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Effect of Different Composite Resin Types on the Repair Strength of Resin Matrix Ceramics: An in Vitro Study

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ABSTRACT

Aim: The aim of this study is to investigate the effect of different composite resins and surface treatments on the repair strength of a resin matrix ceramic.

Material and Methods: Sixty resin matrix ceramic samples were divided into three main groups based on the surface treatments (Diamond bur roughening, hydrofluoric acid roughening, no surface treatment). Each main group was further divided into two subgroups depending on the type of composite resin (Nanoceramic and nanohybrid composite resins) bonded. Shear bond strength testing was performed for all groups at a 0.5 mm/min approach speed after thermal ageing. For all statistical comparisons in the study, $p<0.05$ was the level of statistical significance.

Results: The results showed that the highest shear bond strength was obtained in the group that underwent hydrofluoric acid surface treatment and was bonded with nanoceramic composite (18.17±4.48 MPa). On the other hand, the lowest shear bond strength was observed in the nanohybrid group (3.64±0.9 MPa), which did not undergo any surface treatment. The group that underwent hydrofluoric acid roughening showed significantly higher shear bond strength than those without surface treatment and those roughened with a diamond bur. Additionally, the nanoceramic-bonded groups had significantly higher shear bond strength than the nanohybrid-bonded groups.

Conclusions: Based on these findings, it can be concluded that resin matrix ceramics that are treated with hydrofluoric acid and bonded with nanoceramic provide better repair strength.

Farklı Kompozit Rezin Türlerinin Rezin Matriks Seramiklerin Tamir Dayanımı Üzerine Etkisinin Değerlendirilmesi

Makale Bilgisi

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Makaslama dayanımı.

ÖZET

Amaç: Bu çalışmanın amacı, farklı kompozit rezinlerin ve yüzey işlemlerinin rezin matriks seramiğin tamir dayanımı üzerindeki etkisini araştırmaktadır.

Gereç ve Yöntemler: Altmış rezin matriks seramik örneği yüzey işlemlerine göre üç ana gruba ayrıldı (Elmas frezle pürüzlendirme, hidroflorik asitle pürüzlendirme, yüzey işlemi yok). Her ana grup ise bağlanan kompozit rezin tipine (Nanoseramik ve nanohibrit kompozit rezinler) bağlı olarak iki alt gruba ayrılmıştır. Termal yaşlandırma sonrasında tüm gruplara için 0,5 mm/dk yaklaşım hızında makaslama bağlanma dayanımı testi gerçekleştirilmiştir. Çalışmadaki tüm istatistiksel karşılaştırmalar için anlamlılık düzeyi $p<0.05$ olarak belirlenmiştir.

Bulgular: En yüksek makaslama bağlanma dayanımının hidroflorik asit yüzey işlemi uygulanan ve nanoseramik kompozit ile bağlanan grupta elde edilmiştir (18,17±4,48 MPa). Öte yandan, en düşük makaslama bağlanma dayanımı ise herhangi bir yüzey işlemi uygulanmayan nanohibrit grubunda (3,64±0,9 MPa) gözlenmiştir. Hidroflorik asitle pürüzlendirme yapılan grup, yüzey işlemi yapılmayanlara ve elmas frezle pürüzlendirilenlere göre istatistiksel olarak anlamlı dercede daha yüksek makaslama bağlanma mukavemeti göstermiştir. Ek olarak, nanoseramik bağlı gruplar nanohibrit bağlı gruplara göre istatistiksel olarak anlamlı ölçüde daha yüksek makaslama bağlanma dayanımına sahiptir.

Sonuçlar: Bu bulgulara dayanarak, hidroflorik asit ile yüzey işlemi uygulanan ve nanoseramik kompozit rezin bağlanan rezin matriks seramiklerin daha iyi onarım gücü sağladığı sonucuna varılabilir.

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INTRODUCTION

Dental ceramics are frequently employed in dentistry for their mechanical and aesthetic aspects.[1] According to the current classification, ceramic restorative materials can be categorized into glass matrix, polycrystalline, and resin matrix ceramics, depending on their chemical structure.[2,3]

Combining the advantages of ceramics and composites, resin matrix ceramics are easier to machine due to their soft matrix structure and have better physical and mechanical properties than direct composites. They can also successfully mimic the physical properties of natural teeth and can be repaired intraorally. Dental materials experience continuous stress in the oral environment due to masticatory forces, temperature changes, and variations in saliva pH. Ceramic restorative materials are particularly vulnerable to fatigue and fracture due to their low tensile strength and high modulus of elasticity. Although dental materials with high stiffness exhibit durable mechanical properties, they are more prone to fracturing under masticatory forces. Intraoral repairs of defective restorations with composite resins are widely used in clinical practice because this method is more advantageous in terms of time, cost, and preservation of dental tissue.[4-6] Dental composites have come a long way over the last five decades with significant developments. They are classified under several headings, such as filler size distribution, filler content, or composition.[7,8] As a result of nanotechnological developments in dentistry, nanohybrid composite resins containing nanoscale fillers are being produced.[9,10] The nano-sized clustered agglomerate fillers of nanohybrid composite resins give them superior mechanical and optical characteristics.[11] Nanoceramic composites are another type of composite resin produced thanks to nanotechnology developments. This resin contains methacrylate-modified, silicon dioxide–containing nanofiller, chemically similar to glass or ceramics.[12-14] While the literature assessing the repair strength of resin matrix ceramics often concentrates on surface preparation and the ceramic material type, there is limited research on the consequences of differing composite resin types. This research analysed the shear bond strength (SBS) of nanohybrid composite resins compared to resin matrix ceramics after undergoing different surface treatments. The null hypotheses were that the surface treatments could not affect the SBS between nanohybrid composite resins and resin matrix ceramics and that the type of composite resins could not vary the SBS.

MATERIAL and METHODS

All materials used in this study are given in Table 1, and the schematic diagram of the study is given in Figure 1.

