MMDJ
MEANDROS MEDICAL AND DENTAL JOURNAL
December 2025 26(4):436-445

Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1762141

Research Article

EVALUATION OF PREHEATING COMPOSITE RESINS FOR REPAIRING RESIN NANOCERAMIC RESTORATIONS

Tuğgen ÖZCİVELEK[1]*, Berna ÖZCAN[1], Bahadır KASAR[2], Mehmet Ali KILIÇARSLAN[3]

[1]Department of Prosthodontics, Gülhane Faculty of Dentistry, University of Health Sciences, Ankara, TÜRKİYE.
[2] Tepebaşı Oral and Dental Healthcare Hospital, Turkish Ministry of Health, Ankara, TÜRKİYE
[3]Department of Prosthodontics, Faculty of Dentistry, Ankara University, Ankara, TÜRKİYE

*Correspondence: tuggen.mersin@sbu.edu.tr

Received: *11 August 2025*
Revised: *01 October 2025*
Accepted: *10 October 2025*
Published: *25 December 2025*

Copyright: © 2025 by the authors. Published by Aydın Adnan Menderes University, Faculty of Medicine and Faculty of Dentistry. This article is openly accessible under the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License.

ABSTRACT

Objective: Resin nanoceramic dental restorations may need repair. This study evaluates the shear bond strength (SBS) of two composite resins applied at two temperatures to repair two resin nanoceramic materials.

Materials and Methods: Ninety-six specimens were sliced from Lava Ultimate and CeraSmart resin nanoceramic blocks and subjected to thermal aging. Following surface roughness measurements, specimens were divided into eight subgroups(n=12) based on repair material and application temperature. Resin nanoceramic specimens were repaired using a Teflon mold with RubyCompP or RubyCompNano composite resins at 23°C or 50°C. All specimens were subjected to a SBS test at a 0.5mm/min crosshead speed until failure. Failure types were classified at 5X magnification. Statistical analysis of SBS test results was performed by a three-way ANOVA test, followed by post hoc Tukey's pairwise comparisons(α=0.05). The relationship between failure modes and resin nanoceramic, composite resin, or preheating was analyzed with a chi-square test.

Results: Surface roughness of resin nanoceramics was not statistically different($p>0.05$). The resin nanoceramic type and preheating of repair materials had a significant effect on SBS($p=0.006$, $p<0.001$). Results of three-way ANOVA displayed substantial differences among groups($p=0.038$). Tukey's pairwise comparisons revealed significant differences between SBS values for LavaUltimate repaired with posterior composite(LP) and CeraSmart repaired with preheated posterior composite(CPP) ($p=0.034$), LP and CeraSmart repaired with preheated nano composite(CNP) ($p=0.030$), CeraSmart repaired with nano composite(CN) and CPP($p=0.035$), and CN-CNP($p=0.030$). Mixed failure was predominant among groups.

Conclusion: These findings imply that repairing CeraSmart resin nanoceramic and preheating the repair composite resin to 50°C attenuated the shear bond strength.

Keywords: CAD-CAM; Ceramics; Polymers; Composite resins; Nanocomposites; Dental restoration repair

MMDJ
MEANDROS MEDICAL AND DENTAL JOURNAL
December 2025 26(4):436-445
Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1762141

INTRODUCTION

Dental ceramics are aesthetic, biocompatible, chemically inert, and resistant to high temperatures and wear; therefore, they are frequently used in dental practice (1). Leucite-reinforced ceramics, lithium silicate and lithium disilicate ceramics, zirconia, and resin matrix ceramics have been proposed in various indications (2). Resin nanoceramic (RNC) materials can be used for chairside single-visit restorations, including inlays, onlays, and veneers (3). Resin nanoceramics combine several advantageous properties of ceramics, including high aesthetics, durability, and color stability, and of composite materials, such as improved flexural properties, and low abrasiveness (4). However, technical complications, such as fracture or chipping, may occur during clinical use of RNC restorations due to their low to moderate fracture toughness and brittleness under tensile forces (1,5,6). Resin nanoceramic restorations have physical properties closer to natural teeth compared to other types of ceramic restorations, and due to their polymer content, they are repairable (7). Renewal of a cracked or chipped restoration requires time and cost. Although specialized kits for repair procedures are available on the market, alternative materials and methods, such as preheating of polymer-based restorative materials, need to be tested to improve the durability, effectiveness, accessibility, and ease of application of materials and reduce the repair expenses.

The best surface treatment protocol for ceramic restoration repair varies according to the fractured or chipped fixed dental restoration material (8). CAD/CAM RNC blocks are polymerized at high pressure and temperature that provides less residual monomer with a high degree of conversion. Therefore, various surface treatment protocols, such as etching, air-particle abrasion, and diamond bur grinding, have been proposed in the literature to enhance the repair bond between RNC and composite (9). Airborne-particle abrasion with Al_2O_3 or preparation with a diamond rotary instrument was reported as the surface treatment option for RNC repairs (3).

