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Comparisons of the Bonding Strength of Heat-Treated Composite Resins to Different CAD/CAM Ceramics

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Research Article

History

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ABSTRACT

Objectives: The aim of this study was to evaluate the bonding strength of pre-heated composite resins used in the repair of CAD/CAM ceramic materials.

Materials and Methods: Specimens prepared from Feldspathic ceramic (VITABlocs Mark II, VITA Zahnfabrik, Germany), Hybrid ceramic (Vita Enamic, VITA Zahnfabrik, Germany), Zirconia-reinforced lithium silicate ceramic (Vita Suprinity, VITA Zahnfabrik, Germany) CAD/CAM materials were fixed in autopolymerised acrylic. The specimens were separated into two groups (n = 10) according to the temperature of the composite resin. As the surface procedure, 9% hydrofluoric porcelain acid (Ultradent Products Inc., Cologne, Germany) was applied to the ceramic surface for 20 seconds. In accordance with the manufacturer's instructions, Monobond was applied for 20 seconds and Heliobond for 10 seconds. The composite resins at different temperatures were placed in silicone moulds (4 mm diameter, 2 mm height) and polymerised. The bonding strength of the specimens was measured in a Universal test device and the data were analyzed using the Kruskal-Wallis and Mann-Whitney U test in SPSS vn. 23.00 software.

Results: The highest bonding strength value (60.58 MPa) was obtained in Group VS-RT and the lowest (4.36 MPa) in Group VB-PHT. No significant difference was observed between Group VB and Group VE ($p > 0.05$). A significant difference was determined in Group VS ($p < 0.05$).

Conclusions: Within the limitations of the study, the results showed that heat-treated composite resin reduced the bonding strength of Vita Suprinity material and increased the bonding strength of Feldspathic and Vita Enamic ceramics.

Keywords: CAD-CAM, composite resin, prosthesis repair, shear bond strength

Isıl İşlem Görmüş Kompozit Rezinlerin Farklı Cad/Cam Seramiklere Bağlanma Dayanımının Karşılaştırılması

Araştırma Makalesi

Süreç

Geliş: 21/10/2025
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ÖZ

Amaç: CAD/CAM seramik materyalinin tamirinde kullanılan kompozit rezinlere uygulanan ön ısıtma işleminin bağlantı dayanımının değerlendirilmesi amaçlandı.

Gereç ve Yöntemler: Feldspatik seramik (VITABlocs Mark II, VITA Zahnfabrik, Almanya), Hibrit seramik (Vita Enamic, VITA Zahnfabrik, Almanya), Zirkonya ile güçlendirilmiş lityum silikat seramik (Vita Suprinity, VITA Zahnfabrik, Almanya) CAD/CAM materyallerden hazırlanan örnekler, otopolimerizan akrilikle sabitlendi. Örnekler kompozitin rezinin sıcaklığına göre iki gruba ayrıldı (n = 10). Yüzey işlemi olarak, %9 hidroflorik porselen asit (Ultradent Products, Inc., Köln, ALMANYA) seramik yüzeyine 20 sn uygulandı. Üretici firma talimatları doğrultusunda (60 sn Monobond, 10 sn Heliobond) uygulandı. Farklı sıcaklıklardaki kompozit rezin yüzeylere silikon kalıplar yardımıyla (4 mm çap, 2 mm yükseklik) yerleştirildi ve polimerize edildi. Örneklerin bağlanma dayanımı, Universal test cihazında ölçüldü ve veriler SPSS 23.00 uygulamasıyla Kruskal-Wallis ve Mann-Whitney U testi kullanılarak analiz edildi.

Bulgular: En yüksek bağlanma dayanımı değeri (60,58 MPa) GroupVS- RT grubunda görülürken, en düşük bağlanma dayanımı değeri (4,36 MPa) GrupVB-PHT grubunda elde edilmiştir. Gruplar arasında GrupVB ve GrupVE'de anlamlı farklılık görülmezken ($p > 0,05$), GrupVS'de anlamlı farklılık bulunmuştur ($p < 0,05$).

Sonuçlar: Çalışmanın sınırları dahilinde; ısıl işlem uygulanan kompozit rezin, Vita Suprinity materyali için bağlanma dayanımını azalırken, Feldspatik ve Vita Enamic seramikler için arttırmıştır.

