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Effect of Surface Pretreatments on the Bond Strength and Removal Efficiency of Temporary Restoration

Yüzey Hazırlık Yöntemlerinin Bağlanma Dayanımı ve Geçici Restorasyonun Uzaklaştırma Etkinliği Üzerine Etkisi

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Abstract

Objectives: To evaluate the effect of temporary restoration and different surface pretreatment methods on the shear bond strength (SBS) of resin cement to dentin surfaces coated with immediate dentin sealing (IDS), and assess the relationship between removal efficiency and SBS.

Materials and Methods: Forty extracted human molars were prepared to obtain flat dentin surfaces and IDS was applied. Specimens were randomly assigned into four groups (n=10): air abrasion with silica-coated alumina or polishing using abrasive paste, with and without temporary restoration. In the test groups, temporary restorations were applied, stored in distilled water for 7-days, and removed using dental probe. The surfaces of all specimens were pretreated with either air abrasion or polishing and then restored with a dual-cure resin cement. After thermocycling, SBS was tested. Fluorescence images obtained before and after surface pretreatment were used to quantify residual temporary material and to calculate removal efficiency. Data were analyzed using one-way ANOVA, Tukey's post hoc, and Pearson's correlations tests.

Results: The mean SBS values of temporary groups were significantly lower than control groups ($p<0.05$). No significant difference was observed between pretreatment methods. The mean removal efficiency was 72.6±22% for air abrasion and 59.7±34.5% for polishing ($p=0.380$). A positive correlation existed between removal efficiency and SBS ($r=0.83$, $p<0.01$).

Conclusion: Temporization significantly reduced the SBS to IDS-applied dentin, regardless of the surface pretreatment method. Both cleaning approaches removed residues effectively but neither restored initial strength. Higher removal efficiency correlated with improved adhesion, emphasizing the importance of effective cleaning after using temporary material.

Keywords: *Air-abrasion, Dental bonding, Shear strength, Temporary dental restorations.*

Özet

Amaç: Geçici restorasyon uygulaması ve yüzey hazırlık yöntemlerinin, immediate dentin sealing(IDS) uygulanan dentin yüzeylerinde rezin simanın makaslama bağlanma dayanımı (SBS) üzerindeki etkisini değerlendirmek ve geçici restorasyonun uzaklaştırılma etkinliği ile SBS arasındaki ilişkiyi incelemek amaçlanmıştır.

Gereç ve Yöntemler: Kırk adet çekilmiş insan molar dişinde düz dentin yüzeyleri hazırlanarak IDS uygulandı. Örnekler rastgele dört gruba ayrıldı(n=10): geçici restorasyon uygulanmaksızın silika kaplı alüminyum oksit ile air-abrazyon veya aşındırıcı pasta ile yüzey hazırlığı yapılan kontrol grupları, geçici restorasyon uygulanan ve restorasyonun uzaklaştırılmasını takiben air-abrazyon veya aşındırıcı pasta ile yüzey hazırlığı yapılan test grupları. Test gruplarında geçici restorasyonlar uygulandı, distile suda 7-gün bekletildi ve dental sond ile uzaklaştırıldı. Tüm örneklerin yüzeyleri ilgili yüzey hazırlık protokolüne göre temizlenerek dual-cure rezin siman uygulandı. Termal döngü işlemini takiben SBS testi gerçekleştirildi. Yüzey işleminden önce ve sonra alınan floresans görüntüleri ile rezidüel geçici materyal miktarı belirlendi, uzaklaştırma etkinliği (%) hesaplandı. Elde edilen veriler tek yönlü varyans analizi, Tukey post-hoc ve Pearson korelasyon testi ile değerlendirildi.

Bulgular: Geçici restorasyon uygulanan grupların ortalama SBS değerleri, kontrol gruplarına göre anlamlı derecede daha düşüktü($p<0,05$). Yüzey hazırlık yöntemleri arasında SBS açısından anlamlı bir fark izlenmedi. Ortalama uzaklaştırma etkinliği air-abrazyon için %72,6±22,0, aşındırıcı pasta için ise %59,7±34,5 olarak hesaplandı ($p=0,380$). Uzaklaştırma etkinliği ile SBS arasında pozitif bir korelasyon saptandı ($r=0,83$, $p<0,01$).

Sonuç: Geçici restorasyonların uygulanması, yüzey hazırlık yönteminden bağımsız olarak IDS-uygulanan dentin yüzeylerinde SBS'yi önemli ölçüde azaltmıştır. Her iki temizlik protokolü de rezidüel geçici materyali etkin biçimde uzaklaştırmasına rağmen, kontrol grubundaki SBS değerlerini sağlayamamıştır. Uzaklaştırma etkinliğindeki artışın yüksek bağlanma dayanımı değerleri ile ilişkili olması, etkili yüzey temizliğinin önemini vurgulamaktadır.