Various materials can be used in the intraoral repair of ceramic restorations. Nanohybrid composites are frequently used for their high mechanical strength and low polymerization shrinkage. Additionally, bulk-fill composites, which can be applied in larger layers at a time, and flowable composites, which provide advantages in filling imperfect surfaces, are also restorative material options (5).

Preheating the composite resins is notable for their improved manipulation and physicochemical properties of the restorative material (10). Preheating resin-based restorative materials can be considered a simple, safe, and relatively successful technique according to in vitro studies, because it increases microhardness and degree of transformation, reduces viscosity, and provides better adaptation to cavity walls (11). Preheating has been shown to increase the shear bond strength (SBS) of composite resins to dentin (12). However, there are not enough clinical studies to confirm the clinical benefit of the preheating technique during RNC repair.

For this reason, this study aimed to evaluate the SBS of two different RNC blocks when repaired with different composite resins and subjected to two preheating procedures. The null hypothesis was that bond strength between CAD/CAM resin nanoceramic and composite resin is not affected by (1) the RNC block, (2) composite resin, or (3) preheating of composite resin.

MATERIALS AND METHODS

In this study, two CAD/CAM resin nanoceramic materials, Lava Ultimate (3M ESPE Dental Products, St. Paul, Minnesota, USA) and CeraSmart (GC Dental Products, Tokyo, Japan), were repaired with two nanohybrid composite resin dental restorative materials RubyComp P Posterior (Incidental Co. Ltd., İstanbul, Türkiye) and RubyComp Nano, (Incidental Co. Ltd., İstanbul, Türkiye), at room temperature 23°C and preheated at 50°C. CeraSmart (CS) is an RNC block composed of 71% silica particles by weight and a 29% polymer matrix of bisphenol-A ethoxylate dimethacrylate (Bis-MEPP), urethane dimethacrylate (UDMA), and dimethacrylate (DMA). It can absorb forces and does not require glazing or sintering (4,13). Lava Ultimate (LU) is another RNC block, which has a 20% highly cured resin matrix filled with 80% nanoceramic particles by weight (4). Materials that are used and their composition are displayed in Table 1. The surface roughness (Ra values in μm) of all specimens was measured before repair procedures. The bond strength of the specimens was assessed using the shear bond test. Then, the failure types of specimens were examined.

Calculation of sample size

An a priori power analysis was conducted using a statistical program (G*Power 3.1.9.7) for ANOVA. With an anticipated effect size of f = 0.40, an α level of 0.05, and a desired power of 0.80, the analysis indicated a required minimum sample size of N = 97. Initially, 104 samples

MMDJ
MEANDROS MEDICAL AND DENTAL JOURNAL
December 2025 26(4):436-445
Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1762141

Table 1. Materials used in the study.

Material (Manufacturer)	Type	Composition	Lot Number
Lava Ultimate (3M ESPE Dental Products, St. Paul, Minnesota, USA)	CAD/CAM Resin nanoceramic	Nanoceramic 80%, 20 nm silica particles, 4 to 11 nm zirconia particles, Bis-GMA, UDMA, Bis-EMA, TEGDMA, SiO_2 (20 nm), ZrO_2 (4–11 nm), ZrO_2/ SiO2 clusters, filler mass (80 wt%). CAD/CAM block size (12×14×18 mm).	3314A3-LT
Cerasmart (GC Dental Products, Tokyo, Japan)	CAD/CAM Resin nanoceramic	Bis-MEPP 1, UDMA 2, dimethacrylate 71% silica (20 nm), barium glass (300 nm)	1802271
RubyComp P Posterior (Incidental Co. Ltd., İstanbul, Türkiye)	Polymer-based dental restorative material	Methacrylate resins (20 wt-%), inorganic fillers (80 -wt%), filler particle size 0.02-0.7µm. Fillers contain barium glass, mixed oxides, photo initiators and stabilizers	RCPA2223
RubyComp Nano (Incidental Co. Ltd., İstanbul, Türkiye)	Polymer-based dental restorative material	RubyComp Nano Light Curing Nanohybrid composite, Resin based Bis-GMA, Methacrylate polymers (20 wt-%), Inorganic fillers (80 -wt%), Filler particle size 0.02-0.7µm. The fillers contain barium glass, mixed oxides and copolmers, photo initiators and stabilizers	RCYA2309
G-Multi Primer (GC Dental, Tokyo, Japan)	Primer for glass ceramics, hybrid ceramics, Zirconia, composites, and metal bonding	Ethanol, γ-MPTS, 10-MDP, MDTP, bis-GMA, TEG-DMA	2208051
RubySEBond (Incidental Co. Ltd., İstanbul, Türkiye)	7th generation Universal Adhesive	Methacrylate, photoiniciators, ethanol, water	RSB153

