Original Article

A randomized clinical study evaluating the 30-month clinical performance of class II indirect restorations in endodontically treated teeth using ceramic, hybrid, and composite computer-aided design/computer-aided production blocks

Soley Arslan, Mehmet Karagön, Hacer Balkaya, Burak Köse

Department of Restorative Dentistry, Faculty of Dentistry, Erciyes University, Kayseri, Turkey

Abstract

Context (Background): In the literature, the information about which indirect material is the most appropriate for the restoration of endodontically treated teeth is insufficient. Therefore, studies evaluating the clinical performance of root canal-treated teeth will shed light on this issue for clinicians.

Aim: This clinical study aimed to evaluate the clinical performances of class II indirect restorations using ceramic, hybrid, and composite blocks to endodontically treated teeth.

Materials and Methods: A total of 60 indirect class II restorations were performed in 51 patients using Cerasmart (GC Dental Products Europe, Leuven, Belgium) composite, IPS e.max computer-aided design CAD (Ivoclar Vivadent, Schaan, Liechtenstein) ceramic, and Vita Enamic (Vita Zahnfabrik, Bad Sackingen, Germany) hybrid blocks. All the restored teeth had root canal treatment. The restorations were evaluated using modified FDI criteria for 30 months.

Statistical Analysis Used: The data were analyzed using Kruskal–Wallis analysis and Friedman two-way analysis of variance.

Results: A total of 53 restorations of the 60 restorations could be followed up at the end of 30 months. No statistically significant difference was observed between the groups after 30 months in terms of all criteria evaluated ($P > 0.05$).

Conclusion: Composite, ceramic, and hybrid blocks showed successful clinical performance in endodontically treated posterior teeth with large material loss.

Keywords: Computer-aided design/computer-aided production; ceramic block; composite block; hybrid block; indirect restoration

INTRODUCTION

The success of endodontically treated teeth depends not only on the clinician's ability to eliminate intracanal microorganisms and prevent new contamination but also on the conducting of sealed coronal restoration and the avoidance of crown/root fractures.[1,2] Various materials and techniques have been used in the restoration of endodontically treated teeth. Although resin composites are frequently used, they still have a number of negative properties that have not been eliminated, such as

Address for correspondence:
Dr. Hacer Balkaya,
Department of Restorative Dentistry, Faculty of Dentistry, Erciyes University, Kayseri 38039, Turkey.
E-mail: dhacer89@hotmail.com

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polymerization shrinkage. Polymerization shrinkage disrupts bond integrity by creating stress at the interface.[3] Especially in large restorations whose cervical edges end in dentin, edge deformations, and microleakages may occur because of shrinkage stresses exceeding the bonding agent's bonding forces to the tooth.[4] Microleakage negatively affects the long-term success of the restoration by causing marginal discoloration, postoperative sensitivity, secondary caries, and pulpal irritation.[5,6]

Various treatment options, such as direct composite restoration, indirect restoration, crowns, and postsupported crowns, are available in the restoration of endodontically treated teeth. However, there was no single solution for all clinical situations. The best approaches for the restoration of endodontically treated teeth are removing the minimum amount of tissue, especially in the cervical area, to create a ferrule effect, strengthening the remaining tooth structure, increasing the stability and retention of the restoration using adhesive procedures, and using a material closest to the physical properties of dentin for restoration.[7-9]

In large cavities, problems experienced during the placement and adaptation of the composite material to the cavity are minimized by the indirect method. In a laboratory environment, it is easier to provide the appropriate proximal contours and contacts of the restorations and to create the ideal anatomical structure.[10]

The most up-to-date system used in the production of indirect restorations today is the system entitled "computer-aided design/computer-aided production" (CAD/CAM). The term CAD/CAM infers that the restoration designed in three dimensions on a computer is produced by machine.[11] CAD-CAM systems have numerous advantages such as saving time and labor because restorations can be finished in the same session, allowing high quality and anatomical restorations with natural appearance to be made, and eliminating the need for gagging measurements.[11] The CAD/CAM system used in the clinic offers clinicians different restorative material options suitable for particular cases. Industrially produced engravable CAD/CAM blocks can be in the form of a hybrid structure that includes some of the properties of composite, ceramic, or both materials.[12]

