

# Direct ceramic restoration using digital technologies

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The use of computer-aided design/computer-assisted manufacturing (CAD/CAM) represents one approach to providing single-tooth crowns for select indications. The prosthodontic principles for tooth preparation and restoration are well defined. Patient, tooth and material factors converge to guide the selection of one or another restorative material. When these factors lead to selection of a crown, the therapeutic principles involved are balanced by tooth, peri-coronal or peri-implant tissue, and functional and esthetic parameters. The selection of an all-ceramic material for tooth restoration opens a floodgate of information about emerging materials and techniques. Central among these techniques is CAD/CAM. In its proper place, CAD/CAM offers a therapeutic pathway to clinical dental excellence using all-ceramic materials for single tooth restorations.

The stated advantages of CAD/CAM technology for crown fabrication include: a) the application of new materials, b) reduced labor, c) cost effectiveness and d) quality control (Miyazaki et al. 2009). However, an added principle value of

CAD/CAM is the computer control of data and its embodiment of clinical information. The correct acquisition of data regarding tooth- and tissue-specific information and the management of information related to the designated restorative form, as well as the engineering details related to the proscribed material, can be organized around three-dimensional representations of the tooth or teeth in question. This empowers thought and discussion and permits careful interrogation of the tooth preparation, the restoration contour and interproximal or occlusal contacts of the restoration, as well as a detailed analysis of the dimensional requirements based on material selection (Fig. 1). CAD/CAM offers a platform for collaboration that has not existed between clinical and laboratory processes.

Data acquisition for fabrication of a crown has historically been an iterative process blending clinical skills and laboratory arts. A classical impression is made using one of many impression materials that is subject to procedural and material issues of fidelity. Contemporary materials, including vinyl polysiloxane impression materials, offer high fidelity and dimensional accuracy, thus leaving the responsibility of good impression making to the clinician. Creating working dies and articulating master casts to produce an analog of the clinical situation is also supported by excellent material choices, but again requires the diligence of the dental laboratory technician.

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**Figure 1:** Tooth Preparation should always respect tissue health and integrity. This buccal view exemplifies ideal tissue health following removal of the provisional crown. Note that the margin placement is not deep at any aspect of the crown, and all margins are visible.

The fidelity of the laboratory die and casts must be maintained throughout the process of sculpting and creating a metal, metal-ceramic or all-ceramic crown by a lost wax or build-up technique. This is another example where materials are optimized, but skill and care are demanded. Ultimately, a crown can be well made using classical techniques involving a multistep process demanding careful attention to detail. This attention to detail represents the classical approach to data acquisition and management. An iterative review of the data requires physical steps to create physical proposals – typically in wax – for discussion. The computer aspects of CAD/CAM bring this data management to a focus in a proposed preparation and restoration in three dimensions on a computer screen. Its value is that it is an efficient and effective point for critical inspection and discussions of the proposed restoration prior to its fabrication.

Data acquisition in the digital arena is clinically based on optical methods. Laser displacement line beam or interference stripe technologies predominate in the marketplace. Both video and still CCD cameras or laser-specific sensors capture images for intraoral imaging using handheld devices capable of scanning single tooth regions or entire dental arches. The general concept of collecting a digital representation of the tissue and teeth involved in a restoration is to provide a direct patient-to-computer conduit of accurate data that permits the construction of a three-dimensional model of the clinical site in question. An advantage of increasing computing power is that the process can be viewed in real time and the proposed models can be generated (calculated) nearly as fast.

Unfortunately, digital impressions require the same clinical

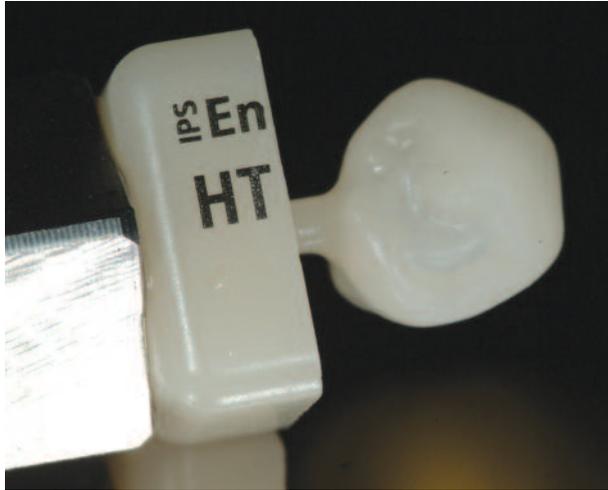


**Figure 2:** Retraction cord is placed into the sulcus to reveal root structure beyond the crown margin. Note that there is an absence of fluid in the retracted sulcus, leaving the margin clearly visible.

features of tooth and tissue management excellence as conventional impressions. The optical methods utilized in intraoral imaging imply a simple rule of physics that light travels in a straight line, and thus, if you can't see it, you can't image it (Fig. 2). Clearly, careful margin management and the control of axial undercuts are essential to any tooth preparation and impression process. The main advantage of the digital process is its direct link to the computer and its software. Other relative advantages include the magnified, real-time viewing of the preparation (for acceptance or refinement), the speed and patient comfort of the procedure and the absence of incremental costs of additional impressions as required.

Digital technology captures images of prepared teeth with fidelity. It is necessary that preparations meet clinical, technological- and material-specific guidelines. For single-tooth crowns, ideal preparation form involves consideration of margin location, depth of preparation, height of axial wall, axial wall parallelism and occlusal/functional reduction. A crown manufactured by milling via CAD/CAM technology will be made of one or another ceramic material requiring adequate reduction (depth of preparation, occlusal/functional reduction) and carefully rounded line angles.

