



Evaluation of the repair capacities and color stabilities of a resin nanoceramic and hybrid CAD/CAM blocks

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PURPOSE. This study evaluated the color stabilities of two computer-aided design and computer-aided manufacturing (CAD/CAM) blocks and a nanofill composite resin and the microtensile bond strength (μ TBS) between the materials. **MATERIALS AND METHODS.** Twelve specimens of 4 mm height were prepared for both Lava Ultimate (L) and Vita Enamic (E) CAD/CAM blocks. Half of the specimens were thermocycled (10,000 cycle, 5° to 55°C) for each material. Both thermocycled and non-thermocycled specimens were surface treated with one of the three different methods (Er,Cr:YSGG laser, bur, or control). For each surface treatment group, one of the thermocycled and one of non-thermocycled specimens were restored using silane (Ceramic Primer II), universal adhesive (Single Bond Universal), and nanofill composite resin of 4-mm height (Filtek Ultimate). The other specimens were restored with the same procedure without using silane. For each group, 1 × 1 × 8 mm bar specimens were prepared using a microcutting device. Bar specimens were thermocycled (10,000 cycle, 5° to 55°C) and microtensile tests were performed. Staining of the materials in coffee solution was also compared using a spectrophotometer. Data were analyzed using one-way ANOVA, t-test and post-hoc Scheffe tests.

RESULTS. μ TBS were found similar between the thermocycled and non-thermocycled groups ($P>.05$). The highest μ TBS (20.818 MPa) was found in the non-thermocycled, bur-ground, silane-applied E group. Silane increased μ TBS at some E groups ($P<.05$). Composite resin specimens showed more staining than CAD/CAM blocks ($P<.05$). **CONCLUSION.** CAD/CAM blocks can be repaired with composite resins after proper surface treatments. Using silane is recommended in repair process. Color differences may be shown between CAD/CAM blocks and the nanofill composite after a certain time period. [*J Adv Prosthodont 2020;12:140-9*]

KEYWORDS: Computer-aided design and computer-aided manufacturing (CAD/CAM); Color stability; Er,Cr:YSGG laser; Microtensile bond strength; Thermal cycle

INTRODUCTION

Tooth-colored and metal-free indirect restorations are

increasingly preferred by patients in restorative dentistry. These restorations are esthetically pleasing and have some advantages over tooth-colored direct restorations, such as improved physical properties, resistance to wear and coloration, better contouring of proximal surfaces, reduced polymerization stress, residual monomer and biocompatibility.¹ Resin-ceramic computer-aided design and computer-aided manufacturing (CAD/CAM) blocks, with their resin and ceramic combined structures, are widely used in restorative dentistry due to their advantages over glass-ceramic blocks. The advantages of resin-ceramic blocks over glass-ceramic blocks are their flexural strength against brittleness,² easier milling,³ increased marginal adaptation,⁴ and better repair capacity.⁵ As examples of these blocks, Vita Enamic (Vita Zahnfabrik, Bad Säckingen, Germany) is a resin-infused hybrid ceramic block, and Lava Ultimate (3M ESPE, St.

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Received November 22, 2019 / Last Revision April 2, 2020 / Accepted April 28, 2020

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This study was funded by Kırıkkale University Scientific Research Projects Coordination Unit (Project No. 2018-012).

Paul, MN, USA) is a nanoceramic-filled resin block called “resin nanoceramic”.⁶ Lava Ultimate is a resin structure containing silica nanoparticles with diameters of 20 nm and zirconia nanoparticles with 4 - 11 nm diameters. These nanoparticles constitute approximately 80% of the structure by weight. The organic polymer matrix of the material contains urethane dimethacrylate (UDMA) and bisphenol-A polyethylene glycol diether dimethacrylate (Bis-EMA) 20% by weight.^{7,8} Vita Enamic typically consists of a polymer-infiltrated ceramic network. While the leucite-based, zirconia reinforced ceramic network constitutes 86% by weight and 75% by volume of the structure, the polymer-based network constitutes 25% by weight and 14% by volume. The specific composition of the ceramic is SiO₂, Al₂O₃, Na₂O, K₂O, B₂O₃, Zr₂O, and CaO. The polymer network consists of UDMA and triethylene glycol dimethacrylate (TEGDMA).^{8,9}

Fractures may occur due to internal stress, parafunctional habits, degradation, design features, trauma, and so on in CAD/CAM and all dental restorations.⁸ Repairing the fractured site is often more advantageous than replacing the restoration completely. With the development of adhesive systems, restoration repair has become an important part of minimally invasive dentistry. Repairing CAD/CAM restorations is also important for preserving the remaining tooth tissue. It is an important disadvantage that replacing a repairable restoration accelerates the restoration cycle or leads to premature tooth loss. While replacing the restoration, cutting sound tooth tissue always causes irreversible damage and increases cavity size.¹⁰ Repair process should be evaluated according to the case and it is important to make the appropriate decision for restoration repair. There are many advantages to properly repairing a fractured restoration. Repairing procedure protects against the removal of sound tissue and increases survival rate of the restoration. The repair process of CAD/CAM restorations is more cost effective and represents a faster solution due to elimination of the laboratory procedures.^{10,11}

Various procedures have been described in the literature to increase the repair bond strength, such as mechanical (etching with hydrofluoric acid, sandblasting, roughening with diamond burs, roughening with Er,Cr:YSGG laser) and chemical surface treatments (silane application).¹² Along different surface treatment procedures, the aging of the material may also have an effect on repair capacity. To simulate the aging process, water storage and thermocycling have been used in various studies.¹³⁻¹⁵ Thermocycling is an effective procedure for aging dental materials that affects the physical properties and repair bond strength of the dental materials.^{16,17} In an esteemed study, it has been reported that 10,000 thermal cycles can correspond to 1 year.¹⁸ Thermocycling process adversely affects the physicochemical properties and the number of unreacted double bonds decreases on the surface of the composite structure. This reduces the repair bond strength of the composite material.^{16,19} However, the repair bond strength of resin containing CAD/CAM blocks prepared by polymerizing under high temperature

and pressure has not yet been investigated.

