Original Article

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Effect of dentin cleansing techniques on the shear bond strength of self-adhesive resin cement after temporary bonding with two provisional cements

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Objective: The objective of this study was to evaluate the effect of different cleansing techniques on the shear bond strength of self-adhesive cement to dentin after temporary fixation with two provisional cements.

Materials and Methods: Ninety human premolars were sectioned horizontally and embedded in self-cured acrylic resin blocks. Self-cured acrylic discs were fixed on the dentin surfaces with two provisional cements, zinc oxide non-eugenol temporary cement (TempBond NE) or temporary resin-based cement (TempBond Clear). The specimens were stored in distilled water at 37˚C. After 5 d, the provisional restorations were removed and randomly divided into 5 groups (n=10), based on cleansing treatments: no temporary cement (control group), explorer, prophy brush with pumice, rubber cup with pumice, and ultrasonic scaler. Self-adhesive cement (RelyX U200, 3M ESPE) was applied into a metal mold (3 mm diameter, 2 mm thick), which was placed on the dentin surfaces and polymerized with a light-emitting diode curing unit for 40 sec. The specimens were stored in distilled water at 37 ˚C for 24 h. The shear bond strength test was performed with a universal testing machine at a crosshead speed of 0.5 mm/min until failure. The data were analyzed using two-way analysis of variance (ANOVA) and post-hoc Dunnett T3 test.

Results: There were no significant differences in shear bond strength between the two types of temporary cement and cleansing methods (p=0.105 and 0.083, respectively). The control group presented a significantly higher shear bond strength compared with the prophy brush with pumice and rubber cup with pumice in TempBond NE groups (p=0.001 and 0.005, respectively). The control group also had a significantly higher shear bond strength compared with the explorer (p=0.004) in TempBond Clear group.

Conclusion: Cleansing methods and types of temporary cements did not affect the shear bond strength of self-adhesive resin cement and dentin. However, cleaning temporary resin-based cement with an explorer generated the significantly lowest shear bond strength in the TempBond Clear group.

Keywords: cleansing, shear bond strength, self-adhesive resin, temporary cement

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Introduction

The use of indirect restorations has increased in restorative dentistry due to the improved materials and cement systems that provide esthetics and improve restoration retention and longevity. However, restoration dislodgement, which occurs in 2–21% of cases, results in fixed restoration clinical failure [1]. After tooth preparation, the provisional restoration needs to be fixed with provisional cement before the final cementation of the permanent prosthesis at the next appointment. Therefore, the error can occur at any step due to several

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factors that affect retention and longevity, such as preparation design, coarseness of the abutment teeth, provisional luting agent, cleansing protocol, fit of the definitive restoration, and type of definitive luting agent [2, 3].

Provisional cement and cement remnants on the tooth surface can reduce restoration retention. Resin-based luting cements cannot infiltrate into the dentinal tubules to form resin tags that promote micromechanical locking because the provisional cement remnants obstruct the dentinal tubules. In 2011 [4, 5], an American Dental Association product review classified provisional cement into 4 types according to their different compositions; polycarboxylate, zinc oxide eugenol (ZOE), zinc oxide non-eugenol (ZONE), and resin-based cements. The provisional cement commonly used in the dental clinic is zinc oxide non-eugenol luting cement, which replaced eugenol with various types of carboxylic acids; therefore, there is no interference with resin polymerization caused by eugenol. Additionally, resin-based provisional cement is a material that provides excellent retention, high strength, and better esthetics because of its translucent color. Thus, it can be used with anterior temporary restorations.

Residual provisional cement and debris on the prepared abutment teeth can reduce the performance of the definitive cement [6]. Moreover, this residual cement and its penetration can change the characteristics of the tooth structure, contact angle [7], and dentin permeability [8]. Removing the provisional cement debris is desirable to promote contact between the dentin and the adhesive system, and improves bond strength [2, 3]. The techniques commonly used to clean the dentin surface can be performed by mechanical and chemical methods. The mechanical cleaning methods commonly used in the clinic include rotary instruments with pumice, ultrasonic scaler, or sandblasting with aluminum oxide. The chemical agents that are used to clean the cavity include chlorhexidine digluconate, sodium hypochlorite, hydrogen peroxide, and polyacrylic acid.