Preparation of specimens

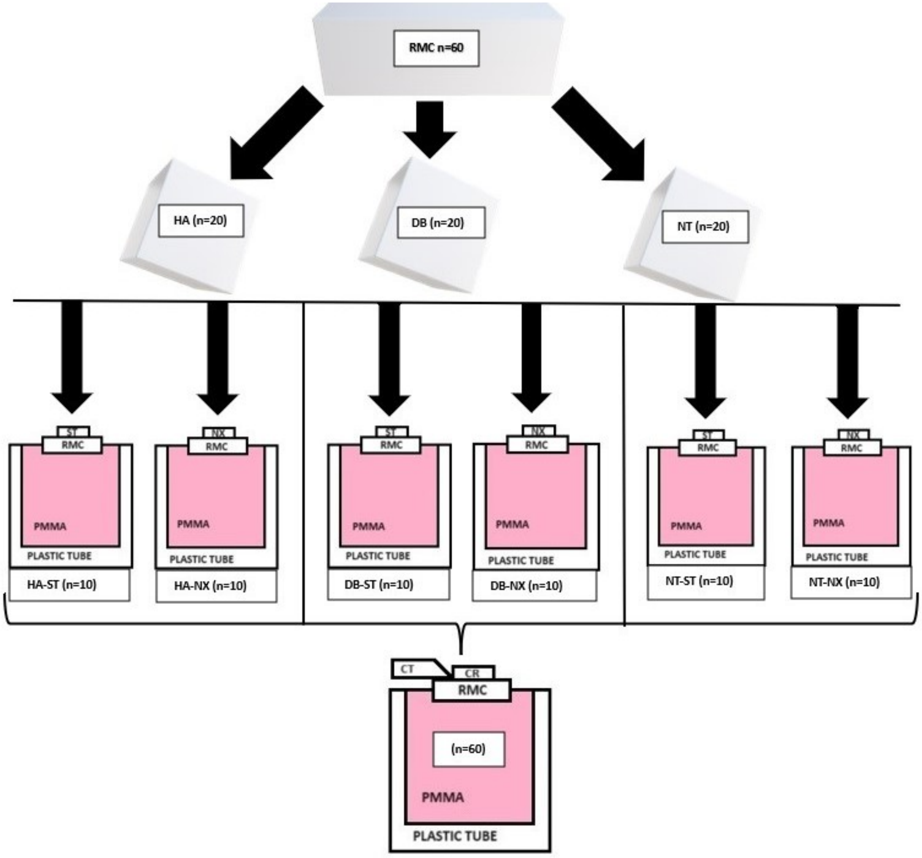
A total of 60 specimens with a size of 10x10x2 mm were obtained from a resin matrix ceramic block (VITA ENAMIC; VITA Zahnfabrik) with a size of 12x14x18 mm using a water-cooled diamond blade (Diamond Cutting Disc; Dimos-M) and a low-speed saw (Micro Cut 125; Metkon). The specimens' surfaces were standardized using silicon carbide papers (Wurth Industry Products) with grids of 80, 180, 600, 800, and 1200. The prepared samples were kept in an ultrasonic cleaner (VEVOR) at 25°C for 10 min and dried with air. The specimens were divided into three groups (n=20 per group): roughened with 9% hydrofloric acid, Porcelain etch; Ultradent Products), roughened with a diamond bur (MDT; Micro Diamond Technologies) and no treatment control group. Each group was then divided into two subgroups (n=10 per group), bonded with nanoceramic (Spektra ST HV; Dentsply Sirona) and bonded with nanohybrid composite resins (Nexcomp; META-BİOMED).

Table 1: Materials used in the study

Material	Chemical Content	Brand-Manufacturer, Country
RMC Blocks	Feldspar ceramic network: 86 wt% (58–63% SiO_2, 20–23% Al_2O_3, 6–11% Na_2O, 4–6% K_2O, 0.5–2% B_2O_3, < 1% CaO, < 1%TiO_2) Polymer network: Methacrylate polymer (14wt%)	VITA ENAMIC- VITA Zahnfabrik, Germany
Nanoceramic composite resin	Matrix: Methacrylic modified polysiloxane nanoparticles, dimethacrylate resin, ethyl-4-(dimethylamino)benzoat Filler: Spherical, pre-polymerized SphereTEC fillers (particle size ≈ 15 µm), non-agglomerated barium glass, CQ 1 , ytterbium fluoride (78–80 wt%)	SpektraST HV- Dentsply Sirona, Germany
Nanohybrid composite resin	Matrix: Bis-GMA(bisphenol A-glycidyl methacrylate), UDMA(urethane di-methacrylate), Bis-EMA (ethoxylated bisphenol A glycol dimethacrylate), TEGDMA (Triethyleneglycol dimethacrylate) borosilicate. Fillers: Barium aluminum boro silicate (75% wt)	Nexcomp- META-BİOMED, Germany
HA	9% Hydrofluoric acid	Porcelain Etch- Ultradent Products, USA
DB	Diamond particles	MDT- Micro Diamond Technologies, Israel
Silane coupling agent	Isopropyl alcohol, silane	Porcelain silane- Ultradent Products, USA
Adhesive agent	Oligomeric methacrylates, HEMA, camphorquinone	C-Bond WP Dental, Germany

RMC: Resin Matrix Ceramic, HA: Hydrofluoric Acid, DB: Diamond Bur

Figure 1: The schematic diagram of the study. RMC: Resin Matrix Ceramic, HA: Hydrofluoric Acid, DB: Diamond Bur, NT: No Treatment, ST: Nanoceramic composite resin, NX: Nanohybrid composite resin, PMMA: Polymethylmethacrylate, CT: Chisel Tangent. NT-ST(No treatment applied and nanoceramic composite resin bonded), NT-NX(No treatment applied and nanohybrid resin bonded), DB-ST(Roughened with diamond bur and nanoceramic composite resin bonded), DB-NX(Roughened with diamond bur and nanohybrid composite resin bonded), HA-ST(Roughened with hydrofluoric acid and nanoceramic composite resin bonded), HA-NX(Roughened with hydrofluoric acid and nanohybrid composite resin bonded)



Roughening of surfaces and repairing with composite resins

Diamond bur roughening was performed by contacting the entire surface of the blue belt diamond bur with the specimens for 10 seconds under water cooling. Once the surface roughening was complete, a silane coupling agent (porcelain silane; Ultradent Products) was applied to the surface of the specimens for 60 seconds. An adhesive agent (C-Bond; WP Dental) was applied to the samples for 10 seconds, followed by light polymerization for 20 seconds. Half of the samples (n=10) were bonded with nanoceramic, and the other half (n=10) with nanohybrid composite resin using a 4mm diameter x 2mm height mould made of plastic pipe and polymerised with light for 20 seconds. The hydrofluoric acid roughening process was carried out by the application of 9% hydrofluoric acid for 60 seconds, followed by the air-water spray washing and drying process; the silane bonding agent, adhesive agent, and composite resin bonding applications were carried out using the same protocol as the diamond bur roughened group. Similar silane, adhesive, and composite resin applications in the control group were carried out with other groups without any surface roughening process.