Another side effect of the repair procedure is the possible color difference between the repaired material and the repair composite that may occur in the coming years. This should also be considered in repair protocols.

The aim of this study is to evaluate the μ TBS of two different CAD/CAM blocks with a nanofill composite resin. While half the specimens were thermocycled, the other half were not. Silane's effects on μ TBS and the color stability of the materials were also evaluated. The tested hypotheses are as follows:

- H₁: There are no significant differences in the repair capacities of CAD/CAM blocks after 10,000 thermal cycles;
- H₂: Silane application and different surface treatment procedures affect μ TBS; and
- H₃: Color differences occur between CAD/CAM blocks and repair composite resin in a short time.

MATERIALS AND METHODS

Two different CAD/CAM restorative materials, Lava Ultimate (3M ESPE, St. Paul, MN, USA) and Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany), were used in the study. The manufacturers and material compositions are given in Table 1.

Twenty-four specimens of 4-mm height were prepared using Lava Ultimate ($n_L = 12$) and Vita Enamic ($n_E = 12$) CAD/CAM blocks. To obtain standard surfaces, the specimens were polished using 400-, 600-, 800-, and 1,200-grit silicon carbide papers each for 60 s. Then, the specimens were cleaned by standing in distilled water for 5 min. While half the specimens were thermocycled 10,000 times in water baths between +5°C and +55°C with a rest time of 20 s in each bath, the other half were not. Thermocycled specimens were tagged as “1” and the nonthermocycled specimens as “2.” Following this, all the specimens were randomly divided into three subgroups for different surface treatments, as follows:

- Group A (control group): No treatment;
- Group B (diamond bur): The specimens were roughened with a green-banded diamond fissure bur (Meisinger, Neuss, Germany) with a 107 - 181- μ m grain size using a high-speed rotary tool under water cooling for 4 s. The bur was changed to a new one after every 5 specimens; and
- Group C (Er,Cr:YSGG laser): The specimens were roughened with an Er,Cr:YSGG laser (Waterlase, Biolase Technology, San Clemente, CA, USA) with a wavelength of 2780 nm. The specimens were applied with a 600- μ m diameter fiber tip at a distance of 1 mm and sweeping for 20 s. The parameters used during laser application were 3 W, 20 Hz, air level 60%, and water level 50%.

After the surface treatments were applied, all the samples were washed with distilled water and dried with oil-free air spray. Then, all the groups were divided further into two subgroups, and GC Ceramic Primer II (GC, Tokyo, Japan) was applied as a thin layer with a small-tipped applicator for

Table 1. Manufacturers and the compositions of materials used

Material	Manufacturer	Composition	Lot number
Lava Ultimate CAD/CAM Block	3M ESPE, St. Paul, MN, USA	80% wt nanoceramic, 20% wt resin (UDMA, Bis-EMA)	N550735
Vita Enamic CAD/CAM Block	Vita Zahnfabrik, Bad Säckingen, Germany	86% wt feldspaa ceramic, 14% wt polymer (UDMA, TEGDMA)	60250
Filtek Ultimate Composite Resin (A2 Body)	3M ESPE, St. Paul, MN, USA	Bis-GMA, UDMA, TEGDMA, Bis-EMA, 20 nm silica and 4 - 11 nm zirconia filler, camphorquinone, accelerators, pigments and others.	N841976
Single Bond Universal	3M ESPE, St. Paul, MN, USA	MDP monomer, dimethacrylate resins, HEMA, Vitrebond™ copolymer, filler, ethanol, water, initiators and silane	665259
Ceramic Primer II	GC, Tokyo, Japan	90 - < 100% ethyl alcohol, 1 - 2,5% MDP, 1 - 2,5% 2.2 'Ethylene dioxyethyl dimethacrylate, 0,5 - 1 % (1-methyl Ethylidene) bis [4,1-phenylenoxy (2-hydroxy-3,1-propanedyl)] bis methactylatelate	1608041
Coarse Fissure Bur	Meisinger, Neuss, Germany	107 - 181 µm grain size, diamond fissure bur	Q56782
MZ6 Laser Tip	BioLase Technology, CA, USA	600 µm diameter, fiber laser tip	4003138
OptiDisk	Kerr, CA, USA	Polyester containing aluminum oxide particles, translucent polishing discs, three-stage polishing system	4655466

Abbreviations: Bis-GMA: bisphenol A glycol dimethacrylate, UDMA: urethane dimethacrylate, Bis-EMA: bisphenol A ethoxylated dimethacrylate, TEGDMA: triethylene glycol dimethacrylate, HEMA: 2 hydroxyethyl methacrylate, MDP: methacryloyloxydecyl dihydrogen phosphate

