

Araştırma Makalesi/Research Article

## The Clinical Performance of CAD/CAM-Generated Different Inlay/Onlay Materials: A One-Year Follow Up

*Cad/Cam ile Üretilen Farklı Yapıdaki İnceley/Onley Materyallerinin Klinik Performanslarının Değerlendirilmesi: 1 Yıllık Takip*

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**Abstract:** Objective: This study aimed to evaluate the clinical performances of four different CAD/CAM blocks with varying content and advantages. Methods: A single dentist performed inlay/onlay restorations using Lava Ultimate, IPS e.max CAD, Vita Mark II and Vita Enamic CAD/CAM blocks on 60 vital posterior teeth (n=15) of the patients enrolled in the study. The restorations were evaluated by two inter-comparison dentists (Cohen Kappa Index=0.88) according to the modified USPHS criteria at 1 week, 6 months and 12 months. The data were statistically analyzed using SPSS 15.0. Cochran's Q test was used for within-group comparisons and the chi-squared test ( $\chi^2$ ) for between-group comparisons. Results: The follow-up rate of the restorations at the end of 1 year was 100%. At the end of the follow-up period, all restorations were found to be clinically acceptable. There was no statistically significant difference between the clinical performance of the different CAD/CAM materials used ( $p>0.05$ ). Conclusion: According to the results of this 1-year follow-up clinical study, inlay/onlay restorations fabricated with four different CAD/CAM blocks showed similar clinical performance.

**Keywords:** CAD/CAM, Indirect restorations, Inlay/onlay, Clinical evaluation, Modified USPHS.

**Öz:** Amaç: Bu çalışmada, farklı içerik ve avantajlara sahip dört ayrı CAD/CAM bloğun klinik performanslarının değerlendirilmesi amaçlanmıştır. Gereç ve Yöntem: Çalışmaya dahil edilen hastaların 60 adet vital posterior dişine (n=15) Lava Ultimate, IPS e.max CAD, Vita Mark II ve Vita Enamic CAD/CAM blokları kullanılarak tek bir hekim tarafından inley/onley restorasyon yapıldı. Restorasyonlar, birbirleriyle kalibre edilmiş (Cohen Kappa indeksi=0,88) iki diş hekimi tarafından 1 hafta, 6 ay ve 12 ay sonrasında modifiye USPHS kriterlerine göre kontrol edildi. Elde edilen veriler SPSS 15,0 programı kullanılarak istatistiksel olarak analizi edildi. Grup içi karşılaştırmalar Cochran's Q, gruplar arası karşılaştırmalar ise Ki-kare ( $\chi^2$ ) testi kullanılarak yapıldı. Bulgular: Restorasyonların 1 yıl sonundaki takip edilme oranı %100 oldu. Takip süresi sonucunda tüm restorasyonlar klinik olarak kabul edilebilir seviyede başarılı bulundular. Kullanılan farklı CAD/CAM materyallerinin klinik performansları arasında ise istatistiksel olarak anlamlı bir fark bulunmadı ( $p>0,05$ ). Sonuç: 1 yıllık takibin yapıldığı bu klinik çalışmanın sonuçlarına göre, dört farklı CAD/CAM bloğu kullanılarak yapılan inley/onley restorasyonlar benzer klinik performans sergilemiştir.

**Anahtar Kelimeler:** CAD/CAM, İndirekt restorasyonlar, İnceley/onley, Klinik değerlendirme, Modifiye USPHS.

### Introduction

With the increasing aesthetic demands in dentistry and the improvement of the mechanical properties of composite resins, direct composite restorations are widely preferred in the posterior region (Giachetti et al., 2006). However, despite the improvements in composite resin ingredients, polymerisation shrinkage of the resin matrix is still considered to be the main

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problem leading to the failure of direct composite restorations (Karaarslan et al., 2012). In addition, studies have shown that problems such as poor wear and fracture resistance, difficulty in achieving contour and contact in the proximal regions, lack of marginal integrity and postoperative sensitivity can occur with direct composite restorations (van Dijken, 1994; Wassell et al., 2000). To avoid these disadvantages, inlay and onlay restorations fabricated with an indirect technique have been developed (Gracis et al., 2015; Yamanel et al., 2009).

