The Clinical Application of CAD/CAM Technology and Materials

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The Clinical Application of CAD/CAM Technology and Materials

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EDUCATIONAL OBJECTIVES

The overall goal of this article is to provide the reader with information about the use of CAD/CAM technology and materials for the fabrication of definitive restorations. After reading this article, the reader will be able to:

1. Delineate the main differences between digital impressions and traditional techniques;
2. List and describe the various CAD/CAM materials and their uses;
3. Review the treatment of restorative surfaces and luting agent options; and
4. Describe the chairside steps required to deliver an indirect, resin nano-ceramic, same-day restoration.

ABSTRACT

Restoring indirect restorations using digital impressions and CAD/CAM technology is a topic that has created a tremendous amount of interest in both the dental office and the dental laboratory. CAD/CAM technology has evolved into several systems that can be used for the fabrication of indirect restorations, together with the development of several restorative materials. The properties of these restorative materials and their indications and appropriate use must be understood in order to enable the achievement of predictable and esthetic results for patients.
Introduction

CAD/CAM technology and materials are currently used in a number of clinical applications, including the fabrication of indirect restorations, occlusal splints, and implant-related components. More recently, CAD/CAM has become available for the treatment planning and execution of orthodontic treatment, and it is also possible for clinicians to measure and track the morphology of gingival tissues during treatment associated with different clinical disciplines. Indirect single-unit restorations are one of the most common procedures currently performed in the dental office. For many years, porcelain-fused-to-metal (PFM) and gold crowns were the materials of choice for the fabrication of indirect restorations for teeth with inadequate tooth structure remaining for direct restorations. In addition, porcelain-only single-unit restorations were fabricated in selected non-stress-bearing situations due to their esthetic qualities relative to PFM crowns. In the last several years, a number of different material options have been introduced as alternatives to these more traditional materials, including some that have the ability to be milled in the office for indirect same-day restorations. Digital scanning and CAD/CAM fabrication of indirect single- and multi-unit restorations is a procedure performed with increasing frequency. Furthermore, more advanced adhesive luting cement systems have become available that enable reliable placement and retention of these restorations. This paradigm shift, involving both CAD/CAM technology and new materials, has changed the way both dentists and dental laboratories think about restoring teeth, and the use of CAD/CAM technology has increased. Many of these restorations not only make the dentistry more predictable, but offer great convenience to patients. Patients also are increasingly demanding all-ceramic restorations.

Fabrication of Indirect Single-Unit Restorations Using Traditional Techniques

Traditional materials used for restoring a tooth indirectly include the use of cast metal crowns, metal-ceramic crowns with or without porcelain margins, and ceramic crowns. All these materials are used for the fabrication of single-unit crowns using traditional techniques. First, the preparation must be made in accordance with the restorative material being used, and the adjacent soft tissue managed to prevent bleeding or fluid encroaching on the preparation and to expose any subgingival margins. For this purpose, one or more of the following may be used: retraction cord, lasers, hemostatic agents, electrosurgery, or one of the more recently introduced silicone polymer retraction materials. Gingival retraction cord was reported in one survey to be the most frequently-use method. Clinical preference, ease-of-use, the specific clinical case and familiarity play a role in the selected method. The next step is to take an impression of the preparation as well as the adjacent and opposing teeth so that the die and models can be poured for laboratory fabrication of the crown. During this period, the patient is provided with a provisional restoration for function and/or esthetics, as well as to protect the preparation and gingival margins, prevent sensitivity in a vital tooth, and maintain periodontal health and the position of the prepared tooth relative to the adjacent and opposing teeth. This traditional procedure is still the most prevalent method of restoring teeth with indirect restorations – it is what clinicians have been most familiar with and how they were taught in dental school. As such, there is no new learning curve for the clinician.

