The effect of resin cement type and cleaning method on the shear bond strength of resin cements for recementing restorations

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PURPOSE. This laboratory study assessed the effect of different dentin cleaning procedures on shear bond strength of resin cements for recementing prosthesis. **MATERIALS AND METHODS.** A 4 × 4 flat surface was prepared on the labial surface of 52 maxillary central incisors. Metal frames (4 × 4 × 1.5 mm) were cast with nickel-chromium alloy. All specimens were randomly divided into 2 groups to be cemented with either Panavia F2.0 (P) or RelyX Ultimate (U) cement. The initial shear bond strength was recorded by Universal Testing Machine at a crosshead speed of 0.5 mm/min. Debonded specimens were randomly allocated into 2 subgroups (n = 13) according to the dentin cleaning procedures for recementation. The residual cement on bonded dentin surfaces was eliminated with either pumice slurry (p) or tungsten carbide bur (c). The restorations were rebonded with the same cement and were subjected to shear test. Data failed the normality test ($P < .05$), thus were analyzed with Mann Whitney U-test, Wilcoxon signed rank test, and two-way ANOVA after logarithmic transformation ($\alpha = .05$). **RESULTS.** The initial shear bond strength of group P was significantly higher than group U ($P = .001$). Pc and Uc groups presented higher bond strength after recementation compared to the initial bond strength. However, it was significant only in Pc group ($P = .034$). **CONCLUSION.** The specimens recemented with Panavia F2.0 provided higher bond strength than RelyX Ultimate cement. Moreover, a tungsten carbide bur was a more efficient method in removing the residual resin cement and increased the bond strength of Panavia F2.0 cement after recementation. ***[J Adv Prosthodont 2017;9:110-7]***

KEYWORDS: Resin bonded restorations; Shear bond strength; Resin cement; Dentin surface cleaning

INTRODUCTION

A resin bonded restoration is considered a conservative treatment for reconstruction of edentulous areas, and its attachment to dental tissues rely on resin cements. Systematic reviews of the literatures evaluated the long term clinical prognosis of these prosthesis and reported loss of retention as the main reason of failure.[1,2] Changes have been made in the design and preparation of the abutment teeth in order to improve the resistance and retention form and consequently to enhance the success rate of these restorations.[3-5] Yet, debonding is still the major problem of the treatment.[1,4,6,7] Tooth reduction with the aim of increasing the retention is still being debated.[3,4] Besides causing irreversible damage to dental tissues, tooth reduction results in exposure of the dentin whose bond strength is lower than enamel.[4,6] Even when conservative design is considered, dentin exposure is probable during reduction and preparation of abutments. Hence, knowledge of the performance of these prostheses and their bond strength after dentin exposure helps estimation of their survival rate.

The recementing process seems to be similar to initial cementation, but the presence of residual cement weakens the bond between resin cement and dentin and disrupts the bonding.[8,9] Remnants of previous permanent cements interfere with the etching quality of self-etch primer. They can

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even prevent the infiltration of adhesive system and subsequent polymerization reaction of monomers.[8,10] Removing residual resin improves the dentin-adhesive system interface and consequently the bond strength.[8,11-13]

Although several researchers evaluated the methods for mechanical and chemical cleaning of temporary cement off the tooth surface;[8,10-18] only a few have assessed the effect of cleaning permanent resin cements before recementation on the bond strength.[8,19] The most common cleaning method is rotary instrumentation with pumice or burs whose effect on the smear layer and temporary cement remnants varies from partial to complete elimination of debris or smear layer.[15] According to Button, the retentive strength of cemented restorations was dependent on the cement and the cleaning protocol used. For Ketac-Cem cement, cleaning the prepared teeth with pumice resulted in a significant increase in retentive strength over cleaning with degreasing agents.[20] Similarly, Chaiyabutr showed that small-particle abrasion of eugenol-containing temporary cement as a dentin cleaning protocol did not have an adverse effect on the bond strength of definitive cementation with self-adhesive resin cement.[11] Unfortunately, the effect of cleaning methods on the removal of permanent cement remnants and consequently bond strength of recementation is unknown.