Indirect aesthetic restorations can be fabricated from composite or ceramic materials. In the early days, the limitations of restorative materials, namely their weakness, fragility and inability to provide an ideal marginal fit, in combination with cementation issues, resulted in suboptimal outcomes for these restorations (Ausiello et al., 2004; Mangani et al., 2015). However, especially since the 1980s, the use of indirect restorations has increased considerably due to the strengthening of ceramic systems and adhesive systems that allow better bonding of porcelain to dental tissues (Hayashi et al., 2003).

The fabrication of indirect ceramic restorations can be achieved through a variety of techniques, including casting, refractory die casting, heat pressing, and CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) systems (Bonfante et al., 2023). In comparison with other techniques that require long laboratory phases, the CAD/CAM system makes it possible to carry out indirect restorations at the chairside and in a single visit (Otto and De Nisco, 2002). Because CAD/CAM systems allow the treatment process to be completed in a single visit, it saves time for both the patient and the dentist. Furthermore, by eliminating the need for additional impressions and provisional restorations, it eliminates the clinical problems associated with these steps and provides cost savings, albeit small (Davidowitz and Kotick, 2011; Feuerstein, 2004). In addition, the production of restorations using CAD/CAM technology has the advantages of reducing labour, lowering production costs and allowing the use of new materials (Miyazaki et al., 2009). The CAD/CAM system can fabricate restorations using materials such as feldspathic ceramics (e.g. Vita Mark II, VITA Zahnfabrik, Bad Säckingen, Germany) and lithium disilicate reinforced ceramics (e.g. IPS e. max CAD, Ivoclar Vivadent, Amherst, NY), as well as 'resin matrix ceramics' with an organic matrix such as Lava Ultimate (3M ESPE, USA) and Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany). Lithium disilicate reinforced ceramics have better mechanical properties than conventional feldspathic ceramics. Resin matrix ceramics are reported to offer advantages such as better mimicking of the elastic modulus of dentin compared to conventional feldspathic ceramics, easier processing and placement compared to lithium disilicate reinforced ceramics and

polycrystalline ceramics, and easier repair or restoration with composite resin (Gracis et al., 2015).

The aim of this study was to evaluate the clinical performance of inlay/onlay restorations on vital posterior teeth using four different CAD/CAM blocks (Lava Ultimate, IPS e.max CAD, Vita Mark II, Vita Enamic) with different contents and benefits over one year.

The null hypothesis posited that CAD/CAM inlay/onlay restorations on posterior teeth using four different blocks would have similar clinical performance.

## Methods

Before starting the study, the ethics committee approval required for clinical studies was obtained from the Kırıkkale University Faculty of Medicine Clinical Research Ethics Committee (Decision No: 20/02, Date: 18/08/2014). Clinical and radiological examinations were performed on patients who came to Kırıkkale University Faculty of Dentistry, Department of Restorative Dentistry, and patients who met the criteria of our study were identified.

Inclusion criteria are as follows:

- Be over 18 years of age.
- Have good oral health.
- The tooth to be restored must be a vital molar.
- No bruxism or parafunctional habits.
- No pain in the tooth to percussion and palpation.
- Not pregnant or breastfeeding.
- No psychiatric or systemic disease requiring long-term anti-inflammatory, analgesic use.

Eligible patients were informed about the purpose of the study, the treatments and the controls. Patients who agreed to be included in the study were asked to complete and sign an informed consent form. Treatment started after verbal and written informed consent was obtained.

Sample size was calculated using G\* Power v3.1 (Heinrich Heine, Universität Düsseldorf, Germany) at a significance level of 0.05, an effect size of 0.45, and a power of 0.85. A total of 60 permanent molars of the patients included in our study were planned to receive inlay/onlay restorations using the CAD/CAM system. For the 4 different CAD/CAM blocks

used in the construction of the restorations, 4 different groups were formed by randomized lottery method. Accordingly; Group 1 was Lava Ultimate (3M ESPE, USA), Group 2 was IPS e.max CAD (Ivoclar Vivadent, Amherst, NY), Group 3 was Vita Mark II (VITA Zahnfabrik, Bad Säckingen, Germany) and Group 4 was Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany). The materials and their contents used in the study are given in Table 1.

A total of 41 patients, 25 males and 16 females, who were clinically and radiologically evaluated and who met the inclusion criteria, were included in this study.

