

The Expanding Role of CAD/CAM in Restorative Dentistry

By Lee Culp, CDT, and Lida Swann, DDS

ABSTRACT

The new millennium has brought with it a change in digital dentistry, as more than 30 different CAD/CAM systems have now been introduced as solutions for restorative dentistry. Dentistry has cautiously welcomed this influx of technology, which is based on technology adopted from aerospace, automotive, and even the watch-making industry. Today's CAD/CAM systems – both chair-side and laboratory based – 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.

RÉSUMÉ

Le nouveau millénaire a apporté avec lui un changement dans la dentisterie numérisée, puisque plus de 30 systèmes différents CAO/FAO ont maintenant été introduits comme solutions pour la dentisterie restauratrice. La dentisterie a accepté avec une certaine réserve cet influx de technologie qui est basée sur l'industrie aérospatiale, automobile et même l'horlogerie. Les systèmes CAO/FAO actuels – pour le cabinet ou le laboratoire – sont utilisés pour concevoir et fabriquer des modèles en métal, en alumine et en zircone ainsi que des couronnes

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en céramique et matériau composite, des incrustations et des facettes qui peuvent être plus résistantes, qui s'ajustent mieux et qui sont plus esthétiques que les restaurations fabriquées en utilisant les méthodes traditionnelles.

This article presents a case report of a 42-year-old male patient who presented with an amalgam restoration and a composite restoration that both showed recurrent decay. The existing restorations were removed, and all-ceramic restorations were created using accepted CAD/CAM technology. This case illustrates how CAD/CAM dentistry represents a totally new way to diagnose, treatment plan, and create functional esthetic restorations for our patients in a more productive and efficient manner.

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 30 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 chair-side 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 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 relationship. 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.

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.

Let us imagine first that our laboratory is not a place, does not have walls, and exists only in the talents for the partners in the restorative process – the dentist and technician. The equipment we use to create the restoration may be located next to the chair, in an in-office laboratory area, remotely, or any or all of the above. Our "laboratory" is actually nothing more than a workflow, which is flexible to the degree that our abilities, access, and equipment will allow. The primary decision becomes where the hand-off from one partner to another should occur. Moreover, a dentist who has the ability to optically scan intraorally for impres-

sions and who often choose CAD-CAM restorations as the best treatment option for their patients, have enhanced freedom as to where we believe the hand-off to the technician partner should occur. The laboratory 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 chair side 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 introduction of E4D Dentist System (D4D Technologies LLC, Richardson, TX) in 2008, (Figure 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 automatically take into consideration the occlusal affect of the opposing and adjacent dentition. As well as, the ability to design 16 individual full contour anatomically correct 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 labour-intensive procedures (waxing, investing, burnout, casting, and/or pressing) involved in the conventional fabrication of a dental restoration, allowing the dentist and technician the ability to create functional dental restorations

with a consistent, precise method.

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 in 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, we 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 42-year-old male patient presented with an amalgam restoration in # 30 and a composite restoration in #31. Both of them showed recurrent decay that was diagnosed using radiography (Figure 3). He possessed a negative medical history and good oral hygiene with resultant periodontal health. Teeth were asymptomatic. Treatment options of a gold onlay and a porcelain fused-to-metal crown or a single-appointment CAD/CAM ceramic inlays/onlays were considered and discussed with the patient. While a gold restoration 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 restorations were removed and both teeth were prepared for the all-ceramic restorations, following accepted CAD/CAM glass-ceramic preparation guidelines; adequate clearance, rounded internal aspects, supragingival butt joint margins.



Figure 1. The dental operator, with clinical CAD/CAM unit.

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 16 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 MZ 100 or C (3M ESPE, St. Paul, MN) and preferred shade. System defaults that can be set ahead of time



Figure 2. D4D System.

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 (Figure 4).

Since the E4D Dentist system is the only system that can scan the tooth structure and preparations without a contrast agent, an impression (alginate included) and a stone model, the system also requires you to enter the method of scan (intraoral; mouth or extra oral; impression or model).

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 then taken. In this case a static bite registration will be taken to record the shape and position of the opposing dentition. The D4D software will automatically change the impression of the bite into a 3-D representation of the opposing dentition. 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 neighbouring 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 neighbouring and preparations to aid in proper proximal contact and overall anatomical contours.

Once the images of the preparation, neighbours 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 3-D virtual model is then presented to you on screen and can be rotated and viewed from any perspective (Figure 5). 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



Figure 3. Preoperative condition of teeth #30 and #31.

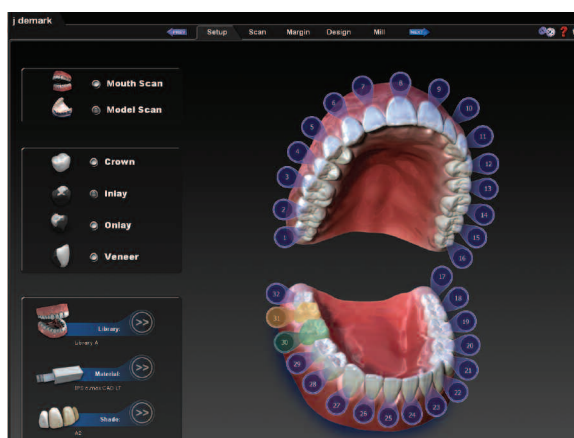


Figure 4. The data file in the D4D CAD/CAM system.

clinical conditions allowing the operator to distinguish discolourations, 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 neighbouring 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 automati-

cally 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 (Figures 6–8). In addition visual representations of material thickness, X, Y, or Z slicing or a number of other variables 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



Figure 5. Digital model proposal.