Anahtar Kelimeler: CAD-CAM, kompozit rezin, makaslama, protez tamir

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Introduction

Computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies are a part of modern dentistry that allow restorations to be produced rapidly and sensitively. Due to advantages such as the need for fewer measurements and moulding stages, and the elimination of

potential incompatibility, this technology is a good alternative to traditional techniques.[1,2]

As a result of developments in dentistry and increased aesthetic expectations, full ceramic restorations (feldspathic ceramic, hybrid ceramics, zirconia-supplemented lithium silicates) are frequently used in clinical applications.[2] Despite the advantages of ceramic restorations, complications such as fractures and cracks can be seen to result from trauma because of poor performance under parafunctional forces and mechanical loads.[3,4] The most commonly seen complication of full ceramic restorations compared to metal-supported ceramics is delamination between the two materials.[5–7]

The renewal process for a full ceramic restoration that has separated from the upper structure porcelain is a costly and time-consuming process. Therefore, intra-oral repair procedures can be applied when seen to be appropriate by the clinician.[8] The clinical success of this procedure is associated with a high level of preservation of the integrity of the bond formed between the restoration and the composite resin. This bond may be chemical, mechanical, or the two combined[9] and is based on the bonding of composite resins with an appropriate adhesive system. However, there is no consensus among clinicians about an effective repair system that can provide positive clinical results in the full sense.[10] Different composite resin types (microfiller nanohybrid composites, bulk-fill composites, flowable composites) can be used for this purpose currently, but the bonding strength of these materials can show variability depending on the ceramic type and adhesive protocol used.[11,12]

A pre-heating process, which has become more widespread recently, has been reported to change the bonding strength by decreasing the viscosity of composite resins and increasing the flowability and adaptation of the material.[13,14] Moreover, heating composite resin has been found to contribute to the development of mechanical properties by decreasing the residual monomer rate during polymerisation.[15] Nevertheless, there is limited research in the literature related to the use of pre-heat treated composites in the repair of full ceramic restorations.

The aim of this study was to evaluate the bonding strength of composite resins that have undergone a pre-heating process, which are used in the repair of CAD/CAM ceramic materials. The null hypothesis of the study was that a pre-heating process would not increase the bonding strength of composite resins to CAD/CAM materials.

Materials and Methods

The materials used in the study are shown in Table 1. Three groups were formed (n = 10) according to the substructure material: Group VB: feldspathic ceramic (VITABlocs Mark II, VITA Zahnfabrik, Germany), Group VE: hybrid ceramic (Vita Enamic, VITA Zahnfabrik, Germany), and Group VS: zirconia-reinforced lithium silicate ceramic (Vita Suprinity, VITA Zahnfabrik, Germany). Disc-shaped specimens (7 mm diameter, 3 mm thickness) were prepared under water cooling in a CAD/CAM device (Yenamak, Yenadent Ltd., Istanbul, Türkiye).

G Power 3.0.10 programme (University Kiel, Germany) was used to calculate the effect size. Based on the Kim et al's study[16] Cohen's d of 1.947 was accepted as sufficient for significance. It was calculated that at least 20 specimens were required, three for each study group, with a 0.05 type 1 error and 99% power.

The specimens embedded in cold acrylic (Imicryl, Konya, Türkiye) leaving one surface exposed were abraded for 60 seconds under cold water using 600, 800, and 1200 grit silicon carbide sandpaper sequentially (English Abrasives Ltd., UK). All the specimens were then cleaned with distilled water for 10 mins in an ultrasonic cleaner (General Home, PRC) and dried with an air spray. 9% hydrofluoric porcelain acid (Ultradent Products Inc., Cologne, Germany) was applied to the ceramic surface of the specimens for 20 secs. In accordance with the manufacturer's instructions, Monobond was applied for 60 secs and Heliobond for 10 secs. Polymerisation was applied for 30 secs using an LED device (Woodpecker LED-D Light Device GuilinWoodpecker Medical Industry Ltd, Guangxi, PRC, 850-1000 mW/cm^2)

Tetric EvoCeram (Ivoclar Vivadent, Schaan, Liechtenstein) composite resin was used as the upper structure material. The specimens were separated into two groups acccording to the temperature applied to the composite resin. The distribution of the specimens groups is presented in Figure 1.