Surface roughness measurements

For the surface roughness measurement, the profilometer was calibrated with a reference calibration block with a Ra value of 6.0 µm and adjusted to 0.1 mm/s with a diamond tip with a radius of 10 µm. Measurements were then taken in the exact directions at three different points on three samples from each group. The three different measurements of each sample were averaged, and the Ra values were recorded by calculating the average of three samples from each group.

Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) investigation

SEM and EDS investigated the microstructures of the hydrofluoric acid and diamond bur etched ceramic surfaces and the composite resin-ceramic interface with 500 and 3000X magnification.

Thermal ageing and shear bond strength test

The bonded specimens were then subjected to thermocycling (5500 cycles, between 5 and 55^{o}C, 20s dwell time). Samples were fixed to the autopolymerising acrylic resin in plastic tubes and placed in the universal tester (Mod-dental, Ankara). Then, the ceramic and composite resin interface was loaded in shear using a knife-edged chisel tangent to the tooth surface at a cross-head speed of 0.5 mm/min. The test was stopped automatically when the separation occurred, and the computer calculated the results in MPa. The failures were examined with a camera (Canon EOS 1000D) connected to a stereomicroscope (Stemi 305; Carl Zeiss Microscopy GmbH) at X15 magnification.

Evaluation of the failures

Failures in which the composite resin separated from the RMC were considered an adhesive failure, ruptures of the composite resin or resin matrix ceramic were considered a cohesive failure, and these two conditions were seen together as a mixed failure.

Statistical analyses

Statistical analyses were performed using SPSS version 22.0 for Windows (IBM Corp). Descriptive statistics of the continuous variables included in the study were presented as means and standard deviations. Two-way ANOVA was used to show the effect of different surface treatments and composite resin types. Bonferroni's post hoc test was used for pairwise comparisons when the ANOVA test was significant. The Kruskal-Wallis test compared SBS between surface treatment groups within a composite resin type. Independent samples t-test and Mann-Whitney U test were used to compare SBS between composite resin groups within a surface treatment type. For all statistical comparisons in the study, $p<0.05$ was the level of statistical significance.

RESULTS

Shear bond strength results

The mean and standard deviation of SBS (MPa) for each group and statistical analyses are shown in Table 2. To evaluate the effect of the composite resin type on the bond strength in the groups where the same kind of surface treatment was applied, the bond strengths of the specimens belonging to the no-treatment and diamond bur groups were examined by the Mann-Whitney U-test. Independent samples t-test was used to investigate the hydrofluoric acid roughened groups. The SBS of the nanoceramic composite resin bonded group (6.95±2.15 MPa) was significantly higher than that of the nanohybrid composite resin (3.64±0.90 MPa) in the no surface treatment group ($p<0.05$). The bond strength of the nanoceramic composites bonded group in the diamond bur roughened group (9.43±3.74 Mpa) was also significantly higher ($p<0.05$) than that of nanohybrids (5.40±1.30 Mpa). In contrast, in the hydrofluoric acid roughened group, the bond strength of the nanoceramic composite bonded group (18.17±4.48 Mpa) was higher than that of nanohybrid composite resins (815.94±4.78 Mpa). However, the difference was not statistically significant ($p>0.05$). The Kruskall-Wallis test was used to evaluate the effect of surface treatments on bond strength in groups bonded with the same type of composite resin. In both composite resin groups, the SBS after hydrofluoric acid roughening was statistically significantly higher than the diamond bur and no treatment groups ($p<0.05$). In both composite resin groups, the SBS of the diamond bur group was higher than that of the none-treatment group, but the difference was not statistically significant. ($p>0.05$).

Two-way ANOVA showed no statistically significant interaction between surface treatment and resin type ($p = 0.683$). However, each surface treatment ($p<0.001$) and resin type ($p<0.001$) had a statistically significant effect on SBS. When comparing the surface treatments, according to the Benforroni test, the SBS of the hydrofluoric acid roughened group (17.05±4.65 MPa) was significantly higher than that of the no treatment (5.29±2.34 MPa) and the diamond bur roughened group (7.41±3.42 MPa) ($p<0.05$). The difference between the none treatment and the diamond burr group was not significant ($p>0.05$). In addition, the surface preparation parameter had a large effect size (ηp2=0.73). When comparing the composite resin types, the nanoceramic composite resin bonded group (11.52±5.99 MPa) showed statistically significantly higher SBS values than the nanohybrid composite resin (8.32±6.19 MPa) bonded group ($p<0.05$) according to the Benforroni test. The composite resin type parameter had a moderate effect size ($\eta p^2=0.20$) (Table 3).

Table 2: Mean±SD of the SBS (MPa) for each group and statistical analyses

Composite resin	Surface treatment		
	NT	DB	HA
ST	6.95±2.15$^{A\,a\,*}$	9.43±3.74$^{A\,a\,*}$	18.17±4.48$^{B\,a\,**}$
NX	3.64±0.90$^{A\,b\,*}$	5.40±1.30$^{A\,a\,*}$	15.94±4.78$^{B\,a\,**}$

Mean values represented with same superscript lowercase letter (column) are not significantly different according to independent samples t-test and Mann Whitney U-test($p>0,05$). Mean values represented with different superscript uppercase letter (row) are significantly different according to Kruskal-Wallis test ($p<0,05$). HA:Hydrofluoric Acid, DB:Diamond Bur, NT: No Treatment, ST:Nanoceramic composite resin, NX:Nanohybrid composite resin. * Mann Whitney U-test, ** Independent samples t-test.

Table 3: Bonferroni's post hoc tests for pairwise comparisons after Two-Way Anova

	Mean±SD (MPa)	n
Surface Treatment		
NT	5.29^a±2.34	20
DB	7.41^a±3.42	20
HA	17.05^b±4.65	20
Composite resin		
ST	11.52^c±5.99	30
NX	8.32^d±6.19	30

Different letters indicate significant differences (p<0,05). HA:Hydrofluoric Acid, DB:Diamond Bur, NT: No Treatment, ST:Nanoceramic composite resin, NX:Nanohybrid composite resin. SD: Standard Deviation

Surface roughness results

The Ra values of three samples from each group were averaged, and the surface roughness values were found to be 0.74±0.11µm for the no treatment group, 4.82±0.62µm for the diamond bur roughened group, and 1.22±0.21µm for the hydrofluoric acid roughened group. According to the Kruskal-Wallis test, there was a statistically significant difference between the NT and DB groups (p=0.02).

