Aesthetics has gained significant importance in restorative dentistry besides the potential requirements including the continuity and integrity of tissue and regaining the function and phonation. The demand for esthetic posterior restorations gave way to the use of resin composites in the posterior region as well as the anterior restorations. However, polymerization shrinkage of resin composites limits this application to only with small sized restorations. In order to eliminate the disadvantage of polymerization shrinkage, various methods have been suggested to improve the properties and application methods of resins with the aim of increasing the longevity and function of restorative materials. For this purpose, computer aided design/computer aided manufacturing (CAD/CAM) systems have been used for the past 10 years to fabricate indirect restorations with resin composites as an alternative material in digital system. This review aims to provide an update on the resin composite materials used with indirect restorations and CAD/CAM systems.

Key words: chairside CAD/CAM systems, indirect restoration, CAD/CAM composite resin, composite block
INTRODUCTION

The main purpose of restorative dentistry is to protect the continuity and integrity of remaining tissue, recover function, phonation and provide aesthetics. Based on all these objectives, it can be claimed that ceramic material holds a special place in dentistry. Advantages of providing the most pleasing aesthetic results, the best color match with natural dentition, compatibility with tissues make the ceramic material unique.¹

In this context, computer aided design/computer aided manufacturing (CAD/CAM) systems that have gained popularity for the past 10 years use ceramic as the basic material which is continuously being developed. However, ceramic material has many disadvantages such as fragility, requirement of excess time for fabrication and abrasive effect. Additionally, low modulus of elasticity of ceramic material makes it unable to absorb the pressure of mastication. These disadvantages of ceramics have led to increased interest in resin composites that can be repaired intra-orally and have ease of fabrication.²⁻⁶

The procedure of bonding resin composites to hard dental tissues along with adhesive dentistry is one of the most promising developments in restorative dentistry. The use of dental resin composites in load bearing posterior restorations has gain significant progress by improving the properties of composites for the last 10 years.⁴,⁷ Excellent mechanical and optical properties were obtained in direct resin composites however the use of the composite material is limited to only with small sized restorations because of its main disadvantage of polymerization shrinkage.⁸

Various clinical methods have been used to eliminate the disadvantage of polymerization shrinkage of resin composites. Application of incremental technique in direct restoration, the use of ceramic inserts with resin composites, control of amount and insertion of the material, appropriate placement of etchant, primer and adhesive in order to improve bonding and also restoration of lost tissue with indirect technique are some of these methods.⁹,¹⁰

Indirect restorations that are fabricated extra orally and luted/cemented onto/into the tooth can be categorized as either intracoronal or extracoronal restorations.¹¹ Intracoronal restorations are preferred when remaining tooth structure is adequate to retain the restoration and for protecting the tooth against stress formed during mastication. One of the intracoronal restorations, inlay, is the simplest cemented restoration containing occlusal, gingival, proximal lesions and covering at most one tubercule.¹² Extracoronal restorations are those that cover the outer surface of tooth to create anatomic contours. Full or partial crowns and veneers are examples of extracoronal restorations.¹¹ A veneer is a layer of tooth-colored material that is applied to a tooth to restore localized or generalized defects and intrinsic discolorations⁹ and crown is the restoration that caps clinical tooth length fully or partially.¹³

Those of in-between inlay and full crown restorations termed onlay restorations, cover all over the tubercules of tooth. Additional to the occlusal surface of tooth, restorations that cover the buccal or the lingual surfaces are called overlay.⁹,¹¹,¹² Beside these restorations, in 1999, Bindl and Mörmann defined 'endocrown' as an alternative restoration to post-core and crown for the endodontically
treated teeth that have excessively lost tissue. Endocrowns can be defined as either one-piece ceramic structure bonded by adhesion or only restorations applied on endodontically treated teeth.\textsuperscript{14,15}

The advantages including elimination of requirement of taking conventional impression and preparing temporary restorations, automation of fabrication procedures with increased quality in a short period of time, elimination of hazards of infectious cross-contamination associated with conventional multistage fabrication of indirect restorations and having potential to minimize inaccuracies in technique have made CAD/CAM technology an alternative method to the dental laboratory procedures. Due to the capability of usage as laboratory-processed blocks, composites have been able to be used in the fabrication of inlays, onlays, crowns and fixed partial dentures with chairside CAD/CAM systems.\textsuperscript{16-18}

Chairside systems used in CAD/CAM technology

Chairside CAD/CAM systems have become a treatment option for the first time with the acquisition of the ceramic inlay in a single session in 1985.\textsuperscript{19} The advantage of these systems are chairside designing and fabricating the restoration in a short period of time and impressing patients with the latest technologic devices. On the other hand, the high cost is an important disadvantage of these systems. In today's technology, there are two chairside systems: CEREC (Sirona Dental Systems, Bensheim, Germany) and E4D Dentist system (D4D Technologies, Richardson, TX, USA).\textsuperscript{20}

