THE EVOLUTION OF DIGITAL DENTISTRY AND THE DIGITAL DENTAL TEAM

LEE CULP AND ED MCLAREN

There was tension and excitement in the room as the lights were slowly dimmed in the auditorium. For the next two hours there was a glimpse of the future of dentistry. The topic was something out of a science fiction novel, and it instilled in the audience a sense of awe, wonder and just a touch of fear.

As the auditorium lights came up everyone sat in stunned silence as they contemplated all the possibilities offered by the presenter … dentistry going digital.

That presentation was given over 20 years ago by one of digital dentistry's pioneers, Francois Duret, on the application of computer-assisted design/computer-assisted manufacturing (CAD/CAM) technology into restorative dentistry. While it took slightly longer than anticipated to integrate into the daily practice of dentistry, the new millennium seemed to be the catalyst for change in digital dentistry, as more than ten different CAD/CAM systems have now been introduced as solutions for restorative dentistry.

Dentistry has cautiously welcomed this influx of technology that was promised so long ago. Based on technology adopted from aerospace, automotive, and even the watch-making industry, this technology is being accepted now due to its advantage of increased speed, accuracy, and efficiency without a compromise in quality. Today's CAD/CAM systems - both chairside and laboratory – based (e.g., Procera, Nobel Biocare, Yorba Linda, CA; Lava, 3M ESPE, St. Paul, MN; Cercon, Dentsply Ceramco, Burlington, NJ; CEREC, Sirona, Charlotte, NC; E4D, D4D Technologies, Richardson, TX) are being used to design and manufacture metal, alumina, and zirconia frameworks, as well as all-ceramic and composite full-contour crowns, inlays, and veneers that may be stronger, fit better, and are more esthetic than restorations fabricated using traditional methods.

The dentist's, dental team members' and dental technician's primary role in indirect restorative dentistry is to perfectly copy all functional and esthetic parameters that have been defined by nature into a restorative solution. It is an architect/builder elationship. Throughout the entire restorative process, from the initial consultation through treatment planning, provisionalization (if needed), and final placement, the communication routes between the clinician and the laboratory technician require a complete transfer of information pertaining to existing, desired, and realistic situations and expectations to and from the clinical environment. Functional components, occlusal parameter, phonetics, and esthetic requirements are just some of the essential types of information that are necessary for the technician to complete the fabrication of successful, functional, and esthetic restorations.

Lee Culp, CDT
Ed McLaren, DDS

The primary and conventional tools of communication between the dentist and the technician are photography, written documentation, and impressions of the patient's existing dentition, the clinical preparations and the opposing dentition. From this information models are created and mounted on an articulator, which simulates the jaw movements of the mandible.

As restorative dentistry evolves into the digital world of image capture, computer design and creation of dental restorations through robotics, our perceptions and definitions of the dental laboratory must evolve also. First, in order to fully understand this concept, we must clearly define what a laboratory is. At first thought we might say that a lab is the place that a dentist sends his or her patient's impressions which are then processed by that laboratory into restorations, which are sent back to the dentist for adjustment and delivery. This definition does seem to fit well with the traditional concept of a dentist-laboratory workflow. However, just as the internet has forever changed the landscape of communication through related computer technology, the possibility to use CAD-CAM restoration files electronically has provided the catalyst for a significant change in the way we view and structure the dentist-lab relationship.

Imagine first that the laboratory is not a place, does not have walls, and exists only in the talents for the partners in the restorative process – the dentist, auxiliaries, and technician. The equipment used to create the restoration may be located next to the chair, in an in-office laboratory area, or remotely or any or all of the above. The "laboratory" is actually nothing more than a workflow, which is flexible to the degree that abilities, access and equipment will allow. The primary decision becomes where the handoff from one partner to another should occur. Moreover, a dentist who has the ability to optically scan intraorally for impressions and who often choose CAD-CAM restorations as the best treatment option for their patients, have enhanced freedom as to where the authors

Figure 1. The dental operatory, with clinical CAD-CAM unit (dentistpatient photo)

believe the hand-off to the technician partner should occur. The lab is no longer a place, it is to a large degree, virtual and a fluid entity.