In a study by Bavbek,[19] various mechanical dentin cleaning procedures were assessed prior to recementation. None of the cleaning methods completely removed the cement remnants; however, the carbide bur exhibited the most efficiency. Also, pumice slurry showed similar removal of Clearfil SA cement remnants.

In order to achieve an ideal cleaning protocol for permanent resin cement removal, more investigations should be conducted on this issue.

The purpose of this study was to evaluate the effect of dentin cleaning procedures with pumice and carbide bur for recementation of resin bonded prosthesis on shear bond strengths of Panavia F2.0 and RelyX Ultimate cements. Thus, the null hypothesis was that dentin cleaning protocols have no effect on bond strengths of Panavia F2.0 and RelyX Ultimate cements for recementation.

MATERIALS AND METHODS

Fifty-two healthy maxillary central incisors, extracted due to periodontal problems, were used in the present study. The teeth were rinsed and the residual soft tissues and periodontal fibers were removed. They were stored in 1% chloramine solution (Solarbio Bioscience and Technology Co., Ltd., Shanghai, China) at 4°C for at most three months after extraction.

By using a dental surveyor, the root of each tooth was vertically imbedded in a tube filled with auto-polymerized acrylic resin (Unifast II, GC Co., Tokyo, Japan). The enamel of incisal, proximal, and labial surfaces was removed with a diamond bur (Diamant Gmbh, D&Z, Goerzallee 307, Berlin, Germany) at low speed. A 4 × 4 mm square was created on the buccal surface of the dentin parallel to the applied force. In order to level the thickness of smear layer, the dentin surface was wet-ground on a succession of silicon carbide abrasive papers (Shanghai Hangli Co., Shanghai, China) with grit sizes of 200, 400, and 600.

The final impression was made by using polyether impression material (Impregum, 3M ESPE AG, Seefeld, Germany) and pouring with a type IV dental stone (Vel Mix, Kerr, Orange, CA, USA). A 4 × 4 mm pattern with the thickness of 1.5 mm was waxed up on the buccal surface of the die, without die spacer, by using blue wax inlay sticks (Blue inlay casting wax, Kerr Italia SpA, Salerno, Italy) and was cast with nickel-chromium alloy (Verabond, Alba Dent Co., Fairfield, CA, USA). After divesting, the inner side of each casting was inspected under a stereomicroscope (Nikon, Tokyo, Japan) at ×20 magnification and the nodules were removed with a tungsten carbide round bur at low speed. Finally, the castings were sandblasted with aluminum oxide particles (50 µm) for 10 seconds at an air pressure of 0.1 MPa from a distance of 10 mm (EXTRAmatic, KaVo Dental GmbH, Biberach, Germany).

Based on the type of cement, the samples were randomly divided into 2 groups (group U and P, n = 26) (Fig. 1). Table 1 represents the brand names, compositions, lot numbers, and the manufacturers of the resin cements used in this study. According to the manufacturer's instructions summarized in Table 2, the resin cement was applied on the blasted surface of each casting and smoothly placed on the dentin surface with finger pressure. All specimens were subjected to constant seating pressure of 10 N in Universal Testing Machine (Hounsfield Test Equipment, Model H5-KS, Surray, UK) for 1 minute. Cement excess was removed and the specimens were light polymerized for 40 seconds on each surface with LED light cure unit (Astralis 7, Ivoclar, Vivadent, Schann, Lichtenstein). The cemented specimens were stored in distilled water at 37°C for 24 hours. Then, they were subjected to 1000 thermal cycles at 5 - 55°C with a 20 second dwell time. After thermocycling, the specimens were again restored in distilled water.

