Original Article

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Bond Strength of Different Composite Resin Materials and CAD/CAM Restorative Materials to Each Other and Dentin Tissue

Farklı Kompozit Rezin Materyaller ve CAD/CAM Restoratif Materyallerin Birbirine ve Dentin Dokusuna Bağlanma Dayanımı

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ABSTRACT

Objective: The aim of the current study is to investigate the strongest and weakest points of the three different structures of prosthodontic restorations constituting the coronal structure when considered as a whole: the remaining tooth, composite resin, and computer-aided design and computer-aided manufacturing (CAD/CAM) restorative materials.

Methods: Seventy extracted caries-free molars, CAD/CAM blocks [Lava Ultimate (LU), Vita Enamic (VE), IPS e.max CAD (IPS)], and composite resin materials Clearfil Majesty Posterior [CMP], Light Core [LC], Filtek Bulk Fill Posterior [FBP], EverX Posterior [EP] were used for this study. Dentin and CAD/CAM sections were embedded in acrylic. Clearfil SE Bond was used as adhesive material. Composite resin materials were applied to the dentin surface using a Teflon mold. LU and VE were sandblasted with 50-µm Al2O3 for 10-sec. IPS was etched with HF for 20-sec. Ceramic Primer-2 was applied to the surfaces. Composite bars (2.3x3 mm) were adhered to CAD/CAM blocks using RelyX-U200. In addition, CAD/CAM bars were also adhered to dentin. The shear bond strength test was performed. Failure modes were examined using a stereomicroscope. Differences were analysed using one-way ANOVA and Tukey Post Hoc test.

Results: The highest shear bond strength values of the composite resin materials to dentin tissue were observed in EP ($p<0.05$). Shear bond strength values of composite resin materials to IPS were found

ÖZ

Amaç: Bu çalışmanın amacı koronal yapıyı oluşturan üç farklı yapıyı bir bütün olarak ele alarak protetik restorasyonların en güçlü ve en zayıf noktalarını geriye kalan dental dokular, kompozit rezin ve CAD/CAM materyalleri yönünden incelemektir.

Yöntemler: Bu çalışmada 70 adet çürüksüz çekilmiş azı dişi, CAD/CAM bloklar [Lava Ultimate (LU), Vita Enamic (VE), IPS e.max CAD (IPS)] ve kompozit rezin materyaller Clearfil Majesty Posterior [CMP], Light Core [LC], Filtek Bulk Fill Posterior [FBP], EverX Posterior [EP] kullanıldı. Dentin ve CAD/CAM kesitleri akriliğe gömüldü. Adeziv materyal olarak Clearfil SE Bond kullanıldı. Kompozit rezin materyaller dentin yüzeyine Teflon kalıp kullanılarak uygulandı. LU ve VE 50 µm Al2O3 ile 10-sn kumlandı. IPS, 20-sn HF ile asitlendi. Yüzeylere Ceramic Primer-2 uygulandı. Kompozit çubuklar (2.3x3 mm) RelyX-U200 kullanılarak CAD/CAM bloklara yapıştırıldı. Ayrıca CAD/CAM çubuklar da dentine yapıştırıldı. Makaslama bağlanma dayanım testi yapıldı. Kırılma tipleri stereomikroskop kullanılarak incelendi. One-way ANOVA ve Tukey Post Hoc testi istatistiksel değerlendirmede kullanıldı.

Bulgular: Kompozit rezin materyallerin dentin dokusuna olan makaslama bağlanma dayanımı için en yüksek değerler EP'de gözlendi ($p<0,05$). Kompozit rezin materyallerin IPS'ye bağlanma dayanım değerleri LU ve VE'den daha yüksek bulundu. Üç farklı CAD/CAM restoratif materyalinin dentin dokusuna makaslama bağlanma dayanımları istatistiksel olarak benzerdi.

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higher than to LU and VE. The shear bond strengths of the three different CAD/CAM restorative materials to the dentin tissue were statistically similar.

Conclusion: The type of composite resin materials affects the shear bond strength to dentin tissue and CAD/CAM restorative materials. However, the type of CAD/CAM restorative material does not affect the shear bond strength to dentin tissue.

Keywords: CAD/CAM, shear bond strength, composite resin, dentin

Sonuç: Kompozit rezin materyalinin tipi, dentin dokusuna ve CAD/CAM restoratif materyallere olan makaslama bağlanma dayanımını etkilemektedir. Ancak CAD/CAM restoratif materyalinin tipi dentin dokusuna olan makaslama bağlanma dayanımını etkilememektedir.

Anahtar Sözcükler: CAD/CAM, makaslama bağlanma dayanımı, kompozit rezin, dentin

Introduction

At present, different restorative materials are available for the restoration of teeth with high coronal loss. The choice of restorative materials is critical in the long-term success of the coronal restoration. The restorative materials must provide resistance and retention to dental tissues and have sufficient mechanical resistance to occlusal forces (1). In previous years, amalgam, glass ionomer, and hybrid ionomer were used as restorative materials (2). Nowadays, resin-based restorative materials with different physical and mechanical properties that can be bonded to dental tissues are frequently used.

Materials that mimic different tooth structures such as enamel and dentin (biomimetic) have been developed, and products on a very wide scale have been introduced to the market. One of the main objectives of restorative dentistry is that restorative materials should be compatible with natural dental tissues and should have similar physical and mechanical properties (3). Despite the variety of materials available, long-term success in the restoration of teeth with excessive material loss depends on many factors. At this stage, each of the variables such as the amount of remaining dental tissues, the structural properties of the restorative material, and the bond strength of the ceramic or composite resin restorative material to dental tissue and each other are effective on the long-term clinical success of the restorations.