In some instances, it makes sense for the dentist to work independently and to prepare, design and finish the restoration chairside in a single visit with the obvious advantages a clinical CAD-CAM system has to offer. (Figure 1) These might include less complex restorations or fewer numbers of restoration for the same patient that do not require any special characterization other than perhaps stain and glaze or polish. Other times, it is advantageous to engage the services of the restorative partner, a dental technician, because he or she possesses the skill and perhaps more importantly, the time, to create restorations that either demand more complex characterization or can be more efficiently created in an indirect manner.

The Digital Process

The first successful introduction of CAD-CAM into dentistry was the chairside CEREC 1 system (Sirona 1982). The fundamental principle of this concept was to electronically capture a preparation's image and then use software to interpolate the information and create a digital model. A virtual restoration design was then suggested and after user-defined parameters were set, the restoration design was milled from a ceramic block and seated, all in one appointment. Subsequent software and hardware upgrades with the introduction of the CEREC 2, 3 and 3D systems primarily focused on improvements in user-friendliness, accuracy, and material milling options.

The introduction of E4D Dentist System (D4D Technologies LLC, Richardson, TX) in 2008, (FIG 2) along with its accompanying DentaLogic software and Autogenesis™ libraries became the first computerization model to accurately present a real 3-D virtual model and take into consideration the occlusal affect of the opposing (antagonistic) dentition with the ability to design multiple teeth at the same time. It essentially takes a complex occlusal scheme and its parameters and condenses the information, displays it in an intuitive format that allows dental professionals with basic knowledge of dental anatomy and occlusion to make modifications to the design, and then sends it through to the automated milling unit. For the dental profession, the introduction of the E4D Dentist system effectively automated some of the more mechanical and labor-intensive procedures (waxing, investing, burnout, casting, and or pressing) involved in the conventional fabrication of a dental restoration, allowing the dentist, dental assistant or technician to create functional dental restorations with a consistent, precise method.

The Chairside Dental Designer (CDD)

Taking complicated dental design software and packaging it into a logical and recognizable format has expanded the opportunities of dental professionals, other than the clinician,

Figure 2. D4D System (system only)

Figure 3. Preoperative conditon of teeth #30,31

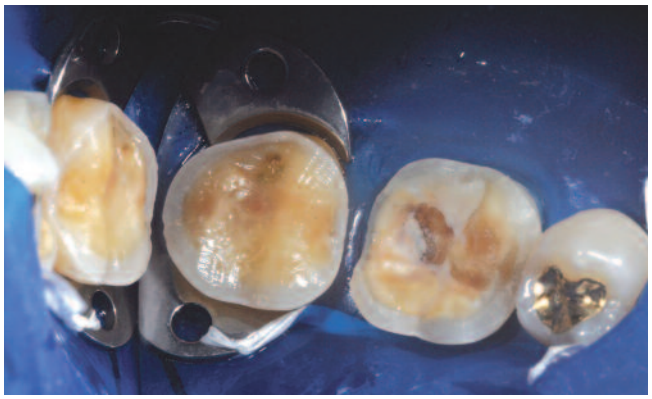

Figure 4. CAD-CAM ceramic onlay preparations

to contribute to the restorative process.

Through educational initiatives, E4D University offers a Chairside Dental Designer (CDD) opportunity expanding the auxiliaries role with scanning principles, designing guidelines and predictive milling practices and strategies allowing the team to maximize productivity and efficiency in the restorative process. Based upon state and provincial guidelines and the delegation of the clinician, a properly trained and utilized CDD or dental assistant can reduce the clinical operators chair/restorative time by 50%. Additionally, CADCAM courses are offered regularly to dental assistants wanting to maximize their contributions to the chairside restorative process with CAD CAM Dentistry.