All patients were treated by a single dentist at Kırıkkale University Faculty of Dentistry, Restorative Dentistry Clinic. The patients to be included in the study were motivated about oral hygiene prior to treatment. The teeth to be restored were polished with a mixture of pumice-water and silicone-based rubber. After removal of the existing old filling material or carious tissue under water cooling, inlay/onlay cavities were prepared using a diamond bur No. 850-012-16 ML (Diatech, Swiss Dental Instruments, Heerbrugg, Switzerland) attached to an air-powered rotary motor (W&H Synea, Dentalwerk Bürmoos GmbH, Australia). In the cavities, an angle of approximately 6 degrees was formed between the cavity floor and the sidewalls for the insertion path of the restorations, and the corners of the cavity were rounded. A resin-modified calcium silicate material (TheraCal LC, Bisco Inc, Schaumburg, IL) was used as a cavity liner to protect the pulp where the pulp was too close. The liner material was applied in a thin layer to the required area and polymerised for 20 seconds. A flowable composite (Clearfil Majesty Flow, Kuraray, Japan) was used as a base on the cavity liner and to organise the small incisors in the cavity. A two-step self-etching adhesive (Clearfil SE Bond, Kuraray, Japan) was used to bond the flowable composite.

A digital model of the oral cavity was obtained using an intraoral scanner (3Shape Trios, Copenhagen, Denmark). The obtained digital data were sent to the laboratory.

In the laboratory, the restorations were designed by the CAD/CAM technician using the 3Shape Trios Dental system. The selected block was placed in the milling unit (Coritec 550i, imes-icore, Germany) and then milled. The CAD/CAM block to be used for the restorations to be placed on the teeth was decided according to the group numbers. After every 5 restorations, starting from group 1, the material of the next group was used.

**Table 1:** Materials and Contents Used in the Study

Material	Manufacturer	Contents	Lot Number
Lava Ultimate Cad/Cam Block	3M Espe	<b>Ceramic Network:</b> 20 nm silica nanoparticles, 4-11 nm zirconia nanoparticles <b>Polymer Network:</b> Bis-GMA, Bis-EMA, UDMA, TEGDMA	N597734
IPS e.max Cad/Cam Block	Ivoclar Vivadent	0.2-2 µm lithium disilicate crystals	U16405
Vita Mark II Cad/Cam Block	Vita Zahnfabrik	SiO <sub>2</sub> and Al <sub>2</sub> O <sub>3</sub>	43660
Vita Enamic Cad/Cam Block	Vita Zahnfabrik	<b>Ceramic Network:</b> SiO <sub>2</sub> , Al <sub>2</sub> O <sub>3</sub> , Na <sub>2</sub> O, K <sub>2</sub> O, B <sub>2</sub> O <sub>3</sub> , Zr <sub>2</sub> O, CaO <b>Polymer Network:</b> UDMA and TEGDMA	52210
Panavia F2.0 Resin Cement	Kuraray	<b>Paste A:</b> 10-MDP, hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated silica filler, silanated colloidal silica, dl-camphorquinone, catalysts, initiators <b>Paste B:</b> hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated barium glass filler, surface treated sodium fluoride, catalysts, accelerators, pigments <b>Primer A:</b> 10-MDP, 5-NMSA, HEMA, accelerators, water <b>Primer B:</b> 5-NMSA, accelerators, catalysts, water	000030
TheraCal LC	Bisco	Type III Portland cement, HEMA, polyethyleneglycol dimethacrylate, barium zirconate	1500002439
Clearfil SE Bond	Kuraray	<b>Primer:</b> 10-MDP, 2-HEMA, water, camphorquinone, hydrophilic dimethacrylate (pH = 1.9) <b>Bond:</b> MDP, Bis-GMA, HEMA, camphorquinone, hydrophobic dimethacrylate, N,N-diethanol p toluidine, colloidal silica	000150
Clearfil Majesty Flow	Kuraray	TEGDMA, hydrophobic aromatic dimethacrylate, silanated barium glass filler, silanated colloidal silica, di-camphoquinone, accelerators, pigments and others	1K0008

*Bis-GMA: bisphenol A glycidyl methacrylate; Bis-EMA: ethoxylated bisphenol A-dimethacrylate; UDMA: urethane dimethacrylate; TEGDMA: triethylene glycol dimethacrylate; 10-MDP: 10-methacryloxydesyl dihydrogen phosphate; 5-NMSA: N-methacrylic-5-aminosalicylic acid; HEMA: hydroxyethyl methacrylate.*

