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REVIEW ARTICLE

Indirect Resin Composite Restorations Fabricated With Chairside CAD/CAM Systems

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A B S T R A C T

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

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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 discolorations[9] 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 onley restorations applied on endodontically treated teeth.[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 charside CAD/CAM systems.[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.[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).[20]

Cerec CAD/CAM system

Dr. Mörmann's[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.[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.[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.[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.[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 cavo-surface 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 system[24]

CATEGORY	BRAND NAME (MANUFACTURER)	CEREC	E4D
Esthetic Ceramics (Feldspathic)	*Vitablocs Mark II (Vident)*	X[1]	
	CEREC Blocs (Sirona Dental Systems)	X	
Esthetic Ceramics (Leucite reinforced)	*IPS Empress CAD (Ivoclar Vivadent)*	X	X
High strength ceramic (Lithium disilicate)	*IPS e.max CAD (Ivoclar Vivadent)*	X	X
Nanoceramic	*Lava Ultimate (3M ESPE)*	X	X
Composite Resin (Final restorations)	*Paradigm MZlOO (3M ESPE)*	X	X
Composite Resin (Temporary restorations)	*Vita CAD-Temp (Vident)*	X	
	Telio CAD (Ivoclar Vivadent)	X	X

[1] X: Material available for chairside system

Table II. Studies evaluating the CAD/CAM restorations[25-31]

EDITION	PURPOSE	RESTORATION TYPE	MATERIAL	RESULT
Batalha-Silva et al.[25]	Evaluation of influence of material/technique selection of adhesive MOD restorations and its effect on accelerated fatigue resistance and crack propensity.	MOD restorations produced with direct technique	Miris2 (Coltène-Whaledent, Altstätten, Switzerland)	Compared to direct restorations, CAD/CAM inlays showed increased accelerated fatigue resistance and decreased crack propensity of large MOD cavities. Under the physiological masticatory loads both restorations proved excellent fatigue resistance but for high-load patients CAD/CAM inlays found to be more suitable
		MOD CAD/CAM inlays	Paradigm MZ100	
Tsitrou et al.[26]	Composite CAD/CAM crowns manufactured with CEREC3 system were examined according to 3 different margin design prepared and cementation technique used.	Shoulder	Paradigm MZ100	Acceptable clinical results were observed for the marginal gap of resin composite crowns regardless of all three margin design prepared and two cementation technique used.
		Chamfer		
		Bevel		
Liu et al.[27]	Evaluation of effects of the fracture resistance on proximal cavity design and type of restorative material for MOD inlay restorations under compressive loading.	Proximal-box cavities	ParadigmMZ100	Composite materials were detected to show higher fracture resistance than ceramics. It was concluded that proximal-box cavities may be more advantageous, although the improvement of fracture resistance was not statistically significant under axial compression.
		Non-proximal cavities	IPS Empress CAD (Ivoclar Vivadent, Schaan, Liechtenstein)	
Zaruba et al.[28]	Evaluation the effect of the minimally invasive MOD cavities prepared on marginal adaptation of direct composite restorations, CAD/CAM composite inlays and CAD/CAM ceramic inlays with the aim of protecting sound dental substance.	Cavities prepared with 6^0 divergent angle and minimally invasive cavities prepared with 10^0 convergent angle were evaluated.	IPS Empress CAD	There was no significant difference in terms of marginal adaption between composite and ceramic inlays inserted in minimally invasive prepared MOD cavities and inlays inserted in conventional cavities. Conventional indirect restorations have margins superior to those attained by direct composite filling margins.
			Paradigm MZ100	
Ilgenstein et al.[29]	Evaluation of effect of proximal box elevation with composite resin on marginal integrity and fracture behavior of deep proximal defects in root-filled molars with MOD cavities, which were subsequently restored with CAD/CAM ceramic or composite onlay restorations.	MOD cavity prepared with 2 mm depth under CEJ[2] at distal side of the tooth.	Vita Mark II (Vita Zahnfabrik, Bad Sackingen, Germany)	It was concluded that for ceramic onlays proximal box elevation had no effect on either marginal integrity or fracture behavior. In terms of marginal integrity and fracture resistance composite onlays were found to be superior to ceramic onlays, specially in specimens without proximal box elevation.
			Lava Ultimate	
Ramirez-Sebastia et al.[30]	Examination of fracture resistance of endodontically treated anterior teeth retained without use of posts or with post of 5 mm and 10 mm in length of crowns restored with composite or ceramic material.	Composite and ceramic CAD/CAM crowns retained by endocrown or post of 5 mm and 10 mm in length.	IPS Empress CAD	No significant difference was observed on fracture resistance effected by post, post length and crown material. It was concluded that endocrowns had highest number of repairable fractures.
			Paradigm MZ100	
Chen et al.[31]	Evaluation of influence of restoration material used on stress distribution of endocrown restorations of endodontically treated mandibular first molar teeth under vertical and oblique simulated by finite element stress analysis.	Endocrown restorations	Composite resin	It was concluded that ceramic material transferred least amount of stress and it was defined as most protective material to tooth structure.
			Ceramage; Zirconium Silicate Ceramic (Shofu; Kyoto; Japan)	
			Ceramic	