Anahtar Kelimeler: *Air-abrazyon, Dental bonding, Geçici diş restorasyonları, Makaslama dayanımı.*

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Introduction

In current restorative dentistry, adhesive procedures are essential for achieving retention and marginal integrity in both direct and indirect restorations.[1] With the use of contemporary clinical protocols and restorative materials, the goal is to establish a durable bond between the restorative materials and dental tissues. Nevertheless, the complex structure of dentin tissue and the difficulty of achieving a long-term bond remain significant challenges. During restorative procedures, contamination of dentin with blood, saliva, or temporary restorative materials may cause collapse of the exposed collagen network, adversely affecting hybrid layer formation and resin infiltration.[2] The introduction of techniques that permit bonding of freshly prepared dentin surfaces with adhesive resin immediately after tooth preparation has substantially reduced these limitations. Evidence suggests that immediate dentin sealing (IDS) improves bond strength, provides a barrier against bacterial penetration, and substantially lowering postoperative sensitivity.[3-6] As with conventional indirect restorations, laboratory-based CAD/CAM workflows for indirect restorations may also necessitate more than one clinical appointment. Although IDS contributes to improving and preserving dentin adhesion throughout the period before final cementation, temporary restorations are needed to protect the pulp, preserve tooth structure, and maintain occlusal function and esthetics.[7] The quality of the adhesive interface can be significantly affected by the interim period during which these temporary restorations are in place, as well as by their subsequent removal.[8] Notably, residues remaining on IDS-applied surfaces following removal of temporary materials may inhibit adhesive infiltration and compromise the bond strength of definitive restorations.[9,10] Consequently, appropriate surface conditioning following the removal of temporary restorations is a necessity to re-establish the bonding potential of the adhesive interface and to achieve the long-term clinical success of indirect restorations.[8] While the contamination of blood or saliva can generally be rectified through the re-etching and re-application of adhesive systems[11], the elimination of temporary materials requires the implementation of supplementary surface cleaning protocols.[12] Among the methods examined, air abrasion and pumice polishing are frequently applied in clinical protocols.[13-15] Air abrasion, which involves the application of particles such as aluminum oxide or silica-coated aluminum oxide to the adhesive surface, aims to effectively remove residues of temporary material.[16] The capacity of this method to generate a micro-roughened surface has been demonstrated to enhance micromechanical retention for adhesive systems.[17] However, it is important to note that excessive abrasion has the potential to expose dentinal tubules and thereby compromise bond strength.[18,19] On the other hand, cleaning with pumice is a more conservative mechanical technique commonly used to remove plaque deposits as well as temporary cement residues. Its relatively low abrasiveness makes this method safe for dental surfaces, while also serving as a preliminary pretreatment step that can increase the success of subsequent adhesive applications.[8,15,20] Despite the existence of studies that indicate the superiority of aluminum oxide abrasion to pumice in terms of bond strength[8,18], there are also studies that find no statistically significant difference between the two approaches.[21-23] A recent review suggested that alumina air abrasion may improve bonding to sound dentin but reduce bond strength when applied to IDS-treated surfaces.[10]

In dentistry, fluorescence is defined as the emission of visible light by a material when it is exposed to near-ultraviolet light. Current restorative materials exhibit distinct fluorescence properties under near-UV illumination, enabling to be visualized with enhanced contrast against dental hard tissues or various materials. In addition to enabling esthetic evaluation, this feature also provides a valuable diagnostic advantage for the detection and quantification of residual material on treated surfaces.[24] Similarly, some resin-based temporary restorative materials have a property of inherent fluorescence under near-ultraviolet illumination. In this context, the ability to visualize and document the residual temporary material more precisely than with conventional examinations has been considered a methodological advantage. This facilitates a more precise evaluation of residual material and may allow a reliable comparison of different surface conditioning protocols with regard to their cleaning efficiency. Previous studies have predominantly focused on the effect of temporary cements on dentin bonding[8,12,15,22] whereas limited evidence is available regarding the influence of resin-based provisional restorative materials, such as Clip F, on IDS-applied dentin.[9,14,17] Moreover, further comparative investigations are required to determine the effectiveness of various surface pretreatment protocols following the temporary restoration removal. Therefore, the current study aimed to examine the effect of temporary restorations and two different surface pretreatment methods (air abrasion with silica-coating and polishing with abrasive paste) on the SBS of resin cement to dentin surfaces treated with IDS. The fluorescence property of Clip F enabled a more accurate detection and quantification of residual material using Image J analysis, thereby allowing direct comparison of two different surface pretreatment protocols.

The hypotheses were:
1. The application of temporary restoration would not affect the SBS of resin cement to IDS-applied dentin.
2. Different surface pretreatment methods would not influence the SBS of resin cement to IDS-applied dentin.

Materials and Methods
This study was approved by the Clinical Research Ethics Committee of Marmara University Faculty of Dentistry (Approval no: 2025-05-04/2025-17). Teeth extracted less than three months prior that did not exhibit any caries, restorations, or structural defects were selected for this study.

Using a power analysis, the sample size was determined using G*Power software (Version 3.1.9.7; Franz Faul, University of Kiel, Germany) and methodology reported previously.[25] A minimum sample size of n=7 was estimated per group, for which there would be 80% statistical power in a two-way ANOVA design (α=0.05, f=0.75 effect size). Due to the possibility of losing samples during the experiment, a total of n=10 samples per group (N=40) were included.

Group Allocation
The 40 teeth were randomly assigned into four groups (n=10) for SBS evaluation.