60 s and dried with an oil-free air spray to one of the subgroups randomly. The silane primer applied groups were tagged "+ S". Then, Single Bond Universal (3M ESPE, St. Paul, MN, USA) was applied to all the specimens for 20 s, thinned with mild air for 5 s, and polymerized with an LED curing device (Elipar S10, 3M ESPE, St. Paul, MN, USA) for 10 s. After the bonding process, specimens were placed in specially prepared stainless-steel molds, and Filtek Ultimate composite resin (3M ESPE, St. Paul, MN, USA) was placed at a thickness of 2 mm and polymerized with Elipar S10 for 20 s. The composite resin was totally restored to 4 mm in height. After the final layer of the composite resin was placed, it was covered with a Mylar strip to remove the oxygen inhibition layer. After the specimens were removed from the molds, they were polished with aluminum oxide-coated flexible polishing discs (OptiDisc, Kerr, Orange, CA, USA). Specimens of 1 × 1 × 8 mm in size were prepared by sectioning ceramic-resin blocks longitudinally with a low-speed cutting device (Microcut 201, Metkon, Bursa, Turkey). At least 23 sticks were obtained from each group. Following this, the sticks were thermocycled for 10,000 cycles between +5°C and +55°C, with a rest time of 20 s in each bath. The study design and grouping of the specimens are shown in Figure 1.

For performing µTBS test, the specimens were put into a universal testing machine (Microtensile Tester, Bisco Inc., Schaumburg, IL, USA). Sticks placed on the device were fixed with cyanoacrylate-based adhesive at both ends, and care was taken to avoid putting the adhesive on bonding

surfaces. The sticks were subjected to a tensile force of 0.5 N at a speed of 1 mm/min. Microtensile bond strength values were measured, and the force unit was determined in Newton (N). Then, these values (N) were converted to MPa for each sample according to following formula: MPa = force / area (N/mm²). The split surfaces of sticks were examined by stereomicroscope (S100 OPMI pico, Carl Zeiss MeditecAG, Yena, Germany) to determine the type of fracture. The fracture types are classified as follows:

- Type I: Adhesive fracture between the ceramic and composite;
- Type II: Cohesive fracture in the ceramic or composite; and
- Type III: Mixed fracture between the ceramic and composite, with more than half the composite on the ceramic surface.

To determine the surface roughness of materials, twelve specimens were prepared with a 1.2-mm height for each surface treatment procedure of each material ($n_{\text{total}} = 72$). After applying the same surface treatment procedures, the specimens were washed with distilled water and dried with oil-free air spray. Roughness values were measured using a profilometer (Perthometer M2, MAHR GmbH, Göttingen, Germany) and average roughness values (R_a) were recorded. The profilometer was calibrated for each measurement. The surfaces of the specimens were also evaluated using atomic force microscopy (AFM; Veeco MultiMode V, Santa Barbara, CA, USA). An NP-type V-shaped Si₃N₄ tip (Santa Barbara, CA, USA) with a radius of 100 nm was used. Surface mea-

measurements were performed at a scanning speed of 2.03 Hz, and 20 × 20 μm areas were scanned. Three-dimensional images with 256 × 256-pixel resolution were recorded. AFM images from the specimens were obtained in tapping mode. The calibration was repeated at each measurement stage. The same specimens were coated with palladium and examined using scanning electron microscopy (SEM; JEOL JSM-5600, Tokyo, Japan). For standardization, SEM images were taken at ×1,000 magnification.

For color measurement, a total of 72 specimens (2 mm thick) were obtained from each of the Vita Enamic (n = 24), Lava Ultimate (n = 24), and composite resin (n = 24) materials. Then, all the specimens were thermocycled for 10,000 cycles between +5°C and +55°C with a rest time of 20 s in each bath. After the thermocycling procedure, the initial color values of all the specimens were determined using a spectrophotometer (VITA Easyshade Compact, Vident, Germany). The device was calibrated before each measurement. Each measurement was performed on a standard white background to eliminate the background effect, at the same time of the day. During the measurements, the fiber optic tip of the device was placed perpendicular to the specimens and parallelized to the ground. Color measurements were performed three times for each specimen. After the initial color values were determined, half of all the specimens were immersed in distilled water and half in coffee solution. Two grams of Nescafe powder (Nestle, Vevey, Switzerland) and 200 mL of hot water were used in the preparation of the coffee. The solutions were renewed every day. Color measurements were determined on the 1st, 7th, 14th, and 28th days. The color change in the specimens was formulated with the ΔE parameter calculated with L, a, and b value:

$$\Delta E = [(\Delta L_0 - \Delta L_1)^2 + (\Delta a_0 - \Delta a_1)^2 + (\Delta b_0 - \Delta b_1)^2]^{1/2}$$

Table 2. The mean μTBS (MPa), standard deviation (SD) and statistical results of E group specimens

Eb2 + S (n = 36)	20.818 ± 6.266	A
Ec2 + S (n = 30)	14.811 ± 4.372	B
Ec1 (n = 39)	14.632 ± 15.281	B
Ea1 + S (n = 40)	13.255 ± 5.969	BC
Eb1 + S (n = 26)	11.878 ± 4.987	BCE
Ec1 + S (n = 27)	11.578 ± 5.184	BCFG
Ea2 + S (n = 27)	11.115 ± 6.159	BCFG
Ec2 (n = 30)	9.539 ± 4.122	BCFG
Ea2 (n = 30)	8.389 ± 4.214	CH
Eb2 (n = 25)	6.817 ± 2.863	EGH
Ea1 (n = 23)	6.475 ± 5.66	EGH
Eb1 (n = 32)	5.775 ± 3.908	FH

Different letters indicate significant differences ($P < .05$).