Most studies examined shear bond strength after cleaning with zinc oxide eugenol or zinc oxide non-eugenol that are used as temporary cements [9, 10]; however, there are few studies concerning the shear bond strength after cleaning with a temporary resin-based cement. Therefore, the aim of this study was to evaluate the effect of different cleansing techniques on the shear bond strength of self-adhesive cement to dentin. The null hypothesis was that the type of temporary cement and dentin cleansing method did not affect the shear bond strength of self-adhesive resin and dentin.

Materials and Methods

The study protocol was approved by the Institutional Review Board of the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Bangkok, Thailand, following the guidelines for Human Research Protection (MU-DT/PY-IRB 2017/DT048).

Tooth preparation

Ninety sound extracted human premolar teeth were collected for this study. The teeth were cleaned with running water and any adherent tissue was mechanically removed. The specimens were stored in 1% chloramine-T trihydrate solution for 1 week and then stored in distilled water grade 3 at 4 °C in the refrigerator. The distilled water was changed every 2 months until the specimens were tested (ISO/TS 11405:2015) [11].

The teeth were sectioned horizontally 1 mm below the central groove using a slow speed saw (Isomet, Buehler Ltd. Lake Bluff, IL, USA) under water cooling. The sectioned teeth were embedded in chemically-cured acrylic resin in cylindrical polyvinyl chloride rings (2 cm diameter). Each specimen was polished with silicon carbide paper (Struers, Cleveland, USA) under water coolant, ending with 400 grit paper to obtain a flat dentin surface.

Temporary bonding procedure

Eighty self-cured acrylic discs (Unifast™ Trad, Tokyo, Japan) (3 mm diameter and 2 mm thick) were fixed with two types of provisional cement on the center of the dentin surfaces. Forty specimens were applied with non-eugenol containing temporary cement (TempBond™ NE, Kerr Corp, Orange, CA, USA) and other 40 discs were luted with temporary resin-based cement (TempBond™ Clear, *Kerr*, Orange, CA, USA). Both temporary cements were processed according to the manufacturer's recommendation (Table 1). The control groups (n=10) comprised specimens without any temporary cement. Self-cured acrylic discs were placed on the tooth surface with a static load of 2.5 kg until the material setting time. The specimens were stored in distilled water at 37 °C for 5 d [12].

Table 1 Materials tested in this study and application techniques

Product names and manufacturers	Compositions	Application technique*
Temp Bond Clear (Kerr, USA)	Base: unpolymerized urethane-acrylate monomers Catalyst: unpolymerized urethane-acrylate monomers, dibutyl phthalate.	TempBond Clear is available in an automix dual barrel syringe. First, removed a cap from syringe. Placed automix tip onto syringe. Turned automix tip 90 degree to lock in place. No hand mixing is necessary. The material was place on the dentin surface.
Temp-Bond™ NE (Kerr, USA)	Base: zinc oxide, white mineral oil (petroleum) Catalyst: polyorganic acid	Extruded equal lengths of base and catalyst onto the mixing pad provided. Thoroughly mixed the pastes for approximately 30 s and then placed the material on the dentin surface.
RelyX™ Unicem (3M ESPE, Germany)	Base: Metharylate monomers containing phosphoric acid groups, methacrylate monomers, initiators, stabilizers, rheological additives. Catalyst: Methacrylated phosphoric esters, alkaline fillers, silanated fillers, initiator components, stabilizers, pigments, rheological additives. Zirconia/silica fillers. Clicker delivery system.	Dispensed equal volume of base and catalyst pastes. Mixed the pastes for 10s and applied into metal mold and curing for 40s using LED.

Permanent bonding procedure

After 5 d, the provisional cements were mechanically removed using the side of the explorer tip (Hu-Friedy Mfg.Co. LLC, Chicago, IL, USA) until the temporary cement was not visible. The specimens were randomly assigned into four groups (group 2–5) (n=10) and the dentin surfaces were cleaned according to cleaning protocols; group 2 hand instrument using a #5 explorer (Hu-Friedy Mfg.Co. LLC, Chicago, IL, USA, group 3 prophy brush (Dent- Mate Co.Ltd., Bangkok, Thailand) and a mixture of pumice and water, group 4 rubber cup (Dent-Mate Co.Ltd., Bangkok, Thailand) and a mixture of pumice and water, and group 5 ultrasonic scaler with metal tip (Bonart P10 scaler tip with Cavitron Bobcat Pro, Dentsply Sirona, USA). Group 1 comprised the control specimens (CT) that received no treatment. All cleansing procedures were performed by the same investigator (Table 2).

