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Original research

INFLUENCE OF DIFFERENT REPAIR PROTOCOLS AND ARTIFICIAL AGING ON BOND STRENGTH OF COMPOSITE TO POLYMER-INFILTRATED CERAMIC NETWORK MATERIAL

ABSTRACT

Objectives: The aim of this in vitro study was to evaluate the effects of different repair protocols and artificial aging on the shear bond strength (SBS) of a composite to polymer-infiltrated ceramic network (PICN).

Materials and methods: A total of 120 PICN (Vita Enamic, Vita Zahnfabrik) specimens were prepared, artificially aged (5000 thermal cycles between 5°C-55°C), and assigned to 5 repair protocols: (1)TS: tribochemical silica coating (Rocatec Soft; 3M ESPE)+Single Bond Universal (SBU; 3M ESPE) (2)ES: etching with hydrofluoric acid (HF; Bisco)+SBU (3)EU:HF+Ultradent Porcelain Repair (UPRS; Ultradent Products Inc.) (4)GU: grinding with diamond bur (G)+UPRS (5)GI:G+Ivoclar Vivadent Ceramic Repair (Ivoclar Vivadent). All specimens received a composite resin cylinder (Clearfil Majesty Esthetic,Kuraray) formed with a silicone mold (4mm diameter, 2mm height) to simulate repair. Then, 2 subgroups were composed according to the artificial aging procedures as baseline and aging (5000 thermal cycles between 5°C-55°C) (n=12). The SBS tests were performed by using a universal testing machine. Failure types were classified as cohesive failure in PICN, cohesive failure in composite, adhesive,and mixed. The SBS data were analyzed with 1-way ANOVA, factorial ANOVA, LSD, and Duncan tests (α=0.05). Failure modes were calculated as a percentage for each group.

Results: The baseline results showed that the mean SBS values for ES and GU were higher than TS ($p<0.05$). Considering artificially aged groups, ES showed higher SBS than EU and GU ($p<0.05$). SBS values for ES, EU, and GU groups decreased significantly after the artificial aging procedure compared to baseline ($p<0.05$). At baseline, the dominant failure mode was cohesive in PICN for all groups and no adhesive failures were observed for ES and GU groups. However, after aging, the only group that did not show adhesive failure was ES.

Conclusions: Considering the time-efficiency and effectiveness, etching with HF followed by Single Bond Universal application can be recommended as the intraoral repair protocol for PICN.

Keywords: CAD/CAM, dental restoration repair, shear strength, composite resins.

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INTRODUCTION

The use of computer-aided design and computer-aided manufacturing (CAD/CAM) has become a popular treatment option with a wide range of materials available for this technology.[1] Among these materials, glass-matrix ceramics are highly preferred due to their improved esthetic appearance, biocompatibility, and color stability.[2,3] However, disadvantages include abrasive effect on opposing dentition, brittleness, and susceptibility to cracks or fractures.[3-5] The CAD/CAM hybrid ceramic blocks are developed with the idea of combining favorable characteristics of ceramics and composites.[6,7] Hybrid ceramic restorations have flexural properties similar to dentine and they are more flexible and less brittle than ceramic materials.[4,8-11] A recent material, Vita Enamic, is a hybrid ceramic composed of an organic polymer of 14% which penetrates into the inorganic feldspathic ceramic matrix of 86%.[3,11] Thus, Vita Enamic is called as polymer-infiltrated ceramic network (PICN) hybrid material.[6,12]

Despite the advantages of shock absorption and decreased crack propagation as a result of the combination of crystalline matrix and polymeric material, PICN materials still present a low elastic modulus and biaxial strength.[3,9,11-13] Therefore, fracture of a PICN restoration can be encountered in clinical practice due to parafunctional habits, aging, and trauma.[14] Considering the replacement cost and the possibility of sound tooth structure loss or pulpal trauma, intraoral repair of these restorations may be preferred over replacement.[7,15,16] Moreover, intraoral repair can be advantageous considering reduced chair time for both patient and dentist.[14]