The composite resin specimens were prepared in plastic moulds with an inner empty cavity 4mm in diameter and 2mm in height, which were prepared specifically for this study. The control group specimens were prepared at room temperature (23 ± 2°C) and the composites treated with pre-heating were exposed to a pre-heating process at 65°C for 15 mins in a commercial device (HotSet-Technolife, Joinville, SC, Brazil). Placing the composite on the surfaces with the aid of the mould, the specimens were polymerised from the upper surface for 15 secs (Woodpecker LED-D Light Device GuilinWoodpecker Medical Industry Ltd, Guangxi, PRC, 850-1000 mW/cm^2). As the resins were designed for a working time of approximately 15 secs, the amount of heat loss was standardised.[17]

After completion of the polymerisation process, the specimens were left in pure water at 37 °C for 24 hours. The bonding strength was then tested with the application of force in a Universal Test Device (Lloyd LRX, Lloyd Instruments Ltd., Hants, UK) at a loading rate of up to 0.5 mm/min until breakage. The bonding strength values of each specimen were recorded in Newton (N) units, which were then converted to megaPascal units (MPa).

Statistical Analysis

Data obtained in the study were analyzed statistically using SPSS vn. 23.00 software (IBM SPSS Statistics 2013, Chicago, IL, USA). Conformity of the data to normal distribution was assessed using the Kolmogorov-Smirnov test. For the analysis of data not showing normal distribution, the Kruskal-Wallis test was used, and in the comparisons of groups that created a difference, the Mann-Whitney U-test was applied. A value of $p < 0.05$ was accepted as the level of statistical significance.

Table 1. The materials used in the study

Material	Content	Manufacturer
	CAD/CAM Ceramic	
Vita MarkII	56-64% SiO_2, 20-23% Al_2O_3, 6 9% Na_2O, 6-8% K_2O	Vita Zahnfabrik, Germany
Vita Enamic	86% feldspathic ceramic and 14% polymer	Vita Zahnfabrik, Germany
Vita Suprinity	56-64% SiO_2, 1-4% Al_2O_3, 15 21% Li_2O, 8-12% ZrO_2,1-4% K_2O	Vita Zahnfabrik, Germany
	Repair System	
Monobond	Ethanol,3-trimethoxysilylpropyl methacryilate, methacrylate phosphoric acid ester, disulphide acrylate	Ivoclar Vivadent AG, Schaan, Liechtenstein
Heliobond	Butanol, tetrabutylammonium dihydrogen trifluoride, methacrylate phosphoric acid ester, Bis(trimethoxysilyl)ethane	Ivoclar Vivadent AG, Schaan, Liechtenstein
Ultradent Porcelain Etch	9% content hydrofluoric acid	Ultradent Products, Inc., Cologne, Germany
Tetric N Ceram	DMA (weighted 17–18%), Filler rate (weighted 82–83%), catalyser, stabilizers and pigments (weighted <1.0%)	Ivoclar Vivadent AG, Schaan, Liechtenstein

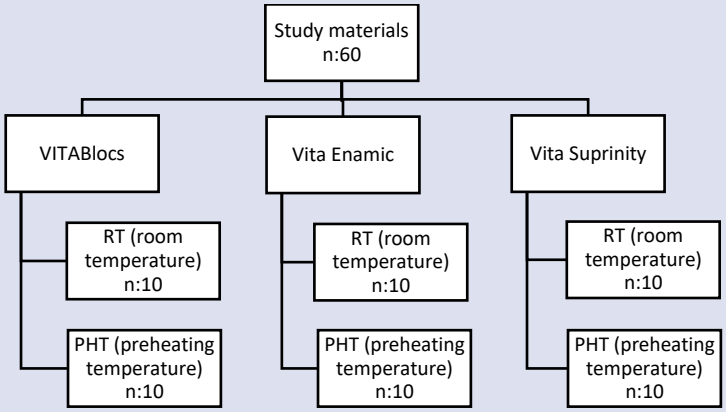


Figure 1. Schematic illustration of the distribution of the specimens.

Results

The results of the shear bonding strength test and descriptive statistics obtained in the study are shown in Table 2 and Figure 2. The highest bonding strength value (60.58 MPa) was obtained in Group VS-RT and the lowest (4.36 MPa) in Group VB-PHT.

In the statistical analysis performed according to the bonding strength values of the substructure materials, a significant difference between the groups was determined in Group VS ($p < 0.05$). When the statistical analysis was performed according to the composite applied, the groups creating a difference were observed to be Group VB – Group VS and Group VE-Group VS ($p > 0.05$).