Abbreviations: Bis-GMA: Bisphenol A-glycidyl methacrylate; UDMA: Urethane dimethacrylate; Bis-EMA: Ethoxylated bisphenol A glycol dimethacrylate; TEGDMA: Triethylene glycol dimethacrylate; Bis-MEPP: Bisphenol-A ethoxylate dimethacrylate; γ-MPTS: γ-Mercaptopropyltrimethoxysilane; 10-MDP: 10-Methacryloyloxydecyl dihydrogen phosphate; MDTP: 10-Methacryloyloxydecyl dihydrogen phosphate; TEG-DMA: Triethylene glycol dimethacrylate

were prepared and divided into 8 subgroups (n = 13) according to two different resin nanoceramics, two repair composites, and application temperature at 23°C room temperature or with preheating to 50°C. During the experiments, one sample from each of four different groups was damaged and had to be excluded. To maintain a balanced design for the ANOVA, one sample was randomly selected and excluded from each of the remaining groups. Consequently, the final analysis was performed with 12 samples per group (total N = 96). A post-hoc power analysis based on this final sample size yielded an observed power of approximately 79%, which is close to the initial target of 80%. Study groups and abbreviations are presented in Table 2.

Specimen preparation and thermal aging

CAD/CAM RNC blocks were precisely cut using a low speed cutting device (Microcut Precision Cutter, Metkon, Bursa, Türkiye) under water cooling, yielding a total of 96 samples with dimensions of 7 mm x 7 mm x 1.5 mm. To simulate intraoral clinical use of the restorations, the samples were artificially aged in a thermal aging device (SD Mechatronik Thermocycler, Westerham, Germany) for 5000 cycles, with each cycle between 5°C and 55°C with a 25-second dwell and a 5-second transfer time (14,15). Then, they were embedded in chemically polymerized acrylic resin (BMS Acrylic Resin Kit, BMS Dental S.r.l., Capannoli, Italy) in ⌀=13mm, h=13 mm dimensions.

Table 2. Study groups and abbreviations

Resin Nanoceramic Material	Repair Composite Resin	Application temperature	Group abbreviation
Lava Ultimate	RubyComp P Posterior	23°C	LP
Lava Ultimate	RubyComp P Posterior	50°C	LPP
Lava Ultimate	RubyCompNano	23°C	LN
Lava Ultimate	RubyCompNano	50°C	LNP
CeraSmart	RubyComp P Posterior	23°C	CP
CeraSmart	RubyComp P Posterior	50°C	CPP
CeraSmart	RubyCompNano	23°C	CN
CeraSmart	RubyCompNano	50°C	CNP

MMDJ
MEANDROS MEDICAL AND DENTAL JOURNAL
December 2025 26(4):436-445
Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1762141

Surface treatment

To standardize the repair surfaces to be tested, they were polished with silicon carbide abrasive papers #600, #800, #1000 using a polishing and grinding machine (Metkon Gripo 2V Grinder, Bursa, Türkiye) in cold flowing water for 15 seconds. Test surfaces were air-particle abraded for 5 seconds with 50 micrometer Al2O3 sand (Korox 50; BEGO, Bremen, Germany) at 2 bar pressure and the nozzle 10 mm away from the surface using a sandblaster (EasyBlast; BEGO, Bremen, Germany). The specimens were ultrasonically cleaned (Bandelin Sonorex Super RK 102P Rangendingen, Germany) in distilled water for 10 minutes and air-dried (6,14).

Surface roughness measurement

The surface roughness of all ceramic samples was measured using a confocal microscope (Zeiss Smartproof 5, Carl Zeiss, Germany). A 500 μm × 500 μm area from the center of each sample was scanned in 3D imaging mode at 20x magnification (C Epiplan-Apochromat 20x/0.7 DIC, Carl Zeiss, Jena, Germany). The images were transferred to surface analysis software (ConfoMap ST 7.4.8076, Carl Zeiss, Jena, Germany), and the surface roughness parameter mean surface roughness (Ra) was measured according to ISO 21920 standards.

Repair procedures

A primer (G Multi-Primer, GC Dental, Tokyo, Japan) was applied to the RNC repair surface, then air-dried for 10 seconds. Then, a thin layer of 7th generation universal adhesive (RubySEBond, Incidental Co. Ltd., İstanbul, Turkey) was gently brushed for 10 seconds, air dried for 5 seconds, and polymerized for 10 seconds using an LED curing light (RubyDent LED Curing Light, Incidental Co. Ltd., İstanbul, Türkiye, 3.6V 2600mAh) (6).