Various intraoral repair systems have been developed to enhance the functionality of the restoration.[7] The choice of the most appropriate system that would provide a certain outcome can be complicated for the clinician.[7,17] Those systems differ in terms of the surface treatments and adhesive agent used which improve the bond strength between the restorative material and composite resin for repair.[2,9] Surface treatments include grinding with a diamond bur[7], etching with hydrofluoric or phosphoric acid in different concentrations[18,19], and air-abrasion with alumina particles or tribochemical silica coating.[9,12] The success and maintenance of the repaired restoration may vary according to the repair system or protocol used.[2,9,14,20] Surface grinding followed by the application of a universal adhesive was advised by Silva *et al*.[9] for the repair of Vita Enamic restorations. On the other hand, a recent study suggested hydrofluoric acid (HF) etching and silanization.[20] Furthermore, the bond strength of the repair composite to PICN restoration may be influenced after a period of intraoral service.[7,20]

Restorations may fail after aging in a humid oral environment.[7] Also, the repair potential of the material may alter with aging conditions which may cause some alterations on the surfaces of restorative materials.[2,14] Clinical service is simulated artificially in in vitro studies with storage in water, acids or artificial saliva[7,20], and thermal cycling alone[7,14] or in combination with loading.[14] After a certain artificial aging period, the bond strength of repair composite to restorations can be evaluated by using macro or micro techniques of shear and tensile tests.[2,7,9,12,14] The previous studies have commonly used the shear bond strength (SBS) test because it is an easy and reliable method.[2] Also, due to its widespread use, comparing the results with a wide range of in vitro studies is more feasible.

The best repair protocol to treat a fractured or chipped PICN restoration is still controversial. The aim of this study, therefore, was to investigate the effects of five different repair protocols and artificial aging on the shear bond strength (SBS) of composite implemented on the PICN material. The null hypothesis was that different repair protocols and artificial aging would not influence the SBS values.

MATERIALS AND METHODS

The design of this research was approved by the Clinical Research Ethics Committee of Ankara University Faculty of Dentistry, Turkey (2020-11/03).

Specimen Preparation

Materials used in this study are presented in Table 1.

Table 1. Materials used in this study

Brand	Chemical Composition	Manufacturer
Vita Enamic (Polymer infiltrated ceramic)	**Ceramic Network (86 wt%):** SiO2 (58–63%), Al2O3 (20–23%), Na2O (9-11%), K2O (4-6%), B2O3 (0,5-2%), ZrO2 (< 1%), CaO (< 1%) **Polymer Network (14 wt%):** UDMA, TEGDMA	VITA Zahnfabrik, Bad Säckingen, Germany
Single Bond Universal	10-methacryloyloxydecyl dihydrogen phosphate (MDP) monomer, Dimethacrylate resins, HEMA, Vitrebond copolymer, Filler, Ethanol, Water, Initiators, Silane	3M ESPE, St. Paul, MN, USA
Rocatec Soft	High-purity aluminium oxide 30 µm, modified with silica (SiO_2)	3M ESPE, St. Paul, MN, USA
Porcelain Etchant	4% Hydrofluoric acid	Bisco Inc., Schaumburg, IL, USA
Ultradent Porcelain Repair System	**Ultradent porcelain etch:** 9% Hydrofluoric acid, **Ultradent silane:** 8% Methacryloxypropyl-trimethoxysilane, Isopropyl alcohol, Acetic acid **Peak Universal Bond:** 7.5% Ethyl alcohol, 0.2% Chlorhexidine, Methacrylic acid, 2-HEMA	Ultradent Products, South Jordan, UT, USA
Ceramic Repair N System Kit	**Monobond Plus:** Adhesive monomers (4%), Ethanol (96%) **Heliobond:** Bis-GMA and tri-ethylene glycol dimethacrylate (99 wt.%), initiators and stabilizers (<1%).	Ivoclar Vivadent AG, Schaan, Liechtenstien
Clearfil Majesty Esthetic Composite	Silanated barium glass filler (average: 0.7 µm), Pre-polymerized organic filler including nano filler, Bis-phenol A diglycidylmethacrylate (Bis-GMA), Hydrophobic aromatic dimethacrylate, dl-Camphorquinone, Initiators, Accelerators, Pigments, Others	Kuraray, Tokyo, Japan

