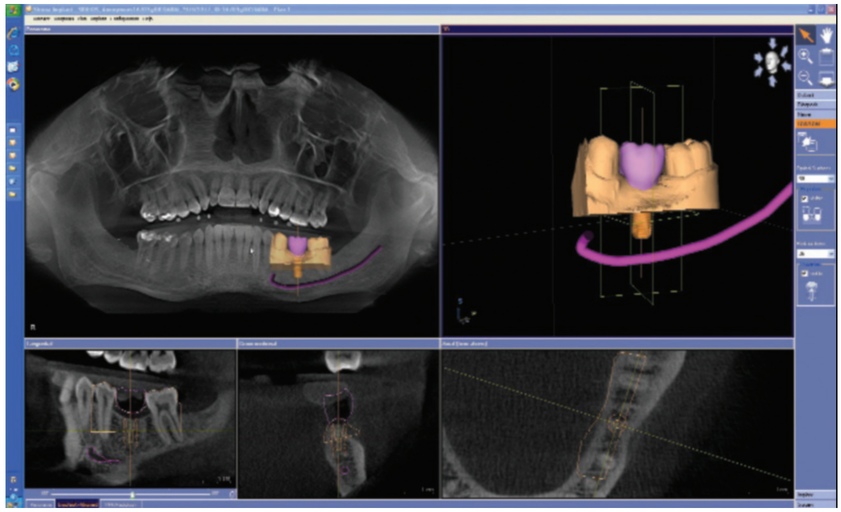

Figure 1. Sidexis and Galileos implant software (Sirona Dental Systems, Charlotte, N.C.) provides tools such as nerve mapping and implant planning. Galileos CEREC (Sirona Dental Systems) integration allows for computer-aided design/computer-aided manufacturing data to be imported into software to create virtual prosthetics, giving dentists the opportunity to plan comprehensive restorative treatment in a single visit. Image of Galileos Sidexis software reproduced with permission of Sirona Dental Systems, Charlotte, N.C.

INTEGRATION OF CONE-BEAM COMPUTED TOMOGRAPHY AND CAD/CAM

The primary emphasis in a surgery-focused approach to implant placement is on the anatomy, bone physiology and surgical success. The restorative demands of the case may be secondary when determining the placement of the implant fixture. During the restorative phase, compensation for deviations in implant fixture location involves the use of complex custom prosthetics components. A technique that requires custom prosthetics designed after surgical placement of the endosseous dental implant does not allow for the implant to be restored in a single visit because of the required laboratory fabrication process.

Dentists need to consider the restorative goal and surgical requirements to plan optimally for the surgical placement of implants. This process requires a plan for the final restoration's optimal function, esthetics and biomechanics before making the surgical plan. The traditional technique for such planning begins with using diagnostic casts, impressions and clinical records. Using the diagnostic casts, the dentist or laboratory technician produces a wax-up to simulate the desired restorative outcome. A stone duplication of the wax-up is necessary for processing either a laboratory surgical guide to help with traditional implant placement or a radiographic scanning appliance for subsequent diagnostic implant planning. This work flow involves multiple patient appointments and separate laboratory procedures involving the clinician and the laboratory technician before the implant can be placed. Because of procedural complexity, the clinician may favor a surgically focused technique for implant placement and treat the restorative process as secondary.

Sirona Dental Systems introduced a combination of three-dimensional (3-D) radiographic imaging and 3-D planning by integrating CEREC Acquisition Center (AC) design with Galileos (Sirona Dental Systems) cone-beam computed tomographic (CBCT) imaging to facilitate comprehensive implant treatment. Galileos CEREC integration (GCI) simplifies restorative-focused implant placements through the use of intraoral surface data (the digital impression) and radiographic data (Figure 1). The GCI technique gives dentists the opportunity to plan optimum prosthetic and surgical outcomes for implants during the diagnostic and planning phases of treatment while minimizing the number of procedures and increasing work-flow efficiency.