Specified composite resins were bonded to the specimens to mimic the repair process. A Teflon mold (Ultradent Jig, Ultradent, South Jordan, UT, USA) of 2.38mm diameter and 3.5mm height was used to standardize the repair with the bonded resin. The Teflon mold was filled with the specified composite resin at the specified temperatures (13,16,17). Specimens of LavaUltimate repaired with posterior composite (LP), LavaUltimate repaired with nano composite (LN), CeraSmart repaired with posterior composite (CP), and CeraSmart repaired with nano composite (CN) groups were prepared at 23°C room temperature. The specimens of LavaUltimate repaired with preheated posterior composite (LPP), LavaUltimate repaired with preheated nano composite (LNP), CPP, and CeraSmart repaired with preheated nano composite (CNP) groups were prepared by heating the composite resin at 50°C with a heating unit (Ease-It Composite Heater, Ronvig Dental Mfg, A/S Daugaard, Denmark) for 20 minutes (17). After photopolymerization with a 1000 mW/cm² LED curing light (RubyDent LED Curing Light, İncidental Tıbbi Malz. San. ve Tic. San., İstanbul, Türkiye) for 20 seconds, all specimens were immersed in distilled water for 24 hours (4,6,14) and subjected to the SBS test.

Shear bond strength test

Each specimen was positioned in a metal fixture. All samples were subjected to SBS testing at a crosshead speed of 0.5 mm/min until failure in a shear bond tester machine (Bisco, Schaumburg, IL, USA), and the force at failure was recorded in Newton (N). The SBS was calculated with the formula: SBS =F/A, in which: SBS = shear bond strength (MPa); F =force (N); A =bonding area (mm2) (16).

Failure analysis

Following the shear bond test, the bond surfaces of all ceramics were examined with a 5X 0.7 lens confocal microscope (Zeiss Smartproof 5, Carl Zeiss, Germany). Failure types were classified as adhesive, mixed, or cohesive. Complete separation of repair resin from the ceramic surface indicated adhesive failure, partially remaining composite resin on the ceramic surface indicated mixed failure, and failure entirely within the composite or ceramic layer indicated cohesive failure.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics 21.0 software (IBM Corp., Chicago, IL, USA). Surface roughness and SBS data revealed a normal distribution with the Shapiro-Wilk test. The Levene's test of variance confirmed the validity of the equivariance assumptions of mean values. The effects of different resin nanoceramic materials, composite resins, and preheating procedures on bond strength were analyzed using 3-way ANOVA. Tukey correction was performed for post-hoc pairwise comparisons at a significance level of $p<0.05$ with a 95% confidence interval. Surface roughness was analyzed using one-way ANOVA at a significance level of $p<0.05$ with a 95% confidence interval. Failure types concerning RNC, repair composite resin, and application temperature were analyzed using the chi-square test at a significance level of $p<0.05$ with a 95% confidence interval.

RESULTS

Surface roughness measurement

Based on the surface roughness measurement, the mean surface roughness (Ra)±standard deviation of Lava

MMDJ
MEANDROS MEDICAL AND DENTAL JOURNAL
December 2025 26(4):436-445
Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1762141

Ultimate was higher than that of Cerasmart at 1.861±0.242 and 1.750±0.348, respectively. However, the ANOVA test revealed that the effect of RNC type on surface roughness was not statistically significant (p=0.071).

Shear bond test

The descriptive statistics for the SBS values in MPa of the study groups are presented in Table 3. The mean SBS of the specimens ranged from 6.919±3.241 to 18.251±10.332 MPa. Results of the ANOVA test revealed that SBS was significantly affected by RNC (p=0.006) and preheating procedure (p<.001), whereas the effect of repair material was not statistically relevant (p=0.076). When repaired with composite resins, Lava Ultimate specimens exhibited higher bond strength than CS specimens. Moreover, polymer-based restorative materials applied at room temperature (23°C) exhibited higher bond strength than those preheated to 50°C.

Table 3. Shear bond strength mean values (MPa) and standard deviations

Group	N	Mean (MPa)	±Standart Deviation
LP	12	16.685	6.849
LPP	12	11.184	8.859
LN	12	17.460	10.547
LNP	12	16.277	10.237
CP	12	9.344	4.604
CPP	12	6.919	3.241
CN	12	18.251	10.332
CNP	12	7.357	3.942

The results of the three-way ANOVA displayed statistically significant interaction between groups (p=0.038). Tukey's pairwise comparisons, displayed in Table 4, revealed statistically significant differences between the SBS values of LP-CPP (p=0.034), LP-CNP (p=0.030), CN-CPP (p=0.035), and CN-CNP (p=0.030).

Failure mode distribution

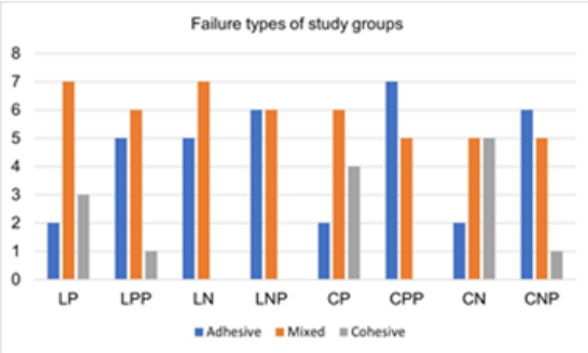


Figure 1. Distribution of failure types of study groups

Distribution of failure types of the study groups are displayed in Figure 1. The most common failure among the groups was mixed failure (49%), followed by adhesive (36.4%) and cohesive failure (14.6%). According to the chi-square test results, the type of failure observed did not differ significantly depending on the RNC and repair composite used (p=0.209, p=0.754, respectively).