PICN CAD/CAM blocks (Vita Enamic, Vita Zahnfabrik, Bad Sackingen, Germany) were sectioned under continuous water cooling by using a low-speed diamond saw (Micracut 201, Metkon, Turkey) and 120 specimens with 1,5 mm thickness were obtained. All specimens were embedded in self-curing acrylic (Integra, Birlesik Group Dental, Ankara, Turkey). Then, the surfaces of the specimens were grounded with 600, 800, and 1000 grit silicon carbide papers for 30 seconds to standardize the surfaces. Afterward, the specimens were ultrasonically cleaned in distilled water for 5 min. Artificial aging was applied on all specimens by using a thermocycler (THE-1100, SD Mechatronik, Feldkirchen-Westerham, Germany) with the following parameters: thermal application between 5ºC and 55ºC, 30 seconds dwelling time, and 5000 cycles. Aged specimens were randomly allocated into 5 groups (n=24) according to the repair protocol performed on the PICN surface: 1) TS: tribochemical silica coating-Single Bond Universal 2) ES: etching with HF-Single Bond Universal 3) EU: etching with HF-Ultradent Porcelain Repair System 4) GU: grinding with diamond bur-Ultradent Porcelain Repair System 5) GI: grinding with diamond bur-Ivoclar Vivadent Ceramic Repair System. Test groups and repair protocols are described in Table 2.

Table 2. Test groups, abbreviations, and application protocols used in the present study.

Test group	Group abbreviations	Application protocol
Tribochemical silica coating & Single Bond Universal	**TS**	- Air abrasion with Rocatec soft for 10 sec at a distance of 10 mm with 2 bar pressure - Ultrasonic cleaning for 5 minutes in alcohol - Single Bond Universal application for 1 min
Etch & Single Bond Universal	**ES**	- Bisco Porcelain Etchant application for 5 min - Rinsing with a water spray for 10 sec/ air-drying for 5 sec - Single Bond Universal application for 1 min
Etch & Ultradent Porcelain Repair System	**EU**	- Porcelain Etch application for 90 sec - Rinsing with a water spray for 10 sec/ air-drying for 5 sec - Application of %37 phosphoric acid for 5 sec - Rinsing with a water spray for 10 sec/ air-drying for 5 sec - Ultradent silane application, allowed to evaporate for 1 min and dried - Peak Universal Bond applied for 10 sec
Grinding & Ultradent Porcelain Repair System	**GU**	-Surface grinding with a coarse diamond bur (181 μm grit) -Application of the EU protocol
Grinding & Ivoclar Vivadent Ceramic Repair System	**GI**	- Surface grinding with a coarse diamond bur (181 μm grit) - Monobond plus application and allowing to react for 60 sec then drying with air - Heliobond application and thinned with air

Surface treatments and porcelain repair systems were applied in line with the manufacturers' recommendations.

Polymerization of the bonding agents in all groups was performed with a light-emitting diode (LED) curing unit (Bluephase 20i, Ivoclar Vivadent, Schaan, Liechtenstein) at 1200 mW/cm^2 for 10 seconds. The specimens treated with different surface conditioning protocols were repaired by using a composite resin (Clearfil Majesty Esthetic, Kuraray, Tokyo, Japan) applied in cylindrical silicone molds (diameter: 4 mm; height: 2 mm). LED curing was implemented on composite cylinders for 20 seconds. Afterward, the specimens were immersed in distilled water at 37ºC for 24 hours.

Half of the specimens from each group were subjected to SBS test immediately (Baseline groups), while the other half were aged for 5000 thermal cycles between 5ºC and 55ºC with a dwelling time of 30 seconds before SBS testing (Aging groups) to simulate a period of intraoral service after the repair (n = 12).