Discussion

The results of this study demonstrated that the null hypothesis that a pre-heating process applied to composite resins would not increase the bonding strength was accepted. According to the study results, the applicaton of a pre-heating process decreased the bonding strength of composite resins to CAD/CAM substructure materials.

Intra-oral repair is a simpler technique than extra-oral repair methods and renewal of the restoration.[18] Porcelain fractures occurring in the substructure material make intra-oral repair procedures more difficult and staged applications are required. In metal-supported restorations, it is not easy to obtain an aesthetic appearance and compensate for the colour of the substructure with repair processes.[19] In the repair of local fractures seen in ceramic restorations, the bond between the fracture surface and the repair material is important to be able to obtain a successful outcome.[19]

Therefore, for the repair material to be able to bond to the ceramic structure at the desired level, the surface to be repaired must be brought to an appropriate condition. Mechanical bonding occurs through micro-mechanical locking obtained with surface roughening.[20] For chemical bonding, silanisation and adhesive systems are of benefit.[21] As there are double function groups in the structures, silane can bond organic and inorganic components to each other.[22] In a study by El-Damanhoury et al., the application of silane and roughening with hydrofluoric acid was evaluated as the gold standard for the surface preparation process of glass ceramic restorations.[23] In the current study, 9% hydrofluoric porcelain acid was applied to the ceramic surface for 20 secs as the specimens surface process.[24]

Table 2. Mean bonding strength values of the specimens

Groups		Mean ± SD	Min. (MPa)	Max. (MPa)	p
GroupVB	RT	8.95 ±5.55	9.91	29.15	0.7
	PHT	11.25 ±7.10	4.36	25.94	
GroupVE	RT	13.85 ± 6.31	7.46	25.59	0.4
	PHT	19.30 ±7.43	13.89	38.70	
GroupVS	RT	23.70±13.88	13.71	60.58	0.01*
	PHT	15.95 ±7.71	8.02	32.07	

RT: room temperature, PHT: preheating temperature

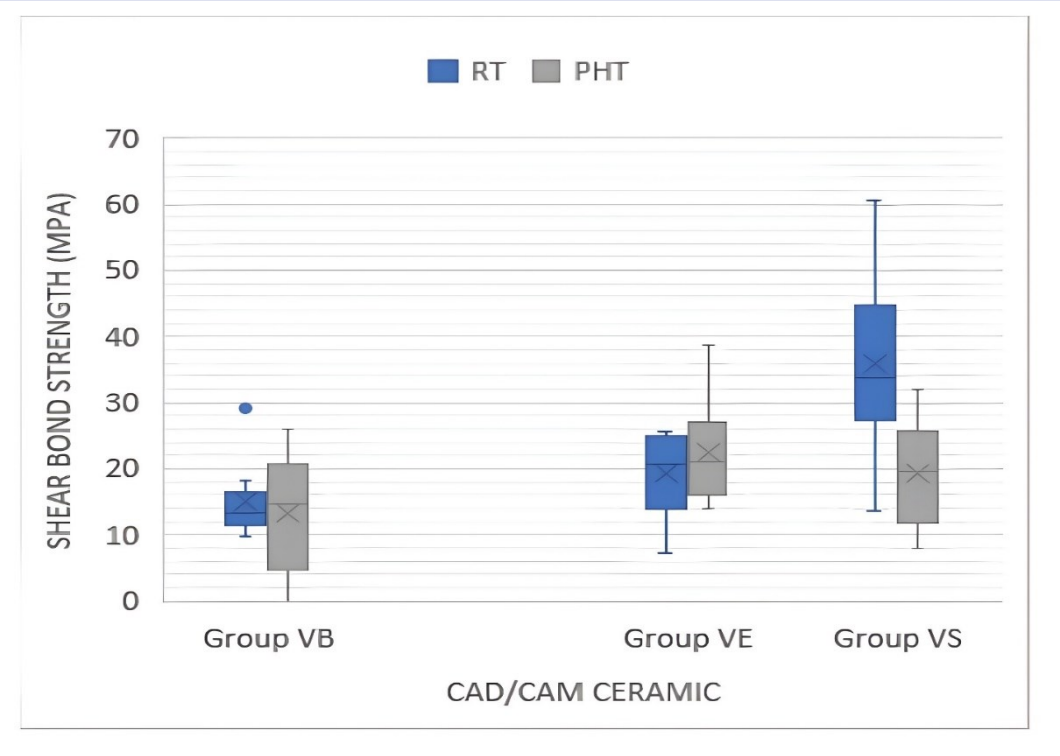


Figure 2. Block graph showing the bonding strength values of the groups according to the heat value (RT-PHT)