SEM and EDS results

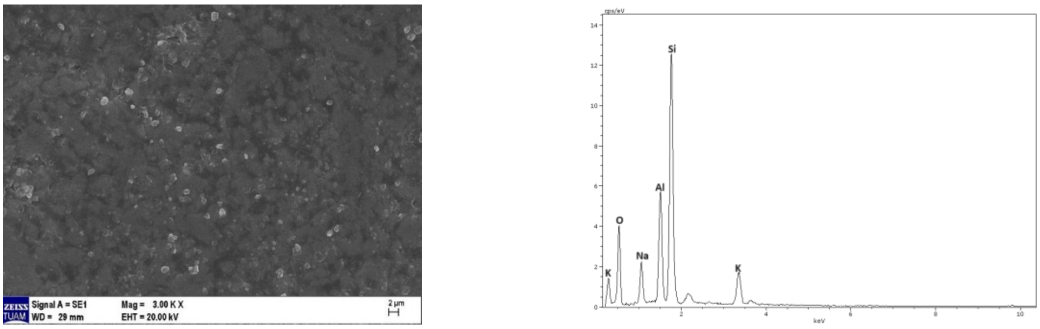
The SEM images of the samples with different surface treatments are shown in Figure 2. It was found that both hydrofluoric acid and diamond bur roughening significantly altered the ceramic surface topography compared to the control group, and it was also observed that hydrofluoric acid produced more microporosity on the ceramic surface compared to diamond bur. The results of an EDS analysis showed that the distribution of elements was similar in the samples belonging to diamond bur and none treatment groups. However, in the sample belonging to the hydrofluoric acid group, it was found that the signals related to the elements O, Al, K, Si, and Na decreased compared to the samples belonging to the other groups. In addition, element C was not found in the samples of the diamond bur group and no treatment but was detected in the sample of the hydrofluoric acid group at a level of about 38% by weight (Table 4).

Table 4: Elemental distribution on RMC surfaces after different surface treatments

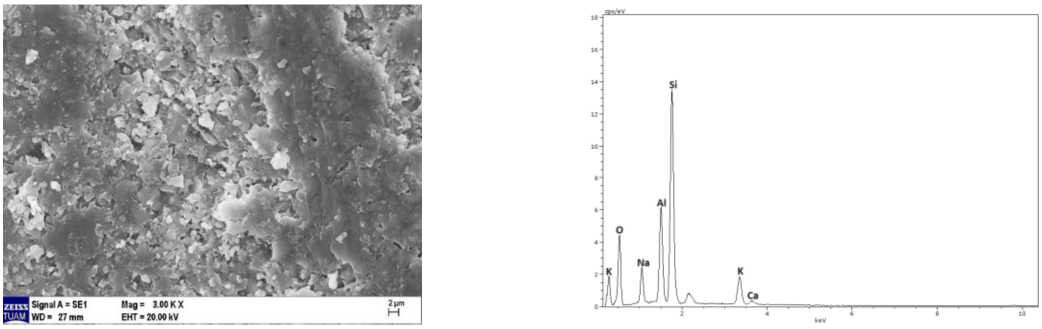
	Surface treatments		
Elements	**NT**	**DB**	**HA**
Oxygen	51.16	51.74	40.09
Potassium	4.80	4.97	2.62
Aluminium	10.99	10.71	4.25
Silicon	26.94	26.08	12.09
Sodium	6.11	6.11	2.36
Carbon	-	-	38.01
Calcium	-	0.39	0.58

HA:Hydrofluoric Acid, DB:Diamond Bur, NT: No Treatment

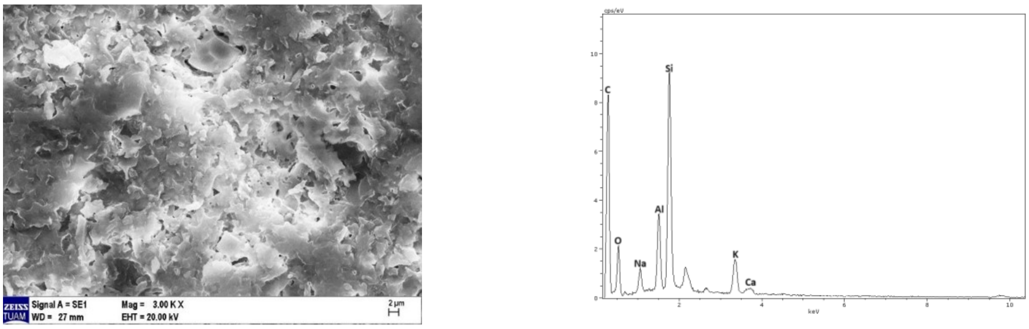
Figure 2: SEM images and EDS analysis of RMC samples after different surface treatments. HA: Hydrofluoric Acid, DB: Diamond Bur, NT: No Treatment