SBS Test

A computer-controlled universal testing machine (Lloyd Instruments, Fareham Hants, England) with 1 mm/min crosshead speed was used to perform the SBS tests. The maximum load at failure was recorded in Newtons (N). The SBS value in megapascals (MPa) for each specimen was calculated by dividing the SBS in N by the adhesive surface area (mm²).

Failure Mode Analysis

A stereomicroscope (M3Z, Leica Microsystems, Wetzlar, Germany) was used to determine the failure mode for each debonded specimen. Failure modes classified under 25x magnification were as follows: 1) cohesive failure in the PICN, 2) cohesive failure in the composite, 3) adhesive failure at the PICN-composite interface, 4) mixed failure (a combination of adhesive and cohesive failures). Recorded failure modes were calculated as a percentage for each group.

Statistical Analysis

One-way ANOVA and Duncan's multiple comparison tests were used to compare the SBS data for different surface treatment protocols. Factorial analysis of variance (ANOVA) and post-hoc least significant difference (LSD) tests were used to determine significant differences between the SBS values of each surface treatment protocol before and after artificial aging (baseline vs aging) (α = 0.05). All the statistical analyzes were performed by using R v.3.5.3 (Microsoft Corporation, Redmond, WA, USA).

RESULTS

The ANOVA results are shown in Tables 3 and 4.

Table 3. One-way ANOVA results for SBS tests

Aging procedure	Effect	Sum of squares	df	Mean squares	F	P Value
	Between Groups	266.560	4	66.640	3.258	.018
Baseline	Within Groups	1125.072	55	20.456		
	Total	1391.632	59			
	Between Groups	164.442	4	41.111	3.053	.024
Aging	Within Groups	740.554	55	13.465		
	Total	904.996	59			

Table 4. Factorial ANOVA results for SBS tests.

Effect	Sum of squares	df	Mean squares	F	P Value
Intercept	22108.08	1	22108.08	1303.524	0.000
Repair protocol	255.454	4	63.86	3.765	0.007
Aging procedure	165.85	1	165.85	9.779	0.002
Repair protocol * Aging procedure	175.54	4	43.89	2.588	0.041
Error	1865.63	110	16.96		

One-way ANOVA demonstrated that different surface treatment protocols influenced the SBS results for both baseline (p=0.018) and aging (p=0.024) groups (Table 3). Considering baseline results, the mean SBSs for ES and GU groups were not significantly different from each other (p>0.05) but were higher than that for the TS group (p<0.05). EU and GI showed comparable mean SBS results with all groups and with each other (p>0.05). After aging, SBS for the ES group was found out to be higher than the EU and GU groups (p<0.05) which demonstrated comparable results (p>0.05). TS and GI demonstrated similar SBS values with all groups (p>0.05) (Table 5).

Table 5. Means (x̄, in MPa) and standard deviations (SD) of shear bond strength tests for each group

Surface treatment protocol	Baseline x̄ ±SD	Aging x̄ ±SD
TS	11.2 ± 3.2 Ba	12.82 ± 4.05 ABa
ES	17.15 ± 4.43 Aa	15.02 ± 2.8 Ab
EU	14.1 ± 5.42 ABa	10.36 ± 3.3 Bb
GU	16.6 ± 5 Aa	10.9 ± 4.95 Bb
GI	14.69± 4.2 ABa	12.89 ± 2.87 ABa

*Means followed by different uppercase in the same column and lowercase in the same line indicate a statistically significant difference (p<0.05).
**TS, tribochemical silica coating & Single Bond Universal; ES, etch & Single Bond Universal; EU, etch & Ultradent Porcelain Repair System; GU, grinding & Ultradent Porcelain Repair System; GI, grinding & Ivoclar Vivadent Ceramic Repair System.

Factorial ANOVA showed that the interaction between the repair protocol and aging procedure was significant (p=0.041), indicating that the SBS result of a particular repair protocol differed significantly with regard to artificial aging (Table 4). Mean SBS values for ES, EU, and GU decreased significantly after aging ($p<0.05$). However, TS and GI groups showed comparable SBS results before and after aging ($p>0.05$) (Table 5).