Restorative materials used in computer aided design/computer aided manufacturing (CAD/CAM) systems are frequently preferred for teeth with excessive coronal material loss. For long-lasting restorations or to obtain clinical success, adequate adhesion must be provided between the ceramic structure, composite resin material, and tooth. However, the literature is insufficient on which bonding agent or adhesive cement, or which ceramic material or composite resin material produces the greatest bond strength to tooth structures. Recently, there has been a significant increase in CAD/CAM restorative material diversity. As an alternative to CAD/CAM ceramic blocks, composite containing CAD/CAM blocks have been developed. Resin blocks have a softer structure compared with ceramic blocks, which facilitates the milling of the material. While all-ceramic systems have disadvantages such as repair difficulties, deterioration of polishing properties during the adaptation process, necessity to be repolished by a technician, and rapid crack formation in the material; the soft structure of composite materials allows them to be easily produced and these materials can be easily repaired by clinicians with direct composite resin materials. In addition, various studies have shown that resin-based CAD/CAM restorative materials are as successful as ceramic materials when the bond strength (4-6), flexural strength and modulus of resilience are evaluated (7,8).

In this study, we considered teeth with excessive material loss as a single structure and investigated the strongest and weakest connection points. The aim of the study was to investigate the connection between the three different structures constituting the coronal structure (tooth, composite resin materials, and CAD/CAM restorative materials). Therefore, this study had three different objectives: the first objective was to investigate the bond strength of composite resin materials (conventional posterior composite, fiber reinforced composite, bulk-fill composite, and light-cured core build-up composite) to dentin tissue. The second objective was to investigate the bond strength of different composite resin materials to the CAD/CAM restorative materials (resin nanoceramic, nanohybrid, or lithium disilicate ceramic). The third objective was to investigate the bond strength of different CAD/CAM restorative materials to dentin tissue.

The tested null-hypotheses were as follows: (1) the type of composite resin materials does not affect bond strength to dentin tissue; (2) the type of composite resin materials does not affect bond strength to different types of CAD/CAM restorative materials; and (3) the type of CAD/CAM restorative materials does not affect bond strength to dentin tissue.

Methods

The present study was approved by the Kocaeli University Non-Invasive Clinical Research Ethics Committee (no: 2019/264). Seventy extracted molar teeth, three different CAD/CAM restorative materials [Lava Ultimate (3M ESPE, St Paul, MN, USA), Vita Enamic (Vita Zahnfabrik, Bad Sackingen, Germany), IPS e.max CAD (Ivoclar Vivadent AG, Schaan, Liechtenstein)] and four different composite resin materials [Clearfil Majesty Posterior (Kuraray, Okayama, Japan), Light Core (Bisco Dental Products, Schaumburg, IL, USA), Filtek Bulk Fill Posterior (3M ESPE, St Paul, MN, USA), EverX Posterior (GC Corporation, Tokyo, Japan)] were used for the shear bond strength test in this study. The above-mentioned materials are presented in Tables 1, 2, and 3.

The enamel tissue of the teeth was removed with a low-speed diamond precision-cutting machine (Micracut 151/Metkon,

Table 1. CAD/CAM restorative materials used in the study

Materials	Type	Inorganic composition	Organic composition	Filler content (wt%)	Manufacturer and batch
Vita Enamic (VE)	Hybrid-ceramic (Polymer infiltrated feldspar ceramic)	SiO_2, Al_2O_3, Na₂O, P_2O_5, B_2O_3, ZrO_2, CaO	UDMA, TEGDMA	86 wt% feldspar ceramic, 14 wt% polymer	Vita Zahnfabrik, Bad Sackingen, Germany-51540
IPS e.max (IPS)	Lithium disilicate	SiO_2, Li_2O, K_2O, P_2O_5, ZrO_2, Al_2O_3, MgO, coloring oxides	-	-	Ivoclar Vivadent AG, Schaan, Liechtenstien-U16370
Lava Ultimate (LU)	Nano-ceramic	SiO_2, ZrO_2, Si/ZrO_2 cluster	Bis-GMA, UDMA, Bis-EMA, TEGDMA	80 wt% nanoceramic, 20 wt% resin	3M ESPE St Paul, MN- N664028

Bis-EMA: Bisphenol-A-polyethylene-glycol-diether dimethacrylate, Bis-GMA: Bisphenol-A-diglycidyl dimethacrylate, TEGDMA: Triethylene gly-col dimethacrylate, UDMA: Urethane dimethacrylate

Table 2. Composite resin restorative materials used in the study

Materials	Type	Inorganic composition	Organic composition	Filler content (wt%)	Manufacturer and batch
Clearfil Majesty Posterior (CMP)	Nano-hybrid	Alumina and glass ceramics	BisGMA AUDMA TEGDMA	92	Kuraray, Okayama, Japan-4D0060
Light Core (LC)	-	7.8% fiber and glass filler	Bis-GMA Bis-EMA	79	Bisco Dental Products, Schaumburg, IL, USA-1800006221
Filtek Bulk Fill Posterior (FBP)	Nano-hybrid	Based on silica, zirconia, and ytterbium trifluoride	AUDMA UDMA DDDMA	76.5	3M ESPE, St Paul, MN, USA-N721168
EverX Posterior (EP)	Short Fiber reinforced composite	E-glass short fibers and barium borosilicate glass particulate	Bis-GMA TEGDMA PMMA	74.2	GC Corporation, Tokyo, Japan-1506222

AUDM: Aromatic urethane dimethacrylate, Bis-EMA: Bisphenol-A-polyethylene-glycol-diether dimethacrylate, Bis-GMA: Bisphenol-A-diglycidyl dimethacrylate, DDDMA: 1,12-dodecanediol dimethacrylate, PMMA: Polymethyl methacrylate, TEGDMA: Triethylene gly-col dimethacrylate, UDMA: Urethane dimethacrylate