**Group 1 (Lava Ultimate):** In the laboratory, restorations fabricated from Lava Ultimate blocks were polished after intraoral adjustment. The restorations were ultrasonically cleaned for 5 minutes and dried. The inner surface of the ceramic was roughened with 50 µm aluminium oxide powder. Clearfil Porcelain Bond Activator and Clearfil SE Bond Primer were mixed according to the manufacturer's recommendations and applied to the inner surface of the restoration using an applicator brush. Panavia F2.0 ED Primer II A and B were mixed and applied to the cavity surface and air dried for 30 seconds. Panavia F2.0 Dual Cure Cement Paste A and Paste B were mixed and applied to the inner surface of the restoration for 20 seconds, and the restoration was placed on the tooth. After removing excess cement with a probe and dental floss, the treatments were completed by polymerisation with an LED light (3M ESPE Ellipar S10, 3M ESPE, Seefeld, Germany) for 20 seconds from each surface.

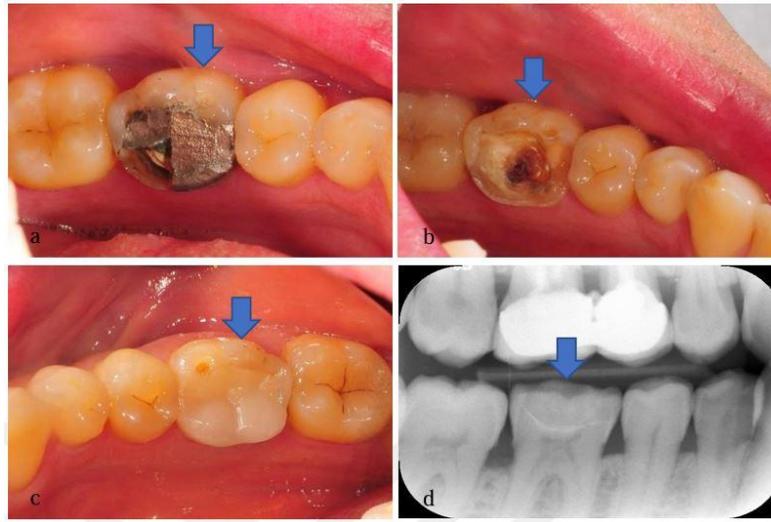
**Group 2 (IPS e.max Cad):** Inlay/onlay restorations were fabricated from IPS e.max Cad blocks in the blue/purple pre-crystallised phase in the milling unit. Intraoral adjustments were made while the restoration was in this phase. In the laboratory, the crystallisation process was completed in the Programat P300 furnace (Ivoclar Vivadent, Schaan, Liechtenstein) at 850°C for 10 minutes. Finally, the glaze layer was applied. The inner surface of the ceramic was roughened with 9.5% hydrofluoric acid (IPS Ceramic Etching Gel, Ivoclar Vivadent, Schaan, Liechtenstein) for 60 seconds, washed, ultrasonically cleaned and dried. The same cementation steps as for the first group were applied to this group.

**Group 3 (Vita Mark II):** After intraoral adjustment of the restorations fabricated from Vita Mark II blocks, glazing was applied in the laboratory. The inner surface of the ceramic was roughened with hydrofluoric acid for 60 seconds, washed, cleaned with an ultrasonic cleaner and dried. The cementation steps of the other groups were also applied to this group.

**Group 4 (Vita Enamic):** After intraoral adjustment of the restorations fabricated from Vita Enamic blocks, the restorations were polished. The inner surface of the ceramic was roughened with hydrofluoric acid for 60 seconds, washed, cleaned with an ultrasonic cleaner, and dried. The cementation steps in the other groups were also applied to this group. A double-blind procedure was used in this study. The material from which the restorations were made and the study group to which the restorations belonged were known to the clinician, but this information was not disclosed to the patients or to the dentists who performed the control examinations of the restorations.

All restorations were evaluated at 1-week, 6-month, and 1-year by two experienced, inter-calibrated dentists (Cohen kappa index = 0.88). At each control visit, bitewing radiographs were

taken of the restored teeth and pulp vitality tests were performed on the intact buccal or palatal/lingual surfaces of the teeth using an pulp vitality tester (Digitest II Digital Pulp Vitality Tester; Parkell Products, Edgewood, NY). Modified United States Public Health Service (USPHS) criteria developed by Ryge (Table 2) were used to evaluate the restorations (Ryge and Snyder, 1973; Schmalz and Ryge, 2005). An example of the restorations is shown in Figure 1.