Control groups: *Group A.* Surface pretreatment with 30 µm silica-coated aluminum oxide particles, without temporary restoration. *Group P.* Surface pretreatment with polishing using 1 µm diamond-based abrasive paste, without temporary restoration. Test groups: *Group TA.* Following the temporary restoration and its removal procedures, surface pretreatment with 30 µm silica-coated aluminum oxide particles. *Group TP.* Following the temporary restoration and its removal procedures, surface pretreatment with polishing using 1 µm diamond-based abrasive paste.

Groups A and P served as controls to assess the influence of temporary restorations, whereas Groups TA and TP were used to assess the effects of different pretreatment methods after temporary restoration removal (Fig. 1).

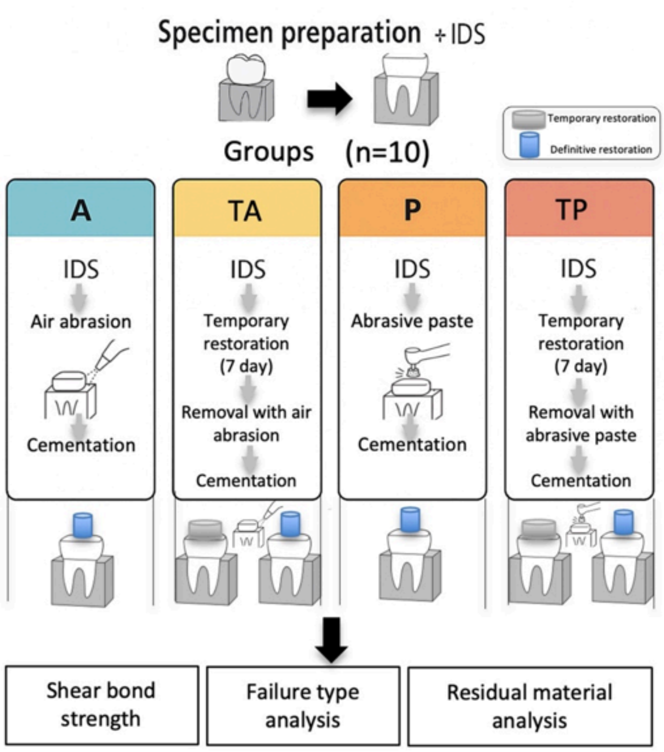

Figure 1. Schematic representation of the experimental design and allocation.

Preparation of Samples

The occlusal one-third of each crown was sectioned under water cooling with a separating disc to expose a flat dentin surface. The prepared surfaces were then aligned parallel to the base of the acrylic blocks. These surfaces were polished using Sof-Lex discs (3M ESPE, USA) and examined under a stereomicroscope (×25 magnification, Leica MZ 75, Leica Microsystems, Germany) to ensure that no pulp tissue was exposed. The dentin surfaces were etched with 35% orthophosphoric acid (Vococid, VOCO, Germany) for 15 s, rinsed thoroughly, and gently air-dried. Futurabond DC (VOCO, Germany) was applied to the dentin surface in accordance with the manufacturer's instructions, and then light-cured. For the IDS protocol, a thin flowable composite resin-coating was applied over the adhesive to protect the sealed dentin during provisionalization and to provide a stable bonding substrate for cementation. The flowable composite (Admira Fusion x-base, VOCO, Germany), was applied using a glass slide to ensure an even and smooth layer and polymerized for 20 s (Valo Cordless, Ultradent, USA; 1000 mW/cm² in standard mode) (Fig. 2.a). To minimize the oxygen-inhibition layer, the surface was covered with glycerin gel and light-cured for an additional 10 s (Valo Cordless, Ultradent, USA).

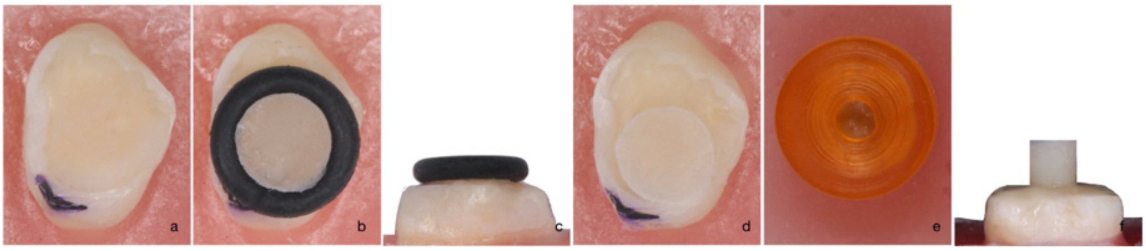

Figure 2. Specimen preparation and restoration workflow. **a.** Prepared flat dentin surface with IDS. **b.** Placement of a silicone mold on the occlusal surface for the application of temporary restorative material. **c.** Standardized cylindrical mold positioned to define the bonding area. **d.** IDS-treated surface with temporary restorative material after mold removal. **e.** Positioning of the silicone mold for the application of resin cement simulating the permanent restoration. **f.** Application of resin cement representing the permanent restoration.