The Way it Was

In the conventional indirect restorative process, the procedure begins with the usual steps: the clinician prepares the case according to the appropriate preparation guidelines, impressions the case, and sends these and other critical communication aspects to the laboratory. After the laboratory received all the materials from the dentist, the impression was poured, the models mounted, and the dies trimmed. These models were then used to fabricate appropriate restorations – either layered, pressed, milled, cast or combinations.

Even though this application offers many advantages to the dentist-technician team it still required the taking of an intraoral impression using conventional techniques, sending these impressions to the laboratory for the creation of stone models, and the fabrication of traditionally created dental restorations.

In this article, the authors would like to go to the next phase in the evolution of the dentist-technician working relationship.

The Way it Will Be

Case Study

A 48-year-old male patient presented with a missing cast gold restoration on tooth #31 and a fractured ceramic onlay on #30. (FIG 6) He possessed a negative medical history and good oral hygiene with resultant periodontal health. Decay was diagnosed with digital radiography, undermining the existing and previous restoration. Teeth were asymptomatic. Treatment options of a gold onlay, a porcelain fused-to-metal crown or a single appointment CAD/CAM ceramic onlays were considered and discussed with the patient. While a gold onlay certainly is an excellent, prudent choice, properly placed CAD/CAM designed and milled onlays have been extremely successful when proper preparations and occlusal design considerations are considered, even in these areas. The patient was appointed for a single prep and seat appointment. Upon arrival, his mandibular right quadrant was anesthetized. The existing ceramic restoration was removed and both teeth were prepared for the all ceramic onlays, following accepted CAD/CAM glass-ceramic preparation guidelines; adequate clearance, rounded internal aspects, supragingival butt joint margins.

THE E4D Digital Process

An individual file is created within the DentaLogic software for each patient. The operator can input the patient's name or record number. Then the appropriate tooth number(s) to be treated (up to 7 restorations can be designed and restored at the same time with the E4D Dentist system) and entered and then the type of restoration anticipated checked (full crown, veneer, inlay/onlay). Additional preferences include material choices (IPS Empress CAD, e.max CAD (Ivoclar Vivadent, Amherst NY) Paradigm MCXL or C (3M ESPE, St. Paul, MN) and preferred shade. System defaults that can be set ahead of time or changed per patient/case are preferred contact tightness, occlusal contact intensity, and the virtual die space, which defines the internal fit of the final restoration to the die/preparation.

Since the E4D Dentist system is currently the only system that can scan the tooth structure and preparations without a contrast agent, an impression (alginates included) and a stone model, the system also requires the method of scan (intraoral;

Figure 5. The data file in the D4D CAD-CAM system

Figure 6. Digital model proposal

mouth or extraoral; impression or model to be entered).

All of this information can be entered prior to patient treatment or changed at any time, should the actual treatment differ than the planned.

Once the preparation has been completed – the intraoral scans are completed. In this case a static bite registration will be taken primarily positioned of the mesial premolar as well as a series of scans to capture the entire preparation and neighboring areas.

A static bite registration was created by injecting a blue resilient bite registration material (Virtual Bite, Ivoclar Vivadent, Amherst, NY) onto the preparations while having the patient occlude . Although this particular bite registration has metallic additives to allow for scanning without powdering even for those systems that require it, the E4D System can be used with any bite registration material. The IOD scanner was used to capture occlusal scans of the bite registration over the preparation and the occlusal surfaces of the neighboring teeth.

Next, scans from the occlusal, lingual and buccal were taken of each preparation with the IOD scanner to build the virtual model to completion. Multiple scans are taken per preparation in order to capture the full contours (and undercuts) of the neighboring and preparations to aid in proper proximal contact and overall anatomical contours.

Once the images of the preparation, neighbors and bite registration are captured, the computer then has all the information it needs to prepare the working model - the preparation and the opposing model (from the bite registration images).