Table 3. Other materials used in the study

Materials	Chemical composition		Manufacturer and batch
Relyx U 200	Base paste: Silane-treated glass powder, 2-Propenoic acid, 2-methyl,1,10 -[1-(hydroxymethyl)-1,2-ethanodiyl] ester, TEGDMA, silane-treated silica, glass fiber, sodium persulfate, tert-butyl peroxy-3,5,5-trimethylhexanoate İnorganic Fillers %43	Catalyzer paste: Silane-treated glass powder, dimethacrylate substitute, silane-treated silica, sodium p-toluenesulfonate, 1-Benzyl-5-phenylbarbituric acid, calcium salts, 1,12-Dodecanediol dimethacrylate, calcium hydroxide, titanium dioxide.	3M/ESPE, St. Paul, MN, USA-665734
Clearfil SE Bond	Primer: MDP, HEMA, hydrophilic aliphatic dimethacrylate, di-camphorquinone, N, N-Diethanol-p-toluidine, water	Bond: MDP, Bis-GMA, HEMA, hydrophobic aliphatic dimethacrylate, di-camphorquinone, N, N-Diethanol-p-toluidine, silanized colloidal silica	Kuraray Noritake Dental Inc., Okayama, Japan- Primer:AW0272 Bond:AX0436
Ceramic primer 2	Ethyl alcohol, phosphoric acid ester, silane, MDP, MDTP, DMA		GC Corporation, Tokyo, Japan-1605251

Bis-GMA: Bisphenol-A-diglycidyl dimethacrylate, DMA: Dimethacrylate, HEMA: 2-hydroxyethyl methacrylate, MDP: 10-methacryloyloxydecyl dihydrogen phosphate, MDTP: Methacryloyloxydecyl dihydrogen thiophosphate, TEGDMA: Triethylene glycol dimethacrylate

Turkey) with water cooling. Then, 2 mm thickness dentin sections were formed. The sections were embedded in acrylic molds. The upper surface of the specimen was abraded with 600 grit silicon carbide paper (LaboPol-1, Struers, Willich, Germany) for 60-sec with water. The obtained samples were randomly divided into four groups and each group was assigned a different type of composite resin material (n=10). Group 1A: Dentin-CMP, Group 2A: Dentin-LC, Group 3A: Dentin-FBP, and Group 4A: Dentin-EP. Clearfil SE Bond (Kuraray Noritake Dental Inc., Okayama, Japan) was used as adhesive agent. It was then polymerized using Elipar S10 (3M/ESPE, St. Paul, MN, USA). Composite resin materials were applied to the flat dentin surface using 2.3x3 mm size Teflon cylinder mold (Ultradent Product, Inc., Utah, USA) (Figure 1) and polymerized.

The IPS, LU, and VE blocks were cut using a low-speed precision cutting machine with a thickness of 2 mm and a total of 120 samples were created (n=10). IPS specimens were fully crystallized at 845 °C for 10-min in a ceramic furnace (Programat P300, Ivoclar Vivadent AG, Liechtenstein). The sections were embedded in acrylic molds. Then, all samples were ground with 600-grit SIC paper for surface standardization. LU and VE samples were sandblasted with 50-µm Al_2O_3 for 10-sec. IPS samples were treated with acid for 20-sec (9% Hydrofluoric acid; Ultradent-Porcelain-Etch), washed for 15-sec and air-dried. The ceramic sections were placed in an ultrasonic bath for 10-min and air-dried. The surface was treated with Ceramic primer 2 (GC Corporation Tokyo, Japan) and air-dried for 10-sec. Composite cylinder bars obtained from the composite resin materials using a Teflon cylinder mold were polymerized for 20-sec. The composite resin materials were adhered to the prepared adherend ceramic surface with self-adhesive resin-cement RelyX U200 (3M/ESPE, St. Paul, MN, USA). Each surface was polymerized using Elipar S10 for 20-sec. The obtained samples were divided into 12 groups. Group-1B: LU-CMP, Group 2B: LU-LC, Group 3B: LU-FBP, Group 4B: LU-EP, Group 5B: VE-CMP, Group 6B: VE-LC, Group 7B: VE-FBP, Group 8B: VE-EP, Group 9B: IPS-CMP, Group 10B: IPS-LC, Group 11B: IPS-FBP, and Group 12B: IPS-EP.

The cylinder bar samples of 2.3 mm diameter and 3 mm height were prepared from CAD/CAM materials (n=10). The obtained samples were divided into three groups. Group 1C: Dentin-LU, Group 2C: Dentin-VE, and Group 3C: Dentin-IPS. The surface of the cylinder bars obtained from LU and VE were sandblasted with 50-µm Al_2O_3 particles for 10-sec. The surface of the cylinder bars obtained from IPS was etched with 9% HF (Porcelain Etch; Ultradent Products, Inc., Köln, Germany) for 20-sec subsequently washed and dried for 15-sec. Ceramic primer 2 was applied to the surface and air-dried for 10-sec. The samples were adhered to the flat dentin surface using self-adhesive resin cement RelyX U200. Each surface was polymerized for 20-sec (Elipar S10). An overview of the groups can be seen illustrated in Figure 2, moreover the test specimen is shown in Figure 1. The polymerized specimens were stored in distilled water for 24-h.

The shear bond strength test was carried out following the guidelines of ISO 29022:2013 (9). A Teflon cylinder mold with a diameter of 2.3 mm was used to obtain the composite resin specimen. The ISO standard was mainly set to compare the adhesion of dental composite to teeth; some modifications were made, such as the use of flat dentin and ceramic surface with composite and ceramic specimens. The composite and ceramic cylinder bar were positioned perpendicular to the dentin and ceramic material surface. They were then subjected to shear bond strength test on a testing machine Shear Bond Tester (Bisco, Schaumburg IL Inc, USA) (Figure 1) at a crosshead speed of 0.5 mm/min and the values were recorded (MPa). Failure modes were analyzed using an M3B stereomicroscope (x30) (Wild, Heerbrugg, Switzerland) and evaluated as adhesive, cohesive, and mixed. The differences between the groups were analyzed using one-way analysis of variance (ANOVA) and Tukey's post hoc test ($p<0.05$).