Typically, reduction for the various materials utilized is greater than 0.75 mm. The margin configuration should be a deep chamfer or a shoulder and these should be carefully refined without undulation, chattering or lips present at the cavo-surface. Chamfers may offer some advantage. When preparation total convergence was examined, Beuer et al. (2008) demonstrated that a preparation with total convergence of 12 degrees provided less marginal opening than more parallel designs. All marginal openings were less



**Figure 3: An Empress crown was milled following scanning and design using the E4D system.**

than 50 micrometers.

A recent evaluation by Castilillo Oyaque et al. (2010) demonstrated that significantly larger vertical marginal discrepancies were noted for shoulder versus chamfer margins when zirconia-milled crowns were evaluated for preparations with 15 or 20 degrees total convergence. The angle formed between the gingival floor (chamfer or shoulder) and the tooth surface (the margin angle) may be important to the integrity of the milled ceramic crown margin. The chipping factor of CEREC and EVEREST copings milled from e.max CAD blocks was found to be 2.8 percent, 3.5 percent and 10 percent (CEREC) and 0.6 percent, 3.25 percent and 2 percent (Everest) for 0-, 30- and 60-degree margins. While marginal chipping is related to the milling path and the system employed, there may be greater chipping for high margin angles (Giannetopoulos et al. 2010).

Despite the limited clinical data available, general guidelines for tooth preparation in anticipation of producing a milled ceramic restoration include: a) consistent preparation depth meeting the needs of the material (less than 0.75 mm), b) total convergence of approximately 12 degrees and c) a deep chamfer margin configuration with a minimal margin angle.

Data management highlights the strength of CAD/CAM for single-tooth restorations. Underscored by proper software, data management can facilitate the procedure of crown manufacture, both from a reproducible quality standpoint as well as from an efficiency standpoint.

From a clinician's or a patient's perspective, it is the quality issue that warrants further discussion. A crown has a number

of features: a) the margin or cavosurface, b) the chamfer and its depth, c) the axial walls and their relative parallelism, d) the occlusal surface and the reduction depth, e) the contour of the crown, f) the occlusal contact(s) and g) the interproximal contact(s). Each of these items must be addressed by the clinician and the laboratory technician (Fig. 3).

The adage for computer programming is "garbage in/garbage out," and nothing is truer in the realm of CAD/CAM dentistry. When good information is provided by a quality preparation, excellent tissue management and a good intraoral scan, the management of these seven features of a single crown is facilitated using CAD/CAM. In the virtual environment, crown margins grow to centimeters, occlusal clearance can be visualized from the lingual surface and interproximal contacts can be directly measured by the computer itself. The generation of high-quality digital models of the crown itself is a critical step in the CAD/CAM workflow, leading to exemplary and robust crowns.

A CAD/CAM restoration can be highly esthetic. There exist different materials for different optical properties of teeth. Translucency can be controlled by material selection (e.g., HT [high translucency] or LT [low translucency] in IPS Empress CAD or IPS e.max CAD, Ivoclar Vivadent, Amherst, N.Y.). Coloration may be controlled by material selection and utilization (e.g., IPS Empress CAD Multiblocks). Additionally, simple modifications can be made using staining and glazing of appropriate substrates. Finally, more sophisticated changes can be made by the milling of cut-back library tooth forms and the esthetic veneering of compatible ceramics to impart the detailed esthetics desired or required.

As an example, a single central incisor can be adequately matched using the proper material selection. The contour and form of the restoration should be carefully managed, and all primary and secondary anatomy is imparted in design. After milling, tertiary anatomy (surface ridges, grooves, pits) can be imparted. Thereafter, surface staining and glazing can provide lifelike color and achieve an acceptable esthetic integration of the tooth.

CAD/CAM offers many approaches to clinical success and provides innovative solutions to clinical problems. The capacity of direct CAD/CAM systems (exemplified here by the E4D Dentist system, D4D Technologies, Richardson, Texas) to solve clinical problems immediately in the clinical setting is based on the ability to acquire, compute, evaluate and utilize the scanned data representing the clinical scenario. A frequently encountered challenge is immediate restoration of a fractured tooth or crown. The patient may present without an existing crown, therefore without information regarding its shape or form. Using computer-



**Figure 4: Intraoral buccal photograph made an hour following the intraoral scan is completed. The quality of the restoration is, in part, due to the tissue management illustrated.**

based libraries of proposed crown anatomy, it is possible to quickly propose, modify and create a suitable replacement for the patient on an immediate or nearly immediate basis. This process is illustrated in Figure 4.

While there remain to be further advances in the development of CAD/CAM fabrication of crowns by a direct clinical approach, current positive experiences with emerging new ceramic materials demonstrate the possibility to fabricate esthetic restorations with acceptable clinical fit and function. Scanning of well-prepared teeth after ideal tissue management can lead to high-fidelity scans that permit iterative deliberation of crown design.

The availability of computer algorithms and tooth form libraries make the generation of crown forms expeditious and effective. The milling of newer ceramic materials using the information created by the design software can provide high-strength, good-fitting crowns with detailed anatomic form. This is the basis for an outstanding all-ceramic crown. When the appropriate clinical scenario is presented, the intraoral scanning and direct fabrication of a milled all-ceramic restoration may be rewarding for the patient and clinician.

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