The real 3D virtual model is then presented to you on screen and can be rotated and viewed from any perspective. The operator can choose to view the model in either animation (stone view) or in a real ICEverything view (ICE) which represents a wrapping of the actual images over the digital mess providing a realistic view of the clinical conditions allowing the operator to distinquish discolorarations, build-ups, soft tissue and even enamel and dentin in many areas.

The first step in designing the restoration is to virtually define the parameters and borders of the final restoration, these are defined using the bite registration information, the adjacent teeth, contact areas and, finally, the gingival margins of the preparation.

The computer, with the aid of E4D Dentist's Autogenesis (morphing) software will place the restorations automatically in a preferred and appropriate position (based on all input and neighboring anatomical detail), but it is now that the operator's experience, training and knowledge of form and function is needed to manually reposition and contour the restoration to the clinically ideal location if needed.

With a few simple mouse clicks, the position and rotation of the crown can be altered as desired and the software's automatic occlusion application will automatically readjust each individual cusp tip, triangular ridge, and the restoration's contours, contacts, and marginal ridges based on the preferences and bite registration information and according to the newly desired position and rotation. The virtual restoration responds and adapts all parameters immediately as they relate to the new position. The position and intensity of each contact point is graphically demonstrated and color mapped immediately on the screen and can be adjusted easily pending operator and clinical preference.

Customized aspects and artistic creativity are also possible through an array of virtual carving and waxing tools. These can be used to manipulate occlusal anatomy, contours, and occlusal preferences, basically mimicking the actual laboratory methods and armamentarium. Each step is immediately updated on screen so the operator can see the effect of any changes (FIG 10). In addition visual representations of material

Figure 7. Digital onlay design

thickness, X,Y or Z slicing or a number of other variable can be checked, confirmed or changed as needed – all within the DentaLogic intuitive software.

When the final virtual restoration has been completely designed, it is simply a matter of loading the milling chamber with the predetermined shade and size of ceramic or composite block, pressing an on-screen button and, in a short time, an exact replica of the design is reproduced in ceramic.

The In Office laboratory Process

The ceramic restorations are then removed from the milling chamber and prepared for final esthetic enhancements.

The "milling sprue" must be removed first, then, if desired, surface texture and occlusal anatomy are defined using diamond and carbide burs. Care should be taken not to alter occlusal or interproximal contacts, as these areas were perfected in the E4D software and accurately reproduced during milling process. After esthetic contouring, restorations are rinsed with water to remove surface ceramic debris, and dried. Since the patient is still anesthetized and in the chair, tryin for proximal and marginal fit can be completed chairside with assurance. Once verified and adjusted, if necessary, conventional ceramic stain and glaze techniques, the restorations are further esthetically enhanced by the addition of subtle colors and glaze application (FIG 12). The ceramic chosen for this case was Empress-CAD Multi-blocks (Ivoclar-Vivadent, Amherst, NY). These ceramic milling blocks were designed to offer optimal esthetics by offering varying degrees of color and translucency designed into the block to mimic the dentin and enamel appearance and polychromatic nature of natural dentition.