**Figure 1.** An Example of the Restorations (a) Initial, (b) Cavity Preparation, (c) Restoration, (d) Bitewing Radiograph.

### Statistical Analysis

Chi-square analysis ( $\chi^2$ ), which is used to compare the proportions of more than two independent groups, was performed to compare more than two independent groups (Lava Ultimate, IPS e.max CAD, Vita Mark II, and Vita Enamic) for each criterion (retention, marginal discoloration, marginal adaptation, color match, surface roughness, anatomical form, post-operative sensitivity, and secondary caries) within each group (Alpha and Bravo) and at each time point (1-week, 6-month, and 1-year). Chi-squared analyses were performed using 4x2 crosstabs (4 groups and 2 scoring methods). As the "Charlie" score was never used in scoring, only the "Alpha" and "Bravo" scores were used for scoring. Cochran's Q test, a variant of McNemar's test, was used for dependent proportions to compare each group in terms of scoring rate at 3 different control sessions (1 week, 6 months and 1 year).  $P \leq 0.05$  level was accepted as significant difference in statistical evaluation. All statistical analyses were performed using SPSS 15.0 (SPSS Inc., Chicago, Illinois, USA).

**Table 2:** Modified USPHS Criteria

Criteria	Score	Description
Retention	Alfa (A)	The restoration is completely in place.
	Charlie (C)	The restoration is completely lost.
Marginal Discoloration	Alfa (A)	No marginal discoloration. No discoloration of the restorative material and the tooth structure adjacent to the restoration.
	Bravo (B)	There is marginal discoloration between the tooth structure and the restoration, but the discoloration has not penetrated the interfaces in the pulpal direction.
	Charlie (C)	There is marginal discoloration between the tooth structure and the restoration and the discoloration has penetrated the interfaces in the pulpal direction.
Marginal Adaptation	Alfa (A)	The restoration adapts very well to the tooth. There is no snagging when checking the restoration surface close to the tooth structure with the probe. There are no visual indentations along the perimeter of the restoration despite the insertion of the probe.
	Bravo (B)	The probe is inserted and visually there are indentations where the margin of the restoration is not very well adapted to the tooth structure and the probe is moves into it.
	Charlie (C)	The probe penetrates the indentations up to the enamel-dentine junction.
Color Match	Alfa (A)	The restoration matches the shade and translucency of the adjacent tooth structure.
	Bravo (B)	The restoration does not match the color and translucency of the adjacent tooth structure, but this mismatch is within the normal range of the tooth color.
	Charlie (C)	The restoration is incompatible with the shade and translucency of the adjacent tooth structure, and this incompatibility is outside the normal limits of tooth shade and translucency.
Surface Roughness	Alfa (A)	As far as can be determined with a sharp probe, it has a smooth surface structure similar to the polished enamel surface.
	Bravo (B)	The surface texture is rough or similar to the surface of white stone or rougher than the adjacent tooth structure.
	Charlie (C)	The surface abrasion is coarse enough to show continuity when probed.
Anatomical Form	Alfa (A)	The restoration shows continuity with the existing anatomical form.
	Bravo (B)	The restoration is not continuous with the existing anatomical form, but the loss of material is not so great that dentin or basement material is exposed.
	Charlie (C)	Enough material is lost to expose dentin or basal material.
Post-Operative Sensitivity	Alfa (A)	No post-operative sensitivity.
	Bravo (B)	There is mild and transient post-operative sensitivity.
	Charlie (C)	There is intense and intolerable post-operative sensitivity.
Secondary Caries	Alfa (A)	No caries under the restoration
	Charlie (C)	There is caries under the restoration.

## Results

All patients included in the study came to all control sessions. After 1 year, all 60 restorations (100%) were evaluated. At the 1-year follow-up, all restorations showed clinically acceptable success. The results of the 1-week, 6-month and 1-year evaluation of the restorations according to the modified USPHS criteria (retention, marginal discoloration, marginal adaptation, color match, surface roughness, anatomical form, post-operative sensitivity, secondary caries) are shown in Table 3.