The data of the microtensile test and surface roughness were analyzed using SPSS v22.0 program. Differences between the two groups were analyzed using the independent group t-test. The one-way analysis of variance (ANOVA) test was used for comparing quantitative continuous data among more than two independent groups. The complementary post hoc Scheffe test was used to determine the differences after the ANOVA test. In the evaluation of color measurements, the mean and standard deviation were used as the descriptive statistical method. In determining the difference between intragroup repeated measurements, the repeated-measures ANOVA test was used. Differences among more than two groups were analyzed by the one-way ANOVA test and post hoc Bonferroni test.

RESULTS

According to the μTBS test results of the specimens, it was found that the non-thermocycled, bur-ground, and silane-applied E group (Eb2 + S group, μTBS = 20.818 ± 6.266 MPa) showed a significantly higher bond strength than the other groups ($P < .05$). The group with the lowest bond strength was found to be the thermocycled, bur-ground, and non-silane-applied E group (Eb1 group, μTBS = 5.775 ± 3.908 MPa). It was found that the silane application significantly increased the bond strength in some E groups (Eb1 + S, Eb2 + S, Ea1 + S groups; $P < .05$). In the other groups, it was observed that silane application did not cause a significant increase in bond strength. Thermocycling 10,000 times did not affect the μTBS except that of the Eb1/2 + S groups (Eb2 + S > Eb1 + S). The microtensile bond strength results of Vita Enamic and Lava Ultimate materials are shown in Table 2 and Table 3.

According to the μTBS results of the specimens prepared from the Lava Ultimate CAD/CAM block, it was

Table 3. The mean μTBS (MPa), standard deviation (SD) and statistical results of L group specimens

Lb2 + S (n = 25)	14.661 ± 6.796	A
Lb2 (n = 34)	14.561 ± 7.719	A
Lb1 + S (n = 27)	13.381 ± 12.044	AC
Lc1 + S (n = 26)	12.196 ± 5.715	ABC
La1 + S (n = 36)	11.745 ± 8.577	ABC
Lb1 (n = 38)	11.030 ± 4.577	ABC
Lc2 (n = 30)	10.195 ± 4.67	ABC
Lc2 + S (n = 35)	1.034 ± 3.224	ABC
Lc1 (n = 29)	7.978 ± 2.977	BC
La2 + S (n = 27)	7.578 ± 2.031	B
La1 (n = 28)	7.524 ± 5.957	B
La2 (n = 27)	7.226 ± 5.161	B

Different letters indicate significant differences ($P < .05$).

found that the Lb2 + S group ($\mu\text{TBS} = 14.661 \pm 6.796$ MPa) showed a significantly higher bond strength than the other groups ($P < .05$). The group with the lowest bond strength was the La2 group ($\mu\text{TBS} = 7.226 \pm 5.161$ MPa). The bond strengths between the groups with and without silane treatment were similar ($P > .05$). In addition, the bond strengths were similar between the thermocycled and non-thermocycled groups ($P > .05$).

The bond strengths of the specimens prepared with Lava Ultimate, with and without thermocycling and bur-ground (Lb1 = 11.030 ± 4.577 MPa, Lb2 = 14.561 ± 7.719 MPa), were found to be significantly higher than those of the specimens prepared with Vita Enamic with and without thermocycling and bur roughening (Eb1 = 5.775 ± 3.908

MPa, Eb2 = 6.817 ± 2.863 MPa; $P < .05$). The bond strength of the specimens prepared with Vita Enamic with thermal cycling and laser roughening (Ec1 = 14.632 ± 15.281 MPa) was found to be significantly higher than that of the specimens prepared with Lava Ultimate with thermocycling and laser roughening (Lc1 = 7.978 ± 2.977 MPa; $P < .05$).

The μTBS of non-thermocycled, bur-ground, and silane applied Vita Enamic specimens (Eb2 + S = 20.818 ± 6.266 MPa) was significantly higher than the non-thermocycled, bur-ground, and silane applied Lava Ultimate specimens (Lb2 + S = 14.661 ± 6.796 ; $P < .05$). The fracture types of the Vita Enamic and Lava Ultimate materials are shown in Fig. 1.