Shear bond strengths were measured by means of a Universal testing machine equipped with chisel-shaped indenter and knife-edge cross section of 0.5 cm^2. The shear force for debonding was applied to the restoration-tooth interface in an incisal-gingival direction at a crosshead speed of 0.5 mm/min until failure occurred. The values of the maximum force were recorded in newtons (N) and converted into megapascals (MPa) by dividing the load (in N) by the bonded area (in mm^2).

After debonding, the residual resin cement on the restoration surface was carefully eliminated with an excavator and the inner surface of the restoration was air abraded with aluminum oxide particles (50 µm) at 0.1 MPa pressure for 10 seconds at 10 mm distance. The specimens in each group were randomly divided into 2 subgroups (n = 13) based on the cleaning method. In each subgroup, the residual cement was removed from the dentin with either pumice (p) or tungsten carbide bur (c). In groups Pp and Up, the residual cement was removed with a mixture of pumice

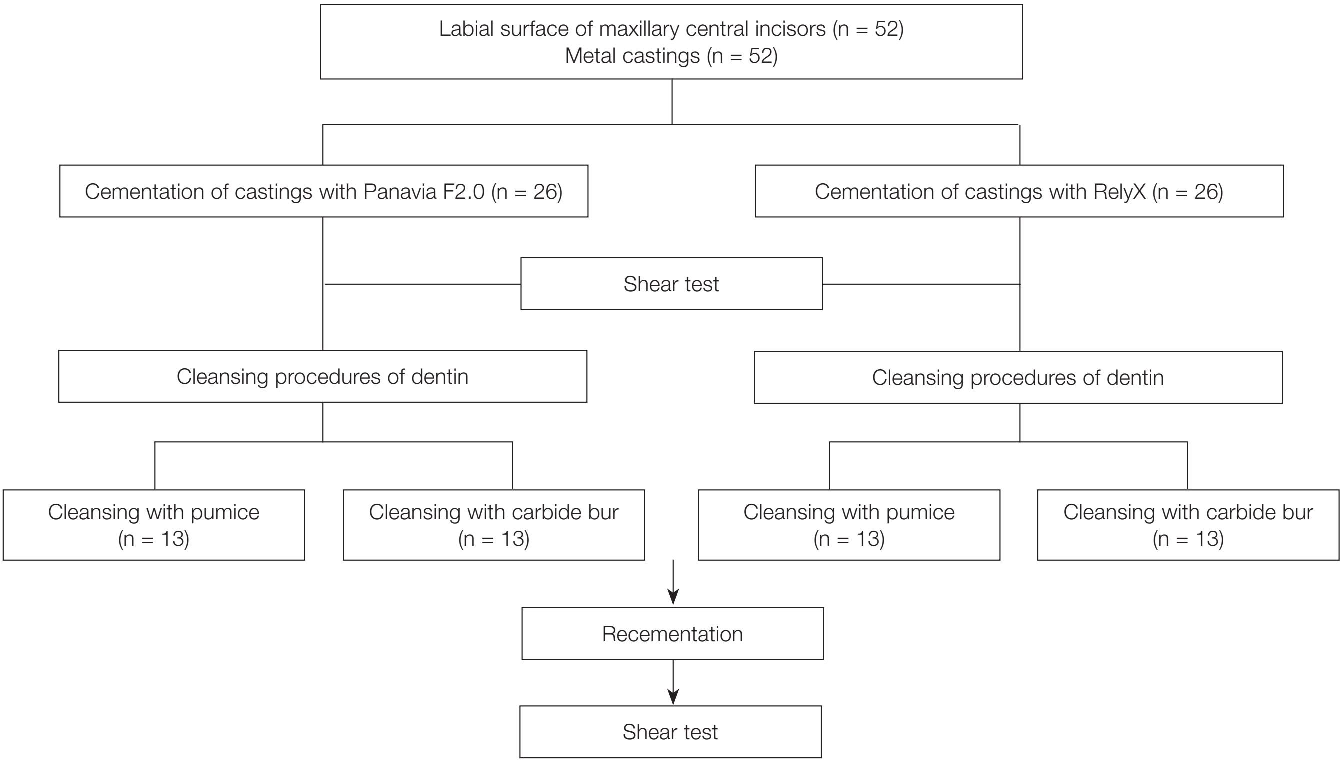

Fig.1. Schematic diagram of the study design.