While generally reliable, this traditional approach involves some limitations, including the period of time it takes to fabricate the restorations (typically one to two weeks), the need for a provisional restoration, and the need for the patient to return for a second visit. Physical models are necessary to create the restoration and must be poured from the impression. However, the impression itself is a potential source of error, despite the availability of highly accurate and dimensionally stable impression materials; some common errors include the inclusion of voids, marginal discrepancies, and minor tears. High-precision impression materials must be handled according to the manufacturers’ instructions, and the soft tissue at the clinical site appropriately managed, to help avoid such errors. Other factors that can result in inadequate impressions include how soon the model was poured, and the man-
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In which the impression was stored and transported before pouring. This is especially important for alginate, which is typically the material of choice for the opposing (preparation-free) arch due to its ease-of-use and low cost. If left out to dry or transported without being wrapped in damp gauze or a damp towel, these impressions will shrink which causes dimensional errors in the model.\textsuperscript{11}

Similarly, models may also include voids and other dimensional errors. These errors are related to the mixing, pouring and handling of the stone (or plaster) models. Marginal discrepancies may not be evident until after the models have been poured or until the time of try-in of the restoration, resulting in additional time and costs. Digital photography and modern shade selection options and techniques have increased the ability of the clinician and the laboratory to communicate, and therefore to deliver a case with the desired esthetics. Nonetheless, this setup may still not be ideal for a given case. Well-executed indirect restorations fabricated using the traditional approach offer excellent fit, functionality, and esthetics.

CAD/CAM Technology

CAD/CAM technology has been around long enough that is not “new”; earlier versions of the technology have been available in dentistry for almost 30 years.\textsuperscript{12} It is now accepted as a viable, predictable, and efficient alternative to traditional methods.\textsuperscript{13} As with the traditional approach, the preparation design must consider multiple factors, including the material that will be used to fabricate the indirect restoration and the required dimensions, as well as the amount of retention that will be achieved as a result of the preparation form. CAD/CAM technology has evolved into several versions using different devices and combinations of techniques: 1) taking the CAD/CAM scans chairside and transmitting these through a secure Internet portal to a standard laboratory or to a central location for fabrication of the indirect restoration in a milling machine; 2) taking the CAD/CAM scans chairside and sending these through a secure Internet portal to a central location for digital creation of the models, after which they are sent to a standard laboratory for traditional fabrication of the restoration; and 3) taking the scan chairside and milling the indirect restoration chairside using CAD/CAM technology at the same visit (Figure 1).

When the clinician uses any of these devices and techniques, it is not necessary to take a traditional impression or to pour dies and models. This removes the risk of associated errors and increases patient comfort. Both chairside milling and laboratory milling of restorations removes the possibility of abrading or damaging dies and models during their use for restoration fabrication – abraded models would result in restorations that were either too tight and
left insufficient space for the luting agent, or simply would not seat on the preparation. Of course, to avoid incurring errors when using CAD/CAM technology, the clinician must accurately take scans and follow procedures according to the instructions of the given manufacturer. All available CAD/CAM devices involve the use of a handheld scanner, although each uses different technology to capture the images. Options for capturing images include continuous video streaming of the teeth, the acquisition of multiple still images that are then melded together with software, and the use of a laser that captures images by reflecting off the surface of the tooth or preparation. “Bite registration” and the determination of centric relation also differ by system.

For CAD/CAM restorations milled in a laboratory or central location, a provisional restoration is required as with the traditional impression technique (Table 1).

### Provisionalization for Laboratory-Milled or Fabricated Indirect Restorations

Provisionalization materials include acrylic resins, prefabricated composite resin temporary crowns, and metal-based prefabricated temporary crowns. The use of acrylic resins allows the provisional restoration to be customized chairside. Desirable features of a provisional material are a setting reaction that does not produce heat (or produces minimal heat) and that avoids shrinkage of the material during setting, as well as being sufficiently durable to last until the definitive indirect restoration is ready for placement. Bis-acryl results in less heat production during the setting reaction than other acrylics, has low polymerization shrinkage and offers adequate durability for provisional restorations, although it is a more costly acrylic compared to polyethyl or polymethyl methacrylate. Prefabricated temporary crowns may be quicker to place, and still offer a smooth surface provided only minimal adjustments are required. On the other hand, they are only available in a number of shapes and sizes, require marginal adjustments, and may not be suitable for a given case. Recently, fillers have been added to bis-acryl to increase surface smoothness and gloss for provisional restorations. Scanning and chairside same-visit milling of the restoration is the only option that removes the need for a provisional restoration or for a second patient visit for try-in and placement of the restoration.