However, the failure type was related with application temperatures ($\chi^2(2) = 12.163$, $p = 0.002$). According to the standardized residual values obtained from the chi-square test, at 23°C cohesive failures were more frequent than expected ($z = +2.892$), while adhesive failures were less frequent than expected ($z = -2.757$). Adhesive failure was more frequent ($z = +2.757$) and cohesive failure was less frequent ($z = -2.892$) in the preheated groups where the composite was and applied at 50°C ($|z| > 1.96$, $p < 0.05$) (Table 5).

Table 5. Application temperatures versus observed failure types of specimens.

Application temperature	Adhesive	Mixed	Cohesive	Total
23°C	11 (22.91%)	25 (52.08%)	12 (25.0%)	48
50°C	24 (50%)	22 (45.83%)	2 (4.16%)	48
Total	35	47	14	96

Chi-square = 12.163, df = 2, p = 0.002

DISCUSSION

In the current study, two different composite resins were applied at 23°C room temperature and at 50°C preheated to repair two different RNCs. According to three-way ANOVA, this in vitro study revealed that SBS was affected by the type of RNC used and the preheating process, but not by the composite resin used. Therefore, the null hypothesis, which stated that bond strength between CAD/CAM resin nanoceramic material and composite would not be affected by the RNC block, composite resin, or preheating procedure, was partially rejected. The results highlight the importance of the repaired material and the appropriate application temperature for successful repair.

Intraoral repair of dental restorations has been investigated previously (4,9,13–15,18–20). Although replacement of the restoration is an option, when an effective and durable intraoral repair is possible, the lifespan of the prosthesis can be extended by preventing

MMDJ
MEANDROS MEDICAL AND DENTAL JOURNAL
December 2025 26(4):436-445
Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1762141

Table 4. Post hoc test with Tukey correction for pairwise comparisons

Comparison		Mean Difference	SE	df	t	p_{tukey}
LP	LPP	0.273	0.121	88	2.249	0.334
LP	LN	0.032	0.121	88	0.262	1.000
LP	LNP	0.079	0.121	88	0.656	0.998
LP	CP	0.280	0.121	88	2.310	0.300
LP	CPP	0.393	0.121	88	3.240	0.034*
LP	CN	0.2008	0.121	88	0.002	1.000
LP	CNP	0.398	0.121	88	3.286	0.030*
LPP	LNP	-0.193	0.121	88	-1.593	0.753
LPP	CPP	0.120	0.121	88	0.991	0.975
LPP	CNP	0.126	0.121	88	1.037	0.967
LN	LNP	0.048	0.121	88	0.393	1.000
LN	LPP	0.241	0.121	88	1.987	0.497
LN	CN	-0.032	0.121	88	-0.261	1.000
LN	CNP	0.367	0.121	88	3.024	0.062
LN	CPP	0.361	0.121	88	2.978	0.070
LNP	CNP	0.319	0.121	88	2.631	0.159
CP	CPP	0.113	0.121	88	0.930	0.982
CP	CNP	0.118	0.121	88	0.976	0.977
CP	CN	-0.280	0.121	88	-2.308	0.301
CP	LPP	-0.007	0.121	88	-0.061	1.000
CP	LN	-0.248	0.121	88	-2.048	0.457
CP	LNP	-0.201	0.121	88	-1.654	0.716
CPP	CNP	0.006	0.121	88	0.046	1.000
CPP	LNP	-0.313	0.121	88	-2.584	0.176
CN	CNP	0.398	0.121	88	3.285	0.030*
CN	CPP	0.393	0.121	88	3.238	0.035*
CN	LNP	0.079	0.121	88	0.654	0.998
CN	LPP	0.272	0.121	88	2.247	0.335

* Indicates $p<0.05$

restoration removal trauma to the teeth and surrounding tissues, reducing chair time and costs (6,8).

In the literature, the bond strength of restorations repaired with composite resins has been evaluated using various setups, including the shear tests (13,14), the shear tests (4,15,18,20), and the tensile tests (9,19). Previous studies have reported that as the surface area of the adhesion zone increases, forces become more unevenly distributed, increasing the likelihood of air bubbles or irregularities, which can negatively impact the test results (16). To minimize these drawbacks, the shear test was preferred in this study. The repair material applied with the Ultradent Jig provided a standard surface area and let packing with minimal irregularity.

Restorative materials age over time due to temperature changes and moisture in the oral environment. Consequently, the fracture risk of restorations under masticatory forces may increase (21). When RNC restorations fracture, the material remains in the mouth until the repair, and the fractured surface is subjected to humidity and temperature changes. Studies have reported that bond strength may be affected by artificial aging procedures (6,14). To simulate the clinical situation,

MMDJ
MEANDROS MEDICAL AND DENTAL JOURNAL
December 2025 26(4):436-445
Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1762141

CAD/CAM RNC specimens were subjected to artificial thermal aging before repair.