Results

The mean shear bond strength and standard deviation values of the groups are presented in Tables 4-7 and Figure 3. According to the result of the bond strength of the composite resin materials to dentin tissue, the highest bond strength values to dentin tissue were observed in EP, and the lowest values were observed in CMP. The bond strength values of the groups in a descending order were Group-4A (20.58±6.55 MPa) > Group-3A (18.56±3.74 MPa) > Group-2A (16.79±2.52 MPa) > Group-1A (14.30±2.31 MPa). Consequently, a statistically significant difference was only found between Group 1-A and Group 4-A ($p<0.05$).

According to the result of the shear bond strength of composite resin materials to CAD/CAM restorative materials, the highest bond strength values were observed between IPS and FBP (34.64±4.65 MPa). The lowest bond strength values were between VE and CMP (22.31±2.84 MPa). There was a statistically significant difference between the groups ($p<0.05$). Generally, bonding of composite resin materials to IPS was found greater than to LU and VE.

The differences in the shear bond strength values of CAD/CAM restorative materials to dentin tissue were statistically insignificant ($p>0.05$).

When groups A, B, and C were compared, significantly lowest shear bond strength values were observed in Group C (dentin tissue-CAD/CAM restorative materials) ($p<0.05$).

Table 4. The shear bond strength values of composite resin materials to dentin tissue

Groups	Mean (MPa) ± Std. deviation
Group-1A: Dentin-Clearfil Majesty Posterior	14.30±2.31^{A}
Group-2A: Dentin-Light Core	16.79±2.52^{AB}
Group-3A: Dentin-Filtek Bulk Fill Posterior	18.56±3.74^{AB}
Group-4A: Dentin-EverX Posterior	20.58±6.55^{B}

Means followed by distinct superscript letters represent statistically significant differences in each column ($p<0.05$).

Table 5. The shear bond strength values of composite resin materials to CAD/CAM restorative materials (mean (MPa) ± std. deviation)

Materials	Clearfil Majesty Posterior	Light Core	Filtek Bulk Fill Posterior	EverX Posterior
Lava Ultimate	Group-1B	Group-2B	Group-3B	Group-4B
	26.10±5.30^{AB1}	26.49±6.93^{AB1}	27.87±7.78^{A1}	26.13±4.58^{A1}
Vita Enamic	Group-5B	Group-6B	Group-7B	Group-8B
	22.31±2.84^{A1}	25.77±5.26^{A1}	29.27±4.66^{A1}	29.09±5.16^{A1}
IPS e.max CAD	Group-9B	Group-10B	Group-11B	Group-12B
	30.59±5.02^{B1}	34.16±6.67^{B1}	34.64±4.65^{A1}	34.23±4.87^{A1}

Means followed by distinct superscript numbers represent statistically significant differences in each row (p<0.05). Means followed by distinct superscript letters represent statistically significant differences in each column (p<0.05).

Table 6. The shear bond strength values of CAD/CAM restorative materials to dentin tissue

Groups	Mean (MPa) ± std. deviation
Group-1C: Dentin-Lava Ultimate	10.15±1.79^{A}
Group-2C: Dentin-Vita Enamic	11.15±2.50^{A}
Group-3C: Dentin-IPS e.max CAD	12.87±4.02^{A}

Means followed by distinct superscript letters represent statistically significant differences in each column (p<0.05).

Table 7. The shear bond strength values of Groups A, B, and C

Groups	Mean (MPa) ± std. deviation
Group-A: Dentin-Composite resin	17.56±4.62^{A}
Group-B: CAD/CAM-Composite resin	28.89±6.41^{B}
Group-C: Dentin-CAD/CAM	11.39±3.05^{C}

Means followed by distinct superscript letters represent statistically significant differences in each column (p<0.05).

Distribution of the failure types corresponding to the groups is presented in Figure 4. The most common failure type was adhesive, and the least common failure type was mixed. The stereomicroscope photographs of failure types are shown in Figure 5.

Discussion

This study was designed to evaluate the bond strength of different CAD/CAM restorative materials and composite resin materials to dentin tissue and each other. The first and second tested null hypotheses were rejected. However, the third null hypothesis was not rejected since there was no influence of the type of CAD/CAM restorative materials on shear bond strength to dentin tissue.

Clinicians frequently face challenging situations while restoring teeth with excessive material loss, and at this stage, material choice is an important issue. The remaining tooth structures and selected composite and ceramic restorative materials must complement each other. A failure of bonding between one of these structures means clinical failure of the restoration. There is a great range of composite resin materials on the market such as conventional composites, fiber reinforced composites, and bulk-fill composites. All of these materials are produced to provide easy clinical stages for clinicians and restore the lost tooth structures.