Restoration of Control Groups

In the control groups, resin cement was applied immediately after surface pretreatment. Depending on subgroup allocation, dentin surfaces were conditioned either by air abrasion with 30 µm silica-coated Al_2O_3 particles (3 bar pressure for 15 s from a distance of 10 mm; Group A) or by polishing with an abrasive paste (Group P). A diamond polishing paste was applied with rotary brush at 1,500 rpm for 15 s under light pressure, following thorough water rinsing and gentle air-drying. After surface preparation, the IDS surface was etched with 35% orthophosphoric acid for 15 s, thoroughly rinsed, and gently air-dried. Subsequently, the Futurabond DC adhesive was applied according to the manufacturer's instructions, light-cured for 20 s using Valo Cordless. Cementation was then performed using Bifix QM dual-cure resin cement (VOCO, Germany) with silicone mold (3-mm in diameter and 4-mm in height) (Fig. 2.c-d). The cement was polymerized for 20 s each from the buccal, occlusal, and lingual surfaces using the Valo Cordless in standard mode.

Restoration of Test Groups

Temporary restoration of test groups

In the test groups, IDS-applied dentin surfaces were restored using Clip F (VOCO, Germany), a temporary resin material with inherent fluorescence. The material was applied using silicone cylindrical molds and light-cured for 20 s (Fig. 2.b-d). Specimens with temporary restorations were immersed in distilled water at 37 °C for 7 days in order to simulate the interim clinical phase before permanent restoration.

Removal of temporary restorations and surface pretreatment in the test groups

After one week, the temporary restorations were removed using a dental probe. Specimens were conditioned according to subgroup allocation and were either polished with abrasive paste with rotary brush at 1,500 rpm for 15 s (Group TP) or subjected to air abrasion with 30 µm silica-coated aluminum oxide particles (CoSil, Velopex, England) at 3 bar pressure for 15 s from a distance of 10 mm (Group TA). All specimens were etched with 35% orthophosphoric acid for 15 s, rinsed, and dried. The Futurabond DC adhesive was applied, and light-cured for 20 s. The Bifix QM dual-cure resin cement was then placed into the silicone molds (3-mm in diameter and 4-mm in height) and light-cured for 20 s from each of the buccal, occlusal, and lingual surfaces using the Valo Cordless in standard mode.

The dental materials used in this study, along with their manufacturers and components, are summarized in Table 1.

Table 1. Materials used in the study, including brand names, manufacturers, and chemical compositions.

Material Type	Brand name and Producer	Context
Temporary Restorative Material	Clip F (VOCO GmbH, Germany)	UDMA, DDMA, polymers, fluoride
Dual-cure Universal Adhesive System	Futura Bond DC (VOCO GmbH, Germany)	HEMA, Bis-GMA, HEDMA, 10-MDP, UDMA, initiator and ethanol
Ormocer-based Flowable Resin Composite	Admira Fusion x-base (VOCO GmbH, Germany)	Ormocer matrix, silicon dioxide, glass ceramics (72 wt%)
Dual-Cure Resin Cement	Bifix QM (VOCO GmbH, Germany)	Bis-GMA, benzoyl peroxide, amines, barium-aluminium boro-silicate glass (71-73 wt%)
Polish Paste	DiaPolisher Paste (GC Corporation, Japan)	Super-fine particle (1 µm) diamond-based paste
Air Abrasion Particles	CoSil (Velopex, England)	30 µm Silica-coated alumina
Etching gel	Vococid (VOCO GmbH, Germany)	35% phosphoric acid

Abbreviations: UDMA, Urethane Dimethacrylate; DDMA, Decanediol Dimethacrylate; HEMA, 2-Hydroxyethyl Methacrylate; Bis-GMA, Bisphenol A-Glycidyl Methacrylate; HEDMA, Hydroxyethyl Dimethacrylate; MDP, 10-Methacryloyloxydecyl Dihydrogen Phosphate; TEGDMA, Triethylene Glycol Dimethacrylate.

Thermocycling

Thermal aging was performed by exposing all specimens to 5,000 cycles between 5°C and 55°C in a Thermocycler 1100 unit (SD Mechatronik GmbH, Westerham, Germany), with an immersion time of 30 seconds at each temperature bath.[26]

Shear Bond Strength Testing

SBS was measured using a universal testing machine (Shimadzu AGS-X, Shimadzu Corporation, Kyoto, Japan) equipped with the Trapezium X software. Each specimen was tested at a crosshead speed of 0.5 mm/min until failure. The maximum load at failure (N) was recorded, and bond strength values were calculated in MPa by dividing the load by the bonding area.

Failure Mode Analysis

The de-bonded surfaces were inspected using a stereomicroscope (x25, Leica MZ75, Leica Microsystems, Germany). Failure modes were classified into three categories: (1) adhesive failure (dentin–IDS/IDS–resin cement), (2) cohesive failure within the resin cement or dentin, and (3) mixed failure (Fig. 3).