NT



DB



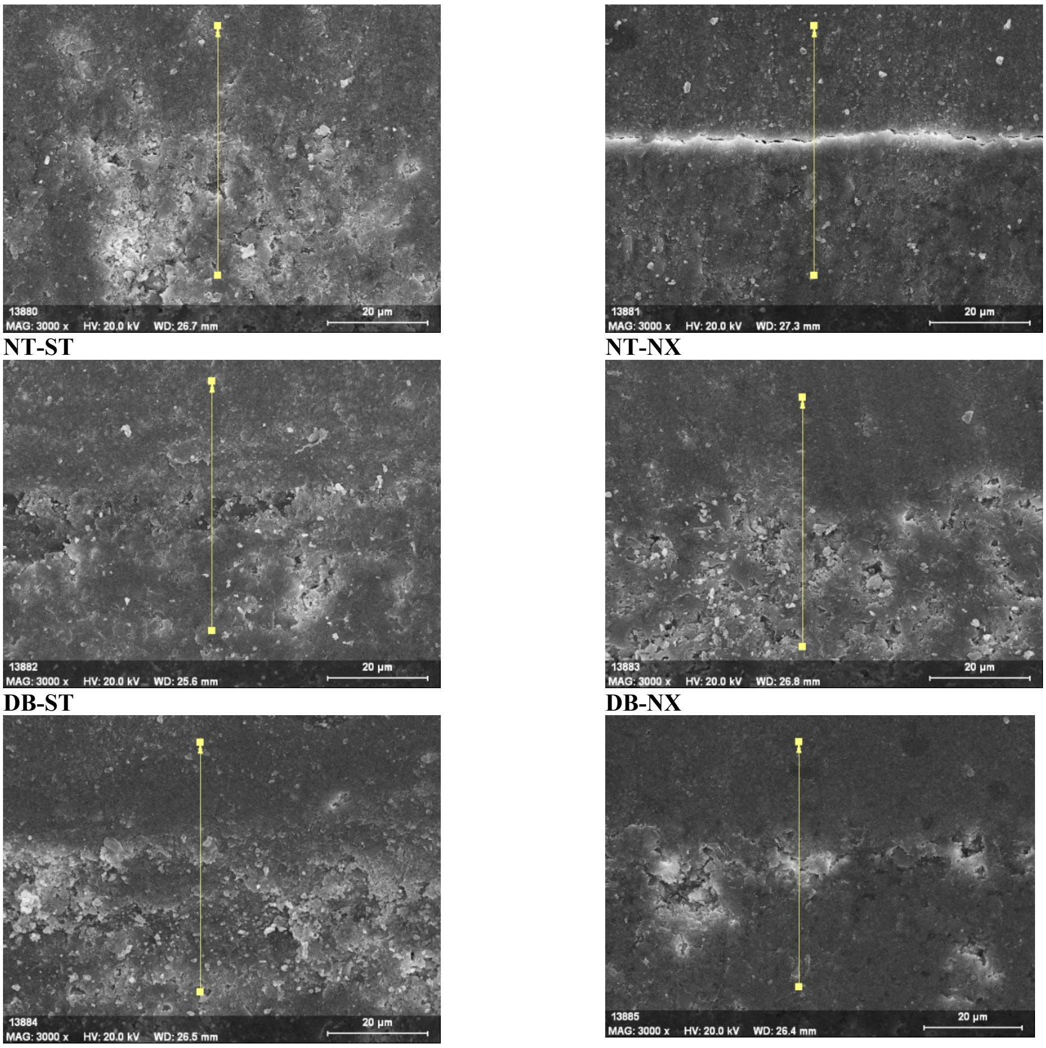
HA

The scanning electron microscopy images and energy dispersive spectroscopy analyses of the ceramic and composite resin interface are shown in Figures 3 and 4. The interfacial layers of the samples belonging to all groups were around 10±2 µm. The scanning electron microscopy images and energy dispersive spectroscopy analyses showed that the signals due to the elements Si, Al, K, and Na decreased through the ceramic towards the composite resin side, and the signals due to the element Ti increased. At the same time, O and Ca remained at similar intensities on both the composite resin and resin matrix ceramic sides. While a decrease in the density of the elements Si, Al, O, Na, and K was observed in the interface regions, it was found that the element K reached its highest density at the interface in the sample belonging to the hydrofluoric acid roughened and nanoceramic composite resin bonded group. In addition, element F was not found in the samples belonging to the other groups. In contrast, the low density of element F was detected in the sample belonging to the hydrofluoric acid roughened and nanoceramic composite resin bonded group throughout the entire cross-section.

Failure types

When the types of failure were evaluated, adhesive failure was the most common type of failure, while cohesive failure was not observed. The rate of mixed failure was higher in the hydrofluoric acid roughened specimens (Table 5).

Figure 3: SEM images of RMC to CR interfaces sectioned at 90° across to the plane of the interface with 3000X magnification. The direction of the yellow arrow is from the RMC side to the CR side. NT-ST (No treatment applied and nanoceramic composite resin bonded), NT-NX(No treatment applied and nanohybrid resin bonded), DB-ST(Roughened with diamond bur and nanoceramic composite resin bonded), DB-NX(Roughened with diamond bur and nanohybrid composite resin bonded), HA-ST(Roughened with hydrofluoric acid and nanoceramic composite resin bonded), HA-NX(Roughened with hydrofluoric acid and nanohybrid composite resin bonded)