After cleaning, a custom-made 3x2 mm^2 stainless-steel mold was placed on the center of the tooth surface and self-adhesive resin (Rely X U200 Clicker, 3M, USA) was dispensed using an equal volume of base and catalyst pastes. The self-adhesive resin was mixed for 10 sec with a dental cement mixing spatula (Dent- Mate Co.Ltd., Bangkok, Thailand) and placed into the metal mold using an interproximal

Table 2 Dentin cleansing techniques and procedures

Dentin cleansing techniques	Procedures
Explorer #5 (Hu-Friedy Mfg.Co. LLC, Chicago, IL, USA)	Explorer was used to remove temporary cement by using side of the tip until temporary cement became invisible. Dentin was rinsed and excess water removed with absorbent paper.
Pumice with prophy brush (Dent-Mate, Bangkok, Thailand)	After removing temporary cement by using explorer, pumice slurry was used with a prophy brush in a slow-speed rotary instrument (TorqTech 1:1 Contra Angle Low Speed Attachment, J. Morita, Tokyo Japan) with speed 10,000 rpm for 10 seconds in a circular motion and rinsed for 10 seconds. Dentin was rinsed and excess water removed with absorbent paper.
Pumice with rubber cup (Dent-Mate, Bangkok, Thailand)	After removing temporary cement by using explorer, pumice slurry was used with a rubber cup in a slow-speed rotary instrument (TorqTech 1:1 Contra Angle Low Speed Attachment, J. Morita, Tokyo Japan) with speed 10,000 rpm in a circular motion for 10 seconds and rinsed for 10 seconds. Dentin was rinsed and excess water removed with absorbent paper.
Ultrasonic scaler with a metal tip (Bonart P10 scaler tip with Cavitron Bobcat Pro, Dentsply Sirona, PA, USA)	After removing temporary cement by using explorer, dentin surface was cleaned with ultrasonic scaler with a metal tip by using the side of the metal tip in a straight-line and the same direction for 10 seconds. The power of scaler was set at one-half of the full power by marking at the setting button. Dentin was rinsed and excess water removed with absorbent paper.

composite carver (Long IPC interproximal carver, XTS® composite instrument, Hu-Friedy Mfg.Co. LLC, Chicago, IL, USA). Each specimen was polymerized for 40 sec using a light emitting diode that was 1 mm from the specimen surface (LED) (Bluephase®, Ivoclar Vivadent, Schaan, Liechtenstein). The metal mold was removed, and the specimens were stored in distilled water at 37 °C for 24 h before the shear bond strength test.

Shear bond strength test

Each specimen was mounted onto a metal holder and placed in the universal testing machine (Instron model 5585H, Instron Corp, Canton, MA, USA) and the load was applied with a flattened rod at a crosshead speed of 0.5 mm/min. Each specimen was tightened and stabilized to ensure that the edge of the shearing rod was positioned as close to the cement-tooth interface as possible. The shear bond strength was calculated in megapascals (MPa) from the maximum stress (N) at failure divided by the specimens' surface area. Means and standard deviations were recorded for each group tested. The failure analysis of all specimens was performed using a microscope (JEOL, JSM-6610LV, Tokyo, Japan). The mode of failure was classified into three types, 1) adhesive failure (failure at the adhesive and dentin interface or composite and adhesive interface), 2) cohesive failure (failure within the dentin or composite), and 3) mixed failure, i.e., a combination of 1 and 2 [13]. In addition, randomly selected specimens were scanned using a scanning electron microscope (SEM) (JEOL, JSM-6610LV, Tokyo, Japan) to evaluate the microstructure morphology of the tooth surface with different mechanical cleansing protocols.

Statistical analysis

The data were analyzed using two-way analysis of variance (ANOVA) and post-hoc Dunnett T3 test to determine significant differences between the types of provisional restorations and cleansing treatments at the 95% confidence level.

Results

The two-way ANOVA results (Table 3) revealed that there was no interaction between the types of temporary cement and cleansing treatments (p=0.085). Furthermore, the differences in shear bond strength between the two types of temporary cement and cleansing treatments were not significant (p=0.105 and 0.083, respectively).