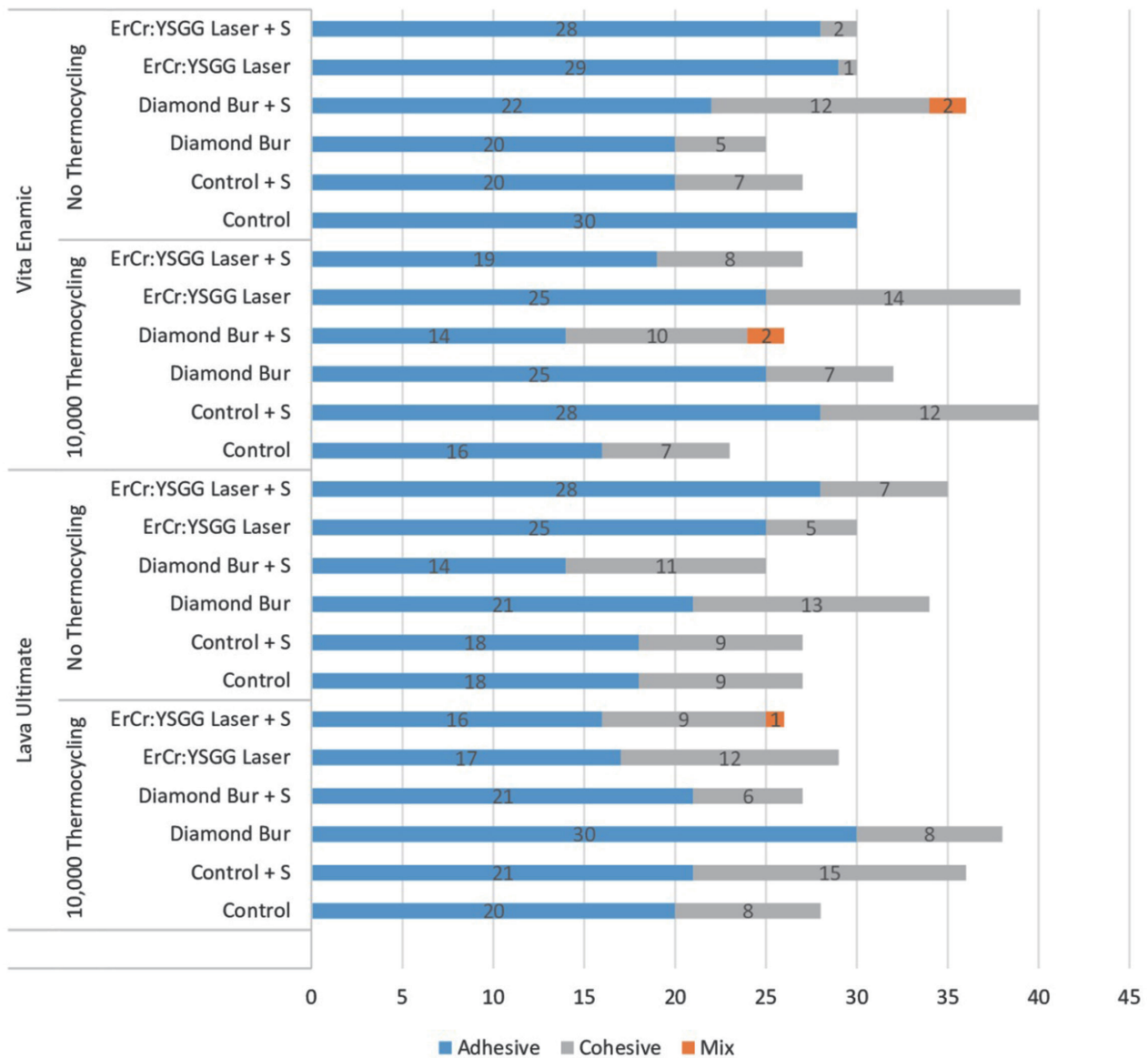


Fig. 1. The fracture types of the groups (Type 1: adhesive fracture, Type 2: cohesive fracture, Type 3: mixed fracture).

According to the average roughness scores (Ra), laser-treated specimens showed the highest results ($E_c = 6.782 \pm 1.120 \mu\text{m}$, $L_c = 6.915 \pm 0.958 \mu\text{m}$; $P < .05$). The Ra scores of bur-ground specimens ($E_b = 2.292 \pm 0.966 \mu\text{m}$, $L_b = 2.529 \pm 0.911 \mu\text{m}$) were found to be higher than those of the control groups ($E_a = 0.250 \pm 0.116 \mu\text{m}$, $L_a = 0.360 \pm 0.243 \mu\text{m}$; $P < .05$). According to the AFM evaluation, relatively flat surfaces were seen in the control groups, whereas

small hills and grooves were observed in the bur-ground groups. The Er,Cr:YSGG laser-treated specimens could not be measured with AFM because of excessive roughness. The same specimens used in AFM evaluation were also evaluated using SEM, and similar grooves were seen, especially in the L group. The SEM images of the laser-treated surfaces showed more irregular and melt-like surfaces. The AFM and SEM images were found to be compatible with

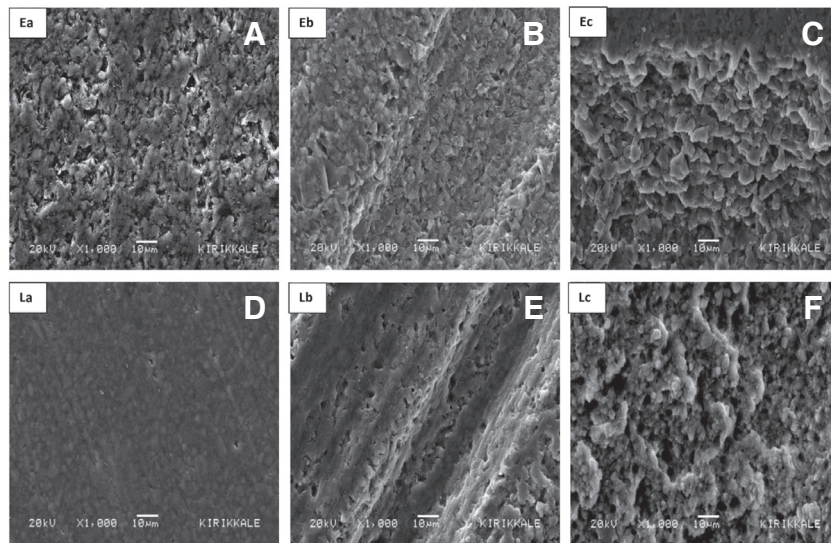


Fig. 2. SEM images of the groups. (A) Ea: Control group of Vita Enamic, (B) Eb: Bur-ground Vita Enamic group, (C) Ec: Laser-treated Vita Enamic group, (D) La: Control group of Lava Ultimate, (E) Lb: Bur-ground Lava Ultimate group, (F) Lc: Laser-treated Lava Ultimate group.