In clinical follow-up studies, how the restorations are made is critical, as well as the criteria by which the restorations are evaluated. Different methods such as the United States Public Health Service (USPHS) evaluation system, the California Dental Association evaluation system, and the World Dental Federation (FDI) evaluation system are used in the clinical evaluation of restorations.[13] The FDI criteria were approved by the FDI World Dental Federation Scientific Committee in 2007 and were accepted as standard criteria for evaluating restorative materials or operative techniques in 2008.[13] The FDI system, which allows clinicians to evaluate restorations in terms of esthetic, functional, and biological, is quite sensitive for identifying differences in restorations and it allows authors to make more reliable comparisons with other studies since it is a frequently used system.[14,15]

In the literature, although there are *in vitro* studies that have investigated the physical and mechanical properties of CAD/CAM blocks with different structures, studies evaluating the clinical performance of these materials are limited. Therefore, this study aimed to evaluate the clinical performance of indirect class II restorations made from composite, ceramic, and hybrid blocks using modified FDI criteria. The null hypothesis of this study was that there would be no significant difference between the clinical performance of the indirect restorations made using these different blocks.

MATERIALS AND METHODS

Study design

The study design was a controlled randomized clinical trial registered at www.clinicaltrials.in.th (TCTR identification No. TCTR20210316004).

Before conducting the study, the research protocol was approved by the Erciyes University Clinical Research Ethics Committee (Approval Number: 2018/286). Among 750 patients who applied to the Erciyes University Department of Restorative Dentistry, 60 teeth with endodontic treatment were included in the study in 51 patients who met the inclusion criteria [Figure 1]. All restorations were performed by an experienced operator. The randomization of restorative materials was done using a table of random numbers.[16] The teeth were randomized for each of the three restorative materials through a table of random numbers generated by the program "Research Randomized Program." "(http://www.randomizer.org /form.htm)." Systemically healthy individuals who had endodontically treated teeth with no clinical signs and symptoms or periapical pathology had teeth opposite and adjacent to the restoration and agreed to participate in regular checkups were included in this study. Individuals with unacceptable oral hygiene or parafunctional habits and teeth with large cavities including tubercles were excluded from the study.

The ages of the patients participating in the study ranged from 18 to 60. After giving detailed verbal information about the research protocol and possible complications associated with inclusion in the study, the informed patient consent form was read and signed by the volunteer participants. Decayed, missing, and filled teeth (DMFT) indices of the patients were determined before starting treatment. Periodontal treatments of the patients were carried out in Erciyes University Faculty of Dentistry, Department of Periodontology. Radiographs were taken to evaluate the margins of the restorations, the presence of secondary caries, evaluation of endodontic treatment, and to check for periapical pathology.

In this study, the reasons to restore the teeth included primary caries (23.3%, *n*: 14), secondary caries/fractures/contact problems related to composite resin (53.3%, *n*: 32), and secondary caries/fractures/contact problems related to amalgam (23.3%, *n*: 14).

Tooth preparation

The materials, manufacturers, chemical compositions, and batch numbers of the main materials used in this study are listed in Table 1.

Two surface cavity preparations (MO or DO) were performed in this study. All old restorations or temporary filling materials were removed, and cement and gutta-percha residues at the canal openings were removed with a small carbide bur. Root canal cavity floor was sealed using a flowable resin composite (Imicryl, Nova Compo-HF, Konya, Turkey). All the walls of the cavity were prepared at an angle of 6°–10° to the long axis of the tooth using inlay/onlay preparation burs. Angles were rounded at the junction points on the inner walls of the cavity, and right-angle butt joint ends were made on the walls facing outside the cavity borders. All remaining walls had dentin support, and no additional occlusal reduction was performed. In addition, in the cavities extending under the gingiva, the cavity gingival margin was elevated 1 mm above the gingiva using composite resin.