Table 1. The commercial brand, chemical composition, and manufacturer of resin cements and adhesives used in this study

Product	Manufacturer	Composition	Lot No.
Panavia F2.0 Paste A	Kuraray	Hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic dimethacrylate, sodium aromatic sulfinate, N, N-diethanol-p-toluidine, surface treated (functionalized) sodium fluoride, silanated barium glass	1L0090
Panavia F2.0 Paste B	Kuraray	MDP, hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic dimethacrylate, silanated silica, benzoyl peroxide, dibenzoylperoxide	1M0017
RelyX Ultimate Base	3M ESPE	Methacrylate monomers, Radiopaque silanated fillers, initiator components, stabilizers and rheological additives	586241
RelyX Ultimate Catalyst paste	3M ESPE	Methacrylate monomers, Radiopaque Alkaline fillers, initiator components, stabilizers, pigments, rheological additives, fluorescence dye, dark polymerize activator for scothbond Universal adhesive	586241
ED Primer 2.0	Kuraray	Liquid A: HEMA, MDP, 5-NMSA, Water, Accelerators Liquid B: 5-NMSA, Water, initiator, Accelerators	160018 170019
Scothbond Universal adhesive	3M ESPE	MDP phosphate monomer, dimethacrylate resins, HEMA, methacrylatemodified polyalkenoic acid copolymer, filler, ethanol, water, initiators, and silane	584909

Kuraray medical Inc., Okoyama, Japan; 3M ESPE, Neuss, Germany
MDP: 10-methacryloxydecyl dihydrogenic phosphate; HEMA: 2-hydroxyethyl methacrylate; 5-NMSA: N-methacryloyl 5-aminosalicylic acid.

Table 2. Techniques of adhesive resin cement system application

Resin cement	Priming procedures	Luting procedures
Panavia F2.0 (film thickness = 19 µm)	Mix ED Primer Liquids A and B in equal portions, gently air-dry after 60s	Mix equal amounts of the two paste for 20s
RelyX Ultimate (film thickness = 12 µm)	Actively apply Single bond for 20s, dilute for 5s with gentle air pressure, light cure for 10s	Dispense equal volumes of the base and catalyst pastes onto mixing pad and mix for 20s

(Maouira dental products, Parana, Brazil) and water applied by the gentle and intermittent pressure of rotary prophylaxis brushes for 30 seconds. The samples in groups Pc and Uc were cleaned by using tungsten carbide burs (Dentsply Maillefer, Ballaigues, Switzerland) at 1000 rpm speed for 10 seconds. The restorations were then cleaned for rebonding. The internal surfaces of the castings were cleaned of cement remnants with air abrasion (50 µm Al_2O_3 at 2.5 bar pressure) for 5 seconds and were inspected under the stereomicroscope at ×20 magnification. Then, the specimens were stored in ultrasonic cleaner and distilled water for 30 minutes.

The specimens were recemented with Panavia F2.0 and RelyX Ultimate cements through the previously mentioned methods. All of the bonded specimens were stored in distilled water for 24 hours at 37°C and then were thermocycled for 1000 thermal cycles (5 - 55°C) with dwell time of 20 seconds. Once more, they were kept in distilled water for another 24 hours at 37°C and the shear bond strength test was repeated.

The dentin surface of the debonded specimens was evaluated by stereomicroscope at ×40 magnification. Failure modes were classified into 3 categories: a) Adhesive failure at cement-dentin interface, b) Adhesive failure at casting-cement interface, and c) Mixed failure.