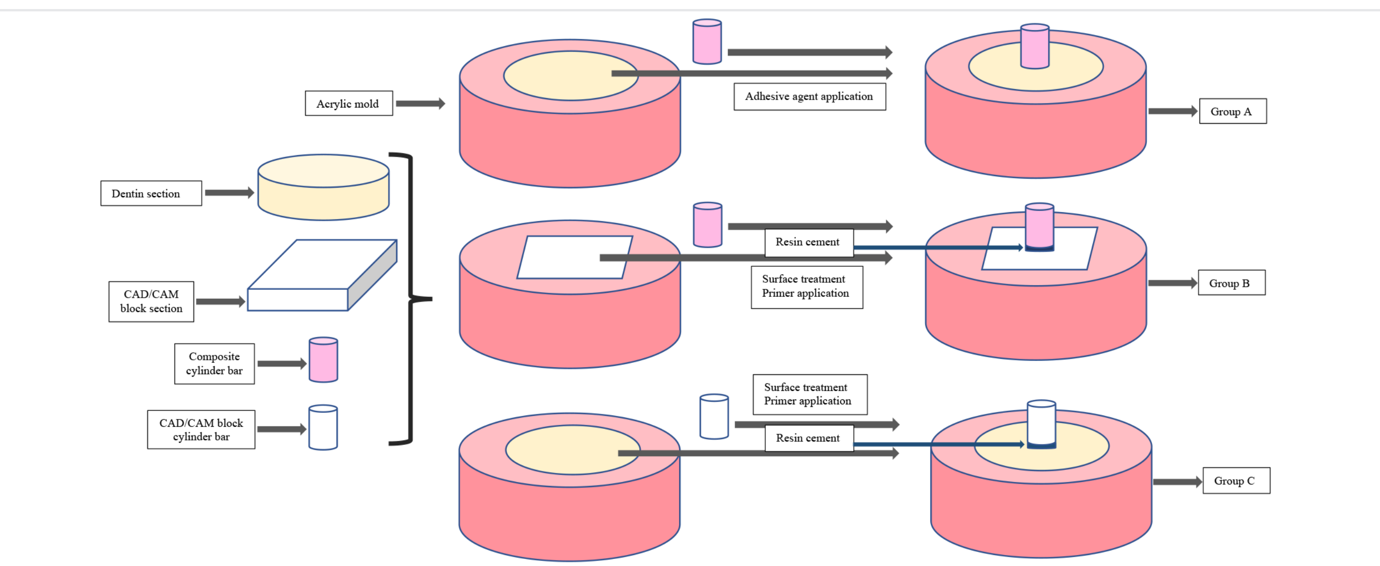

Figure 2. Schematic overview of Group A, B and C

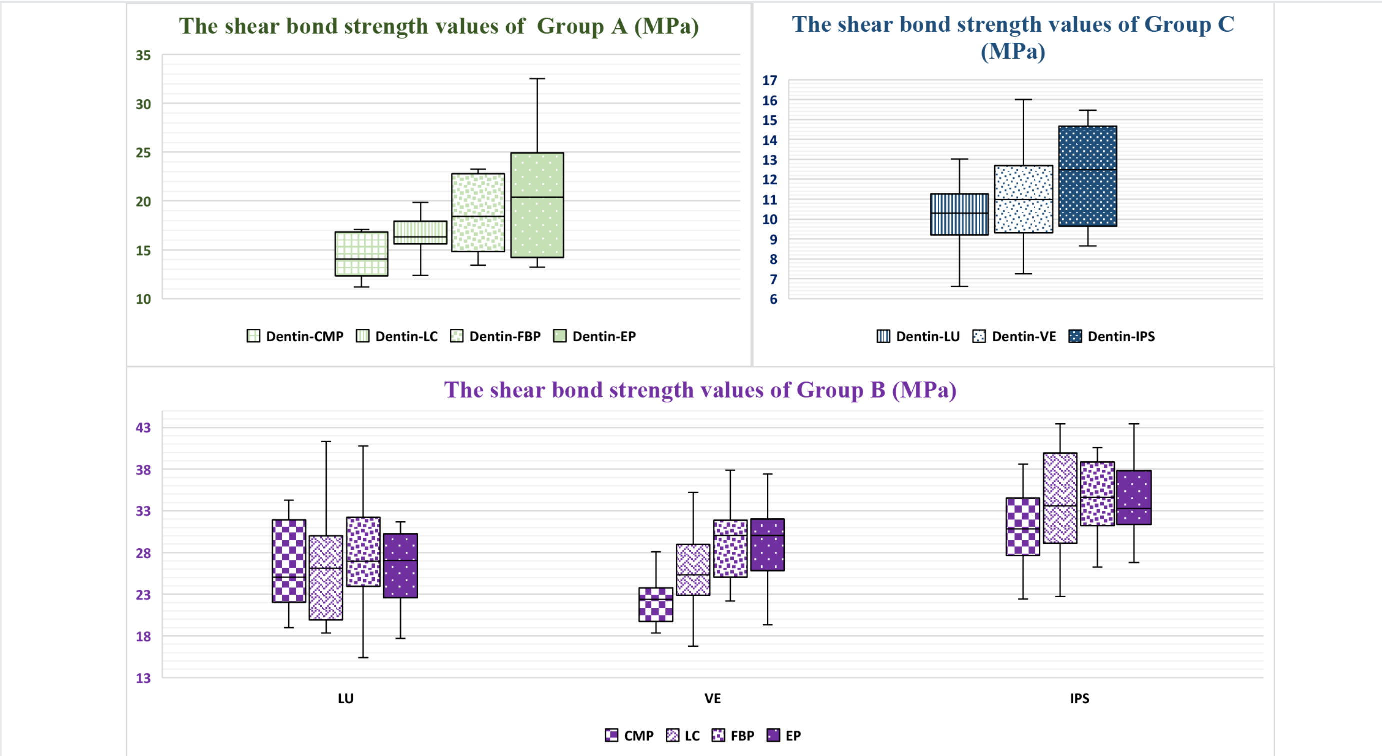

Figure 3. Shear bond strength values (MPa) obtained by the tested groups

Commonly preferred CAD/CAM resin blocks in the clinical practice are Vita Enamic (polymer infiltrated ceramic) and Lava Ultimate (resin nanoceramic). Nanoceramics have a polymeric matrix and contain about 80% by weight ceramic nanoparticle filler. Furthermore, the size of the fillers embedded in the polymer matrix is less than 100 nm. These fillers consist of silica nanoparticles and zirconia nanoparticles or a combination of both. One of the major advantages of this material is that it can be repaired directly in the event of fracture of the prosthetic component (10-12). Polymer-infiltrated ceramics combine ceramic and polymer properties. They have a hybrid structure with a permeable feldspathic ceramic and polymer network. The production of this material requires two stages. Initially, a porous pre-sintered ceramic network is produced and conditioned with a binder, then the polymer is infiltrated into this network. Polymer-infiltrated ceramics have dentin-like wear resistance, elasticity similar to dentin, and high flexural strength (10-13). IPS e.max CAD (Ivoclar Vivadent, Liechtenstein) is a lithium disilicate glass-ceramic structure that is frequently preferred in clinics because of its superior esthetic and mechanical properties. IPS e.max CAD blocks are manufactured in a pre-crystallized metasilicate phase. They are partially crystallized by heat treatment. After the restoration is milled, the lithium metasilicate crystals are modified to lithium disilicate crystals through vacuum heat treatment (11,14,15).