### Preparation and CAD/CAM Scanning

For all systems, as with the traditional technique, the preparation must be isolated and the soft tissue managed at the margins. The same techniques are used for soft tissue management as with the traditional approach. Depending on the system, a light and rapid dusting of an opaquist powder agent may be required prior to capturing the digital scans of the preparation arch, opposing arch, and buccal bite registration. Digital scanning and rapid transmission of the scans to the laboratory, and/or chairside viewing of the scans, allows for immediate or almost immediate feedback on margins and clearance. If corrections are needed, it takes just minutes with the patient still

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**Table 1. Traditional and CAD/CAM procedures**

<table>
<thead>
<tr>
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<th>Traditional Approach</th>
<th>CAD/CAM Laboratory Fabricated</th>
<th>Chairside Milling</th>
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</thead>
<tbody>
<tr>
<td>Soft tissue management</td>
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<tr>
<td>Impression taking</td>
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<td>Scanning</td>
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<td>Model milling</td>
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<td>No</td>
</tr>
<tr>
<td>Restoration milling</td>
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<td>Yes/No</td>
<td>Yes</td>
</tr>
<tr>
<td>Provisional restoration</td>
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<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Second patient visit</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
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in the chair and anesthetized. This avoids having to bring the patient back for a second visit involving adjustments to the preparation or/and a second impression, or not discovering the error until the patient’s seat appointment when the restoration has already been fabricated and then causing additional laboratory costs to be incurred as well as causing patient disappointment.

Clinical Results
Several studies have evaluated CAD/CAM restorations and found that they have a marginal fit as good as or superior to that of traditional impressions. A further benefit found with CAD/CAM restorations has been the reduced incidence of secondary caries (the leading cause of direct restoration failure with both amalgam and composite materials), attributed to the high accuracy of the approximal fit and the ability to ascertain that this is accurate prior to completion of the restoration and cementation. In fact, the longevity of CAD/CAM restorations was reported by Mjör et al to be close to that of gold restorations. A recent review assessed the survival rates of single-tooth indirect restorations fabricated with CAD/CAM and found the long-term survival rate to be similar to indirect restorations fabricated using the traditional approach.

CAD/CAM Restorative Materials
The movement toward CAD/CAM fabrication of restorations has been directly responsible for a number of material innovations over the past few years. For quite some time, both leucite and feldspathic glass ceramics have been used for laboratory-based fabrication of ceramic restorations. These materials result in beautifully esthetic restorations regardless of which method is used for their fabrication, particularly in the anterior region. However, their relatively low flexural and compressive strengths have limited their use in posterior stress-bearing areas. High-strength leucite also has been used as a block for CAD/CAM milled restorations. These materials must be adhesively resin-bonded to the preparation and cannot be placed using traditional luting cements. In recent years, we have seen the evolution of high-strength ceramics – lithium disilicate, alumina, and zirconia – that have allowed CAD/CAM dentistry to move into new territory. The advantages of these materials are twofold: they possess very high compressive and flexural strength, and can be bonded or cemented. This has resulted in a very strong, predictable, and esthetic option for posterior ceramic dentistry. In a recent study, both alumina and zirconia crown copings fabricated using CAD/CAM were found to have clinically acceptable marginal adaptations. A separate study recently conducted on milled lithium disilicate crowns found these to be free of fractures, chipping, or other defects two years post-placement. For CAD/CAM restorations milled with these materials, in addition to the CAD/CAM device a porcelain furnace is required for crystallization of lithium disilicate, and a sintering oven for full-contour zirconia. In the case of lithium disilicate, this can add 15 to 30 minutes to the fabrication time, and with zirconia up to an additional 8 hours may be required. It should be noted that high-speed sintering ovens for zirconia are now sintering these restorations in about 90 minutes and other options include semi-sintered zirconia and fully-sintered zirconia. The advantage of using zirconia for milling and then sintering is the increased strength following sintering and the relative ease of milling prior to sintering.