For further analysis, two samples were randomly selected from each group and mounted on the metallic stub. The debonded surfaces were gold coated by sputtering and evaluated under a scanning electron microscope (TESCAN, VEGAII, XMU, Brno-Kohoutovice, Czech Republic).

Results were collected and statistically analyzed with SPSS version 21.0 software (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA). Descriptive analysis was performed on the data. The mean shear bond strength, standard deviation, and range were calculated for each group. Mann Whitney U-test was done to compare the shear bond strengths of the study groups after first debonding. Meanwhile, two-way analysis of variance (ANOVA) was performed to evaluate the effects of cement type and cleaning procedures on shear bond strength for rebonding, including the possibility of interaction between these two factors. Also, paired sample t-tests were performed to compare the shear bond strength of both cements for rebonding after cleaning procedures with their initial bond strength. However, Wilcoxon Signed Ranks non-parametric analysis was applied in subgroups with non-normal distribution. The significance level was set at 0.05.

RESULTS

Mann Whitney U-test revealed that P (14.73 ± 8.61) had significantly higher initial bond strength compared to U (7.61 ± 7.1) (P = .001). The highest bond strength for rebonding was observed in group Pp with the value of 19.24 ± 8.98 MPa followed by group Pc (16.32 ± 9.56) and Up (11.66 ± 8.7). Group Uc had the lowest shear bond strength for rebonding of 6.40 ± 5.55 MPa.

For the two-way ANOVA, the data failed the normality test (P < .05). This was possibly due to the correlation between variance and mean, a common result for strength measures. Accordingly, the data were transformed by taking logarithms and the analysis was repeated. The normality tests were then passed (P = .20). Also, the power of the test was reported as 0.942. While the effects of cements were significantly different, there was no detected effect from the cleaning procedures. Therefore, the significant interaction can be ignored as uninterpretable (Table 3). Thus, a one-way analysis was performed for cleaning procedures on the transformed data (Table 4).

In terms of comparison between the initial and second

Table 3. Analysis of variance of shear bond strength for rebonding: cement × cleaning procedures (log transformed data)

Variable (Source)	Df	Sum of squares	Mean squares	F	*P* value
Cement	1	1.625	1.625	17.697	.000
Cleansing procedures	1	.057	.057	.619	.435
Interaction	1	.478	.478	5.209	.027
Error	48	4.408	.092		
Total	52	58.578			

Table 4. Analysis of variance of shear bond strength for rebonding (log transformed data)

Comparison	Mean difference	Standard error	*P* value
Pp vs Up	.54540	.11886	.001
Pp vs Uc	.28746	.11886	.087
Pc vs Up	.41969	.11886	.005
Pc vs Uc	.16175	.11886	.530