Figure 1 shows the failure type distrubition for the test groups.

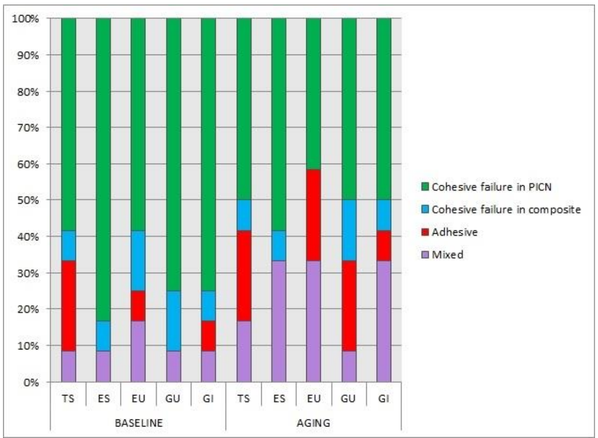

Figure 1. Distribution of the failure modes for each repair protocol before and after artificial aging.
*PICN: Polymer-infiltrated ceramic network; TS, tribochemical silica coating & Single Bond Universal; ES, etch & Single Bond Universal; EU, etch & Ultradent Porcelain Repair System; GU, grinding & Ultradent Porcelain Repair System; GI, grinding & Ivoclar Vivadent Ceramic Repair System.

Cohesive failure in PICN was dominant for all surface treatment protocols at baseline. ES showed the highest cohesive failure in PICN among groups (83%). After the aging procedure, ES demonstrated mostly cohesive failure in PICN (58%) while half of the specimens of TS, GU, and GI groups showed cohesive failure in PICN. No adhesive failures were observed for ES neither at the baseline nor after the aging process. Also, GU did not show any adhesive failures at baseline. However, the TS, EU, and GU groups failed up to 25% adhesively after aging.

DISCUSSION

Small fractures or chippings of hybrid CAD/CAM restorations that occur during the intraoral service can be repaired chairside to allow for extended clinical use.[21] Thus, a strong bond should be ensured between the restoration and repair composite. The bond strength of the composite to the restoration surface may vary according to repair protocols and intraoral aging.[7,20,22] This study applied 5 different repair protocols on the surface of an aged PICN material and SBS of the repair composite was evaluated before and after artificial aging. Based on the present results, SBS differed significantly with regard to the repair protocol used and aging procedure. Therefore, the null hypothesis should be rejected.

The success and longevity of the repaired restoration may be influenced by various factors including the CAD/CAM restorative material,[2] composite material used for repair,[21] and surface conditioning procedures.[7,17] In this study, CAD/CAM material (PICN) and composite resin used for the repair were standardized to evaluate the effect of different repair protocols on SBS and their durability after the aging procedure. The PICN material was aged (5000 thermal cycles) before the application of surface treatments as the thermocycling aging has a significant influence on the repair strength due to the degradation of the microstructure.[23,24]

In the present study, regarding baseline results before the artificial aging, HF etching followed by Single Bond Universal application showed higher SBS than tribochemical air abrasion. This finding is consistent with the results of some studies;[7,9] however, contradicts others suggesting similar bond strengths for HF etching and tribochemical silica coating.[12,19] Etching with HF causes dissolution of silica in the glassy phase of the PICN material, producing a porous micro-retentive surface with high energy.[25,26] Tribochemical air abrasion with 30-μm silica-coated alumina roughens the surface and enhances silica content on the surface, producing silicatization.[27,28] Campos *et al*.[27] demonstrated better micromechanical interaction and higher surface roughness of PICN material for HF etching compared to tribochemical air abrasion. On the other hand, tribochemical air abrasion was found to be more effective than HF on the materials with higher resin content[27-29] Since PICN is composed of 86% ceramic and 14% resin, HF treatment can be expected to present better repair bond strength for this type of material.[29]