NT-ST **NT-NX**

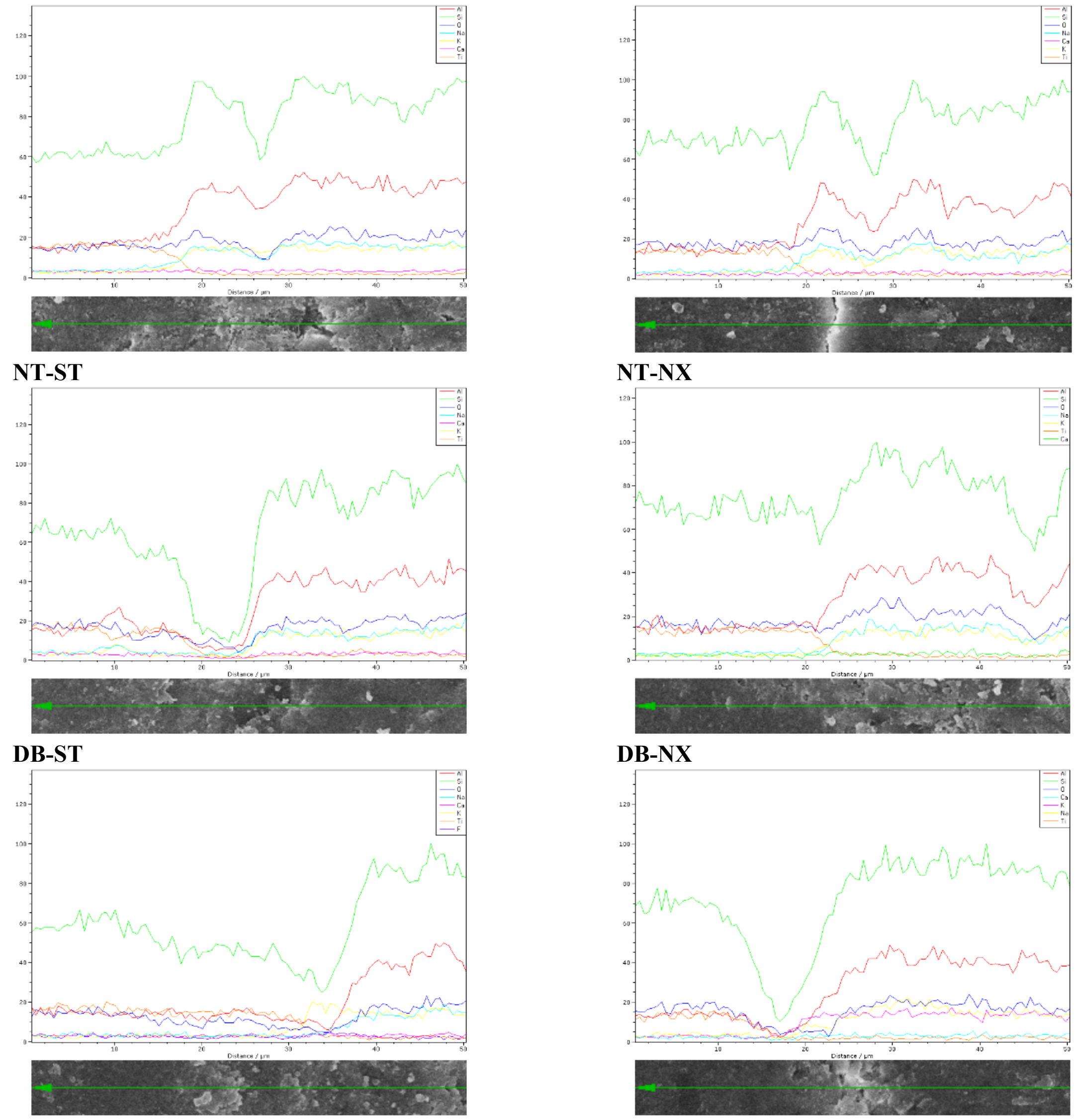
DB-ST **DB-NX**

HA-ST **HA-NX**

Table 5: Distribution of failure types among groups

	Types of failure %		
Groups	**Adhesive**	**Cohesive**	**Mixed**
NT-ST	100	-	-
NT-NX	100	-	-
DB-ST	100	-	-
DB-DX	90	-	10
HA-ST	30	-	70
HA-NX	40	-	60

NT-ST(No treatment applied and nanoceramic composite resin bonded),NT-NX(No treatment applied and nanohybrid composite resin bonded), DB-ST(Roughened with diamond bur and nanoceramic composite resin bonded), DB-NX (Roughened with diamond bur and nanohybrid composite resin bonded), HA-ST(Roughened with hydrofluoric acid and nanoceramic composite resin bonded), HA-NX(Roughened with hydrofluoric acid and nanohybrid composite resin bonded).



NT-ST **NT-NX**

DB-ST **DB-NX**

HA-ST **HA-NX**

Figure 4: The concentration (wt.%) profiles of major elements of RMC to CR interfaces sectioned at 90° across the plane of the interface with 3000X magnification. The direction of the green arrow is from the RMC side to the CR side. NT-ST(No treatment applied and nanoceramic composite resin bonded), NT-NX(No treatment applied and nanohybrid resin bonded), DB-ST(Roughened with diamond bur and nanoceramic composite resin bonded), DB-NX(Roughened with diamond bur and nanohybrid composite resin bonded), HA-ST(Roughened with hydrofluoric acid and nanoceramic composite resin bonded), HA-NX(Roughened with hydrofluoric acid and nanohybrid composite resin bonded).

DISCUSSION

This study evaluated the SBS of resin matrix ceramics with different types of nanohybrid composite resin after different surface treatments. It was concluded that the SBS showed significant differences in the groups with different types of surface treatments or nanoceramic composite resin. Therefore, the null hypothesis were rejected.

Many reports in the literature show that resin matrix ceramics can be repaired with composite resins after various surface treatments. As a result of these surface preparation processes, chemical retention, micromechanical retention, or a combination of both can be used to achieve long-term adhesion.[15-19] Micromechanical adhesion is achieved by roughening the surface with aluminium oxide particles and etching or grinding with hydrofluoric acid or other acidic compounds. At the same time, silane provides chemical adhesion by forming a siloxane bond with the ceramic surface.[20] This study used diamond bur roughening and hydrofluoric acid etching with silane coupling and bonding agents to provide micromechanical and chemical bonding.

One of the methods used to create retention on the repaired ceramic surface is diamond bur roughening, which has the advantages of simplicity and low cost; another method is hydrofluoric acid etching.[21] Bello et al. concluded that resin matrix ceramics could be repaired with composite resins by sandblasting or acid roughening followed by silane application.[22] Compos et al. reported that the bond strength between resin cement and resin matrix ceramics increased with the application of hydrofluoric acid.[23] Wolf et al. reported that Al_2O_3 sandblasting or diamond bur roughening provides a satisfactory bond strength between ceramic and composite resins, but in cases where a higher bond strength is desired, surface roughening with hydrofluoric acid is a more effective step in achieving composite resin-ceramic bonding due to the deeper penetration of the acid.[24] Chen et al. concluded that air abrasion of the porcelain surface is not necessary when acid etching is used as the surface preparation process, as a result of their study on the bond strength between composite resin and ceramics.[25] Schmage et al. reported that the bond strength of samples prepared with hydrofluoric acid was higher than those prepared with a diamond bur.[26] As a result of their study, Neis et al. concluded that the surface preparation process of lithium disilicate-reinforced ceramics and feldspathic ceramics with hydrofluoric acid provides higher bond strength than surface treatment with a diamond bur.[27] This study showed that the hydrofluoric acid-treated groups had significantly higher bond strength values than the diamond bur-treated groups. In addition, the diamond bur-roughened specimens had a higher SBS than the none-treatment group, but this difference was not statistically significant. Hydrofluoric acid removes some of the glass matrices and dissolves the polymer, creating micropores and microchannels.[28] The ceramics used in this study consist of a feldspar ceramic network (86 wt%) fully integrated with a polymeric network (14 wt%), and hydrofluoric acid interacts with this polymeric matrix, disrupting the organic matrix and exposing the carbon chain.[29,30] The EDX results confirm this situation; approximately 38% of carbon elements were found on the resin matrix ceramic surface roughened with hydrofluoric acid, while no carbon atoms were found in the samples belonging to other groups. The high bond strength between ceramic and composite resin in the hydrofluoric acid roughened group may be due to the micropores and microchannels created by the hydrofluoric acid dissolving the polymer matrix in the resin matrix ceramic. In the SEM image of the hydrofluoric acid roughened group sample, it can be seen that more microporous structures are formed compared to the samples in the other groups. This high bond strength may be due to the carbon chain-containing polymer structure of the resin matrix ceramic. Furthermore, although the surface roughness of the hydrofluoric acid roughened group was considerably lower than that of the diamond bur roughened group, the high bond strength of the hydrofluoric acid roughened specimens suggests that a more potent chemical bond rather than a physical bond between the composite resin and the ceramic is responsible for the high bond strength.