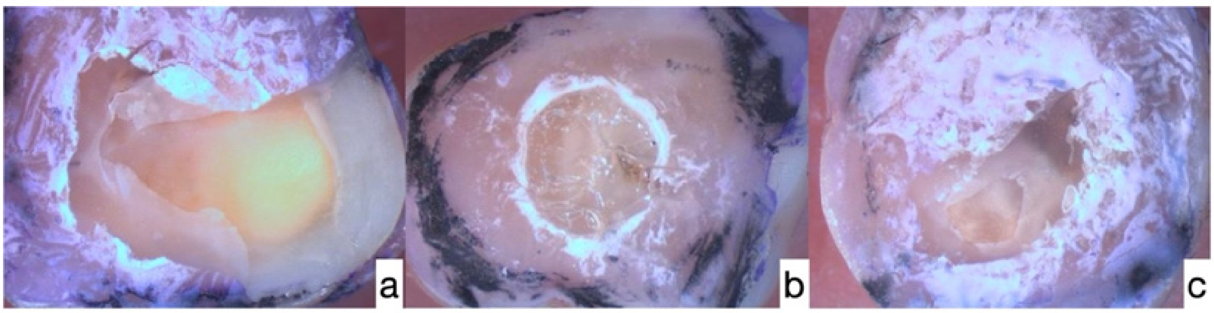

Figure 3. Representative stereomicroscopic images (x25) of failure modes after SBS testing. **a.** Adhesive failure at the dentin-IDS interface. **b.** Adhesive failure at the IDS-resin cement interface. **c.** Mixed failure exhibiting characteristics of both adhesive and cohesive fractures.

Photographic Evaluation for Fluorescence Analysis

Following the removal of Clip F using a dental probe, residual temporary material on the specimen surfaces was examined under near-UV light in the detection mode of the D-Light Pro device (GC Corporation, Tokyo, Japan). The fluorescence properties of the temporary material enabled the visualization of remnants that were not easily detectable under conventional lightning. Standardized photographs were taken using DSLR camera (1300D; Canon Inc., Tokyo, Japan) equipped with 100 mm macro lens, before and after surface pretreatment procedures to document the presence and removal of residual material (Fig. 4).

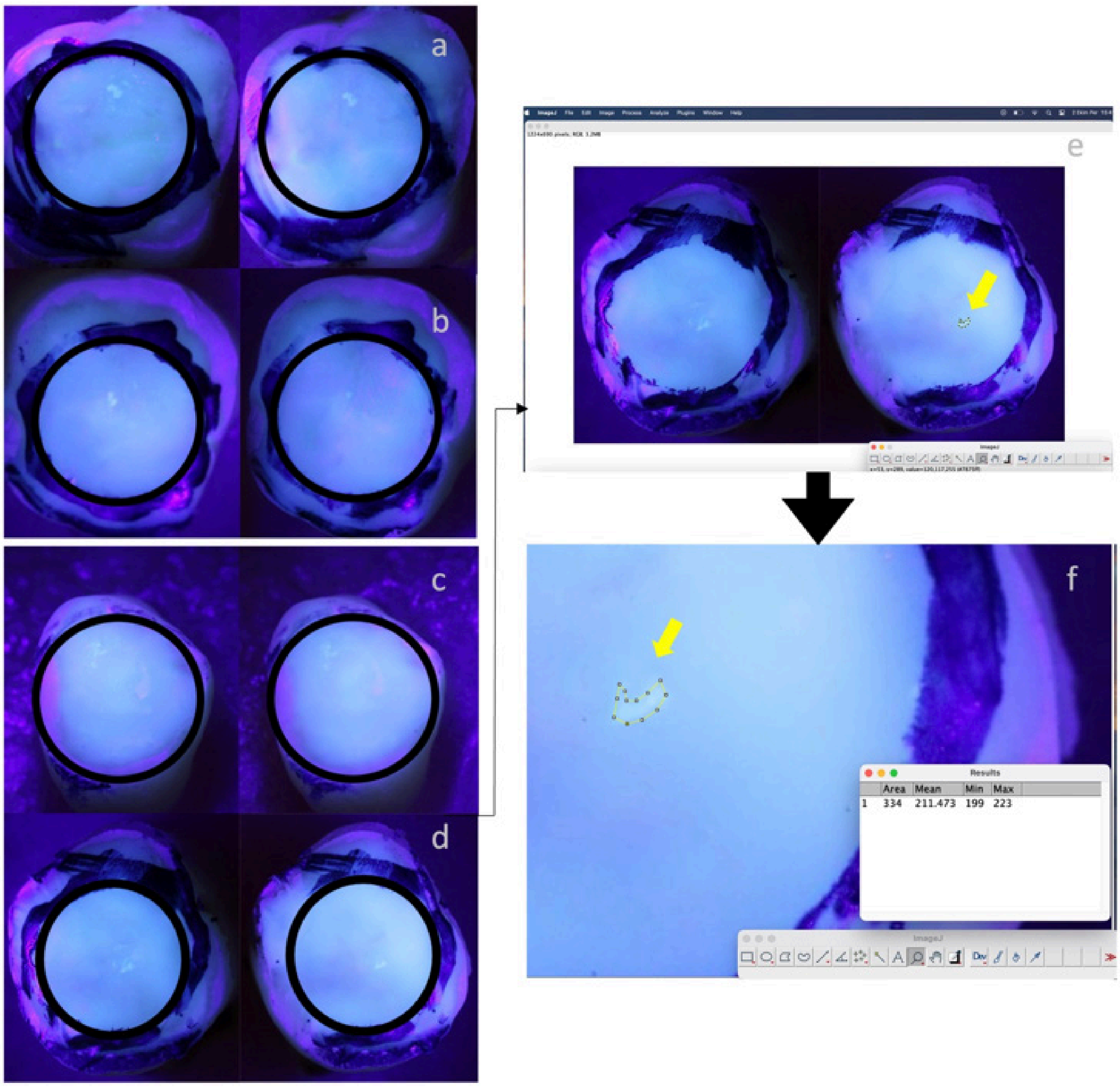

Figure 4. Fluorescent images of IDS-applied dentin surfaces showing residual Clip F material. **a-b.** Residual Clip F material before and after surface preparation using silica coating in Group TA. **c-d.** Residual Clip F material before and after surface preparation with polishing using abrasive paste in Group TP. **e.** ImageJ interface used for area selection, **f.** Quantification of remnants.