After preparation, a retraction cord was placed in the gingival sulcus to remove the gingiva from the cavity. Impressions were taken using a silicone impression material (Heavy and Light Body Zetaplus, Zhermack, Bovazeccihino,

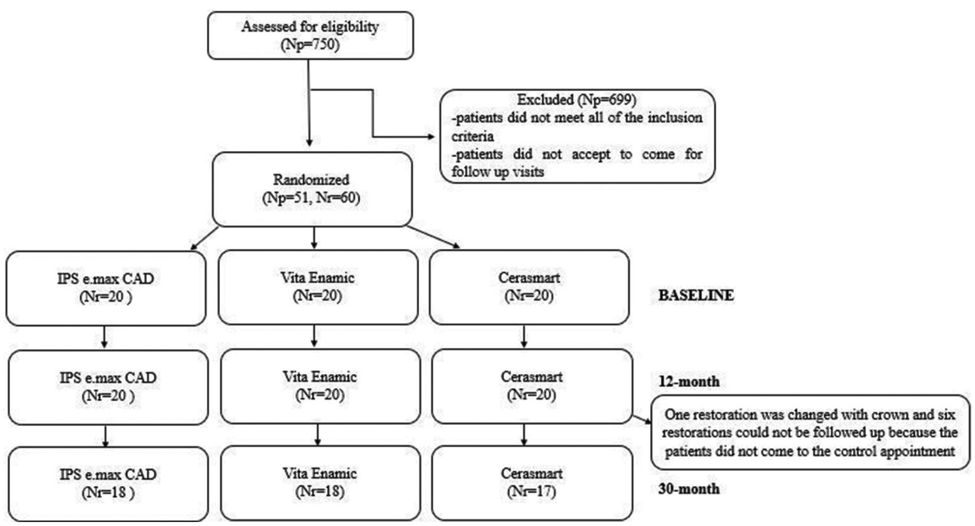

Figure 1: Flow diagram. Np: Number of patients, Nr: Number of restorations, CAD: Computer-aided design

Table 1: Restorative materials used in study

Material	Compositions	Batch number
IPS e.max CAD Ivoclar Vivadent (Schaan, Liechtenstein)	SiO_2 (57%–80%), Li_2O (11%–19%), K_2O (0%–13%), P_2O_5 (0.5%–11%), ZrO_2 (0%–8%), ZnO (0%–8%), Al_2O_3 (0%–5%), MgO (0%–5%), oxide pigments (0%–6%)	W96414
Cerasmart GC (Leuven, Belgium)	Bis-MEPP, UDMA, DMA, silica (71%) (20 nm), barium glass (300 nm) nanoparticles	1602044
Vita Enamic Vita-Zahnfabrik (Bad Sackingen, Germany)	Ceramic: SiO_2 (58%–63%), Al_2O_3 (20%–23%), Na_2O (6%–11%), K_2O (4%–6%), B_2O_3 (0.5%–2%), CaO (<1%), ZrO_2 (<1%) Polymer: UDMA, TEGDMA	75730
Hydrofluoric acid Ultradent (Cologne, Germany)	%9,5 hydrofluoric acid	BFLDV
Silane Ultradent (Cologne, Germany)	Ethanol, 3-trimethoxypropyl methacrylate, 10-MDP (MDP), sulfide methacrylate	BG3TD
RelyX U200 3M ESPE (St. Paul, MN, USA)	Base paste: Fiberglass, phosphoric acid methacrylate esters, TEGDMA, silano treated sílica and sodium persulfate	4088239
Telio CS Onlay Ivoclar Vivadent (Schaan, Liechtenstein)	The monomer matrix consists of methacrylates (36.3%). Dispersed silicon dioxide and copolymers (62%). Fluoride (1500) ppm), catalysts, stabilizers and pigments (0.6%)	W98823

UDMA: Urethane dimethacrylate, DMA: N, N-dimethylacrylamide, TEGDMA: Triethylene glycol dimethacrylate, Bis-MEPP: 2,2-bis(4-methacryloxpolyethoxyphenyl) propane, MDP: Methacryloyloxydecyl dihydrogen phosphate

Italy) using an individually designed impression tray. Temporary restorations were then made chairside using a photopolymerized composite resin material (Telio CS Onlay, IvoclarVivadent, Schaan, Liechtenstein).

Laboratory procedures

The impressions sent to the laboratory were first scanned with a Dental Wings7 (DWOS, Montreal, Canada) device. The scanned models were transferred to a computer, and the restorations were designed using the exocad program. The designed restorations were transferred to the Dentaswiss DS1300 (Biodenta Swiss, Berneck, Switzerland) device, and the restorations were produced by milling the blocks placed in the device.