**Table 3:** Results of Evaluation of Restorations Using Modified USPHS Criteria [number of restorations (n) and percentages (%)]

Criteria	Time	Grup 1 (LU) <i>Lava Ultimate</i> n=15	Grup 2 (EM) <i>IPS e.max CAD</i> n=15	Grup 3 (VM) <i>Vita Mark II</i> n=15	Grup 4 (VE) <i>Vita Enamic</i> n=15	p value (intra-group)
<b>Retention</b>	1-Week	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	6-Month	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	1-Year	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	p value (intra-group)	1.000	1.000	1.000	1.000	
<b>Marginal Discoloration</b>	1-Week	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	6-Month	14A (93.3), 1B (6.7)	15A (100)	15A (100)	15A (100)	0.282
	1-Year	13A (86.7), 2B (13.3)	15A (100)	15A (100)	13A (86.7), 2B (13.3)	0.057
	p value (intra-group)	0.223	1.000	1.000	0.223	
<b>Marginal Adaptation</b>	1-Week	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	6-Month	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	1-Year	14A (93.3), 1B (6.7)	15A (100)	15A (100)	15A (100)	0.282
	p value (intra-group)	1.000	1.000	1.000	1.000	
<b>Color Match</b>	1-Week	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	6-Month	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	1-Year	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	p value (intra-group)	1.000	1.000	1.000	1.000	
<b>Surface Roughness</b>	1-Week	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	6-Month	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	1-Year	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	p value (intra-group)	1.000	1.000	1.000	1.000	
<b>Anatomical Form</b>	1-Week	15A (100)	15A (100)	14A (93.3), 1B (6.7)	15A (100)	0.282
	6-Month	14A (93.3), 1B (6.7)	15A (100)	14A (93.3), 1B (6.7)	15A (100)	0.480
	1-Year	14A (93.3), 1B (6.7)	15A (100)	14A (93.3), 1B (6.7)	15A (100)	0.480
	p value (intra-group)	0.317	1.000	1.000	1.000	

**Table 4 (Continue):** Results of Evaluation of Restorations Using Modified USPHS Criteria [number of restorations (n) and percentages (%)]

Criteria	Time	Grup 1 (LU) <i>Lava Ultimate</i> n=15	Grup 2 (EM) <i>IPS e.max CAD</i> n=15	Grup 3 (VM) <i>Vita Mark II</i> n=15	Grup 4 (VE) <i>Vita Enamic</i> n=15	p value (intra-group)
<b>Post-Operative Sensitivity</b>	1-Week	13A (86.7), 2B (13.3)	14A (93.3), 1B (6.7)	15A (100)	12A (80), 3B (20)	0.102
	6-Month	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	1-Year	15A (100%)	15A (100%)	15A (100%)	15A (100%)	1.000
p value (intra-group)		0.083	0.317	1.000	0.083	
<b>Secondary Caries</b>	1-Week	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	6-Month	15A (100)	15A (100)	15A (100)	15A (100)	1.000
	1-Year	15A (100)	15A (100)	15A (100)	15A (100)	1.000
p value (intra-group)		1.000	1.000	1.000	1.000	

All groups received an "Alpha" score for the criteria of retention, color match, surface roughness and secondary caries criteria at all control sessions. Therefore, there was no statistically significant difference between and within the groups for these criteria at all control visits ( $p>0.05$ ).

At the 1-week first control session, no marginal discoloration was observed in any of the restorations and all restorations received an "Alpha" score. At the 6-month follow-up, one tooth in the Lava Ultimate group received a "Bravo" score, and all other restorations received an "Alpha" score. At the 1-year follow-up, two restorations each in the Lava Ultimate and Vita Enamic groups were scored "Bravo". All restorations in the Vita Mark II and IPS e.max CAD groups were rated Alpha. According to the data at all control periods, there was no statistically significant difference between and within the groups with regard to the marginal discoloration criterion ( $p>0.05$ ).

At the 1-week and 6-month controls, no deterioration was observed in the marginal adaptation of any of the restorations. At the end of 1 year, the marginal adaptation of one restoration in the Lava Ultimate group was graded "Bravo". All other restorations received an "Alpha" score. According to the data at all control periods, there was no statistically significant difference between groups or within groups with regard to the marginal adaptation criterion ( $p>0.05$ ).