The residual areas observed in the images were quantified using ImageJ software (National Institutes of Health, Bethesda, MD, USA) to allow comparison of the effectiveness of the different surface pretreatment protocols. Consistency was achieved by applying the same calibration and threshold settings to all samples. The removal efficiency (%) was calculated by dividing the residual area measured after surface treatment by the initial area measured before cleaning, subtracting this ratio from 1, and multiplying by 100:

$$\text{Removal efficiency } (\%) = \left(1 - \frac{\text{Residual area after cleaning}}{\text{Residual area before cleaning}} \times 100\right)$$

This ratio reflects the proportion of temporary material removed from the surface and was used as an indicator of the effectiveness of the two surface cleaning methods.

Statistical Analysis

All statistical analyses were performed using SPSS (version 26.0, IBM Corp., Armonk, NY, USA). The mean and standard deviation (SD) of SBS values and removal efficiency (%) were calculated for each experimental group (n=10). The normality of data distribution was assessed using the Shapiro–Wilk test. Since the data followed a normal distribution (p>0.05), parametric tests were applied. Differences in SBS among the four groups were analyzed using one-way analysis of variance (ANOVA), followed by Tukey's post hoc test for pairwise comparisons. Independent samples t-tests were used to compare the effect of restoration period (immediate vs. temporary) and to evaluate differences in removal efficiency between two surface pretreatment methods. The level of statistical significance was set at α=0.05. In addition, the relationship between removal efficiency (%) and SBS (MPa) in the temporary restoration groups was examined using Pearson's correlation analysis. The strength of the correlation was interpreted based on the correlation coefficient (r).

Results

The SBS values obtained in the test and control groups are summarized in Tables 2 and 3. In groups with temporary restorations, the mean SBS was 9.77±3.46 MPa for air abrasion with a silica coating and 9.66±3.48 MPa for polishing with abrasive paste. However, no significant difference was found between the two surface pretreatment methods (*p*=0.944). Similarly, in the groups without temporary restoration, the mean SBS values for air abrasion and abrasive paste were 20.89±7.95 MPa and 17.83±5.70 MPa, respectively, with no significant difference between the groups (*p*=0.337). Regardless of the surface pretreatment method, a significant decrease in SBS was observed in the temporary restoration groups compared to the groups without temporary restoration (Table 2).

Table 2. Mean SBS values (in MPa) for groups according to surface pretreatment methods.

Restoration procedure	Surface pretreatment	Mean ± SD	*P**
With temporary restoration	Air abrasion	9.77 ± 3.46	0.944
	Abrasive paste	9.66 ± 3.48	
Without temporary restoration	Air abrasion	20.89 ± 7.95	0.337
	Abrasive paste	17.83 ± 5.7	

*Independent samples t-test.

Surface preparation using air abrasion resulted in bond strength values of 9.77±3.46 MPa and 20.89±7.95 MPa for the temporary and non-temporary groups, respectively (*p*=0.002). Surface preparation with an abrasive paste yielded significantly lower bond strength in the temporary group (9.66±3.48 MPa) compared with the non-temporary group (17.83±5.7 MPa) (*p*=0.002). Regardless of the surface pretreatment method employed, the SBS values decreased significantly following the application of the temporary restoration (Table 3).

Table 3. Mean SBS values (in MPa) of the groups according to restoration protocol (temporary restoration vs. without temporary restoration).

Restoration procedure	Surface pretreatment	Mean ± SD	*P**
Air abrasion	With temporary restoration	9.77 ± 3.46	**0.002**
	Without temporary restoration	20.89 ± 7.95	
Abrasive paste	With temporary restoration	9.66 ± 3.48	**0.002**
	Without temporary restoration	17.83 ± 5.7	

*Independent samples t-test.

Quantitative fluorescence analysis indicated that both air abrasion and abrasive paste polishing were effective in cleaning IDS-applied dentin, with mean removal efficiencies of about 87-90% and 70-75%, respectively. Although air abrasion tended to produce higher removal rates, the difference between the two methods was not statistically significant (p>0.05) (Table 4).

Table 4. Removal efficiency (%) of different surface pretreatment methods following temporary restoration.

	Surface pretreatment	Removal efficiency (%) (Mean ± SD)	F	*P**
With temporary restoration	Air abrasion	72.61 ± 22.12	0.904	0.380
	Abrasive paste	59.71 ± 34.47		

*Independent samples t-test.

In both temporary restoration groups, removal efficiency and SBS demonstrated a strong positive correlation (r=0.85-0.92, p<0.01), indicating that higher removal of temporary material residues was accompanied by improved adhesive performance (Table 5).

Table 5. Relationship between removal efficiency and SBS in groups with temporary restorations.