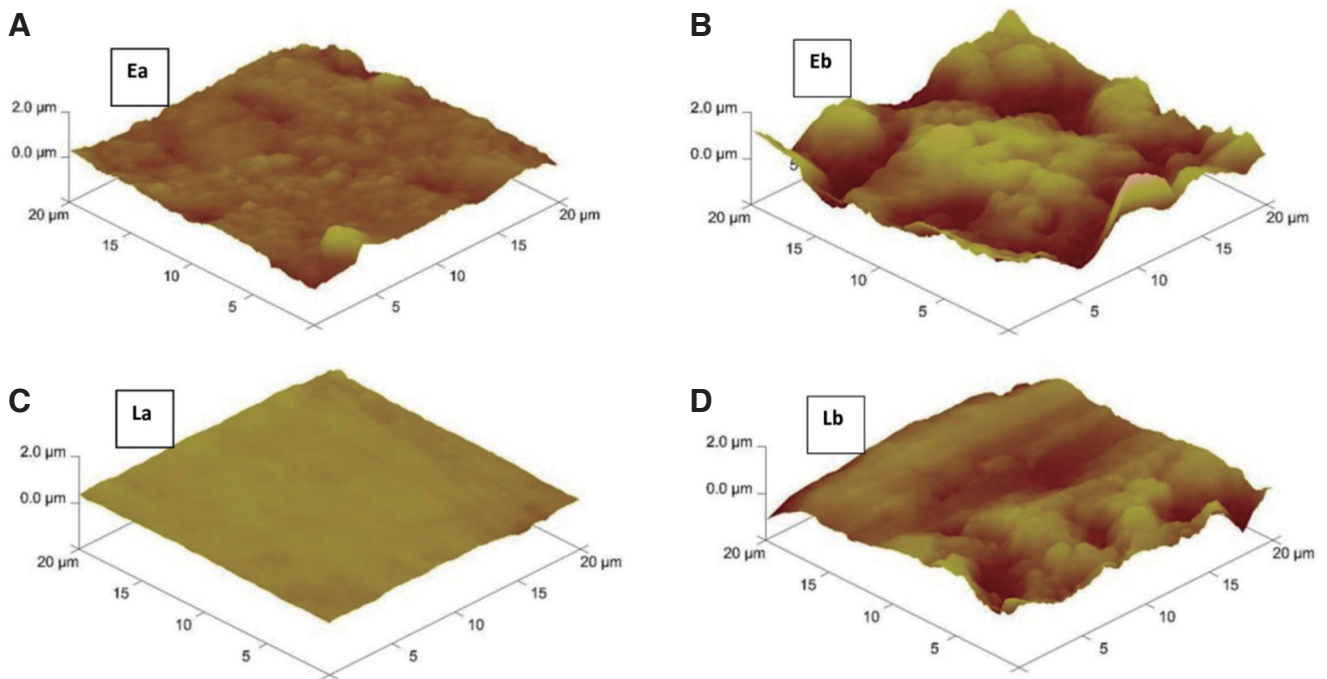


Fig. 3. AFM images of the groups. (A) Ea: Control group of Vita Enamic, (B) Eb: Bur-ground Vita Enamic group, (C) La: Control group of Lava Ultimate, (D) Lb: Bur-ground Lava Ultimate group.

the profilometer results (Fig. 2 and Fig. 3).

The color change values of the composite specimens that were immersed in coffee solution were found to be higher than those of the other specimens after 24 hours ($P < .05$). The composite resin specimens also showed more staining than the CAD/CAM blocks for both distilled water and coffee solution (after 7, 14, and 28 days; $P < .05$). The Lava Ultimate and Vita Enamic specimens that were immersed in distilled water showed similar color change values after 24 hours and 7, 15, and 28 days ($P > .05$). Significant color changes were seen after 14 and 28 days between Lava Ultimate ($\Delta E_{14} = 4.975 \pm 1.027$, $\Delta E_{28} = 5.529 \pm 0.988$ for Lava Ultimate) and Vita Enamic ($\Delta E_{14} = 3.570 \pm 1.805$, $\Delta E_{28} = 3.774 \pm 1.754$ for Vita Enamic) specimens that were immersed in coffee solution ($P < .05$) (Fig. 4).

DISCUSSION

This study evaluated the repair capacities of the resin nanoceramic (L) and hybrid (E) CAD/CAM blocks with and without a 10,000-thermocycle process. According to the findings of this study, the first null hypothesis was accepted, and it was found that 10,000 thermocycling of the materials did not affect the μ TBS. However, the second null hypothesis was partially accepted, and the third hypothesis was also accepted. While silane application caused high μ TBS values, especially in some E groups, no effect was observed in L group specimens. After a short time (24 h), evident color

changes were detected between the composite specimens and CAD/CAM blocks.