Composite resin blocks are also available for CAD/CAM restorations. Another option is the use of a new resin nano-ceramic block that consists of ceramic clusters within a highly cross-linked resin matrix. The resulting block is homogenous, and the restoration can be CAD/CAM-milled chairside or in the laboratory. The wear resistance of this material is reported to be comparable to that of felspathic
glass ceramic and lithium disilicate, and it has a compressive strength similar to high-strength ceramics. Unlike lithium disilicate and zirconia, no porcelain furnace or sintering oven is required, saving fabrication time. In fact, a recent study found that composite blocks (and experimental composite blocks) were more resistant to fracture than reinforced ceramics when used for ultra-thin veneers. The use of nano-fillers and resin technology has improved the strength and esthetics of composite blocks. A 2006 study comparing resin nano-ceramic and zirconia used for CAD/CAM four-unit bridges found that the margins were most accurate and marginal gaps least using the resin nano-ceramic material.

Placement and Retention of CAD/CAM Restorations

As noted above, some CAD/CAM restorative materials can be cemented with either traditional luting cements such as zinc phosphate, polycarboxylate cement, glass ionomers, or resin-modified glass ionomers. Materials that can be luted with these include zirconia, lithium disilicate, alumina, and resin nano-ceramics. The caveat for non-bonded materials is that the preparation form was sufficiently retentive in the first place. Resin-based bonding can be used for all CAD/CAM restorative materials, including those mentioned above (Table 2). Resin-based luting cements bond to the ceramic restorations, not only the tooth structure, and are now regarded by some clinicians as the preferred luting agent for ceramic and other non-metal restorations. They offer excellent esthetics and retention of the restoration to the preparation. These luting cements utilize etching and bonding technology, and they bond by micromechanical locking of the cement to both the tooth and the restorative material. The resin-based luting cement itself may be dual-cured, self-cured, or light-cured – the latter is only suitable if the restoration is thin enough to enable the transmission of light for curing. A further requirement is roughening of the intaglio surface to increase the area available for bonding, with either hydrofluoric acid or sandblasting/air abrasion depending on the restorative material used. The intaglio surface of lithium disilicate restorations is treated with 5% hydrofluoric acid for 20 seconds to etch and roughen that surface. The intaglio surfaces of feldspatic porcelain and leucite-containing restorations are also treated with hydrofluoric acid, with the time of etching depending on the material. Options for other materials are the use of sandblasting or treatment with a silica coating, with the method depending on the material – the restoration material manufacturer’s instructions must be followed and the correct treatment used. Irrespective of the luting agent and technique, the primary objectives are retention and sealing of the restoration-tooth interface.

CASE STUDIES

When considering milling and delivering same-day restorations, there are many options available.

The two case studies below will concentrate on the use of resin nano-ceramic blocks for the chairside fabrication of an inlay and a veneer. Case Study #2 involves the complication of an aligner with attachments that were on the fractured tooth to be veneered.
Case Study #1

A 17-year-old male presented for examination with no chief complaint. Upon routine full-mouth examination and after bitewing radiographs were taken, carious lesions were found on the distal of tooth #12, the mesial and distal of tooth #13, and the mesial and occlusal of tooth #14 (Figure 2).