Correlations		Removal efficiency	SBS
Removal efficiency	Pearson Correlation	1	0.836**
	Sig. (2-tailed)		0.000
	N	17	17
Shear bond strength	Pearson Correlation	0.836**	1
	Sig. (2-tailed)	0.000	
	N	17	20

** Correlation is significant at the 0.01 level (2-tailed).

The distribution of failure modes for the control groups is illustrated in Figure 5.

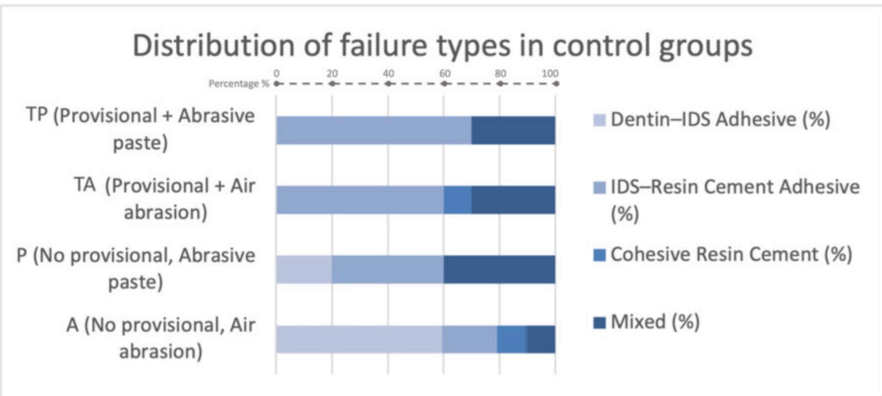

Figure 5. Distribution of failure types in control groups (A: non-temporary, air abrasion; P: non-temporary, abrasive paste) and test groups (TA: temporary+air abrasion; TP: temporary+abrasive paste).

Group TA showed mainly adhesive failures at the dentin-IDS interface, whereas group TP displayed a higher frequency of adhesive and mixed failures. These patterns suggest that the presence of a temporary restoration compromises adhesion, irrespective of the surface cleaning methods used. When comparing the non-temporary groups, air abrasion resulted in a higher proportion of adhesive dentin-IDS interface, whereas polishing with abrasive paste predominantly produced cohesive failures within the resin cement and IDS-resin cement interface.

Discussion

The results of the current study showed that, regardless of the cleaning protocol used, application of the temporary restoration for 7-days significantly reduced bond strength. The first hypothesis, which stated that temporary restorations would not affect the SBS of resin cement to IDS-applied dentin, was rejected. Consistent with the present findings, Leesungbok et al.[27] reported a decrease in the bond strength of IDS-applied dentin after 7-days. The lowest values were observed after 14-days; this was explained by the exposure of the dentin surface and partially collapsed hybrid layer in scanning electron microscope analyzes. Similarly, Tahoun et al.[4] showed that although IDS followed by temporary restoration maintained relatively higher bond strength values compared to delayed dentin sealing, a noticeable decrease was observed compared to immediate bonding. Hayashi et al.[28] found that temporary cement contamination did not significantly affect the average μTBS value but reduced the Weibull modulus, resulting in lower bond reliability and durability under cyclic loading. Brigagão et al.[25] demonstrated that temporary cementation can negatively affect bond strength and specifically highlighted the role of surface contamination as one of the main factors that weaken adhesive performance. Ribeiro da Silva et al.[14] claimed that applying a resin-based provisional material directly to sealed dentin significantly reduced bond strength. They also reported that preserving the integrity of the IDS surface with a water-soluble glycerin gel improved adhesion. Consistent with the current findings, Ding et al.[8] concluded in their systematic review and meta-analysis that resin-based temporary cements tend to reduce bond strength, supporting the view that such materials may leave residues that interfere with subsequent adhesive bonding. In a related study, Gailani et al.[29] compared two IDS strategies, one involving direct bonding immediately after adhesive application and another with a two-week provisionalization period before final bonding. In contrast to the present results, no statistically significant difference in bond strength was found between the two protocols for most adhesive-cement combinations, except for one material, where the immediate bonding group showed higher values. Similarly, Abdou et al.[30]evaluated the effects of resin coating with different adhesive systems under single-visit and multi-visit clinical protocols. For all adhesive systems, the single-visit protocol was reported to produce higher bond strength values than the multiple-visit protocol in the resin-coated groups. The difference was only statistically significant for the MDP containing adhesive. The other adhesives showed a similar trend, but not a statistically significant one. These findings suggest that the effect of the provisional phase on bonding performance is not consistent. Rather, this effect depends on the specific chemical interactions between the adhesive system and the resin cement used.[29] The discrepancy between the results of the current study could be due to differences in preferred adhesives and cements, the length of the provisional phase or variations in surface cleaning protocols before final bonding.[30] As previous studies have emphasized, the decrease in bond strength can be attributed to factors such as the adhesive surface becoming contaminated with temporary material residues, water absorption, and deterioration of the hybrid layer's structural integrity during storage. In general, findings from literature reviews suggest that appropriate surface conditioning is essential for achieving the best possible bonding performance after temporary restoration.[8,31]

The second null hypothesis was accepted on the basis that no statistically significant difference was found between the air abrasion and abrasive polishing groups. Despite the absence of a substantial discrepancy between the two surface pretreatment methods, the bond strength values obtained following air abrasion were consistently higher than those in the polishing group, in both the temporary and non-temporary groups. This tendency is hypothesized to be attributable to elevated surface roughness and surface energy resulting from air particle abrasion, thereby increasing micromechanical interlocking and facilitating adhesive wetting of the surface.[32] The use of silica-coated alumina particles enhances the chemical bonding at the interface by promoting the development of siloxane bonds between the silica layer formed on the surface and the silane-containing components of the adhesive or resin cement.[33] In the present study, removal efficiency showed a strong positive correlation with bond strength ($r = 0.83$, $p < 0.01$), underscoring the need for a pretreatment IDS surface to achieve predictable adhesion.