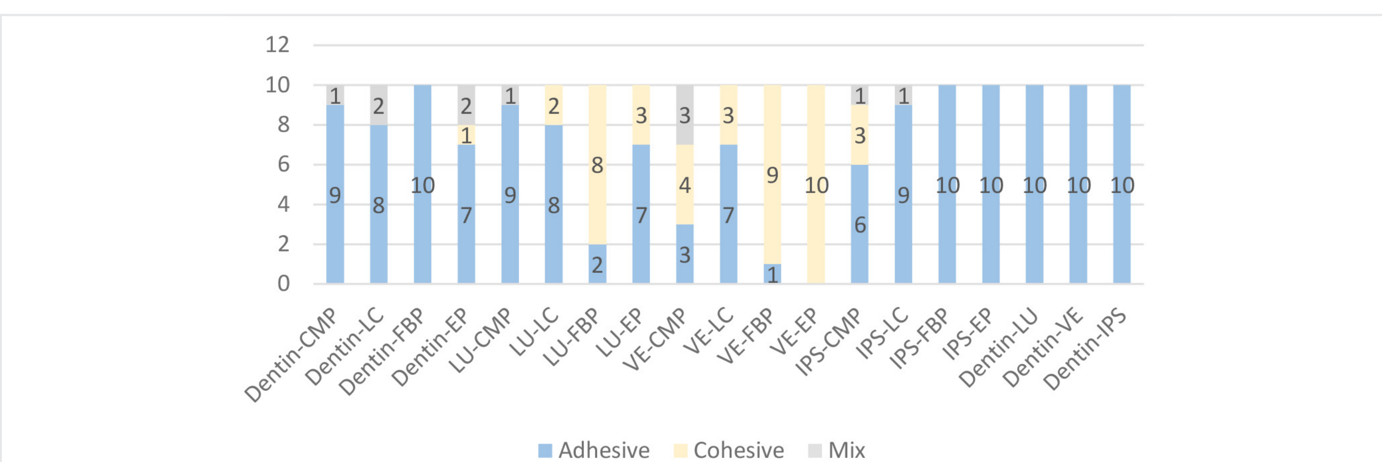

Figure 4. Distribution of fracture types according to experimental groups

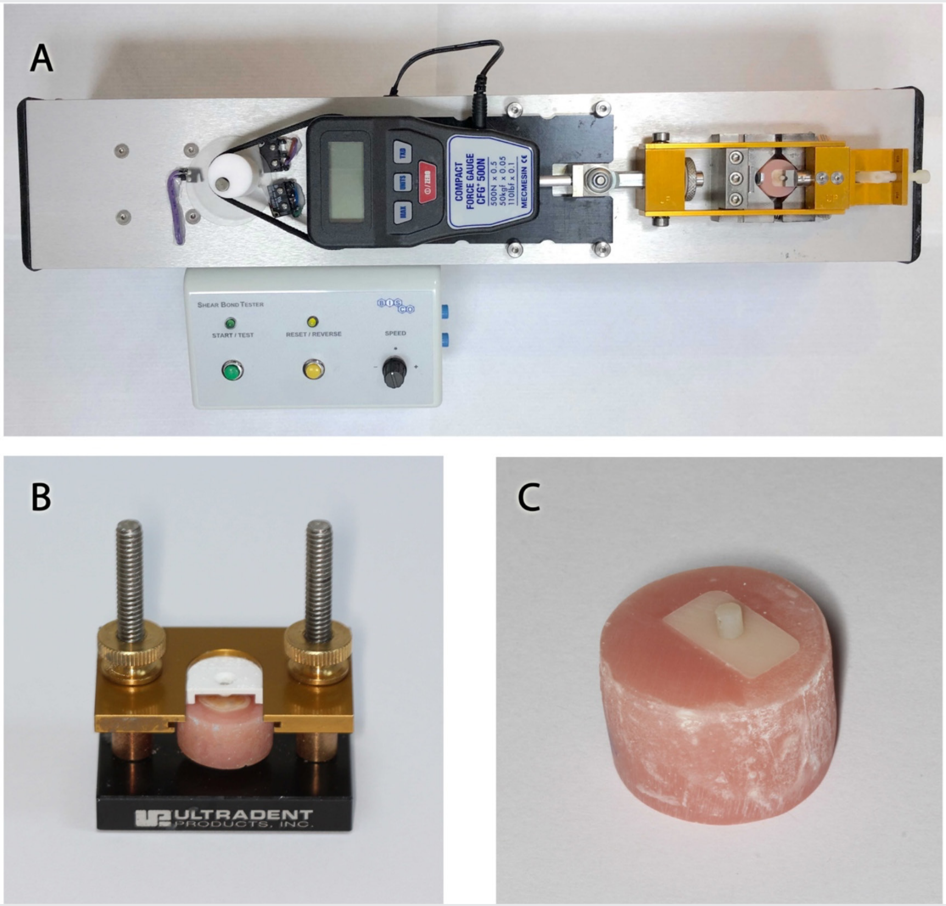

Figure 1. A) Shear Bond Tester B) Teflon cylinder mold C) Test specimen

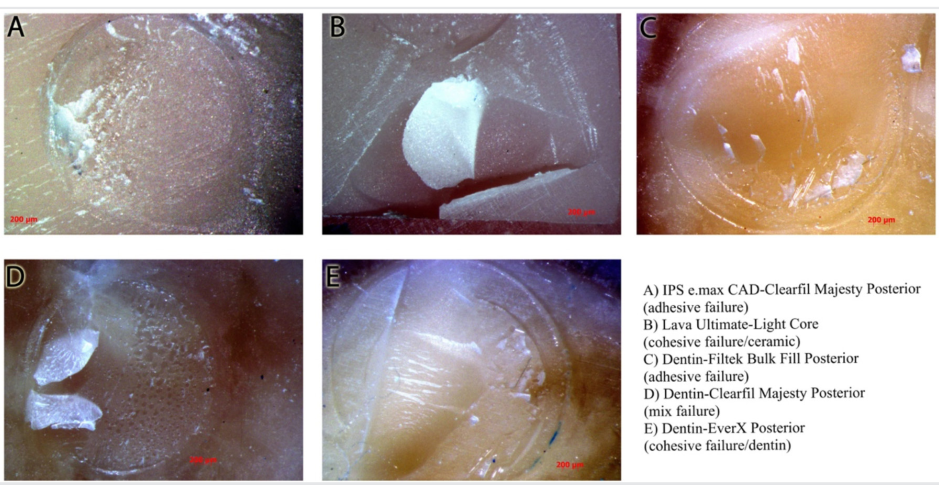

Figure 5. The stereomicroscope photographs of typical failure patterns (x30)

In this study, the highest bond strength values of the composite resin materials to dentin tissue were observed with EP and the lowest values were observed with CMP, and there was a statistically significant difference between them. Garoushi et al. (16), investigated the effect of short fiber fillers on microleakage and shrinkage stress of composites. They reported that the glass fibers content of fiber reinforced composite resins kept polymerization shrinkage stress down and therefore might be effective in reducing microleakage in restorations. Fiber reinforced composites can control polymerization shrinkage stresses by fiber orientation. Thereby, it is assumed that reducing the polymerization shrinkage stresses of composites leads to the increased bonding performance of fiber reinforced composites to dentin tissue compared with conventional composite resins. Tsujimoto et al. (17) conducted a study with the hypothesis that fiber reinforced composites could improve the bonding performance to dentin tissue. They investigated the bonding performance and interface characteristics of short fiber reinforced resin composites (EverX Posterior) in comparison with different composite resins (Clearfil AP-X, Filtek Suprema Ultra Universal Restorative). The authors reported that the bond strength values of short fiber reinforced resin composites to dentin tissue were statistically similar to the other composite resins. They also reported that the bonding performance of composites to dentin was basically influenced by the type of adhesive system. The researchers attributed the different bond strength values of composites to surface free energies of cured adhesives systems and reported that surface free energy had a strong influence on bond strength values. In the current study, unlike Tsujimoto et al. (17), it was observed that the shear bond strength values of fiber reinforced composite resin materials to dentin tissue were significantly higher than conventional composite resin materials. The different results obtained in these studies may be caused by the selection of different types of composite resin materials and the different inorganic content ratios these materials have.