Cerec CAD/CAM system

Dr. Mörmann's\textsuperscript{21} in vivo and in vitro studies with pressed and hot polymerized composites set forward the hypothesis that inlays made of tooth-colored materials and inserted adhesively with a luting agent, could solve the polymerization shrinkage problem of direct composite fillings. Based on this idea, ceramic materials were used to get pleasing aesthetic and durable results. The capability of producing ceramic inlays by scanning the preparation directly from the patient and transferring the data to the milling device led up to the foundation of CEREC system.\textsuperscript{19}

Ceramic inlay, onlay and laminate veneer restorations were milled at one appointment with CEREC1 that was introduced in 1988. However the required formation of occlusal surface of inlay by manual grinding and limitation of digitizing accuracy of the camera caused the unsatisfactory marginal fit of inlay.\textsuperscript{18,19} With the development of CEREC2 in 1994, the requirement of forming occlusal design manually was left and 30\% increase in marginal integrity was obtained.\textsuperscript{19,22} CEREC3 is the new system which includes; CEREC inLab that was developed in 2004 and CEREC3 chairside systems. At first CEREC3 created 2-dimensional designs and in 2003, new software of 3-dimensional design was developed.\textsuperscript{19}

The basic principle of CAD/CAM technology is that preparations should reflect the capabilities of CAD software and hardware and CAM milling devices. CEREC System automatically blocks-out the undercuts during scanning. This eliminates the requirement of preparation having a path of draw that allows insertion and removal of restoration without interferences from undercuts in laboratory-fabricated indirect systems. In some cases
such as preparations with excessive undercuts at the base of tubercules, undercuts should be filled with composite cements to prevent failures during cementation. Some CEREC users prefer to prepare occlusally convergent walls because they accept that CAD software can read the occlusal cavosurface margins easily by this way.9

E4D Dentist System

E4D Dentist System which was introduced in the early 2008 includes design center (computer/monitor), laser scanner and separate milling unit.23 The scanner, termed as IntraOral Digitizer, enables this system to scan the preparation without using reflecting agent, eg.titanium dioxide powder. Compared to the CEREC system, the scanner of E4D has shorter vertical profile preventing patients to open mouth as wide for posterior scans. Actual pictures of the teeth and gingiva before and after tooth preparation and occlusal registration are taken by the ICEverything feature of DentaLogic software of the system. These pictures are then used to create 3D ICE model that let to achieve margin detection simpler. Touch screen monitor of the system let dentist to view the preparation from various angles for accurate results.

The design system of E4D has the ability of auto-detecting and marking finish line on the preparation. The Autogenesis feature of software proposed a restoration, chosen from its anatomical libraries, for the tooth to be restored.23 The system is compatible with less number of materials compared with CEREC3 system. These materials are leucite-reinforced ceramics, lithium disilicate blocks, nanoceramics, permanent and temporary composite blocks (Table I).24 Studies evaluating the CAD/CAM restorations fabricated with different materials and techniques are presented in Table II.25-31

### Table I: Restorative materials available for chairside CAD/CAM system24

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>BRAND NAME (MANUFACTURER)</th>
<th>CEREC</th>
<th>E4D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esthetic Ceramics</td>
<td>Vivahex Mark II (Vident)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>(Vestibular)</td>
<td>CEREC Blocks (Sirona Dental Systems)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Esthetic Ceramics</td>
<td>IPS Empress CAD (Vita Vivadent)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>(Leucite reinforced)</td>
<td>IPS e.max CAD (Vita Vivadent)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>High strength ceramic</td>
<td>Vita Ultimate (3M ESPE)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>(Lithium-dicarbide)</td>
<td>Telio CAD (Vita Vivadent)</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

5 X: Material available for chairside system

### Table II: Studies evaluating the CAD/CAM restorations.25-31

<table>
<thead>
<tr>
<th>STUDY</th>
<th>PURPOSE</th>
<th>MATERIAL TYPE/FILE MATERIAL</th>
<th>MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen et al.</td>
<td>Evaluation of influence of occlusal surface restorations on tooth structure</td>
<td>CEREC E4D</td>
<td>Axial compression</td>
</tr>
<tr>
<td>Liu et al.</td>
<td>Examination of the efficacy of the tooth preparation on tooth structure</td>
<td>Telio CAD</td>
<td>Axial compression</td>
</tr>
<tr>
<td>Wang et al.</td>
<td>Examination of the effect of tooth preparation on tooth structure</td>
<td>Telio CAD</td>
<td>Compression</td>
</tr>
<tr>
<td>Ilgenstein et al.</td>
<td>Evaluation of the effect of tooth preparation on tooth structure</td>
<td>Telio CAD</td>
<td>Compression</td>
</tr>
<tr>
<td>Zaruba et al.</td>
<td>Evaluation of the effect of tooth preparation on tooth structure</td>
<td>Telio CAD</td>
<td>Compression</td>
</tr>
</tbody>
</table>

Resin composite blocks used in CAD/CAM technology

The evolution of direct esthetic materials began with silicate cements developed by Fletcher in 1878. Silicates known as anticariogenic materials have several disadvantages such as fragility, acidity and requirement of accurate application. Acrylic resins overcoming these disadvantages of silicates were widely used as unfilled resins in 1940’s.32,33

In early 1960’s resin composites were developed with advanced mechanical
properties superior to silicates and acrylic resins. Polymerization of composites was activated chemically at first and then photo-activated by ultraviolet (UV) wavelengths and lastly activated by visible wavelengths. As a result of ongoing studies; durable, wear resistant and esthetic composite materials were developed. Significant progress has been achieved in resin composites particularly as a result of developments in nanotechnology and adhesive dentistry.