A traditional way to restore these lesions would be to prepare class II preparations on tooth #12 and tooth #14 and mesial and distal one-surface restorations on tooth #13. It is always the goal to restore teeth in a minimally invasive fashion. When carious lesions are limited in size, it is ideal to restore conservatively with direct composite restorations. However, when carious lesions are more extensive, this method can be complicated with large-cavity preparations by a number of factors that include operative time, polymerization shrinkage, layering in proper thicknesses, and especially contours and contacts. There are many different band, matrix, and wedge combinations on the market that all promise to deliver ideal contours and contact; in this author’s experience, however, these methods rarely provide the predictability of indirect CAD/CAM restorations. After discussing the options with the patient, it was decided to restore these teeth indirectly with resin nano-ceramic CAD/CAM restorations. Prior to preparing the teeth, these teeth were isolated with a non-latex rubber dam and preoperative scans were taken (Figure 3). When these preoperative scans are taken, the software allows use of a design method called “biogeneric copy” (since the carious lesions did not compromise the natural shape and contour of the virgin teeth). It is quite advantageous for the final restorations to be exact duplicates of what nature created, provided the contacts and contours are functionally ideal and esthetically pleasing.

After taking the initial images, all caries was removed and the preparations were finalized. Care was taken to avoid encroaching on the interproximal papillae during preparation, by placing small wooden wedges between the teeth. The preparations should be smooth and flowing, with no undercuts and with clear separation from the adjacent teeth. After removal of the wedges, a light dusting
of the CAD/CAM powder (Optispray) was applied, and the preparations were captured by scanning to create the digital impressions (Figure 4). Figure 5 shows the preparations that were scanned. Once the preparations were digitized and marginated, the software used the overlay of the preoperative condition (Figure 6) to create proposals that were an exact replicate of the patient’s virgin teeth (Figure 7). Furthermore, all interproximal contacts can be manipulated to the desired contact size and strength directly in the software with intuitive three-dimensional tools. This case demonstrates one of the advantages of chairside CAD/CAM fabrication of Class II restorations: by eliminating the need for bands and wedges, predictability for contacts and contours was realized.

After the inlay designs were finalized, the restorations were milled from resin nano-ceramic blocks with the milling unit. Milling resin nano-ceramic material results in excellent marginal integrity; SEM images of restorations milled with these blocks show less marginal chipping than with traditional glass ceramics. When the milling of the restorations was complete, the inlays were steam-cleaned (to remove all milling oil) and the sprue was removed with coarse So-Flex discs. Initial extra-oral polishing was performed using coarse, medium, and fine rubber wheels. Since the restorations were quite small and therefore difficult to handle, final polishing was completed intraorally.
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post-bonding. It should be noted that because this material does not need to be fired in a porcelain furnace, milling and polishing can be completed quite efficiently intra-orally or extra-orally. The restorations were next tried-in to ensure that their marginal fit and contours were correct.

To prepare for bonding of the inlays, the intaglio surface of the restorations was sandblasted with aluminum oxide at two bars (30psi), to increase the surface area available for bonding, and was then cleaned with alcohol. A universal adhesive agent was then applied to the intaglio surface for 20 seconds and air-dried for five seconds. The restorations were placed aside without curing the adhesive. Note also that using a universal adhesive that contains silane primer eliminates the need for a separate silanation step. To prepare the teeth for the restorations, the enamel was selectively etched with phosphoric acid for 15 seconds, rinsed, and dried. The same adhesive agent was agitated on the enamel for 20 seconds with two applications, and then air-dried for five seconds to evaporate the solvents. The resin-based luting cement was then placed into the inlay preparations (with no prior curing of the adhesive), and the restorations were all seated. Initial cleanup was performed with a gingival stimulator, and the remaining excess was tack-cured for one second with an LED light prior to being removed with a curved explorer. Removing excess cement when it is only tack-cured, and before it has set, helps retain the bond while the material is still not at full strength. The resin-based luting cement in the restorations was then light-cured for 20 seconds per surface. Finally, the resin-bonded nano-ceramic inlays were polished with diamond-impregnated composite cups and polishing paste. No adjustments to the occlusion were necessary, and the final restorations mimicked the contours of the original teeth extremely closely and offered excellent esthetics (Figure 8).