After artificial aging, tribochemical air abrasion represented a stable bond; however, the SBS of the composite applied on the surfaces treated with Ultradent Porcelain Repair System and with HF etching followed by Single Bond Universal application decreased significantly. In line with our findings, Silva *et al*.[9] reported a durable bond for tribochemical air abrasion but indicated a decrease in SBS when the PICN surfaces were treated with grinding, HF etching, and Single Bond Universal application. The authors attributed the decrease in bond strength to the tendency for hydrolysis in the MDP content of the adhesive materials during the aging protocol. Water can penetrate small spaces between polymers or functional groups owing to its small molecular size and high molar concentration, leading to a degradation in adhesive properties.[27] Considering tribochemical air abrasion, it can be assumed that additional silicatization provided by silica-coated alumina particles may have promoted the chemical interaction between the repair composite and PICN material.[27]

The ceramic repair systems used in the present study (Ultradent and Ivoclar Vivadent) represented similar SBS results for both aged and nonaged groups consistent with the findings reported by Ustun *et al*.[2] This was not surprising considering that both systems require similar multi-steps including grinding with a diamond bur or acid etching, silanization, and adhesive application. The manufacturer recommended grinding with a diamond bur prior to HF etching for the Ultradent Porcelain Repair System. However, grinding did not significantly improve the SBS neither for non-aged nor for aged specimens. The time-efficiency is of importance in clinical practice and each additional step prolongs the treatment.[30] Therefore, when using the Ultradent system for PICN repair, grinding with a diamond bur may be considered as a redundant step.

The bond strength of HF etched and Single Bond Universal applicated group (ES) was comparable with both ceramic repair systems before aging and was better than the Ultradent Porcelain Repair System after the aging procedure. Universal adhesives are simplified systems that contain some or all of the bonding components in a single bottle.[31] Single Bond Universal unifies both silane and bonding agent in an individual unit. The use of universal adhesives in clinical practice not only reduces the complexity of application procedures but also provides ease of practice for the clinicians[29,32] Furthermore, ES repair protocol provided an adequate repair bond strength within the range of 15 to 25 MPa for both before and after the aging procedure (17.15 ± 4.43 MPa and 15.02 ± 2.8 MPa, respectively).[7] Single Bond Universal diverges from the other adhesives used in this study by the MDP monomer in its content. The MDP is a bifunctional monomer capable of bonding to both oxides and methacrylate monomers on the surface of the PICN.[19] The increased bond strength values for Single Bond Universal was reported in the previous studies and was attributed to the combined effects of MDP monomer, silane, and Vitrebond copolymer.[19,28,31] The first step of the ES protocol is the HF etching which reacts with silicon dioxide, dissolves the glassy phase of the PICN surface, and results in an increased surface energy of the ceramic.[33] The phosphoric acid groups of MDP monomer in the Single bond Universal infiltrates into the micro-irregularities composed by the HF application in the ceramic network.[9] It can be assumed that the enhanced bond strength obtained with ES repair protocol was stemmed from the MDP content. Therefore, when intraoral repair of the PICN material is required, clinicians may choose to etch with HF followed by a silane-containing universal adhesive application as the surface treatment instead of multi-step repair systems considering the time-efficiency and effectiveness of this protocol.

Cohesive and mixed failures indicate high bond strength; however, adhesive failure can be associated with poor bond strength.[34] The groups showed lower SBS results (TS before and after aging, and EU-GU after aging) demonstrated an adhesive failure rate of 25% while the ES group which showed high SBS results for both aging protocols failed cohesively in PICN dominantly.

Therefore, it can be suggested that in the present study, the findings of the stereomicroscobic analysis supported the SBS testing.