Material properties and surface treatments may affect the adhesion. Studies have reported that the application of diamond bur roughening (4,15,20), sandblasting (4,6,15,19,20), hydrofluoric acid (4,20), silane (4,15), adhesive application (20), and silica coating (6,15,19), as well as various combinations of these surface treatments, affects the bond strength of the repair. A systematic review and meta-analysis by Moura et al. (3) reported that the most successful surface treatment protocols for RNC repair were 50 μm aluminum oxide (Al_2O_3) sandblasting or diamond bur roughening. Therefore, in this study, the surface of RNC specimens was standardized using #600, #800, and #1000 grit sandpapers and then sandblasted with 50 μm aluminum oxide (Al_2O_3).

Preheating composite resins reduces viscosity, increases the degree of conversion and microhardness, and improves marginal adaptation of restorations (10). However, quantitative analysis is difficult due to the lack of standardization of preheating parameters and the methodological heterogeneity of the studies. Previous studies have evaluated the bond strength of preheated composite resins to dentin (12,22–24) and lithium disilicate ceramics (25). Some studies have reported higher bond strengths of preheated composite resin to dentin when compared with unheated composite resin (12,24), while no statistically significant difference was found in another study (22). In two studies on lithium disilicate, similar bond strengths were obtained for preheated composite resin with resin cement and flowable composite (25). Further research is needed due to the lack of consensus in the results. Moreover, to the best of the authors' knowledge, the effect of preheating the composite in the repair of resin nanoceramic restorations has not been investigated previously. In the current study composite resins at 23°C and preheated to 50°C has been studied to investigate the change in repair performance.

Studies conducted with different restorative materials revealed that the type of the repaired restorative material affects the bond strength, similar with the findings of the current study (4,15,18). Furthermore, Moura et al. reported that the surface treatments applied during restoration repair affect bond strength by altering surface roughness. In the current study, the average bond strength of LU specimens (15.40 ± 9.28 MPa) was statistically significantly higher than that of CS (10.46 ± 7.58 MPa) ($p=0.006$). However, when the Ra values were compared, a statistically significant difference was not found ($p=0.071$). The detected difference between the two RNCs may be due to differences in the chemical structures of the materials and the chemical bond between the primer-adhesive used and the composite resin. Güngör et al. reported lower average bond strength with LU RNCs compared to CS, suggesting that this may be due to the zirconia particle content in LU. In the current study, the primer used (G Multi-Primer, GC Dental, Tokyo, Japan) consisted of MDP, which may explain the higher bond strength of LU compared to CS.

In a study conducted by Üstün et al., the bond strength between IPS e.max CAD, Vita Suprinity, Vita Enamic, and Lava Ultimate CAD/CAM restorative materials and Ceramic Repair and Clearfil Repair repair systems was evaluated using a shear test. Similar with the present study, the shear bond strength was reported to vary significantly depending on the type of restorative material used. The bond strength of Lava Ultimate samples was measured lower in the case where both repair systems were used (Ceramic Repair: 16.75 MPa; Clearfil Repair: 15.88 MPa) than in the current study (LP: 16.685 MPa LN: 17.460 MPa). This difference may be due to the different surface treatments, primer, and bond application procedures incorporated into the repair systems, or to the fact that the bond strength was evaluated with a different test setup.

In another study, the effects of different surface treatments, artificial aging, and their interaction on the bond strength between Lava Ultimate RNC and a nanohybrid composite were investigated (6). The bond strength between Lava Ultimate and the nanohybrid composite treated with artificial aging and sandblasting was found to be lower at 10.24 MPa than the LN group in the current study, which was at 17.460 MPa. This difference may be due to the use of primers and different adhesive systems in the current study.

In the current study, for both RNC and composite types, the bond strength of the room-temperature repair groups was statistically significantly higher than that of the preheated groups ($p<0.001$). Demirbuga et al. investigated the effect of preheating on the micro-shear bond strength of composite resins to dentin by applying composites at 68°C, at room temperature, or cooled to 4°C. Contrary to current results, preheated composites demonstrated the highest bond strength to dentin (12). An explanation for this may be the decreased viscosity of the preheated composite, resulting in a better adaptation to the dentinal tubules. Similarly, in a study by Mutlu et al., the preheated composite resin used in the cementation of lithium disilicate glass-ceramic to dentin yielded similar bond

MMDJ
MEANDROS MEDICAL AND DENTAL JOURNAL
December 2025 26(4):436-445
Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1762141

strength values to resin cement and flowable composites (25). However, in the current study, the bond strength of the preheated composite resin groups was measured as lower than that of room temperature groups. These studies evaluate different adherent materials; therefore, surface properties and chemical structure play a critical role in establishing the bond. Furthermore, the aforementioned studies evaluated the use of preheated composite as a cement. The repair procedure requires a certain amount of time, and the thickness of the composite is often greater. This creates limitations in comparing the results.