Omran et al. (18), investigated the effect of increment thickness on light transmittance and bond strength of composite materials [G-aenial Anterior (control), Tetric Evo Ceram Bulk Fill, SDR, EverX Posterior] to the dentin tissue. According to the results of the study, bond strength and light irradiance decreased with increasing increment thickness of resin composites. EverX Posterior shows relatively higher bond strength values than bulk-fill composites. The researchers reported that the high values of EverX Posterior were due to micromechanical coupling between short fibers and dentin tissue. That connection may have increased the bond strength values. G-aenial Anterior (control) showed lower bond strength values. This material exhibits a lower translucency and more opacity, which means that the light transmittance is less, and this reduces the bond strength values (18-20). In addition, it has been reported in previous studies that a high filler ratio reduces the translucency of the composite material, which may lead to a decrease in conversion rates (21,22). In the current study, the lowest shear bond strength values to dentin tissue were observed in Clearfil Majesty Posterior; these low bond strength values might be related to the inorganic filler ratio of this material.

Recently developed bulk-fill composite resins aim to reduce polymerization shrinkage and simplify processes. Bulk-fill composites polymerize at a depth of 4 mm or more, which can be achieved without increasing the polymerization time (23,24). The cavity can be filled and polymerized simultaneously with bulk-fill composite resins, inter-layer contamination is avoided, and the time spent in the clinic is reduced (25,26). However, it is reported that as the layer thickness increases, less light reaches the bottom surface of the composite. To eliminate this effect, the filler amount was reduced, the translucency of the composites was increased, and more reactive photo activators, pre-polymerized particles, and glass fibers were added in bulk-filled composites (27-30). Pereira et al. (30), investigated the bond strength, nano-leakage, and marginal adaptation of bulk-fill composites. Filtek Z350 XT (conventional composite), Tetric N-Ceram Bulk Fill, Filtek Bulk Fill Posterior, and Sonic Fill were evaluated. As a result of that study, the Tetric N-Ceram Bulk Fill composite showed higher bond strength values than Sonic Fill. Researchers have reported that composite resin type is more effective on bond strength values than thermal and mechanical aging processes. In the current study, EP bulk-fill composite showed higher bond strength values than conventional posterior composite. The reason that EP exhibits higher bond strength to dentin tissue may be related to differences in the filler components (short fibers), filler ratio, and degree of conversion (22,26), which improve the polymerization rate of these composites.