The restorative component is also crucial in ceramic and metal repair.[31] Although many studies in the literature evaluating bond strength between ceramics and composite resin focus on different surface treatments or ceramic types, studies evaluating the effect of composite resin type are limited. This study investigated the bond strength of two composite resins with resin matrix ceramics and concluded that nanoceramic composite resin exhibited significantly higher bond strength. The matrix part of the nanohybrid composite resin used in this study consists of ethoxylated BISGMA, BISGMA, and UDMA, while the filler part consists of barium aluminium borosilicate.[32] On the other hand, nanoceramic composite contains methacrylate-modified, silicon dioxide–containing nanofiller and resin matrix that is replaced by a matrix full of highly dispersed methacrylate-modified polysiloxane particles, which are chemically similar to ceramics.[13,14] The high bond strength in the nanoceramic composite bonded group may be due to the similar content with dental ceramics.

The nanoceramic composite resin used in this investigation is a high-viscosity dental composite resin with SphereTEC filler technology consisting of spherical pre-polymerized particles of sub-micron glass particles ranging in size from 0.1 to 3.0 µm.[14] Due to their specific morphology, SphereTEC fillers give composite resin unique properties and reduce internal friction under shear stress. This is achieved by the blocked interlocking of the filler particles, and therefore, composite resin has excellent sculptability with hand tools. At the same time, the combination of SphereTEC® fillers with irregularly shaped submicron particles gives the composite resin a slump resistance property when left unagitated.[14]Another reason for the high SBS of the nanoceramic bonded group may be that SphereTEC fillers impart excellent sculptability to composite resin, resulting in better adaptation to the resin matrix ceramic surface. Ozdemir and Yanikoglu investigated the bond strength between different composite resins and feldspathic ceramics after different surface treatments. In contrast to this present study, they obtained lower bond strength in samples bonded with nanoceramic composite. This may be because the ceramics tested for repair strength have different chemical content.[33]

Ageing methods such as thermal cycling and water immersion often predict the long-term clinical behaviour of materials bonded together under in vitro conditions.[34] The ISO TR 11450 (1994) standard states that thermal cycling at 5-55°C for 500 cycles is appropriate. The shear bond test, frequently used to measure bond strength, is an in-vitro test method in which a force is applied to the joint area at a specific rate until separation occurs between two bonded materials. SBS is calculated by dividing the maximum force applied by the connection area.[35,36] In this present study, bonded specimens were thermocycled (5500, 5–55ºC, dwell time: 20s) and SBS test was applied to them (approach speed of 0.5 mm/min.) to predict long-term clinical behaviour. The mean SBS for the nanoceramic composite bonded group was 11.52 MPa, which was 8.32 MPa for the nanohybrid. Also, hydrofluoric acid roughened groups were shown at 17.05 MPa SBS value and 7.41 MPa for diamond bur roughened groups. As a minimum value for acceptable clinical bonding, a limit of 10-13 MPa is suggested.[35] The nano ceramic bonded and hydrofluoric acid roughened groups exhibited clinically acceptable bond strengths in this context.

CONCLUSION

This study aimed to investigate the impact of various composite resins on the strength of repairing resin matrix ceramics under two different surface treatments. The results show that in clinical applications, nanoceramic-based composites, after surface treatment with hydrofluoric acid, can produce acceptable clinical results when used to repair resin matrix-based ceramics. Further research can be conducted using different surface treatments, composite resins, and test methods to expand upon these findings.

Ethical Approval

Since this study did not involve the use of human or animal subjects, ethical committee approval was not required.

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Conflict of Interest

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Author Contributions

Design: Öİ, ÖK, Data collection and processing: Öİ, Analysis and interpretation: Öİ, Literature review: Öİ, ÖK, Writing: Öİ.

REFERENCES

1. Alrabeah G, Shabib S, Almomen R, Alhedeithi N, Alotaibi S, Habib SR. Effect of home bleaching on the optical properties and surface roughness of novel aesthetic dental ceramics. Coatings. 2023;13:330.
2. Gracis S, Thompson VP, Ferencz JL, Silva NR, Bonfante EA. A new classification system for all-ceramic and ceramic-like restorative materials. Int J Prosthodont. 2015;28:227-35.
3. Benalcázar-Jalkh EB, Bergamo ETP, Campos TMB, et al. A narrative review on polycrystalline ceramics for dental applications and proposed update of a classification system. Materials (Basel). 2023;16:7541.
4. Arkoy S, Ulusoy M. Effect of Different Surface Treatments on Repair Bond Strength of CAD/CAM Resin-Matrix Ceramics. Materials (Basel, Switzerland). 2022;15:6314.
5. Zhu H, Jiang J, Wang Y, Wang S, He Y, He F. Additive manufacturing of dental ceramics in prosthodontics: The status quo and the future. *J Prosthodont Res*. 2024;68:380-399.
6. Gali S, Gururaja S, Karuveettil V, Janakiram C. Methodological approaches in graded dental ceramics: a scoping review protocol. *JBI Evid Synth*. 2024;22:1387-92. Published 2024 Jul 1.
7. Randolph LD, Palin WM, Leprince JG. Developing a More Appropriate Classification System for Modern Resin-Based Composite Technologies. In: Miletic V editor. Dental composite materials for direct restorations [Internet]. Switzerland: Springer International Publishing; 2018 [cited 2023 Sep 29]. Chapter 6. Available from: https://link.springer.com/book/10.1007/978-3-319-60961-4
8. Jaramillo-Cartagena R, López-Galeano EJ, Latorre-Correa F, Agudelo-Suárez AA. Effect of Polishing Systems on the Surface Roughness of Nano-Hybrid and Nano-Filling Composite Resins: A Systematic Review. Dent J (Basel). 2021;9:95.
9. Rastelli AN, Jacomassi DP, Faloni AP, Queiroz TP, Rojas SS, Bernardi MI, Bagnato VS, Hernandes AC. The filler content of the dental composite resins and their influence on different properties. Microsc Res Tech. 2012; 75:758-65.
10. Badr C, Spagnuolo G, Amenta F, Khairallah C, Mahdi SS, Daher E, Battineni G, Baba NZ, Zogheib T, Qasim SSB, Daher T, Chintalapudi N, Zogheib CM. A two-year comparative evaluation of clinical performance of a nanohybrid composite resin to a flowable composite resin. J Funct Biomater. 2021;12:51.
11. Karakaya İ , Cengiz E. Effect of 2 bleaching agents with a content of high concentrated hydrogen peroxide on stained 2 CAD/CAM blocks and a nanohybrid composite resin: An AFM evaluation. Biomed Res Int. 2017, 6347145.
12. Elsaka SE. Repair bond strength of resin composite to a novel CAD/CAM hybrid ceramic using different repair systems. Dent Mater J. 2015;34:161-7.
13. Güngör MB, Nemli SK, Bal BT, Ünver S, Doğan A. Effect of surface treatments on shear bond strength of resin composite bonded to CAD/CAM resin-ceramic