By using GCI software, the clinician can identify the restorative requirements virtually, including proper restorative material thickness around the long axis of the planned implant, depth of restorative interface and emergence profile. Such information may help the dentist decide whether to use

ABBREVIATION KEY. AC: Acquisition Center. **CAD/CAM:** Computer-aided design/computer-aided manufacturing. **CBCT:** Cone-beam computed tomography/tomographic. **GCI:** Galileos CEREC integration. **3-D:** Three-dimensional.

Figure 2. Clinical photo with seated custom zirconia implant abutments for teeth nos. 12 through 14 and teeth nos. 18 through 20.

stock abutments or custom anatomic abutments. Until now, the convenience of chairside CAD/CAM for implant restoration was limited by material strength. The ability to plan implant placement with restorative vision by using the GCI software combined with a restorative material whose properties are an improvement over those of conventional glass ceramics provides the dentist with a viable comprehensive protocol for implant placement and chairside CAD/CAM all-ceramic restorative success.

CLINICAL WORK FLOWS

There are a number of possible work flows that can be followed when using the GCI technique.

Single-implant workflow. For a single-implant site, the clinical work flow begins with obtaining a digital impression by using CEREC AC and Galileos CBCT during the initial consultation. Instead of using conventional impressions and diagnostic wax-ups, the dentist can use the digital impression to record the surface anatomy and design an ideal restoration virtually. The digital impression is obtained by coating the tooth and gingival surfaces lightly with an optical reflective medium to create a uniform surface and by using the CEREC AC Bluecam to acquire image data. Obtaining the digital impression includes capturing both the edentulous quadrant and the opposing quadrant in separate image catalogs. The virtual models created from the digital impression are articulated by using an additional image recorded when the patient is in maximum intercuspation (buccal bite technique). The dentist or technician uses CEREC Biogeneric software (Version 3.80, Sirona Dental Systems) to create virtual wax-ups of planned restorations that include parameters such as occlusal contacts, proximal contacts, emergence profile, proximal contours and the desired material thickness for optimal strength of the ceramic restoration. In addition to the optical impression, a Galileos CBCT scan of the patient is obtained by means of a stock scanning bite plate (SICAT, Bonn, Germany). The bite plate is seated clinically by using the bite registration material. The bite plate is converted to the surgical guide at a later stage. The Galileos CBCT scans provide a 3-D volume image of the hard tissue that can be evaluated by using software to evaluate radiographic sections of the anatomy that correlate one-to-one without distortion or magnification.

The CAD/CAM and CBCT systems provide comprehensive diagnostic data. The acquisition of surface anatomy and radiographic anatomy data allows the dentist to design and plan treatment and order precision surgical guides for guided implant placement in one visit. The process requires the dentist to combine the data sets from the two systems by using GCI integration software that uses sophisticated algorithms to match common data points. The dentist need only identify common features between the two digital images (for example, placing an identification marker on tooth no. 2 in the CEREC AC image and on tooth no. 2 in the Galileos image) to allow the software to correlate the data. Once combined, the CEREC AC data are visible within the Galileos software, allowing the dentist to plan the implant position as it relates to both the prosthetic and surgical requirements of the case (Figure 1). Within the software, a library of implant systems from which to plan implant positioning relative to restorative and surgical goals is available. Once the dentist determines the type of implant and surgical positioning, he or she can order the surgical guide. The patient's data set and scanning template are sent to SICAT for fabrication of the implant surgical guide.

The dentist can order the surgical guide with multiple options, including a guided pilot system for guided pilot osteotomy, sleeve-in-sleeve systems for complete guided final osteotomy or a master sleeve for guided implant placement. The surgical guides are compatible with most of the available implant systems. This work flow allows for guided surgical implantation during the patient's second visit. Implant placement accuracy when using the SICAT surgical guides is within 500 micrometers of planned implant placement location.[10] The SICAT surgical guide system's inherent mean deviation rates for drilled pilot osteotomies are less than

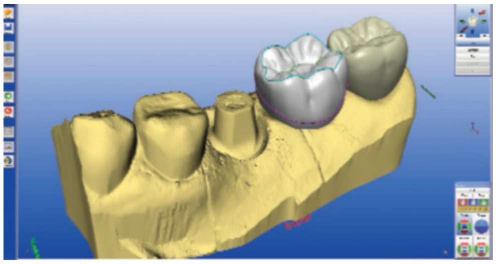

Figure 3. CEREC Biogeneric software (Version 3.80, Sirona Dental Systems, Charlotte, N.C.) showing the design process for chairside fabrication of custom implant crowns. The image shows intraoral scan of seated abutments for teeth nos. 18 through 20. The crown design for tooth no. 18 is completed and virtually seated. The crown for tooth no. 19 is designed for proper emergence profile, contacts and occlusion. Image of CEREC software reproduced with permission of Sirona Dental Systems, Charlotte, N.C.