The bond strength of CAD/CAM restorative materials to dentin tissue or composite resin materials is also effective in the clinical success of restoration with excessive material loss teeth. There are several ranges of CAD/CAM restorative materials on the market. It has been reported in different studies that the moduli of elasticity of ceramic materials are higher than in composites (31-35). The differences in the moduli of elasticity among the materials could have significant impact on the bond strength values. Ustun et al. (4), reported that when chairside CAD-CAM restorative materials were cemented with total etch, self-etch and self-adhesive systems to dentin tissue, differences in shear bond strength values were observed. However, in the present study, LU, VE, and IPS e.max exhibited similar bond strengths to dentin tissue. The reason for the similar bond strength values of the three CAD/CAM restorative materials to dentin may be related to the adhesive system used. The type of adhesive agent or surface treatment processes may affect bond strength values as well as the selected restorative materials.

Elsaka (12), reported that the bond strength values were significantly affected by the surface treatment protocol and the type of CAD/CAM restorative materials. In our study, IPS shows significantly higher bond strength than LU and VE with different composite resin material combinations. IPS was treated with different surface treatment protocols from LU and VE. Differences in surface treatment procedures may be effective in the bond strength values of CAD/CAM restorative materials. Straface et al. (36), investigated the influence of etching time and hydrofluoric acid concentration on the bond strength of CAD/CAM restorative materials. Etching time was found to significantly affect bond strength values. It was recommended to apply 5% and 9% HF acid to the surfaces of the materials from 15 to 60 seconds. Hou et al. (37), evaluated the bond strength of different CAD/CAM restorative materials. Four different CAD/CAM restorative materials (Vita Enamic, IPS Emax CAD, IPS Empress CAD, Vita Mark II) were used and divided into groups according to different surface treatments. Significantly, highest SBS values were obtained with HF acid etching for Vita Mark II and Vita Enamic and 400 mJ laser surface treatment for IPS e.max CAD. It was shown that SBS was significantly affected by different surface treatment protocols. In our investigation, three different CAD/CAM restorative materials were used. LU and VE samples were sandblasted with 50-µm Al_2O_3 particles, and HF and silane were used for IPS samples. The highest bond strength values between IPS and composite resin materials may be related to the HF acid and silane application. The CAD/CAM material type and differences in surface treatment protocols applied to CAD/CAM restorative materials may have affected the bond strength values.

When failure modes were evaluated: for Group-A, mainly adhesive failures occurred; for Group-C, adhesive failures were observed for all samples. Bonding to dentin tissue is a sensitive and complex process. In this study, low values were determined for the shear bond strength of composite resin materials and CAD/CAM restorative materials to dentin tissue. Therefore, more adhesive failures may have been observed for Group-A and Group-C. For Group-B more cohesive failures were observed for Vita Enamic, while adhesive failures were mainly observed for Lava Ultimate and IPS e.max CAD materials. The polymer infiltrated ceramic nature of Vita Enamic may have caused these cohesive failures. As a result, it was observed that more cohesive failures occured with higher shear bond strength values (Group-B) and adhesive failures mainly occured with lower shear bond strength values (Group-A and Group-C).

Study Limitations

In this study, when the shear bond strength of composite resin materials to dentin, composite resin materials to CAD/CAM restorative materials, and CAD/CAM restorative materials to dentin tissue were compared, the lowest shear bond strength was observed in the bonding of CAD/CAM restorative materials to dentin tissue. The high organic content of dentin tissue, dentin tubule structure, intratubular moisture, and pressure affect the bond strength of dentin tissue. The sensitivity of bonding to dentin tissue and the use of self-adhesive resin for cementation may reduce the bond strength values of CAD/CAM restorative materials to dentin tissue. Therefore, care should be taken in the selection of composite resin and CAD/CAM restorative material type and adhesive protocol in clinical practice.

The limitations of the present study were that oral environmental conditions were not provided as in vivo and only one type of adhesive resin was used. In future studies, the shear bond strength of different types of adhesive resin and restorative materials could be examined by representing the oral environment. In this study, the effect of composite resin and CAD/CAM restorative material type on the shear bond strength values were investigated. The composite resin material type was effective in bonding to dentin and CAD/CAM restorative materials. However, CAD/CAM restorative material type did not affect the bond strength values to dentin tissue. The shear bond strength values increased when bulk-fill composites were used as composite resin material and IPS as CAD/CAM restorative material. With the use of these materials, the clinical success of the restorations can be increased.

Conclusion

Within the limitations of this study**,** the type of composite resin materials may affect the SBS to the dentin tissue and different CAD/CAM restorative materials. However, the type of CAD/CAM restorative materials does not affect the bond strength to dentin tissue. Composite resin materials, which can be used in a bulk-fill form provide clinicians convenience in many aspects. The choice of IPS as a restorative material in combination with bulk-fill composite resin materials for the restoration of teeth may provide an advantage in terms of restoration durability. However, we think that this issue should be further investigated by long-term clinical studies.

Ethics

Ethics Committee Approval: The present study was approved by the Kocaeli University Non-Invasive Clinical Research Ethics Committee (no: 2019/264).

Peer-review: Externally and internally peer reviewed.

Authorship Contributions

Surgical and Medical Practices: S.B.A., B.D.İ., Concept: S.S., N.T., Design: S.S., N.T., Data Collection or Processing: S.B.A., B.D.İ., Analysis or Interpretation: N.T., S.B.A., Literature Search: N.T., Writing: N.T., S.B.A.

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