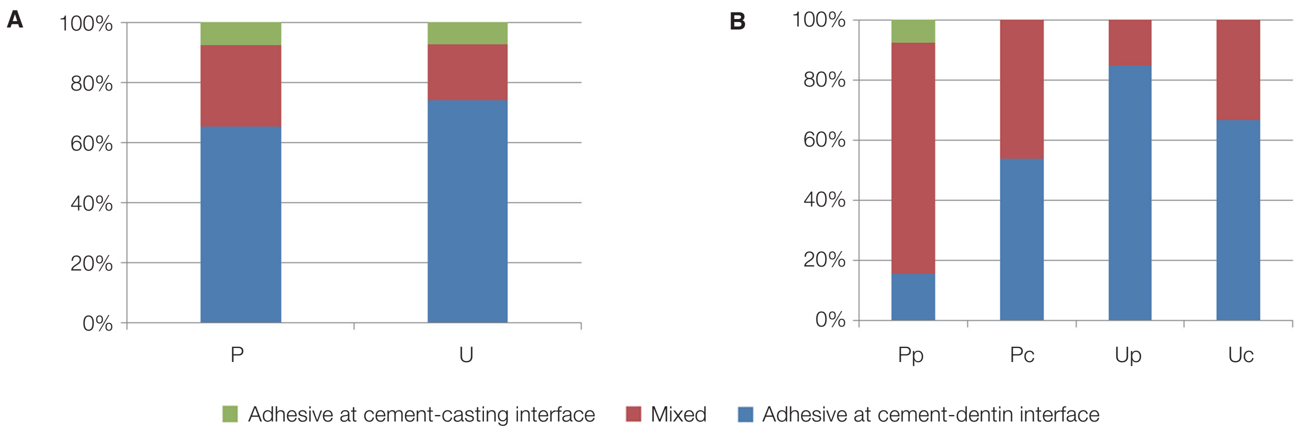

Fig. 2. Frequency of failure patterns after initial debonding in groups P and U (A) and after second debonding in groups Pp, Pc, Up and Uc (B).

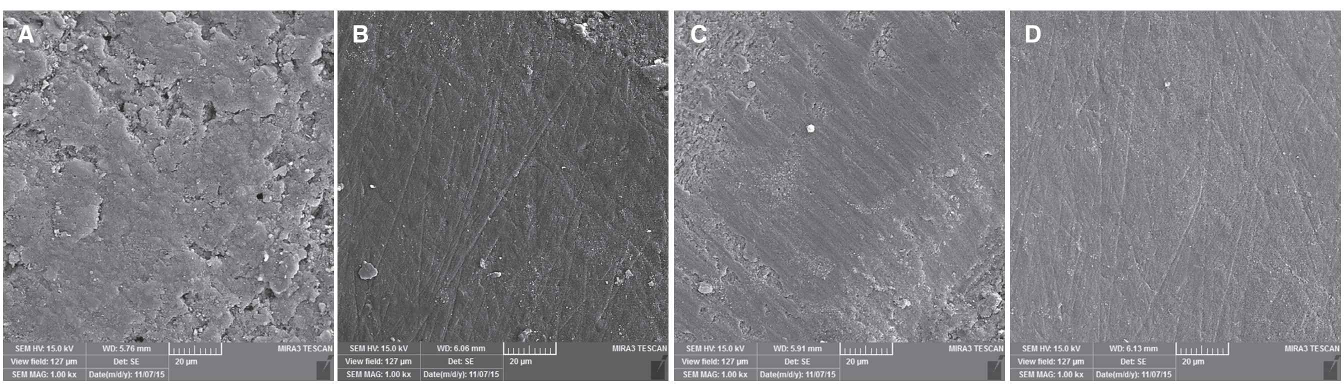

Fig. 3. Images of SEM (×2000) after cleaning the surface with pumice and tungsten carbide bur; Pp (A), Pc (B), Up (C), and Uc (D).

shear bond strengths of cements, surface cleaning with carbide bur (Pc and Uc groups) increased the bond strength of both cement types for rebonding compared with their initial bond strength. However, this increase was significant only in Pc group (P = .034).

The failure pattern experienced after initial debonding was mostly adhesive at the cement dentin interface. Only 5 cases of adhesive failure occurred at the cement-restoration interface. Fracture of tooth structure was seen in none of the specimens. After the second debonding, adhesive failure type was mainly observed in Up (84.61%) and Uc groups (61.53%). As shown in Fig. 2, mixed failure was the most prevalent observation in the groups of Pp (76.92%) and Pc (46.15%).

SEM micrographs showed the characteristics of the dentin surfaces after mechanical surface cleaning. Various amounts of residual cement were observed on the dentin surface of all groups. Between the two cleaning methods, carbide bur provided the cleanest surface for both cement types. Pumice was weaker in cleaning Panavia F2.0 compared with that in RelyX Ultimate cement (Fig. 3).