When failures were examined after shear testing, the application temperature of the composite influenced the type of failure observed ($\chi^2(2) = 12.163$, $p = 0.002$). Cohesive failure was more common in the room temperature groups, while adhesive failure was prominent in the preheated groups. Cohesive failure can be defined as the rupture within the materials. The higher frequency of cohesive failure in repairs at room temperature suggests that repairing RNC with room-temperature composite is more successful in terms of bond strength and might be preferred clinically. However, it should be noted that cohesive failure also reflects the mechanical strength of the composite and RNC materials. Conversely, the higher frequency of adhesive failure in the preheated composite application groups can be interpreted as inadequate micromechanical or chemical bonding at the RNC-composite interface.

A statistically significant difference was not found between the bond strengths of the posterior (RubyComp P Posterior) and nanohybrid (RubyComp Nano) composites used in the study (p=0.076). This result may be due to the similar filler ratio (80%) and particle size (0.02–0.7 μm) of both composites. However, these composites have some important differences in terms of their indications for use, filler structure, and polymer content. These differences should be considered when selecting a composite for clinical use. Posterior composites are resistant to masticatory forces but less polishable. However, nanohybrid composites, are used in both anterior and posterior regions due to their better polishable surface and mechanical reinforcement with additional copolymers. Since bond strength is not affected by the type of composite used in restoration repairs, other advantageous clinical parameters and the flexibility in material selection can be chosen.

This in vitro study was conducted within certain limitations. During clinical use, restorations are exposed to various mechanical stresses in the oral environment, in addition to thermal stresses caused by saliva, bacterial flora, and functional and parafunctional movements. Although thermal artificial aging was used in the study, the possibility of other factors affecting the bond is an issue that needs to be considered.

Another limitation is the standardization and application of the same surface treatments, adhesion protocol to all samples. The aim of this study was to investigate the effect of preheating used in repairing two different content resin nanoceramics. While different applications may yield different results (4,19), in line with the aim of the study an accepted surface treatment and adhesion protocol was applied to facilitate comparison. Future studies may be addressed to investigate the application of the composite at temperatures other than 23 and 50 degrees Celsius, and the application of different surface treatments and adhesion protocols to RNCs.

The loss of four samples during the experiments resulted in a decrease in the total number of samples; however, the power value calculated with post-hoc power analysis was 79% which is close to the planned 80% target power.

The size of the repaired area and the thickness of the composite used are anticipated to affect bond strength, and these are other issues that require further investigation. When the results of our study are evaluated, considering the limitations, the chemical structure of the CAD/CAM restorative material used, the surface treatment applied, and the application temperature of the composite resin all influence the bonding in restoration repairs. While preheating has increased bond strength in some studies, composites applied at room temperature in this study demonstrated higher bonding performance. This demonstrates the importance of selecting the materials used and the protocol to be implemented during clinical restoration repairs. Choosing the right material and surface treatment for the right indication can provide significant advantages in terms of time and cost, allowing for restoration repair without the need for replacement.

CONCLUSION

Within the limitations of this in vitro study, it was concluded that the composition of the RNC and the temperature at which the repair material is applied may affect SBS in RNC repairs. The SBS of the repair was found to be higher when Lava Ultimate RNC was used, and the repair was performed with composite resin at 23°C.

MMDJ
MEANDROS MEDICAL AND DENTAL JOURNAL
December 2025 26(4):436-445

Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1762141

Acknowledgments
None

Authorship contributions
Concept: TÖ, MAK; Design: TÖ, BÖ, BK, MAK; Data collection or processing: TÖ, BÖ; Analysis and interpretation: TÖ, BÖ, MAK; Literature search: TÖ, BÖ, BK; Writing: BÖ, TÖ, MAK.

Data availibity statement
The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declaration of competing interest
The authors have no competing interest, financial interests/personal relationships to declare.

Ethics
This in-vitro study does not require ethical committee approval.

Funding
This study was not supported by any funding.