Case Study #2

An 18-year-old male presented with a significant fracture on tooth #8, sustained while playing basketball (Figure 9). An existing composite bonding was present on both the remaining tooth and the fractured fragment; the fracture did not involve the pulp. To significantly compli-
cate matters, the patient was midway through orthodontic treatment with an aligner, and tooth #8 had two attachments present: one still present on the tooth (cervical) and one that had fractured off with the incisal portion of the tooth. Under normal circumstances, restoring an anterior tooth with these aligner attachments is quite a daunting task; it is often necessary to have the orthodontist replace the attachments and review the patient’s orthodontic treatment plan. Using the tools available with CAD/CAM technology, however, it was possible to restore this tooth to its original shape without compromising the orthodontic treatment. The success rate for CAD/CAM fabricated veneers is high, with one study finding a high clinically acceptable result up to nine years after placement and a 94% survival rate.31

Since the patient had found the fractured portion of the tooth, it was possible to etch and bond this back into position with a total-etch technique (Figure 10). Under some circumstances, rebonding the fragment is a good short-term solution for this situation. However, since this patient was leaving for college and had an esthetic concern with the tooth, it was decided to fabricate a CAD/CAM veneer. In this situation, temporarily bonding the fragment to the tooth in its natural position allowed positioning of the aligner attachments at the appropriate places. The patient’s current aligner was then tried-in to verify proper fit. Prior to preparing the tooth and after rebonding the fragment to the tooth, a preoperative scan was taken (after applying a light dusting of powder). As with Case Study #1, this scan served as a guide for the final restoration using biogeneric copy. The veneer preparation was then made and the tooth isolated with retraction cord (Figure 11). A digital impression of the preparation was taken, which showed the marginated veneer preparation clearly and accurately (Figure 12). The preoperative scan can also be overlaid on top of the preparation using this CAD/CAM technology, and can be copied on a 1:1 basis to obtain a proposed final restoration that exactly duplicates the existing tooth. Note how precisely the camera (scanner) captured the two aligner attachments with the preoperative scan (Figure 12) and
how the software reproduced them in the final initial proposal (Figure 13).

As discussed earlier, when choosing the appropriate material, one has to consider many factors. In this particular situation a low-translucency resin nano-ceramic CAD/CAM block was selected because of the patient’s age, the flexibility of the material, its excellent polishability, the precise marginal edge quality, and the low translucency (which would prevent shine-through, helping to ensure an esthetic result). But the most important factor, considering that the patient would be using an aligner for the next year, was the material’s reparability. After the restoration was milled, the initial polish was achieved using medium and fine diamond-impregnated rubber wheels. Care was taken to avoid over-polishing the surface of the restoration, which would affect the surface texture and aligner attachments. In order to facilitate natural shade transitions and provide an excellent match with the contralateral central incisor, the restoration was characterized with light-cured resin in several shades. To accomplish this, the external (non-bonding side) of the restoration was sandblasted with aluminum oxide at 30psi, cleaned with alcohol, and dried. As with Case Study #1, universal adhesive was
applied to the surface, thinned appropriately, and light-cured. Several shades of resin were then applied to the surface of the restoration and light-cured to characterize the restoration and match it as closely as possible to tooth #9. Final polishing of the restoration was achieved using a fine polishing paste on a #9 soft brush at low rpm (< 10,000 rpm), and a final buff was performed with a muslin rag wheel. Finally, the restoration was bonded using universal adhesive and a resin-based luting cement. The final restoration exhibited contours almost identical to the original, pre-fracture contours, and the patient’s esthetic concerns were satisfied (Figure 14). Furthermore, the aligners snapped into place with no adjustments at all (Figure 15).

Summary

CAD/CAM technology has transformed the ways in which clinicians can provide patients with functional, esthetic, and durable indirect restorations. CAD/CAM technology removes the risk of some errors and offers the opportunity to review restoration designs (and adjust them, if necessary) before they are completed. As the demand for CAD/CAM indirect restorations grow, more advanced materials have become available that can be resin-bonded to preparations with excellent results. The material of choice depends on the clinical situation, with consideration given to strength, esthetics, and ease of use.

References


Webbiography