Restoration Placement

Next, the stained and glazed restorations were prepared for

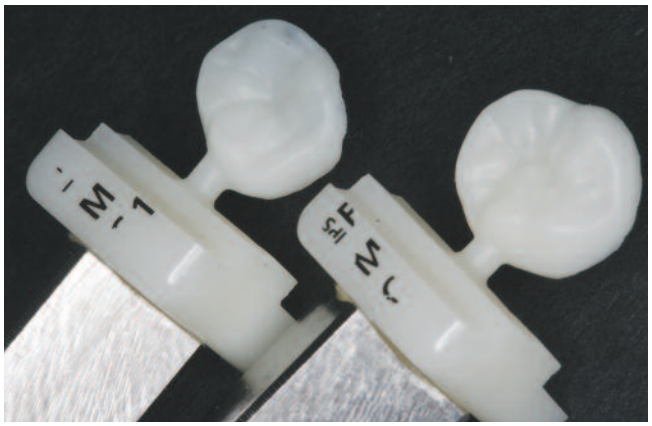

Figure 8. Milled restorations with sprue

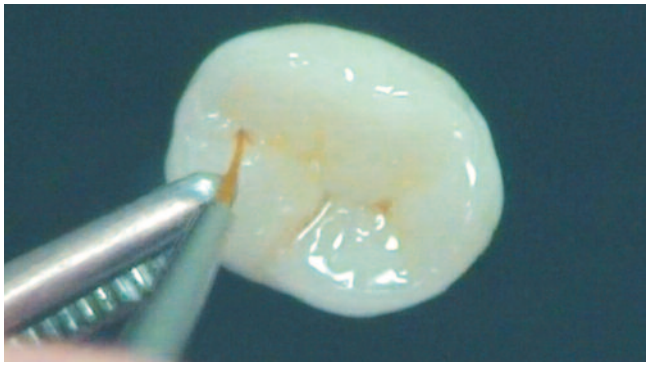

Figure 9. Stain and glaze

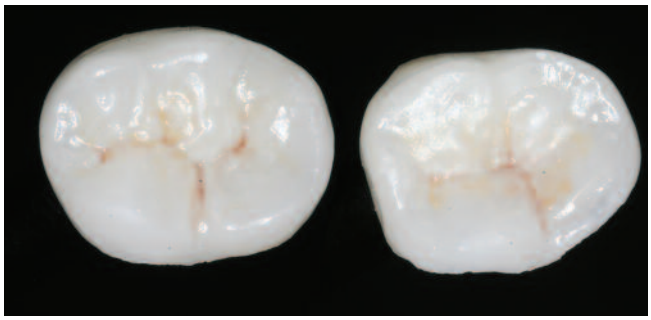

Figure 10. Completed restorations after stain and glaze.

Figure 11. Final restorations after bonding

placement by placing 5% hyrdrofluoric acid (IPS Ceramic Etch, Ivoclar Vivadent, Amherst, NY) onto the internal surfaces for one minute then rinsed and dried. A silane coupling agent (Monobond-S, Ivoclar Vivadent, Amherst, NY) was then placed for a minute onto the internal surfaces and then lightly air dried. On the preparation side, Multilink Automix (Ivoclar Vivadent, Amherst, NY) was selecte for final cementation. A&B primer was mixed vigorously scrubbed onto all preparation surfaces and then the restorations loaded with the appropriate shade of Multilink were seated to place. Excessive cement was removed prior to final self and light cure. The occlusal contacts were checked and harmonized in static occlusion and excursive pathway freedom was verified. Minimal adjustments were needed due to the correct capture and alignment of the bite registration data.

The finished restorations, which were designed and created by the team effort of the dentist (Dr. Ed McLaren; preparation and seating), Chairside Dental Designer (Sherri White, RDA; capture and design) and laboratory technician (Lee Culp, CDT; contour, stain & glaze) without the aid of an impression was found to be in functional and esthetic harmony and was completed in one appointment.

The dental profession currently regards CAD-CAM technology as just a machine that fabricates full contour ceramic restorations or frameworks. Digital Dentistry and the Digital Dental Team, represents a totally new way to diagnose, treatment plan and create functional esthetic restorations for our patients in a more productive and efficient manner. CAD-CAM dentistry will only further enhance the dentist / assistant / technician relationship as we move together into this new era of patient care.

Automation has been slow in coming to dentistry and although new equipment has been introduced to make our jobs easier, we still create complex dental prosthetics using techniques that are thousands of years old. And, even though the “lost wax” technique is still a tried and true method of fabrication, there will come a day in the near future when all frameworks and full anatomical crowns will be designed on computer. Only then will we truly realize the wonder and awe of dental CAD-CAM technology that was intially introduced so long ago.