The particle size of the composite resin used can affect the bonding strength with the restoration. Previous studies in literature have reported comparisons of nanohybrid and microhybrid type composites as repair material.[25] However, no significant difference has been observed in respect of the bonding strength of nanohybrid and microhybrid composites to the ceramic surface.[26,27] Yildirim et al., stated that bonding values will increase when flowable composite is used as the repair material because of the increased adaptation properties.[28]

The shear test is used to evaluate the bonding strength of composite resin with restorations.[29] In a study by Kalra et al., it was reported that the minimum bonding strength value required for repair material could be 8-9 MPa depending on the chewing forces.[30] The findings of the current study showed sufficient bonding strength of the composites at room temperature and of those exposed to a pre-heating process. However, it must be taken into consideration that in-vitro studies are not able to fully simulate the biological structure of the intra-oral environment, chewing dynamics, and long-term use of restorations. Therefore, decreased bonding strength of repair systems can be observed over time. Although in-vitro studies do not fully reflect clinical conditions, the findings obtained provide estimations in respect of the performance of materials and the efficacy of treatment methods.[18]

A pre-heating procedure applied to composite resin can develop the physical and chemical properties of the material by increasing the degree of polymerisation of monomers and the cross-link density in the network structure.[31,32] By increasing the flowability of composite resin, heat treatment allows it to be used for adhesive purposes. Increased flowability facilitates adaptation by minimising the formation of air bubbles.[31,33] Compared to resin cements, these materials offer the advantages of high mechanical performance, greater colour possibilities, high filling content, and low polymerisation shrinkage and marginal shrinkage.[34] However, a disadvantage of this material is heat loss after heat processing. The drop in temperature shows variability among composite resin types.[35] Due to the rapid cooling after pre-heating, composite resin must be applied as quickly as possible. Daronch et al. showed that approximately 50% of the

temperature reached is lost within 120 seconds and 90% within 300 seconds after removal from the heating device.[36,37] Therefore, to minimise heat loss in the current study, care was taken not to exceed an application time of 40 secs for the composite resins treated in the device.[38]

Grangeiro et al. evaluated the bonding strength before and after the ageing of flowable composite, resin cement and heated composite on feldspathic ceramic and Vita Enamic ceramic blocks, and reported that the bonding value of the composite that had undergone a pre-heating process was higher than that of the two ceramic groups.[39] According to the current study, the reason that different results were obtained was thought to be that the bonding strength was affected by polymerisation shrinkage due to the inorganic filler content of the materials.[40,41]

In a study evaluating the bonding strength of lithium disilicate, Shahin et al. reported similar results obtained from pre-heating treated composite resin, resin cement, and flowable composite resin.[42] Bonding strength shows variabilty depending on the ceramic and resin used and the surface processing.[43]

While no statistically significant difference was formed in Group VE and Group VB, a statistically significant difference was observed in Group VS in the current study. Sato et al. stated that because of the zirconia-supplemented lithium silicate structure of Suprinity, the limited response to roughening with acid and silanisation processes could be due to factors such as resistance of the crystal phase to chemical bonding.[24]

In a systematic examination by Patussi et al., the clinical and laboratory success of composite resins treated with pre-heating was seen to be due to variables such as the resin composition, and the temperature and duration of the heating. The differences seen in pre-heating protocols used in studies prevents the identification of a standard and valid method.[43]

From a screening of the literature it can be seen that there is a limited number of studies that have used pre-heating processed composite resins in the repair of sub-structure materials. It is therefore difficult to make comparisons with similar studies. That the current study specimens were not exposed to thermal and mechanical ageing in terms of simulating the oral environment can be seen as a limitation of the study. Nevertheless, it is thought that supporting in-vitro studies by making the material and method of the study more comprehensive or making the follow-up in in-vivo conditions, this study could be of guidance for future planned studies.

Conclusions

From the findings of this study it can be concluded that the pre-heating process did not increase bonding strength. Composite resin applied with the pre-heating process reduced the bonding strength of Vitra Suprinity material, and increased it for Feldspathic and Vita Enamic ceramics. It can be said that the application of a pre-heating process can change the results depending on the sub-structure material used.

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None.

Conflicts of Interest Statement

There are no conflicts of interest related to the study.

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