REFERENCES

1. Shen C, Rawls HR, Esquivel-Upshaw JF. Phillips' Science of Dental Materials. In: Phillips' Science of Dental Materials. St. Louis: Elsevier, 2021: 203–4.
2. Alghauli MA, Al - Gabri RS, Keshk A, Mirah MA, Alqutaibi AY. Clinical complications and survival rate of resin matrix ceramic restorations: A systematic review and meta - analysis. J Esthet Restor Dent 2025; 37(7):1721-1739.
3. Moura DMD, Veríssimo AH, Leite Vila-Nova TE, Calderon PS, Özcan M, Assunção Souza RO. Which surface treatment promotes higher bond strength for the repair of resin nanoceramics and polymer-infiltrated ceramics? A systematic review and meta-analysis. J Prosthet Dent 2022; 128(2):139–49.
4. 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(4):259.
5. Soares PM, Rosa LS da, Pilecco RO, Dal Piva AM de O, Tribst JPM, Werner A, et al. Repair of monolithic zirconia restorations with different direct resin composites: effect on the fatigue bonding and mechanical performance. Clin Oral Investig 2024; 28(2):149.
6. Subaşı MG, Alp G. Repair bond strengths of non-aged and aged resin nanoceramics. J Adv Prosthodont 2017; 9(5):364.
7. Arkoy S, Ulusoy M. Effect of different surface treatments on repair bond strength of CAD/CAM resin-matrix ceramics. Materials 2022; 15(18):6314.
8. Çevik HD, Kartal MN, Sağesen HLE. Sabit protezlerin tamirinde kullanılan ağız-içi uygulamalar. In: Özkan P, editor. Dental Materyaller ve Kullanım Alanları. Ankara: Türkiye Klinikleri, 2025:42–9.
9. Elkassaby AA, Kandil MM, Alian GA. The effect of repair protocols and chewing simulation on the microtensile bond strength of two resin matrix ceramics to composite resin. BMC Oral Health 2024; 24(1):171.
10. Patussi AF, Ramacciato JC, da Silva JG, Nascimento VR, Campos DE, de Araújo Ferreira Munizz I, et al. Preheating of dental composite resins: A scoping review. J Esthet Restor Dent 2023; 35(4):646–56.
11. Lopes LCP, Terada RSS, Tsuzuki FM, Giannini M, Hirata R. Heating and preheating of dental restorative materials—a systematic review. Clin Oral Investig 2020; 24(12):4225–35.
12. Demirbuga S, Ucar FI, Cayabatmaz M, Zorba YO, Cantekin K, Topçuoğlu HS, et al. Microshear bond strength of preheated silorane - and methacrylate - based composite resins to dentin. Scanning 2016; 38(1):63–9.
13. Degirmenci A, Unalan Degirmenci B. Effects of Er,Cr:YSGG laser surface treatments and composites with different viscosities on the repair bond strength of CAD/CAM resin nanoceramic. Polymers 2024; 16(15):2212.
14. Şişmanoğlu S, Turunç-Oğuzman R. Microshear bond strength of contemporary self-adhesive resin cements to CAD/CAM restorative materials: effect of surface treatment and aging. J Adhes Sci Technol 2020; 34(22):2484–98.
15. Wiegand A, Stucki L, Hoffmann R, Attin T, Stawarczyk B. Repairability of CAD/CAM high-density PMMA- and composite-based polymers. Clin Oral Investig 2015; 19(8):2007–13.
16. Bessa MS de, Marinho LCN, Miranda LM de, Carvalho IHG de, Campos BO, Borges BCD, et al. Repair bond strength of resin composite to CAD/CAM glass-ceramic: Influence of cleaning methods, surface treatments, and aging. J Dent 2025; 154:105568.
17. Brkanović S, Sever EK, Vukelja J, Ivica A, Miletić I, Krmek SJ. Comparison of different universal adhesive systems on dentin bond strength. Materials 2023; 16(4):1530.
18. Üstün Ö, Büyükhatipoğlu IK, Seçilmiş A. Shear bond strength of repair systems to new CAD/CAM restorative materials. J Prosthodont 2018; 27(8):748–54.
19. Stawarczyk B, Krawczuk A, Ilie N. Tensile bond strength of resin composite repair in vitro using different surface preparation conditionings to an aged CAD/CAM resin nanoceramic. Clin Oral Investig 2015; 19(2):299–308.
20. Veríssimo AH, Duarte Moura DM, Oliveira Dal Piva AM de, Bottino MA, Fátima Dantas de Almeida L de, Fonte Porto Carreiro A da, et al. Effect of different repair methods on the bond strength of resin composite to CAD/CAM materials and microorganisms adhesion: An in situ study. J Dent. 2020; 93:103266.

21. Song M, Ko K, Huh Y, Park C, Cho L. Edge chipping resistance and flexural strength of CAD‐CAM ceramics before and after thermomechanical aging. J Esthet Restor Dent 2025; 37(4):1096–104.
22. El-Deeb HA, Abd El-Aziz S, Mobarak EH. Effect of preheating of low shrinking resin composite on intrapulpal temperature and microtensile bond strength to dentin. J Adv Res 2015; 6(3):471–8.
23. Urcuyo Alvarado MS, Escobar García DM, Pozos Guillén A de J, Flores Arriaga JC, Romo Ramírez GF, Ortiz Magdaleno M. Evaluation of the bond strength and marginal seal of indirect restorations of composites bonded with preheating resin. Eur J Dent. 2020; 14(04):644–50.
24. Davari A, Daneshkazemi A, Behniafar B, Sheshmani M. Effect of pre-heating on microtensile bond strength of composite resin to dentin. J Dent 2014; 11(5):569–75.
25. Mutlu A, Atay A, Çal E. Bonding effectiveness of contemporary materials in luting glass-ceramic to dentine: An in vitro study. J Adv Oral Res 2021; 12(1):103–11.