hybrid materials. J Adv Prosthodont. 2016;8:259-66.

14. Emsermann I, Eggmann F, Krastl G, Weiger R, Amato J. Influence of Pretreatment Methods on the Adhesion of Composite and Polymer Infiltrated Ceramic CAD-CAM Blocks. J Adhes Dent. 2019;21:433-43.

15. Bayazıt EÖ. Repair of aged polymer-based CAD/CAM ceramics treated with different bonding protocols. Int J Prosthodont. 2021;34:357-64.

16. Turkkal F, Culhaoglu AK, Sahin V. Composite-veneering of polyether-ether-ketone (PEEK): evaluating the effects of different surface modification methods on surface roughness, wettability, and bond strength. Lasers Med Sci. 2023;38:95.

17. Sattabanasuk V, Charnchairerk P, Punsukumtana L, Burrow MF. Effects of mechanical and chemical surface treatments on the resin-glass ceramic adhesion properties. Investig Clin Dent. 2017; 8: 10.1111/jicd.12220.

18. Leibrock A, Degenhart M, Rosentritt M, Handel G. In vitro study of the effect of thermo- and loading-cycling on the bond strenght of porcelain repair systems. J Oral Rehab. 1999;26:130-7.

19. Bello YD, Di Domenico MB, Magro LD, Lise MW, Corazza PH. Bond strength between composite repair and polymer-infiltrated ceramic-network material: Effect of different surface treatments. J Esthet Restor Dent. 2019;31:275-9.

20. Campos F, Almeida CS, Rippe MP, de Melo RM, Valandro LF, Bottino MA. Resin Bonding to a Hybrid Ceramic: Effects of Surface Treatments and Aging. Oper Dent. 2016;41:171-8.

21. Wolf DM, Powers JM, O'Keefe KL. Bond strength of composite to porcelain treated with new porcelain repair agents. Dent Mater. 1992;8:158-61.

22. Chen JH, Matsumura H, Atsuta M. Effect of different etching periods on the bond strength of a composite resin to a machinable porcelain. J Dent. 1998;26:53-8.

23. Schmage P, Nergiz I, Herrmann W, Ozcan M. Influence of various surface-conditioning methods on the bond strength of metal brackets to ceramic surfaces. Am J Orthod Dentofacial Orthop. 2003;123:540-6.

24. Neis CA, Albuquerque NL, Albuquerque Ide S, et al. Surface treatments for repair of feldspathic, leucite - and lithium disilicate-reinforced glass ceramics using composite resin. Braz Dent J. 2015;26:152-5.

25. Duarte S, Sartori N, Phark JH. Ceramic-reinforced polymers: CAD/CAM hybrid restorative materials. Curr Oral Health Rep. 2016;37:32-48.

26. Vita Enamic Concept Brochure [Internet] [cited 2023 Sep 29] Available from: https://www.vita-zahnfabrik.com/en/VITA-ENAMIC-24970.html

27. Porto TS, Medeiros da Silva IG, de Freitas Vallerini B, Fernando de Goes M. Different surface treatment strategies on etchable CAD-CAM materials: Part II-Effect on the bond strength. J Prosthet Dent. 2022 Jan 28:S0022-3913(21)00580-1. Epub ahead of print. PMID: 35101273.

28. Jain S, Parkash H, Gupta S, Bhargava A. To evaluate the effect of various surface treatments on the shear bond strength of three different intraoral ceramic repair systems: an in vitro study. J Indian Prosthodont Soc. 2013;13:315-20. Epub 2013 Mar 14. PMID: 24431753; PMCID: PMC3732709.

29. Nexcomp Composite Material Safety Data Sheet. [Internet] [cited 2023 Sep 29] Available from:https://www.meta-biomed.com/download/dental/Nexcomp_(MSDS)_R1(20161109).pdf

30. Kleinvogel L, Wemken G, Reidelbach C, Garcia-Käufer M, Vach K, Hellwig E, Spies BC, Polydorou, O. (2023). Method development for the intraoral release of nanoparticles from dental restorative materials. Dent Mater. 2023;39:693.

31. Spectra ST Scientific Manual. [Internet] [cited 2023 Sep 29] Available from: https://assets.dentsplysirona.com/flagshi

p/en/explore/restorative/ceramx_spectra_st_hv_only/RES-SpectraST-Scientific%20Manual.pdf.

32. Özdemir H, Yanikoglu ND. The bond strength of nanohybrid and nanoceramic composites to feldspathic porcelain. Contemp Clin Dent. 2017;8:558-64.

33. Zhang LX, Hong DW, Zheng M, Yu H. Is the bond strength of zirconia-reinforced lithium silicate lower than that of lithium disilicate? - A systematic review and metaanalysis. J Prosthodont Res. 2022;66:530-7.

34. Al-Dohan HM, Yaman P, Dennison JB, Razzoog ME, Lang BR. Shear strength of core-veneer interface in bi-layered ceramics. J Prosthet Dent. 2004;91:349-55.

35. Saito A, Komine F, Blatz MB, Matsumura H. A comparison of bond strength of layered veneering porcelains to zirconia and metal. J Prosthet Dent. 2010;104:247-57.

36. Lüthy H, Loeffel O, Hammerle CH. Effect of thermocycling on bond strength of luting cements to zirconia ceramic. Dent Mater. 2006;22:195-200.