At the first one-week follow-up, a small fracture was observed in one restoration in the Vita Mark II group. The fracture was only in the structure of the restoration and did not expose

the enamel or dentin structure. The fracture site was polished by gently trimming the sharp areas so as not to injure the patient's soft tissue. The restoration was graded "Bravo". In the other 3 groups there were no problems with the anatomical form and all restorations were graded Alpha. At the 6-month and 1-year follow-up visits, one restoration in each of the Lava Ultimate and Vita Mark II groups was rated "Bravo". All teeth in the IPS e.max CAD and Vita Enamic groups were rated "Alpha". According to the data at all control points, there was no statistically significant difference between and within groups with regard to the anatomical form criterion ( $p>0.05$ ).

At the first one-week follow-up, patients reported post-operative sensitivity in 2 teeth in the Lava Ultimate group, 1 tooth in the IPS e.max CAD group and 3 teeth in the Vita Enamic group. As all sensitivities were mild, transient and tolerable, no intervention was performed and the teeth were graded "Bravo". None of the teeth in the Vita Mark II group experienced post-operative sensitivity and all restorations were rated "Alpha". At the 6-month and 1-year control visits, no teeth in any group experienced post-operative sensitivity and all restorations were rated "Alpha". There was no statistically significant difference between or within the groups for postoperative sensitivity criteria ( $p>0.05$ ) according to the data at all control periods.

## Discussion

The aim of this clinical study was to evaluate the clinical performance of CAD/CAM inlays/onlays fabricated from different blocks (Lava Ultimate, IPS e.max CAD, Vita Mark II, Vita Enamic) at 1 week, 6 month and 1 year. The modified USPHS criteria (retention, marginal discoloration, marginal adaptation, color match, surface roughness, anatomical form, postoperative sensitivity, secondary caries) were acceptable in all groups and no significant difference was found between any of the groups at the 1-year follow-up. Therefore, the null hypothesis of the study was accepted.

A literature review shows that there are clinical studies evaluating the clinical performance of the materials we used in our study or other materials with similar contents (Coşkun et al., 2020; Otto and Mörmann, 2015; Spitznagel et al., 2018; Tunac et al., 2019). However, no clinical study was found that evaluated these materials with different contents at the same time. Therefore, this study was designed to directly evaluate these materials under the same conditions and using the same criteria.

Examining the literature reveals that there are clinical studies with follow-up periods ranging from 1 to 18 years for inlay/onlay restorations created using a CAD/CAM system (Reiss, 2006; Souza et al., 2021). While it is thought that differences between materials may

become apparent with longer clinical use, studies in the literature also report failures according to certain criteria after one year of clinical follow-up (Behera et al., 2021; Petrova-Pashova et al., 2020). Although one year seems a short follow-up period, it is considered appropriate for evaluating short-term success, given the rapid developments in materials used in restorative dentistry today.

There are many patient-related factors that affect the clinical success of restorations, especially caries risk and bruxism/parafunctional habits (Collares et al., 2016; Van de Sande et al., 2016). In addition, it is known that whether the teeth are vital or devital also affects the clinical success of inlay/onlay restorations applied to posterior teeth (Morimoto et al., 2016). Therefore, to limit the effect of these variables, we selected a narrow group of patients and included only vital posterior teeth in our study. An important factor in the success of restorations is the experience and skills of the clinician (Archibald et al., 2018). For this reason, all clinical procedures were performed by a single operator.

One of the most important factors influencing the success of inlay/onlay restorations is the use of an appropriate cementation technique. Dual-cure resin cements are considered the gold standard for cementing these restorations (Behr et al., 2009; Peumans et al., 2010). In our study, we used Panavia F2.0, a dual-cure and self-etching resin cement that has been shown to reliably bond to enamel and dentin in *in vitro* (Behr et al., 2004; Özcan et al., 2008) and *in vivo* (Kern, 2005) studies for the cementation of CAD/CAM inlay/onlay restorations.

None of the restorations in our study received a "Charlie" score on any of the USPH criteria we evaluated during the 1-year follow-up period, and none of the restorations required replacement. In addition, no loss of vitality was observed in any of the restored teeth. According to these results, the 60 CAD/CAM inlay/onlay restorations fabricated in our study provided 100% clinical success at 1-year follow-up. This result from our study is consistent with the survival rates reported in similar studies in the literature (Fasbinder et al., 2005; Souza et al., 2021; Zimmer et al., 2008).