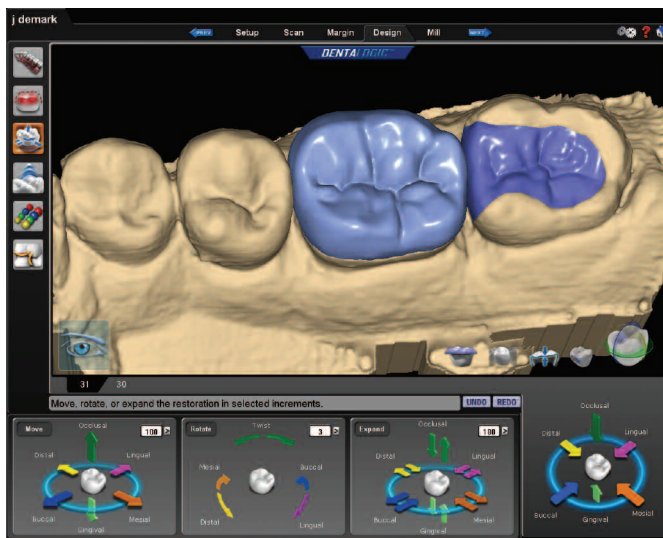


Figure 6. Digital restorative design.

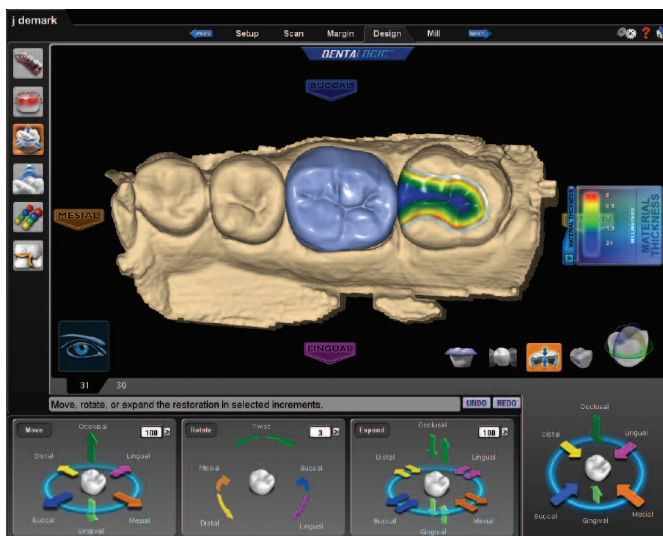


Figure 7. Material thickness indicator graphic.

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, try-in for proximal and marginal fit can be completed chair-side 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 colours and glaze application. The ceramic chosen for this case was the Empress-CAD Multi-block, tooth 31 and E max Cad lithium disilicate (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 (Figure 9).

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 represent 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 technologies that were initially introduced so long ago.

NOTE: clinical dentistry by Dr. Ed McLaren

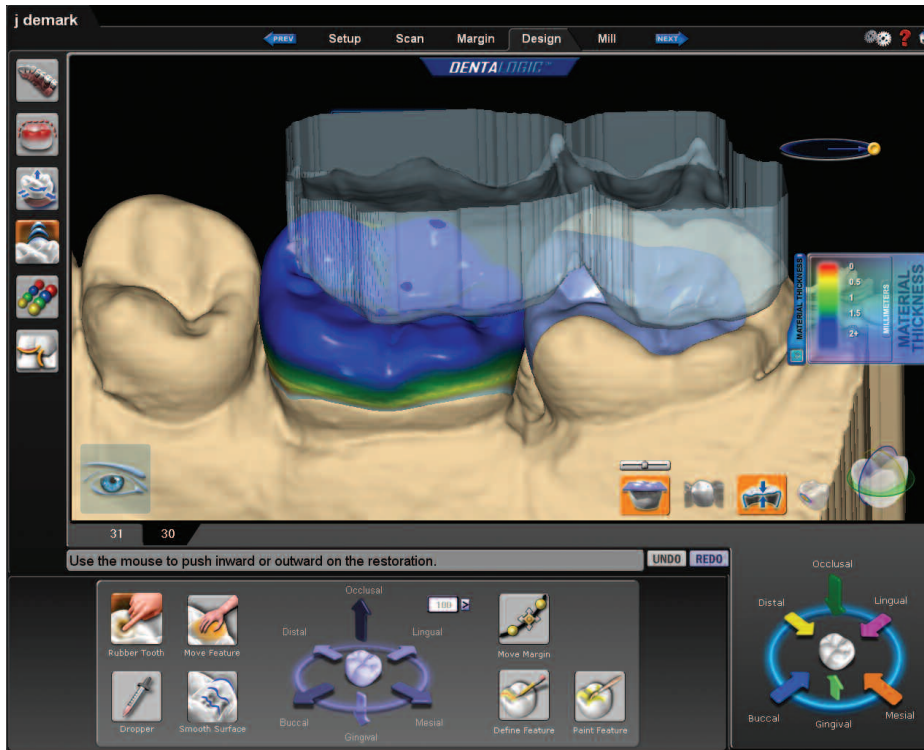


Figure 8. Interproximal-occlusal contact strength indicator.



Figure 9. Final restorations after bonding.