Figure 4. Photo showing IPS e.max CAD (Ivoclar Vivadent, Amherst, N.Y.) block with precrystallized chairside milled implant crown no. 19 and the final crown after crystallization with custom staining and glazing. Image of IPS e.max CAD LT reproduced with permission of Ivoclar Vivadent, Amherst, N.Y.

Figure 5. Clinical photo with seated IPS e.max CAD (Ivoclar Vivadent, Amherst, N.Y.) implant crowns nos. 12 through 14 and crowns nos. 18 through 20.

500 μm even at the apical end and within 1.18° angular deviation, and their crestal deviations are significantly lower than those of apical deviations.[10]

Once osseointegration is complete, the restorative phase of treatment can begin, and the dentist can use the data from CEREC AC and Galileos that were used during the planning phase to understand the restorative options in advance. The dentist can seat a stock or standard abutment clinically and scan it intraorally with CEREC AC to fabricate a full-contour restoration similar to a preparation for a crown on a natural tooth (Figure 2).

Because of the nature of stock abutments, the dentist may need to modify margin placement, reduce axial dimensions, add antirotational facets and produce a proper tissue emergence profile by using high-speed rotary instrumentation with copious water irrigation to reduce heat production. To reduce the risk of heat transfer and implant damage, modification of prosthetic components extraorally may be indicated. After the dentist seats the abutment clinically, he or she can fill the screw access hole with a retrievable material to protect the screw for future access. Tissue retraction is necessary to visualize the abutment margin. The dentist can retract the gingivae by using conventional means such as a retraction cord, retraction gels and pastes, and laser treatment. Once the dentist has isolated the abutment, he or she follows the conventional chairside optical impression protocol by using CEREC AC Bluecam. Within the CEREC AC software, the dentist can evaluate and confirm the abutment's restorative margin, interproximal contacts, occlusal contacts, emergence profile and soft-tissue support. Essentially, the dentist can design a final crown by using the CEREC AC software and customize it to fit the restorative environment chairside (Figure 3). The dentist selects IPS e.max CAD and sends the data to the inLab MC XL (Sirona Dental Systems) milling chamber for chairside computer-aided manufacturing of the crown.

After the dentist retrieves the restoration from the milling chamber, he or she can evaluate the restoration clinically and adjust it if necessary while it is in the precrystallized state (Figure 4). The dentist can introduce custom staining and glazing before the restoration is crystallized to final lithium disilicate transformation for optimal strength and esthetics (Figures 4 and 5). He or she can use adhesive (which requires that zirconia abutments be pretreated with 10-methacryloyloxydecyl dihydrogen phosphate monomers) or conventional cementation options. The dentist should remove residual cement carefully after cementation and use radiographic confirmation of abutment seating and cement removal.

Custom abutment and crown work flow. Another work flow relies on the dentist's sending the CEREC AC digital impression data to a dental laboratory by using the CEREC Connect software (Sirona Dental Systems) via the CEREC inLab (Sirona Dental Systems) system to fabricate a custom abutment and crown. This abutment technique may include having the dentist obtain either a traditional fixture level impression used to fabricate a master implant model or a digital intraoral impression of a clinically seated scan body on the implant. (A scan body is a plastic coping with markers that provide 3-D registration of the implant location.) Both techniques give dentists control over more complex and esthetic cases when they are restoring multiple implants. Either intraorally or