One limitation of this study was the lacking of a control group. A group considered as control with no surface treatment was performed but most of the specimens failed pre-test, therefore implementing the SBS test was not feasible. Another limitation of this study was that the macro-SBS test was used to evaluate the bond strength. The macro-bond strength tests were reported to result in the overestimation of the bond strengths.[35] Therefore, the present results should be interpreted with caution. Also, a single aging procedure (5000 thermal cycles) without any cyclic loading was applied. Repair protocols tested in this study may be varied with different combinations of adhesive systems and composites. Future studies should investigate the effects of the diversified repair and the aging protocols combined with cyclic loading conditions on the repair bond strength of composite to PICN material.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. At the baseline, ES and GU enhanced the bond strength of repair composite to PICN compared to TS repair protocol.
2. After aging, the ES repair protocol provided better repair bond strength than either repair protocols involved Ultradent Porcelain Repair System.
3. TS and GI repair protocols showed more stable bond strengths compared to other protocols after the aging procedure. Although affected negatively by the aging procedure, SBS of ES was higher than both groups, yet not significant.
4. Repair of the PICN with ES protocol demonstrated SBS values within the acceptable clinical range both before and after the aging procedure.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

Farklı Onarım Protokollerinin ve Yapay Yaşlandırmanın Kompozitin Polimer-İnfiltre Seramik Ağ Materyaline Bağlanma Kuvvetine Etkisi

Öz

Amaç: *Bu çalışmanın amacı, farklı onarım protokollerinin ve yapay yaşlandırmanın PICN malzemesinin onarımında kullanılan kompozitin kayma bağlantı dayanımı (SBS) üzerindeki etkisini değerlendirmektir.* ***Gereç ve Yöntemler:*** *Toplam 120 PICN (Vita Enamic, Vita Zahnfabrik) numunesi hazırlandı, yapay olarak yaşlandırıldı (5°C ile 55°C arasında 5000 termal döngü) ve 5 onarım protokolüne göre gruplandı: (1) TS: tribokimyasal silika kaplama (Rocatec Soft; 3M ESPE)+Single Bond Universal (SBU; 3M ESPE) (2) ES: hidroflorik asit ile pürüzlendirme (HF; Bisco)+SBU (3) EU: HF +Ultradent Porselen Onarım Sistemi (UPRS; Ultradent Products Inc.) (4) GU: elmas frezle aşındırma (G)+UPRS (5) GI: G +Ivoclar Vivadent Seramik Onarım Sistemi (Ivoclar Vivadent AG). Onarımı simüle etmek amacıyla tüm örneklere silikon bir kalıpla (4 mm çap, 2 mm yükseklik) oluşturulmuş kompozit silindirler (Clearfil Majesty Esthetic, Kuraray) uygulandı. Daha sonra yapay yaşlandırma prosedürüne göre başlangıç ve yaşlandırma (5 ° C ile 55 ° C arasında 5000 termal döngü) olarak 2 alt grup oluşturuldu (n = 12). SBS testleri universal test cihazı kullanılarak gerçekleştirildi. Başarısızlık tipleri PICN içinde koheziv, kompozit içinde koheziv, adeziv ve karışık olarak sınıflandırıldı. SBS verileri istatistiksel olarak tek yönlü ANOVA, faktöryel ANOVA, LSD ve Duncan testleri ile analiz edildi. (α=0.05) Başarısızlık tipleri her grup için yüzde olarak hesaplandı.* ***Bulgular:*** *Başlangıç sonuçları, ES ve GU için ortalama SBS değerlerinin TS'den daha yüksek olduğunu gösterdi ($p<0.05$). Yapay olarak yaşlandırılmış gruplara bakıldığında ES grubu EU ve GU'dan daha yüksek SBS gösterdi ($p<0.05$). ES, EU ve GU grupları için SBS değerleri, suni yaşlandırmadan sonra başlangıca göre önemli ölçüde azaldı ($p<0.05$). Başlangıçta, dominant başarısızlık modu tüm gruplar için PICN içinde kohezifti ve ES ve GU grupları için* *adezif başarısızlık gözlenmedi. Bununla birlikte, yaşlandırmadan sonra adezif başarısızlık göstermeyen tek grup ES idi.* ***Sonuçlar:*** *Zaman verimliliği ve etkinlik göz önüne alındığında, HF ile aşındırmanın ardından Single Bond Universal uygulaması PICN için ağız içi onarım protokolü olarak önerilebilir.* ***Anahtar Kelimeler:*** *CAD/CAM, dental restorasyon onarımı, kayma mukavemeti, bileşik rezinler.*

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