Resin composite blocks used in CAD/CAM technology

The evolution of direct esthetic materials began with silicate cements developed by Fletcher[32] 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.[34]

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.[35,36]

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.[6,37,38] Factory polymerization resulted in Paradigm MZ100 having superior flexural strength and fracture toughness to those of Z100.[4,39] 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).[37] Block HC (Shofu; Kyoto, Japan) is a composite block composed of 61 wt.% silica powder, zirconium silica and micro-clustered silica particules[40] and Gradia Block (GC; Tokyo, Japan) is an another composite block including 76 wt.% silica, F-Al-silicate glass and pre-polymerized filler.[41]

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.[24] 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.[24,42,43] 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.[44,45]

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.[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.[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.[41,47]

Studies evaluating physical and mechanical properties of CAD/CAM blocks are shown in Table III.[41,48-53]

Table III. Studies Evaluating Physical and Mechanical Properties of Materials[41,47-53]

EDITION	PURPOSE	MATERIAL	PROPERTY	METHOD	RESULT
Lauvahutanon et al.[48]	Examination of mechanical properties of CAD/CAM composite resin blocks.	4 composite resin blocks (Block HC, Cerasmart, Gradia Block , Lava Ultimate)	Flexural strength	Dry storage	It was concluded that properties of all materials were within the acceptable range for fabrication of single restoration according to the ISO standard for ceramics and water immersion and thermocycling have generated degradation on all materials.
		Composite ceramic block (Vita Enamic)	Flexural modulus	Immersion in water at 37^0 C for 7 days	
		Feldspar-ceramic block (Vitablocks Mark II)	Vickers hardness	Immersion in water at 37^0 C for 7 days followed by 10.000 thermocycles.	
Lauvahutanon et al.[41] Koothape et al.[49]	Determination of wear resistance of CAD/CAM composite resin blocks.	4 composite resin blocks (Block HC, Cerasmart, Gradia Block Lava Ultimate)	2-body wear	Volume loss had been measured by using Digital CCD microscope.	Results demonstrated that 2-body wear had minimum wear loss for composite blocks and all blocks had high wear resistance. Values of wear of all blocks compared with values of direct posterior composites from a previous study in 2014 and concluded that blocks had higher wear resistance.
		Composite ceramic block (Vita Enamic)	3-body wear		
		Feldspar-ceramic block (Vitablocks Mark II)			
Magne et al.[50]	Evaluation and comparison of fatigue resistance of CEREC3 CAD/CAM composite and ceramic posterior occlusal veneers.	Composite resin (ParadigmMZ100)	Fatigue resistance	Fatigue resistance of 1.2 mm thick posterior occlusal veneers was measured under cyclic isometric loading.	The results showed that veneers restored with composite blocks had higher fatigue resistance than those with ceramic blocks.
		Leucite-reinforced (IPS Empress CAD) Lithium disilicate ceramic (IPS Empress e.max CAD) (Ivoclar Vivadent, Schaan Liechtenstein)			
Egbert et al.[51]	Comparison of fracture strengths and failure modes of ultrathin occlusal composite or hybrid ceramic veneers.	Composite resin (Paradigm MZ100)	Fracture strength	Occlusal veneers with central fossa thickness of 0.3 mm were milled and were loaded vertically.	Resin nanoceramic material was seem to show highest strength while composite resin and hibrid ceramic had equal results of fracture strength.
		Resin nanoceramic (Lava Ultimate)	Failure mode		
		Hibrid ceramic (Vita Enamic)			
Awad et al.[52]	Determination of translucency of restorative CAD/CAM materials and direct composite resins with respect to thickness and surface roughness.	12 materials including CAD/CAM ceramics, feldspatic ceramic, hibrid ceramic, nanoceramic, CAD/CAM composite resin, interm material, direct composite resin.	Translucency	2 different thickness (1 mm - 2 mm) were used and 3 different surface pretreatments (polished, SiC P1200, SiC P500) were applied to240 disc shaped specimen. Spectrophotometry and tactile profilometry were used to measure translucency and surface roughness respectively.	The parameters effects translucency were thickness material and pretreatment method respectively. Pretreatment method was the first parameter effect surface roughness and material was the second.
Mörmann et al.[53]	Wear characteristics of restorative CAD/CAM materials were examined.	9 esthetic CAD/CAM materials, one direct resin-based nanocomposite and human enamel as a control group were tested.	2-body wear	Computer controlled chewing simulator was used to investigate 2-body wear. Gloss and roughness measurements were assess using a glossmeter and profilometer. 10 N force was applied for 20 seconds to polish surface in order to measure Martens hardness.	It was concluded that permanent esthetic CAD/CAM materials have similarly or better results with respect to 2-body wear, gloss and roughness values than human enamel however this is not available for temporary polymer CAD/CAM block materials. Compare to other materials ceramics have best gloss retention.
			Gloss		
			Roughness		
			Martens Hardness		

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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