The strong bond strength between CAD/CAM materials and composite resin improves the success of the repair process in clinical applications. Different surface treatments and chemical interactions are required to increase the bond strength.²⁰ Er,Cr:YSGG laser with a wavelength of 2.78 μ m has been used for surface roughening of different CAD/CAM materials in the literature.²¹⁻²³ According to Kirmali *et al.*,²⁴ when roughening the composite surfaces with 1.5-W, 2-W, and 3-W Er,Cr:YSGG laser irradiation, rough and irregular surfaces occur and acceptable shear bond strength similar to sandblasting is obtained. Barutçigil *et al.*²³ also reported a mean SBS of 9.137 MPa for Er,Cr:YSGG laser-irradiated Vita Enamic specimens at 2 W. According to the same study, this result was found to be similar to those obtained from CoJet sandblasting, 50- μ m Al_2O_3 sandblasting, and 10% HF acid etching surface treatments. According to the findings of this study, 3W Er,Cr:YSGG laser-treated L and E surfaces showed acceptable μ TBS, and the scores were similar to those of various control and bur groups. After the surface roughening with the Er,Cr:YSGG laser, rough areas were formed on the surfaces of the specimens. The Er,Cr:YSGG laser can be considered as an alternative method to bur grinding and various surface treatment procedures, such as sandblasting and HF acid etching, for relatively soft materials like L and E. According to the literature, Er,Cr:YSGG laser irradiation has shown conflicting

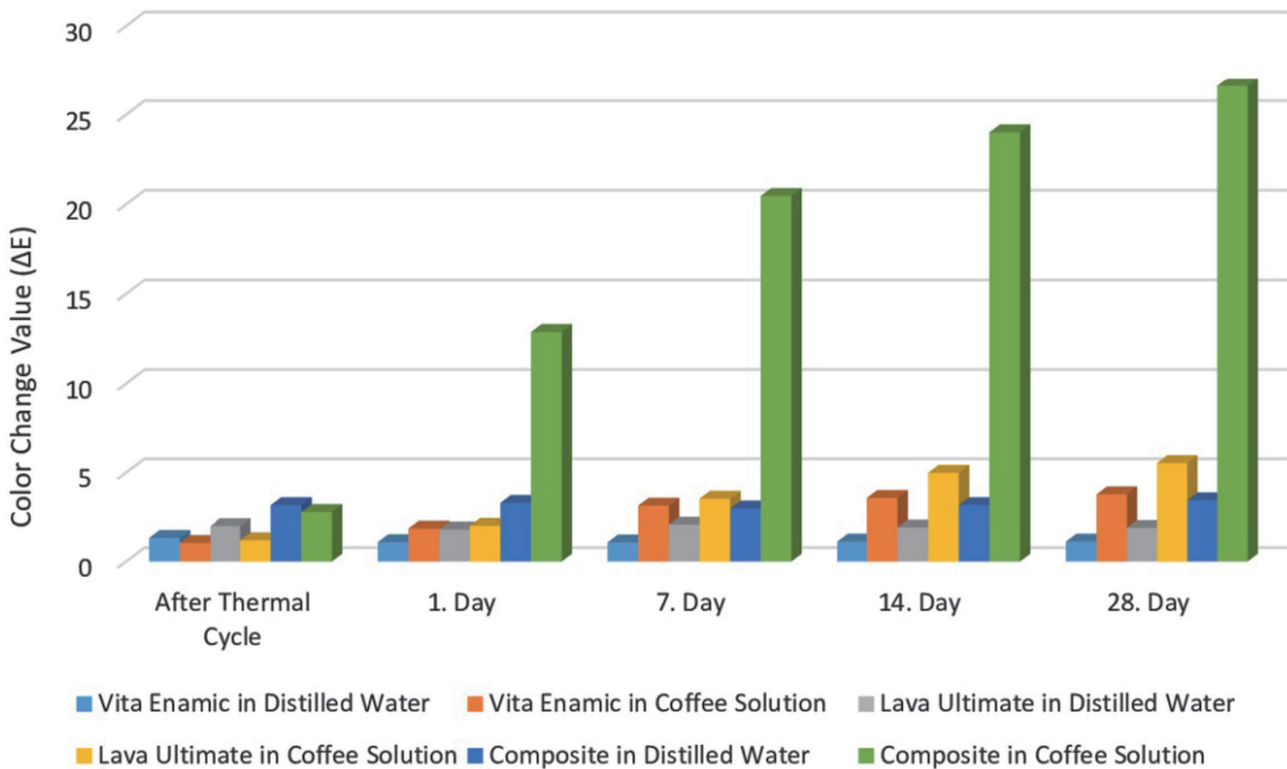


Fig. 4. The color change values (ΔE) of the groups.

results with glass-ceramic materials.²⁵⁻²⁷

Thermocycling is defined as the process of mimicking the temperature changes to which restorations and teeth are exposed in the mouth. This method is frequently used in *in vitro* studies.²⁸⁻³⁰ Gale and Darvell¹⁸ stated that 10,000 cycles are equivalent to approximately 1 year of function *in vivo*. The repairing needs of restorations generally arise after a long process of months or years. Meanwhile, the restorations are exposed to the oral environment and many changes in this environment. This study investigated the repair capacity of CAD/CAM restorations performed using L and E after 10,000 thermocycles, and it was found that 10,000 thermocycles did not affect μ TBS, except in two cases (Eb2 + S > Eb1 + S); this result is attributed to the silane effect. Silane was thought to have the best effect in the group with a uniform roughness and no thermocycling. Özel Bektaş *et al.*²⁹ reported that 10,000 thermocycles affected the repair bond strength for both Er:YAG laser and bur-treated composite resin specimens. According to the findings of this study, 10,000 thermocycles did not affect the repair capacity of the E and L CAD/CAM blocks. This result can be explained by the more stable structures of E and L CAD/CAM blocks in relation to direct composite specimens. However, after increasing the number of thermocycles (20,000, 30,000, etc.), the changes in the repair capacities of the mentioned CAD/CAM blocks is still a matter of concern. Yet, no study was found on the effect of an increasing number of thermocycles on the repair capacity of E and L CAD/CAM blocks. This topic can be considered in another study.