Table 3 Result of two-way ANOVA

Variables	F	*P*-value
types of provisional restorations	2.697	0.105
cleansing treatments	2.311	0.083
types of restorations *cleansing treatments	2.297	0.085

The mean shear bond strengths and standard deviations of TempBond NE and TempBond Clear for each treatment group are presented in Table 4. The results demonstrated that the control group had the highest shear bond strength compared with the TempBondNE and TempBond Clear groups. For the TempBond NE cleansing methods, the explorer had the highest shear bond strength (5.29±3.19 MPa) followed by the ultrasonic scaler (5.22±3.14 MPa), while the prophy brush with pumice provided the lowest shear bond strength (4.27±1.25 MPa). There was no significant difference in shear bond strength among the control, explorer, and ultrasonic scaler groups; however, the rubber cub and prophy brush with pumice group demonstrated a significantly lower shear bond strength compared with the other groups. For the TempBond Clear group, the ultrasonic scaler generated the highest shear bond strength (8.75±4.00 MPa) and the explorer resulted in the lowest shear bond strength (3.48±2.95 MPa). There was no significant difference in shear bond strength between the control and cleansing groups in TempBond Clear, except for explorer that was significantly different from the control group. However, there was no significant difference among cleansing groups.

The SEM images demonstrated the dentin surfaces that were temporary fixed with TempBond NE (Figure 1) and TempBond Clear (Figure 2) and cleaned with different methods. The control group (Figure 1a and Figure 2a) had less debris on the dentin surface compared with the temporary cement groups (Figure 1b, c, d, e, and Figure 2b, c, d, e) that had slightly remaining temporary cement on the surfaces. Furthermore, there were fewer cement remnants on the dentin surface of the temporary resin-based cement group (Figure 2) compared with the zinc oxide non-eugenol group (Figure 1). Comparing the dentin surfaces among the dentin cleaning methods, the ultrasonic scaler group had less residual temporary cement on the dentin surface compared with other groups (Figure 1c and Figure 2c).

The failure analysis (Figures 3 and 4) results indicated that the cleaning using an explorer group had a higher percentage of adhesive failure, approximately 70%. The failure patterns between the rubber cup and prophy brush with pumice groups were similar, with an adhesive failure pattern of approximately 60% and mixed type 30%. The ultrasonic scaler group had approximately 55% adhesive failure, which was slightly better than other cleansing techniques, especially when temporary bonded with TempBond Clear.

Table 4 Mean shear bond strength (MPa) and standard deviation of different dentin cleansing methods after temporary bonding with TempBond NE and TempBond Clear (n=10).

Dentin-Cleansing Techniques	TempBond NE (MPa (SD))	TempBond Clear (MPa(SD))
Control (no temporary cement)	8.55 (2.06)^{a}	8.55 (2.06)^{a}
Explorer	5.29 (3.19)^{a,b}	3.48 (2.95)^{b}
Prophy brush+pumice	4.27 (1.25)^{b}	6.15 (4.67)^{a,b}
Rubber cup + pumice	4.39 (2.35)^{b}	5.62 (3.68)^{a,b}
P10 Scaler	5.22 (3.14)^{a,b}	8.75 (4.00)^{a,b}

Different superscript letters indicate statistically significant difference

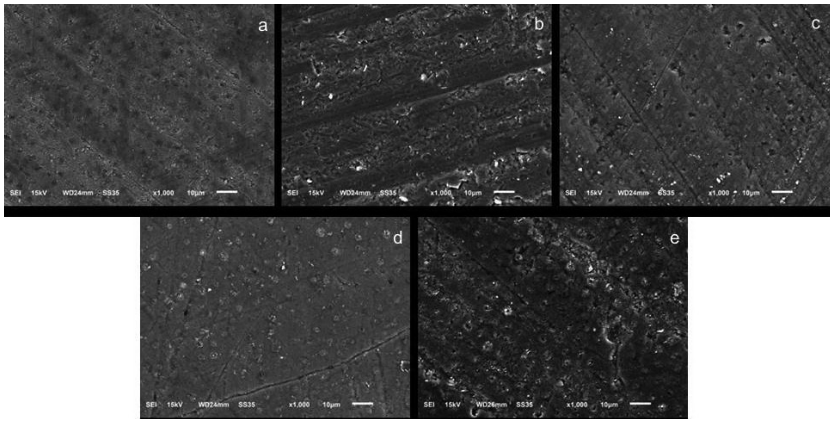

Figure 1 SEM image of dentin surface that temporary fixed with TempBond NE and cleaned with different methods: a) no temporary cement (control), b) explorer, c) pumice with prophy brush, d) pumice with rubber cup, e) ultrasonic scaler.