Indirect ceramic restorations were obtained by milling only IPS e.max. CAD blocks in the CAD/CAM device are present in the blue/purple precrystallized phase at this stage while being crystallized for 10 min at 850°C in the Programat EP 5010 (Ivoclar Vivadent, Schaan, Liechtenstein) furnace in the laboratory. Finally, a glaze layer was applied.

Placement of restorations

Before the permanent restorations were placed on the teeth, the temporary filling material was removed and the cavity was cleaned with alcohol. Each type of material was treated in accordance with the manufacturers' instructions before cementation. The internal surfaces of the IPS e.max CAD and Vita Enamic restorations were etched with 9.5% hydrofluoric acid (Porcelain Etch, Ultradent, South Jordan, UT, USA) (20 s for IPS e.max CAD specimens; 60 s for Vita Enamic specimens) and Cerasmart restorations were abraded with 50 µm aluminum oxide (KaVo, Biberach, Germany), using an intraoral sandblasting device (KaVo RONDOflex plus 360, Biberach, Germany). The tip of the microetcher was kept 5 cm away from the surfaces and applied for 10 s at 2.0 bar pressure.[17] Restorations were subsequently rinsed under running water to remove any debris (20 s), cleaned in an ultrasonic device (2 min), and air-dried.

All restorations were treated with a silane coupling agent (Ultradent, South Jordan, UT, USA) for 60 s. The intraoral working area was isolated with cotton rolls and high-volume suction. In addition, the cavity was isolated with the help of a sectional matrix (Standard matrix, Palodent, Dentsply, York, PA, USA) and a wedge. Phosphoric acid at 37% was then applied to enamel surfaces for 30 s, washed, and dried. All indirect restorations were cemented with self-adhesive resin cement (RelyX U200, 3M ESPE, St. Paul, MN, USA). The cement was applied inside the restoration with the help of an automatic syringe and placed in the cavity. Overflowing cement was removed. The restoration was polymerized from the occlusal, buccal, and palatal/lingual surfaces for 40 s with an LED light device (VALO, Ultradent, South Jordan, UT, USA). Centric occlusion and lateral, and protrusive movements were controlled, and, occlusal arrangements were made with the help of yellow belt diamond finishing burs if necessary. Polishing was then performed using Sof-Lex spiral disks (3M ESPE, Dental products, St. Paul, USA). Overhangs were removed and polished in the same way, proximally with interdental polishing strips (GC Epitex strips, Leuven, Belgium).

Evaluation of the restorations

The restorations were evaluated by a blinded specialist dentist, who did not know which restorative material was used, after 1 week, 12 months, and 30 months. Bite-wing radiographics were taken from the restorated teeth in each control session. Periapical radiographics were also used to evaluate the periapical region during the 30-month follow-up. Modified FDI criteria were used with regard to the evaluation of the restorations.[14] There were three assessment categories (esthetic, functional, and biological), each comprising five subcategories.

Statistical analysis

Data were evaluated in the statistical package program of the IBM SPSS Statistics Standard Concurrent User Version 26 (IBM Corp., Armonk, New York, USA). Descriptive statistics were given as the number of units (n), median (M), minimum (min), and maximum (max) values. Kruskal–Wallis analysis was used to compare FDI scores with respect to materials at each measurement time. Within-group FDI scores at measurement times for each material were compared with the rank-based Friedman two-way analysis of variance. A value of $P < 0.05$ was considered statistically significant.

RESULTS

A total of 60 (30 molar and 30 premolar) indirect restorations were performed in 51 patients (37 female and 14 male) with a mean age of 35.76 ± 10.46 years. The mean DMFT index of the patients was 9.63 ± 4.21. Baseline and follow-up evaluation results are summarized in Table 2.