Fluorescence-based assessment indicated that air abrasion removed provisional residues more effectively than abrasive polishing, supporting that surface cleaning is a critical factor for adhesive performance. The non-significant tendency toward lower bond values after abrasive polishing may be related to its predominantly superficial cleaning action, without additional micromechanical retention.[8,16] Although air abrasion did not fully reach the SBS levels achieved with immediate cementation bond strength obtained with immediate cementation, its higher removal efficiency supports its use as a more reliable option when temporization is unavoidable. In line with our current findings, Özcan et al.[23] reported that mechanical cleaning protocols such as prophylaxis paste and pumice-water mixtures can achieve similar bond strengths on IDS-applied dentin, but no statistically significant difference was observed when compared to air abrasion-based protocols. However, they emphasized that adhesion reliability with mechanical cleaning methods was lower than air abrasion protocol when evaluated using Weibull analysis. In their systematic review, Ding et al.[8] concluded that polishing with pumice using a rotary instrument may be a less reliable approach compared to air abrasion with Al_2O_3, because residual particles can partially obstruct dentinal tubules and reduce surface roughness and wettability. Van den Breemer et al. reported that silica-coated Al_2O_3 particles can change the morphology by depositing silica on the surface and allow for a possible silane-resin chemical interaction. However, it was stated that this process did not provide a significant improvement in bond strength compared to cleaning with pumice alone.[21,22] Maciel et al.[34] compared various cleaning methods for removing eugenol-free temporary cements from IDS-treated dentin surfaces and reported that the chosen technique had a significant impact on both bond performance and surface morphology. The same study showed that sodium bicarbonate sandblasting achieved the highest bond strength and provided a uniform, clean IDS surface. However, mechanical cleaning with a curette left residual cement that has the potential to compromise adhesion. Several reports suggest that complete removal of temporary cement from dentin is a challenging procedure in routine practice. Grinberga et al.[12], using SEM, detected residual temporary cement within the dentinal tubules despite mechanical cleaning and polishing underscoring the difficulty of complete residual removal. Consistently, Abdou et al.[30] found that, despite using a standardized removal protocol (excavator and alcohol-impregnated cotton pellets), temporary cement residues were persistent on both resin-coated and uncoated dentin surfaces. In line with previous reports, our results showed that although both air abrasion and polishing with abrasive paste were able to remove most of the temporary material from IDS-applied dentin, complete surface decontamination was not achieved. Fluorescence analysis showed removal efficiencies of about 87-90% for air abrasion and 70-75% for polishing, implying that undetectable residual particles may persist and potentially hinder adhesive penetration and bond stability.

In the analysis of failure patterns, the high frequency of adhesive and mixed failures in the temporary groups suggests that debonding occurred predominantly at the interface between the resin cement and the IDS-applied dentin, rather than within the cement layer or the tooth structure. The higher frequency of adhesive failures in provisionalized specimens is consistent with lower bond strength values associated with residual provisional material, which may weaken the integrity of the adhesive layer. In contrast, the slightly increased composite failure rate observed in the air abrasion group may reflect more effective micromechanical interlocking and a cleaner bonding surface, consistent with the higher removal efficiency revealed by fluorescence analysis.

This study was an in vitro investigation conducted under controlled laboratory conditions. Therefore, intraoral environmental factors such as pulp pressure, salivary flow, and occlusal forces were not directly simulated. Furthermore, the evaluation of only one resin-based temporary restorative material and two different surface pretreatment methods partially limits the generalizability of the findings to all materials and protocols. While fluorescence-based analysis allowed for the quantitative assessment of the amount of residues removal, it did not fully distinguish between different types of residues (e.g., temporary material, plaque-like deposits, or residual adhesive). Furthermore, this study focused only on a short-term storage and thermal cycling protocol; therefore, the effect of long-term fatigue tests using chewing simulators on bond strength would be a suitable focus of future studies.

Conclusions

Temporary restoration significantly reduced the SBS of resin cement to IDS-applied dentin, regardless of the surface pretreatment method. Both air abrasion with silica-coated alumina and abrasive paste polishing effectively removed residual material but did not reach the levels of SBS achieved through immediate cementation. The strong positive correlation between removal efficiency and bond performance highlights the importance of surface cleanliness in achieving durable adhesion. Within the limitations of this study a cleaning protocol that ensures efficient decontamination of the IDS surface through controlled air abrasion may help optimize bonding outcomes following temporization.

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Ethical Approval
This study was approved by the Clinical Research Ethics Committee of Marmara University Faculty of Dentistry (Approval no: 2025-05-04/2025-17).

Conflicts of interest
No potential conflict of interest relevant to this article was reported.

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