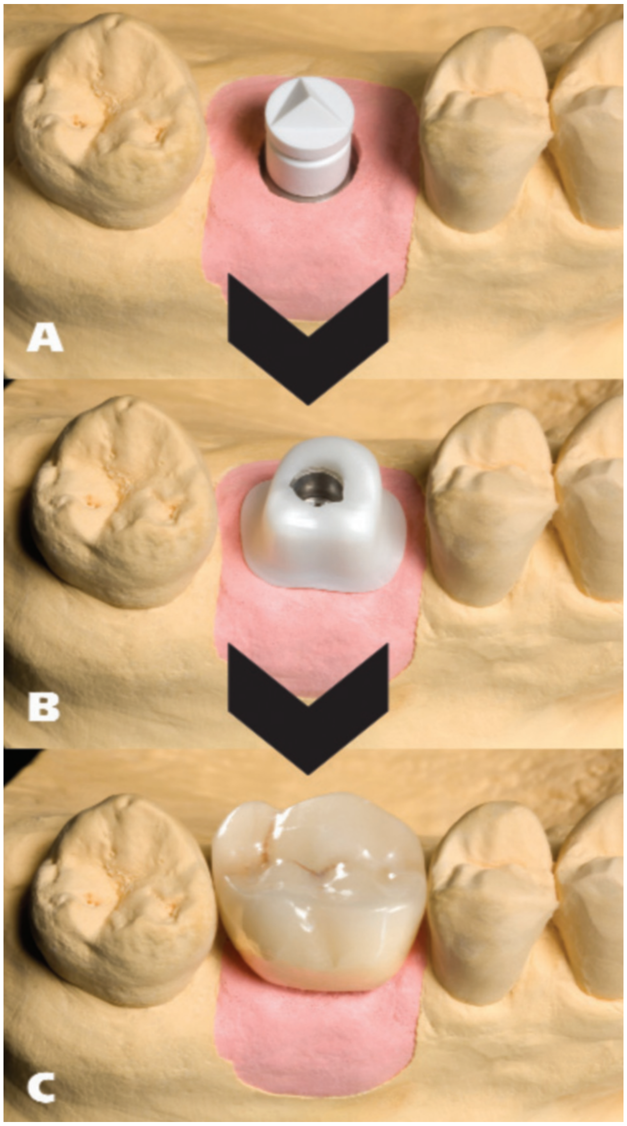

Figure 6. Laboratory process for CEREC inLab abutments (Sirona Dental Systems, Charlotte, N.C.). **A.** A seated scan body over a titanium base on a fixture level implant master model. CEREC inLab software (Sirona Dental Systems) allows for complete customization of an inCoris ZI (Sirona Dental Systems) meso structure for full-contour abutment design to mimic conventional fixed prosthodontic tooth preparation with cutback technique in CEREC inLab software. **B.** Seated custom CEREC inLab implant abutment. **C.** Final crown seated on CEREC inLab abutment.

on a master implant model, the dentist seats the appropriate titanium base on the implant. Then he or she introduces a scan body that allows for digital scanning with CEREC inLab for working models (Figure 6) or CEREC AC for intraoral scanning. For intraoral scanning, the dentist can forward the scan data to technicians who use CEREC inLab for the design and milling of custom implant abutments. Using the CEREC inLab software, the technician has the ability to design the ideal restoration virtually, perform a digital cutback technique or design a full-contour abutment that mimics conventional tooth-borne preparations for fixed prosthodontics. Once the abutment design is complete, the technician mills the zirconia restorative component with an inCoris ZI (Sirona Dental Systems) meso block, which is available in multiple shades, and sinters it for final crystallization. The technician lutes the zirconia meso structure to the titanium base to form the custom abutment. Then the CEREC inLab system can mill the corresponding restoration, or the dentist can seat the custom abutment for chairside CAD/CAM restoration (Figure 6).

CONCLUSION

The integration of chairside CAD/CAM software and CBCT provides dentists with a combined data set they can use for implant planning. This method may allow dentists more flexibility for delivering implant prosthetics—both milled custom abutments and milled crowns—chairside. The digital work flow for implant dentistry and chairside CAD/CAM offers new approaches to the way dentists can practice implant dentistry. ■

Disclosure. Dr. Patel has served as a consultant to and provides clinical education courses in Galileos cone-beam computed tomography and CEREC Acquisition Center computer-aided design/computer-aided manufacturing technology for Sirona Dental Systems, Charlotte, N.C.

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