In our study, 53 (17 Cerasmart, 18 e-max, and 18 Vita Enamic/26 molar, 27 premolars) of 60 restorations could be evaluated at the end of the 30th months, and the restoration follow-up rate at the end of the 30th months was 88.3%. In this study, minor chipping was observed in only one Cerasmart restoration at the end of 30 months, but this restoration was still clinically good. Moreover, dental structure fracture was observed in two teeth restored with Cerasmart and Vita Enamic during the 30-month follow-up. One of the fractured teeth belonging to the Cerasmart group had been restored with a crown at the 20th months. Therefore, this restoration could not be included in the 30th-month evaluation. Debonding had occurred in another

Table 2: Results of the clinical evaluation at baseline and after 12 and 30 months

	Cerasmart			IPS e.max CAD			Vita-enamic		
	Baseline (1/2/3/4/5)	12 months (1/2/3/4/5)	30 months (1/2/3/4/5)	Baseline (1/2/3/4/5)	12 months (1/2/3/4/5)	30 months (1/2/3/4/5)	Baseline (1/2/3/4/5)	12 months (1/2/3/4/5)	30 months (1/2/3/4/5)
Esthetic									
Surface gloss	20/0/0/0/0	20/0/0/0/0	17/0/0/0/0	20/0/0/0/0	20/0/0/0/0	18/0/0/0/0	20/0/0/0/0	20/0/0/0/0	17/0/0/0/1
Surface/marginal staining	20/0/0/0/0	20/0/0/0/0	17/0/0/0/0	20/0/0/0/0	19/1/0/0/0	17/1/0/0/0	20/0/0/0/0	19/1/0/0/0	17/0/0/0/1
Color match	19/1/0/0/0	19/1/0/0/0	16/1/0/0/0	19/1/0/0/0	19/1/0/0/0	17/1/0/0/0	17/3/0/0/0	18/2/0/0/0	15/2/0/0/1
Anatomic form	20/0/0/0/0	20/0/0/0/0	16/1/0/0/0	20/0/0/0/0	20/0/0/0/0	18/0/0/0/0	20/0/0/0/0	20/0/0/0/0	17/0/0/0/1
Functional									
Fracture and retention loss	20/0/0/0/0	20/0/0/0/0	16/1/0/0/0	20/0/0/0/0	20/0/0/0/0	18/0/0/0/0	20/0/0/0/0	20/0/0/0/0	17/0/0/0/1
Marginal adaption	20/0/0/0/0	20/0/0/0/0	17/0/0/0/0	20/0/0/0/0	20/0/0/0/0	18/0/0/0/0	20/0/0/0/0	20/0/0/0/0	17/0/0/0/1
Wear	20/0/0/0/0	20/0/0/0/0	17/0/0/0/0	20/0/0/0/0	20/0/0/0/0	18/0/0/0/0	20/0/0/0/0	20/0/0/0/0	17/0/0/0/1
Contact point	18/0/2/0/0	18/0/1/1/0	13/1/3/0/0	19/0/1/0/0	19/0/1/0/0	17/0/1/0/0	20/0/0/0/0	20/0/0/0/0	15/1/0/1/1
Patient satisfaction	20/0/0/0/0	20/0/0/0/0	17/0/0/0/0	20/0/0/0/0	20/0/0/0/0	18/0/0/0/0	20/0/0/0/0	20/0/0/0/0	17/0/0/0/1
Biological									
Seconder caries/erosion/ abfraction	20/0/0/0/0	20/0/0/0/0	17/0/0/0/0	20/0/0/0/0	20/0/0/0/0	18/0/0/0/0	20/0/0/0/0	20/0/0/0/0	18/0/0/0/0
Tooth integrity	20/0/0/0/0	20/0/0/0/0	16/1/0/0/0	20/0/0/0/0	20/0/0/0/0	18/0/0/0/0	20/0/0/0/0	20/0/0/0/0	17/0/0/0/1
Periodontal response	20/0/0/0/0	18/0/1/1/0	15/0/1/1/0	20/0/0/0/0	19/0/0/1/0	17/0/1/0/0	20/0/0/0/0	19/0/0/1/0	15/0/2/0/1

CAD: Computer-aided design

restoration made from a Vita Enamic hybrid block due to tooth fracture. This restoration was scored as "5" for all criteria except for seconder caries, and the restoration was renewed.