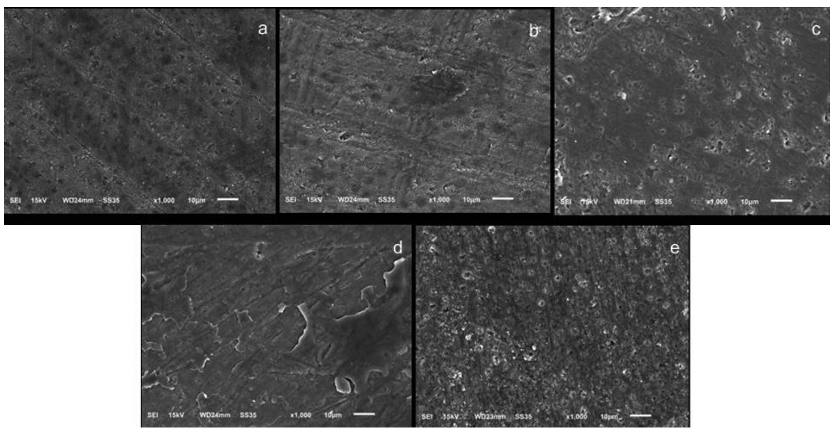

Figure 2 SEM image of dentin surface that temporary fixed with TempBond Clear and cleaned with different methods: a) no temporary cement (control), b) explorer, c) pumice with prophy brush, d) pumice with rubber cup, e) ultrasonic scaler.

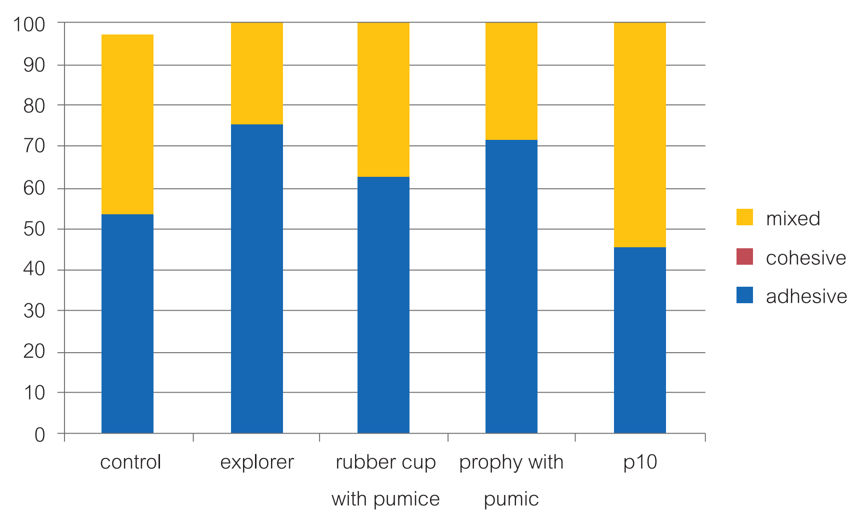

Figure 3 Failure analysis of TempBond NE group.

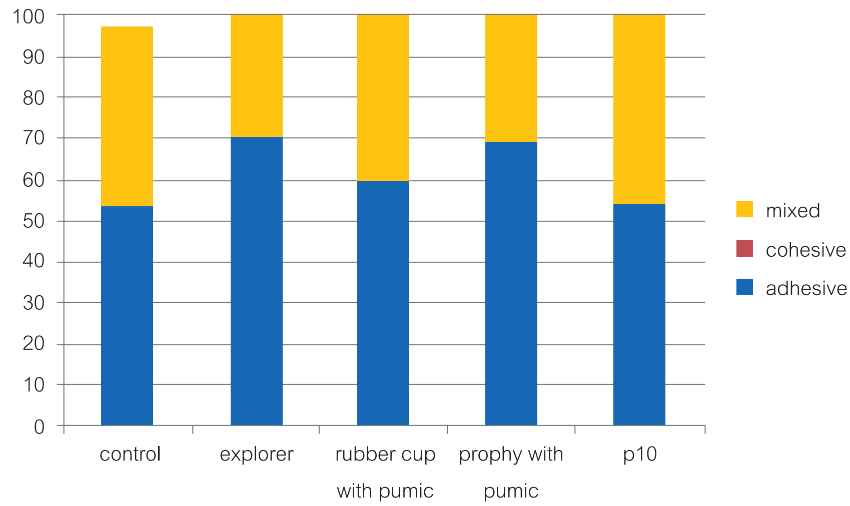

Figure 4 Failure analysis of TempBond Clear group.