Marginal adaptation is one of the most important criteria influencing the clinical success of restorations (Dukic et al., 2010). The success of the marginal adaptation of indirect restorations depends on various factors, including the type of restorative material used, space for the luting cement and the impression techniques employed (Bottino et al., 2015; Sener-Yamaner et al., 2017). Moreover, there are studies that correlate marginal discoloration with marginal adaptation. These studies indicate that a marginal discoloration may also be observed over time due to deterioration of the marginal adaptation (Santos et al., 2016; Spitznagel et al.,

2018). Additionally, some researchers suggest that using self-etching resin cements without etching the enamel may result in marginal discolouration (Frankenberger and Tay, 2005). In the current study, which used self-etching dual-cure resin cement, 4 restorations were rated as 'Bravo' in terms of marginal discolouration and 1 restoration was rated as 'Bravo' in terms of marginal adaptation at the end of the 1-year follow-up. According to these results, although the Lava Ultimate and Vita Enamic groups, which are polymer-containing materials, scored lower than the other groups, no significant difference was observed between the groups. These results are consistent with the literature (Coşkun et al., 2020; Souza et al., 2021) and survival rates (Fasbinder et al., 2005; Souza et al., 2021; Zimmer et al., 2008).

Evaluation of anatomical form integrity revealed small fractures in one restoration from each of the Lava Ultimate and Vita Mark II groups at the 1-year follow-up. This resulted in a 'Bravo' score. These fractures were localised within the restorative material and did not expose the dentine or the underlying cavity floor. They were treated conservatively by polishing the sharp edges, which did not compromise function. The fracture observed in the Vita Mark II restoration may be related to the inherent fragility of feldspathic ceramics under occlusal load, as reported in some studies (Gracis et al., 2015; Bonfante et al., 2023). The fracture in the Lava Ultimate sample could potentially be attributed to its lower flexural strength compared to that of lithium disilicate (IPS e.max CAD), or to the interlocking network structure of the Vita Enamic sample, despite the resin matrix offering higher flexibility than pure ceramics (Spitznagel et al., 2018; Coşkun et al., 2020). The fact that all IPS e.max CAD and Vita Enamic groups received 'Alpha' scores highlights the excellent fracture resistance of these materials in the short term for inlay/onlay applications. This is consistent with the superior mechanical properties reported for these materials in vitro (Gracis et al., 2015). Notably, the absence of any 'Charlie' scores in all groups and the minimal nature of the 'Bravo' events (requiring only polishing) confirm the clinical acceptability of the anatomical form of all four CAD/CAM materials over this one-year period. While no statistically significant differences emerged between groups ( $p > 0.05$ ), the tendency for fractures to occur only in the more brittle ceramics (Vita Mark II and Lava Ultimate) highlights the need for longer-term studies to assess whether material differences become more pronounced over time and with fatigue. These findings are consistent with those of other short-term clinical studies which have reported high anatomic form retention for various CAD/CAM materials (Aslan et al., 2019; Hassan et al., 2024; Souza et al., 2021).

A total of 6 restorations were reported to have postoperative sensitivity at the 1-week follow-up visits. However, these sensitivities resolved within a short period of time without intervention and no complaints of sensitivity were reported at any of the other control visits. These results are also consistent with those reported in the literature (Fasbinder et al., 2020; Tunac et al., 2019).

This study provides information about the clinical performance of CAD/CAM materials, but it also has some limitations. The one-year follow-up period constitutes a significant limitation of the study. Furthermore, the exclusion of patients with poor oral hygiene and bruxism or parafunctional habits from this study may have positively influenced the results.

In order to address these limitations, it is recommended that the performance of the tested materials be examined in patients included in risk groups. It is further recommended that longer-term clinical follow-up studies including a larger number of patients be conducted to obtain more definitive results.

### **Conclusion**

No statistically significant difference was found between the survival and clinical performance of inlay/onlay restorations on vital posterior teeth using four different CAD/CAM blocks (Lava Ultimate, IPS e.max CAD, Vita Mark II, Vita Enamic) with different content after 1-year of follow-up. CAD/CAM inlay/onlay restorations appear to be a suitable treatment option for vital posterior teeth with high material loss.

**Ethical Consideration:** The study protocol was approved by the Kırıkkale University Faculty of Medicine Clinical Research Ethics Committee (Decision no: 20/02, Date: 18/08/2014).

**Conflict of interest:** The authors declare no conflicts of interest. The data of this study has been presented at the 23rd Congress of the Balkan Stomatological Society (BaSS).

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