DISCUSSION

Bond failure is relatively frequent and undesirable in resin bonded restorations.[1-3] Awareness of the bond strength for rebonding is of great clinical importance for the success of recementation. If the bond strength of resin cements for rebonding resin bonded restorations in case of dentin exposure is unknown, it is impossible to predict the performance of resin cements and subsequently recemented prosthesis.

This study was conducted to evaluate the bond strengths for initial bonding and rebonding of two types of resin cements as well as the effects of different surface preparation methods on bond strength. It was detected that a considerable difference existed between the initial bond strengths of the two studied cements. The initial bond strength of Panavia F2.0 was higher than that of RelyX Ultimate cement (*P* = .001). Additionally, removing the residual resin cement by using a carbide bur increased the shear bond strength for rebonding of both cement types; however, the increase was significant only in Panavia F2.0 cement (*P* = .034). Thus, the null hypothesis was rejected.

The difference in the adhesive behavior and bonding mechanism is due to the diversity of composition and chemical structure of the adhesives. The adhesion of resin cements relies primarily on the presence of functional monomers.[9,21,22] The chemical structure of primer in both Panavia F2.0 and RelyX Ultimate cements is based on MDP monomer (10-Methacryloyloxydecyl dihydrogen phosphate). The MDP functional monomer reacts with calcium of hydroxyapatite and forms stable MDP salt, which strengthens the adhesive layer. Salts of other functional monomers are soluble and hydrolytically unstable,[22,23] which explains the reason why they decrease the bond stability. High concentration of MDP monomer is needed for effective chemical reaction with the hydroxyapatite in dentin and enamel. Accordingly, adding other primer components reduces nanolayering and the reaction of self-etch primer.[9,22-25] In addition to MDP, Scotchbond Universal Adhesive contains polyalkenoic copolymer, which competes with the MDP functional monomer for calcium bonding sites in hydroxyapatite.[3,21,23-25] So, not only can it disrupt the bonding of MDP to the dentin, but also its high molecular weight can prevent the approaching of MDP monomer during polymerization and consequently decrease the degree of conversion.[9,23,25] Presence of this copolymer also reduces the total concentration of MDP in Scotchbond Universal Adhesive compared with Panavia F2.0 in which MDP monomer is included in both the cement composition and the primer. It can be concluded that the higher bond strength of Panavia F2.0 cement is attributed to the higher concentration of MDP functional monomer. Yet, further studies should be performed to determine the effect of other components of primer or adhesive on the behavior of nanolayer interface formed by MDP.

It is essential to effectively remove the residual resin cement from the prepared tooth surface before recementing the resin bonded restoration so that the cement remnants do not interfere with recementing process.[8,19,26-28] Despite the efforts to offer the proper chemical and mechanical methods for cleaning the provisional cement off the tooth surface, no definite protocol is in hand for cleaning the residual permanent cement from the dentin surface. The search for an efficient method of eliminating the adhesive resin cement after debonding of orthodontic bracket from the enamel surface has led to the introduction of a wide range of methods including manual removal techniques, scalers, composite polishing systems, tungsten carbide bur in high or low speed handpieces, ultrasonic instruments, and pumice paste.[9,23,28-33] Moreover, air-powder abrasive systems have attempted to eliminate the residual adhesive from the enamel surface, which necessitates using rubber dam, mask, and eye protections.[34,35] According to various researchers, pumice was more efficient than chemical agents in cleaning the residues of temporary cement before permanent cementation. Yap[35] showed that mechanical removal of residual cement by using an ultrasonic scaler followed by pumice paste application increased the bond strength for rebonding and infiltration of resin cement into dentin. Button[20] reported that cleaning the tooth surface with pumice enhanced the retentive strength created by glass ionomer cement and polycarboxylate. Nevertheless, some studies opposed the application of pumice and asserted that it was not effective in all cases.[10,36,37] Claims were also made that preparing the tooth surface with pumice could even decrease the bond strength.[10]

After bracket removal, carbide bur under air or water coolant was efficient for cleaning the residual cement from the enamel surface and left less remnants on the tooth surface.[30] However, if used at high speed, these burs have the potential to damage the tooth surface.[19,30] With respect to the study by Zachrisson and Arthun,[38] a tungsten carbide bur mounted in a low-speed (1000 rpm) contra-angle handpiece removed the minimum tooth structure, produced less heat, and did not jeopardize the restoration fitness. Accordingly, the current study assessed the effects of pumice and carbide bur in removing the resin cement from the dentin surface.