Discussion

This study demonstrated that there was no significant difference between the shear bond strength of self-adhesive resin cement and dentin after cleansing using several standard methods. In addition, no significant difference was found in the shear bond strength after using two different types of temporary cement. The groups that used temporary cements resulted in a slightly lower shear bond strength than the group that did not undergo temporary cementation. This may be due to the temporary cement remnants left behind on the dentin surface that were not completely removed by the cleansing methods used in this study. Sarac *et al.* reported that the provisional cement could potentially plug the dentinal tubules into which the resin luting agent penetrates, resulting in the lowest bond strength being obtained when using a rotary instrument and cleaning bur. The study also indicated that self-adhesive cements bonded to the smear layer that covers the dentin without pretreatment on the dentin surface. In contrast, the residual temporary cements might have acted as a barrier that inhibited the interactions between acidic functional monomers and inorganic components of dentin, thus reducing the surface free energy [14] that led to the reduction of the bond strength of self-adhesive resin. However, some studies have reported that these remnants are insufficient to interfere with the bond strength of these adhesive systems and resin cements, whether they contained non-eugenol or not [15, 16].

Zinc oxide non-eugenol cement contains mainly zinc oxide and polyorganic acid instead of eugenol, and do not interfere with the chemical setting of permanent cements. Additionally, TempBond Clear is a dual cured temporary resin–based cement that contains unpolymerized urethane-acrylate monomers in the base and catalyst. Román-Rodríguez *et al* reported that dual-cured temporary resin-based cement remained on the restoration after the shear bond strength test was completed, while self-cured temporary cement remained on the tooth; therefore, dual-cured temporary resin-based cements provide better retention for permanent restoration than self-cured temporary cement [17]. However, one study found that TempBond Clear had a lower shear bond strength compared with eugenol free and calcium hydroxide temporary cement regardless of the cleaning method used [18]. This study also found that resin-based temporary cement was difficult to clean from the tooth surface due to its translucency

Pumice with a prophy brush and rubber cup are the most commonly used methods to clean plaque and debris on the tooth surface. Pumice is highly siliceous material produced by volcanic activity and is commonly used in abrasive polishing pastes. However, the SEM results indicated that the rotary instrument cleaning with pumice was not an effective method because there were residual particles obstructing the dentinal tubules that prevented self-adhesive resin cement from penetrating the smear layer, therefore reducing the formation of resin tags that form the micromechanical interlocking. Similar results were documented in previous studies that found that the use of pumice powder results in the surface being covered by pumice residues and consequently sealing the dentinal tubules, preventing resin penetration and reducing bonding [3, 19].

Ultrasonic cleaning provided slightly better results in removing the temporary cements compared with other cleaning methods. Yap *et al.* [20] found that the use of an ultrasonic scaler followed by cleaning the dentin surface with a pumice-water slurry increased the bond strength. Moreover, in this study, ultrasonic scaler used with no additional cleansing step had similar shear bond strength as other cleansing test methods, except in TempBond Clear that had a slightly higher shear bond strength than the other cleaning groups.

When evaluating the comparison between TempBond NE and TempBond Clear, the results indicated that the shear bond strength of the specimens temporarily bonded with TempBond NE was slightly than those bonded with TempBond Clear. The residual cement of TempBond NE may be difficult to remove compared with TempBond Clear. However, the explorer only group in resin-based temporary cement had the lowest shear bond strength. This is because the TempBond Clear is translucent in color; therefore, it could be difficult to remove using a hand-held instrument. Furthermore, the statistical analysis results revealed that there was no difference in the shear bond strength among the cleaning methods used in this study.

The failure analysis results revealed that the specimens cleaned with an explorer and pumice with a prophy brush or rubber cup had the high adhesive failure, which might be due to the remaining cement or pumice particles that may have obstructed the dentinal tubule; therefore, the resin could not penetrate to the smear layer, which reduced the shear bond strength. The Ultrasonic scaler group had a higher percentage of mixed type failure compared with the other groups. These results might be because ultrasonic cleaning removes more temporary cement than the other cleaning methods, thereby enhancing the penetration of the self-adhesive resin.

Conclusions

Within the limitations of this study, the types of temporary cements and cleaning methods used in this study did not affect the shear bond strength of self-adhesive resin and dentin. However, cleaning temporary resin-based cement with an explorer resulted in the significantly lowest shear bond strength in the TempBond Clear group.

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Conflict of interest

All authors declared that there is no conflict of interest in this study.

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