However, when the indirect restorations were evaluated in terms of esthetic, functional, and biological properties, no statistically significant difference was found between the groups ($P > 0.05$). In addition, in the 12th- and 30th-month controls of all groups, there was no significant change ($P > 0.05$) compared with the baseline in terms of all criteria.

DISCUSSION

In this study, the 30-month clinical performance of the indirect restorations applied to posterior devital teeth using three different CAD/CAM blocks (Cerasmart, IPS e.max CAD, Vita Enamic) with different contents (ceramic, composite, and hybrid) were evaluated, and no statistically significant difference was found for all evaluation criteria. Therefore, our null hypothesis was accepted.

The success of root canal treatment depends on the sealing of coronal restoration and the effective cleaning and filling of the root canals. Direct composite resins are the most commonly used materials for the restoration of these teeth. However, problems associated with the use of direct composite resins in the restoration of posterior teeth have increased the tendency to use indirect restorations such as inlay–onlays, where dental structures can be preserved at the maximum level.[18] As seen in clinical studies, indirect restorations in the posterior region have shown a higher degree of success than direct restorations.[19,20] Therefore, in our study, indirect restorations were performed on endodontically treated posterior teeth.

Indirect restoration can be produced in different ways. Traditional indirect restorations involve many procedures such as impression, occlusal registration, preparation of a working model from plaster, wax modeling, melting wax, and firing.[21] Dental CAD/CAM systems, which have been developed to overcome these complex procedures, are frequently used today due to a number of advantages such as allowing restorations to be produced in a single session, and the anatomical form and contacts to be formed close to ideal.[22] For this reason, we preferred to use CAD/CAM in our study.

Nowadays, three different materials are used in the production of CAD/CAM indirect restorations: ceramic, composite, and hybrid. Della Bona *et al*.,[23] in a study, in which they evaluated the mechanical properties of Vita Enamic blocks, a polymer-infiltrated ceramic material, reported that polymer-infiltrated ceramic showed mechanical properties between porcelains and resin-based composites, reflecting its microstructural components. Awada and Nathanson[24] the mechanical properties and edge congruence of Lava Ultimate, Vita Enamic, IPS Empress CAD, Cerasmart, Paradigm MZ100, and Vita Block Mark II CAD/CAM blocks in their study. In general, they stated that polymer-based materials perform better than ceramic materials in bending tests. They stated that the difference between the materials in terms of elastic properties was due to the resin component and suggested that the resin component reduced the fragility of the materials.

In the literature, besides the studies reporting that there is no difference between the fracture strength of hybrid and ceramic restorations, there are also studies that argue that the fracture strength of ceramic restorations is higher.[25-27] In our study, although bulk restoration fracture was observed in none of the restorations, minor chipping was observed in only one indirect composite restoration at the end of 30 months. This restoration scored as "2: Clinically good." Moreover, fracture was observed in two teeth restored with indirect composite block and hybrid block during the 30-month follow-up. One of the fractured teeth belonging to the composite block had been restored with a crown at the 20th months. Therefore, this restoration was excluded from the 30th-month evaluation. Another restoration made from a hybrid block had debonded due to tooth fracture. This restoration was scored as "5" for all criteria except for seconder caries, and the restoration was renewed. When our study findings were examined, no difference was observed between the materials in terms of fracture. It should not be forgotten that in addition to the applied force, there is also the effect of occlusion, primary contact points, lateral forces, remaining tooth structure, and endodontic treatment in terms of fracture strength.

In the cementation of indirect restoration, conventional glass ionomer cement, resin-modified glass ionomer cement, chemically polymerized resin cement, and dual-cured resin cement are used. Resin cements seem as ideal material for the cementation of indirect restorations due to their ability to provide good adhesion with different surfaces, good biocompatibility, high durability, resistance to dissolving in the oral environment, superior esthetic properties, and ease of use.[28] Self-adhesive resin cement is a hybrid material that combines the properties of self-etch adhesives and conventional cement. The biggest advantage of self-adhesive resin cement is good adhesion to the restorative material and dental tissues without etching or adhesive application.[29] Therefore, RelyX U200, self-adhesive resin cement, was used for the cementation of all indirect restorations in this study, and the enamel surfaces were roughened with 37% phosphoric acid for 30 s. During the 30-month follow-up, no cement-related failure was observed in any restoration. In parallel with our study, Azevedo *et al.*[30] reported that there was no cement-related failure in any restoration in a 1-year follow-up of 42 indirect restorations involving self-adhesive resin cement.