Silane coupling agents are used to improve the bond strength between certain dental restorative materials such as composite resins and ceramics by providing chemical bonding. These agents are organic silicates with bifunctional structures, in which one function is forming covalent bonds with inorganic structures and the other is forming covalent bonds with organic structures.³¹

According to the findings of this study, the μ TBS of the L specimens in both the silane-treated and non-silane-treated groups were similar. Although some of the L groups showed higher μ TBS, this was not significant. In contrast, silane application significantly increased the μ TBS in some E specimens (EB1 + S, EB2 + S, EA1 + S). This difference between E and L was related to the different microstructures and silica contents of the materials. These results are consistent with the studies of Elsaka³² and Demirtaş and Culhaoglu,³⁰ who evaluated the silane and surface treatment effects on the bond strength of L and E.

Although a silane-containing universal bonding agent was used in this study, an additional silane application further increased the bond strength of some E specimens significantly and a certain amount for L specimens. According to the findings of this study and the literature, even if a universal adhesive system containing silane is used, it is advised to employ a silane coupling agent during repairing procedures of CAD/CAM blocks. This is because universal bonding agents are almost always more acidic (Single Bond

Universal, pH = 2.7) than silane coupling agents (Ceramic Primer II, pH = 4.0); thus, silane in the adhesive can be continuously hydrolyzed and reacted during storage, and consequently, it can be inactivated.³³ Murillo-Gómez *et al.*³⁴ reported that the short and long-term bond strengths are better when silane and the adhesive system are applied separately.

While micro-bond strength tests cause better stress distribution at the adhesive interface and result in more adhesive fractures, macro-bond strength tests result in more cohesive fractures and overstatements of bond strengths. Micro-testing methods are commonly used for reducing flaws in the results of macro-testing methods.^{35,36} According to the findings of the present study, the μ TBS test resulted in more adhesive fractures; this result was in accordance with the literature.

In this study, the color change values of the materials used in the repair process were also examined after immersion in coffee and distilled water. Specimens stored in distilled water were used as the control group. To perform an objective color evaluation, a spectrophotometric device was used in this study, allowing a quantitative color assessment. In the CIE L * a * b * color system, the difference between two colors (ΔE) is expressed as the numerical value of the distance between the L *, a *, b * coordinates of these colors.³⁷ In this study, the acceptability limit of ΔE was determined as 3.5,³⁸ and it was seen that all the materials that were immersed in coffee showed time-dependent color changes. There was no discoloration above the limit value at the end of the 28th day in the specimens kept in distilled water. While the composite resin specimens immersed in coffee were discolored above the limit immediately after 1 day ($\Delta E = 12.870 \pm 4.520$), the L and E specimens showed a discoloration above the limit only after 14 days ($\Delta E L = 4.975 \pm 1.027$ and $\Delta E E = 3.570 \pm 1.805$). The color change of the composite resin in the coffee was found to be greater than that of the L and E. Lauvahutanon *et al.*³⁹ examined the color changes of four composite resin materials containing Filtek Supreme Ultra and eight CAD/CAM blocks containing Vita Enamic and Lava Ultimate in coffee and water over 1-day, 1-week, and 1-month periods. According to the results of this study, while the ΔE values did not change significantly after immersion in water, they increased when specimens were immersed in coffee. Similar to the results of this study, the ΔE values of conventional direct composite resins (Filtek Supreme Ultra and Durafill VS) were found to be significantly higher. In another study, Alharbi *et al.*⁴⁰ reported that a methacrylate-based direct composite Filtek Supreme showed the highest discoloration against UDMA-based and silorane-based composite resins and CAD/CAM blocks. According to the findings of this study, a methacrylate-based direct Filtek Ultimate composite showed the highest discoloration against L and E. Acar *et al.*⁴¹ reported that a methacrylate-based nanocomposite (Filtek Supreme Plus) showed the highest discoloration against a hybrid ceramic CAD/CAM block (Vita Enamic) and lithium disilicate glass ceramic (IPS e.max CAD). Severe

discoloration of the direct composite resin materials is related to water absorption, and this was reported previously in the literature.^{39,42,43} Furthermore, the resin content of CAD/CAM blocks with an improved degree of conversion causes better mechanical properties and resistance to discoloration.^{34,40,44}

Dental ceramics are more resistant to discoloration than composite resin materials are.^{45,46} This can explain the finding that L showed more discoloration than E at the end of 28 days of immersion in coffee; E contains more ceramics, and thus, it is more resistant to coloration. It should be noted that discoloration is also related to the immersion medium.^{39,45} Poor oral hygiene of the individual and frequent consumption of coloring foods may cause color discrepancies between the CAD/CAM material and the repair composite later. However, this may not be a problem for someone who has good oral hygiene and does not consume coloring foods frequently. This must be considered when repairing the CAD/CAM blocks with composite resin materials.

CONCLUSION

Within the limitations of this study, the following conclusions were obtained: both the resin nanoceramic (L) and hybrid (E) CAD/CAM blocks can be repaired with composite resins after proper surface treatments. The repair capacities of resin nanoceramic and hybrid CAD/CAM blocks before and after 10,000 thermal cycles were found to be similar. An additional silane application is recommended even when a silane-containing adhesive system is used for repairing E and L. Surface roughening with ErCr:YSGG lasers used with 3 W and 20 Hz parameters can be employed as an alternative method to coarse bur grinding for repairing E and L. It is likely that there will be a color difference between the CAD/CAM block and the repair composite after a certain time period.

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