In order to improve the biological properties of resin composites and develop their composition; several changes have been applied to organic matrix of composites or the size, shape and distribution ratio of inorganic fillers were changed. Packable, flowable, smart, antibacterial, ormocer, nanofil, low-shrinking/non-shrinking resin composites, giomers, bulk-fill composites, composites used in indirect technique are some of different types of composites named as a result of those changes.

Use of composites in chairside CAD/CAM systems can be preferred both temporarily and permanently. Paradigm MZ100 (3M ESPE, Minnesota, USA), is the first commercial composite block introduced in 2000. Blocks are made from Z100 direct restorative resin composite by factory polymerization. Factory polymerization resulted in Paradigm MZ100 having superior flexural strength and fracture toughness to those of Z100. Paradigm MZ100 is a radio opaque composite block material which contains 85 wt%, 0.6 micrometer sized ultrafine zirconia-silica ceramic particles that reinforce a highly cross-linked polymeric matrix. These blocks are made in two cylindrical sizes (3M size10, 3M size 14), in six shades (A1, A2, A3, A3.5, B3, Enamel). Block HC (Shofu; Kyoto, Japan) is a composite block composed of 61 wt.% silica powder, zirconium silica and micro-clustered silica particles and Gradia Block (GC; Tokyo, Japan) is another composite block including 76 wt.% silica, F-Al-silicate glass and pre-polymerized filler.

Chairside CAD/CAM systems may not be adequate to treat all clinical situations. CAD/CAM temporary blocks have been introduced for chairside fabrication of long-term temporary restorations in order to complete the laboratory fabrication process. TelioCAD and VITA-CAD Temp are temporary blocks used for long-terms temporary crowns and fixed partial dentures. TelioCAD is a block made of 99.5 wt.% polymethyl methacrylate (PMMA) and can be milled both in the laboratory (labside) and in office (chairside). The block is used to mill both full-contour single-tooth and multiple-unit temporary restorations using CAD/CAM technology and is a part of Telio system including desensitizer, self-curing composite and cement. It is in two sizes; 40 mm and 55 mm and in six shades. Another temporary block, VITA CAD-Temp block, is fiber-free, homogeneous, high-molecular and cross-linked acrylate polymer with microfiller. Blocks are used for the fabrication of long-term temporary full and partial crowns and fixed partial dentures up to two pontics. There are two types of blocks which are monoColor and multiColor. MultiColor blocks have four different chroma layers that provides esthetic restorations.

Integration of nanotechnology and ceramics has led to the improvement of a unique CAD/CAM material; nanoceramic, aimed to offer the ease of handling of a composite material with the superiority of surface gloss and finish retention of ceramic. The firstly developed, Lava
Ultimate (3M ESPE; Minnesota, USA), contains three different ceramic particles all embedded in a highly cross-linked polymer matrix (silicate particle of 20 nm, zirconia particles of 4 nm to 11 nm, agglomerated nano particles of 20nm silica and 4-11nm zirconia). The material that has 80 wt. % zirconia and silica nanoparticles and nanoclusters is available for both CEREC and E4D Systems and has eight different shades.\textsuperscript{24,40}

A newly developed hybrid material, ENAMIC (VITA Zahnfabrik, Bad Säckingen, Germany) includes proven properties of composite and ceramic materials. Inorganic ceramic part of this block is 86 wt. % and organic polymer matrix is 14 wt. % and pores in the structure-sintered ceramic matrix are filled with a polymer material.\textsuperscript{46} Another material that combines best characteristics of high strength ceramic and composite is CERASMART (GC, Alsip, USA) which has flexible nanoceramic matrix. It is composed of 71 wt. % silica (20nm) and barium glass (300 nm) nanoparticles.\textsuperscript{41,47}

Studies evaluating physical and mechanical properties of CAD/CAM blocks are shown in Table III.\textsuperscript{41,48-53}

<table>
<thead>
<tr>
<th>Material</th>
<th>Fracture resistance</th>
<th>Flexural strength</th>
<th>Vickers hardness</th>
<th>Translucency</th>
<th>Roughness</th>
<th>Wear resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>ENAMIC</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>CERASMART</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

**CONCLUSION**

Indirect composite restorations fabricated with CAD/CAM technology have been presented as an alternative to the ceramic restorations with improved physical, mechanical and esthetic properties. While available chairside CAD/CAM systems have several advantages, there is also wide range of limitations of them. Studies investigating mechanical properties and physical changes that occur after heat treatment and compliance with natural dentition of materials used in CAD/CAM systems are still not enough. In the future, additional to the studies aimed to eliminate these deficiencies, in vitro studies examining production techniques and production accuracy of systems and in vivo studies following the success of restorations fabricated with these systems should be planned.

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