Different criteria are used in the clinical evaluation of restorations.[13] USPHS guidelines also known as the "Ryge criteria" and FDI (World Dental Federation) are the most preferred criteria for evaluating composite restorations. As stated in the studies, we used FDI criteria as the evaluation criteria because the criteria and scoring of such criteria can be modified and can, therefore, provide a more precise evaluation.[18,20]

In our study, there was no statistically significant difference between the groups in terms of FDI esthetic criteria (surface brightness, surface/edge coloration, and anatomical form). In our study, since the polishing processes of the indirect restorations were carried out in the laboratory in accordance with the manufacturer's instructions, no significant change in surface brightness and color harmony was observed in the restorations during the 30-month follow-up.

The CAD/CAM system enables the creation of the most appropriate anatomical form by evaluating its compatibility with neighboring and antagonist teeth when designing restorations.[20] It has been reported that restorations produced with CAD/CAM are more compatible with respect to the anatomical form and contact point than restorations obtained by traditional methods.[31] In the 3-year controls of a study evaluating 101 posterior teeth with root canal treatment using CAD/CAM feldspathic ceramic (Vita Mark II) and hybrid ceramic (Vita Enamic) blocks, in terms of the anatomical form criteria, the alpha score ratio in the Vita Mark II group was 89.7%, while in the Enamic group, it was 89.2%.[32] In our study, all restorations except one debonded hybrid (Vita Enamic) restoration were found to be successful in terms of the anatomical form criteria during the follow-up period.

The most common cause of failure in short-term clinical follow-up studies has been reported as loss of retention and restoration fracture.[33] Tagtekin *et al.*[34] reported that there was a loss of retention in one restoration after 6 months in a study of 35 inlay/onlay ceramic restorations on canal-treated teeth. They cemented the restoration again, and that no restoration loss had occurred by the end of 2 years. In our study, one hybrid restoration mentioned above showed loss of retention because of tooth fracture at the end of the 30-month. There was no statistically significant difference between the groups compared with the 30-month success rate of the groups. This high success rate may be due to the short duration of the study and the procedures having been carried out in accordance with the manufacturers' instructions.

Achieving a good marginal adaptation of indirect restorations is one of the most important criteria for long-term clinical success.[35] In a clinical evaluation conducted by Hayashi *et al.*,[36] they made 45 inlay restorations using traditional kilnable ceramic; it was found clinically acceptable deterioration in the margin alignment of 5 restorations at the end of 2 years and 6 at the end of 4 years. It was reported that the marginal adaptation was impaired in 11 restorations (24%) in the 8-year controls. In our study, 52 of 53 indirect restorations were scored as "1 "for marginal adaptation at a 30-month follow-up. This high performance of the restorations in terms of marginal adaptation could be attributed to indirect CAD/CAM restorations that are fully compatible with the cavity in all aspects.

The share of secondary caries in the failure of dental restorations is quite high.[37] Zimmer *et al.*[38] made 308 indirect restorations using Dicor and Vita Mark II blocks in their study. They reported that none of the 226 restorations followed up at the end of 5 years had secondary caries. In another study, no secondary caries was reported after 3 years in the case of 101 indirect restorations on teeth with canal treatment using a CAD/CAM system involving Vita Enamic and Vita Mark II ceramics.[32] In the presented study, at the end of the 30 months, no secondary caries was observed in any restorations, and all groups showed 100% success. The short 30-month evaluation period may explain the absence of secondary caries. Furthermore, the prevention of microleakage because of the prevention of polymerization shrinkage due to the preparation of restorations by the indirect method caused this high rate.

The limited sample size is a limitation of this study. This study was a clinical thesis study. The number of samples had to be limited due to time and budget constraints.

CONCLUSION

This study shows that CAD/CAM onlay restorations made of ceramic, composite, and hybrid blocks have a high clinical success rate after 30 months. However, long-term clinical follow-up studies are needed to fully demonstrate the effectiveness of the materials used.

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Conflicts of interest

There are no conflicts of interest.

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