Although no residual resin cement was clinically observable after cleaning the tooth surface, scanning electron microscopy confirmed the presence of fine cement particles. SEM inspections revealed that carbide bur was more effective in removing the residual cement from the dentin surface, while applying pumice slurry by rotary brushes had the least efficiency. Furthermore, the cleaning effect of pumice slurry on Panavia F2.0 cement was quite less than its effect on RelyX Ultimate cement. The size and volume of filler particles greatly influence the resin cement abrasion resistance. According to the manufacturer, Panavia F2.0 cement consists 59% by weight inorganic fillers with particle size of 19 µm; on the other hand, the filler content in RelyX Ultimate is 43% by weight with the average particle size of 13 µm. The greater size and content of inorganic filler in Panavia F2.0 cement might be responsible for its higher abrasion resistance against pumice slurry.

Repeated debonding of resin bonded restorations is considered as failure since the failure rate increases with each rebonding.[1,3,5] Contradictory findings exist in the published literature concerning the effects of multiple bonding on the shear bond strength of brackets. Some demonstrated that the strength decreased considerably after the second bonding;[31] whereas others reported the same values as the initial bond strength.[28,29,31-33] The current study revealed that the initial bond strengths of RelyX Ultimate and Panavia F2.0 cement were equal to the bond strength for rebonding after cleaning the dentin surface with pumice. Besides, dentin clean-up by using a carbide bur increased the bond strength values of both resin cements for rebonding to more than their initial bond strengths. However, the difference was only significant for Panavia F2.0 cement (P = .034). The adhesion mechanism is primarily based on hybrid layer formation and the micromechanical interlocking of infiltrated resin in the demineralized dentin. Extension of resin tags into the opened dentinal tubules and their adaptation to the tubule walls are mainly responsible for the bond strength.[9,14,39] In the present study, the residual resin cement remaining after pumice application sealed the openings of dentinal tubules, reducing the action of primer liquid and preventing resin impregnation. So, the recementation was performed on the remaining cement particles, which had previously altered the underlying dentin substance, consequently yielding lower bond strength values. Moreover, consistent with some studies, applying pumice by rotary brushes could condense the paste over the dentin surface, which interferes with adhesion.[10,15] So, removing the residual cement improves the interface between the dentin and adhesive system and results in enhanced bond strength.[13,16,40,41] This was in line with the findings of Eminkahyagil, which obtained an increased bond strength of for rebonding orthodontic brackets by using carbide burs.[30]

The initial failure pattern was predominately adhesive failure between dentin and resin cement. However, adhesive failure at the dentin-cement interface was mainly observed in the rebonded specimens of RelyX Ultimate and Panavia F2.0 cements after cleaning with a carbide bur. Mixed failure type was experienced mainly in the specimens rebonded with Panavia F2.0 after Pumice application. With respect to the higher bond strength for rebonding of the latter group, these findings are justifiable. In accordance with previous investigations,[26,27,42] when the shear bond strength values of resin cements to dentin surface are lower, adhesive bond failure is more likely to occur. However, clinical replications are necessary to validate the significance of this laboratory finding.

CONCLUSION

Panavia F2.0 cement provided higher initial shear bond strength compared with RelyX Ultimate. Using a carbide bur for surface preparation before rebonding increased the bond strength of Panavia F2.0 cement. After being cleaned with pumice, the specimens rebonded with both resin cements were found to have similar bond strength as the initial strength. Generally, the highest shear bond strength was achieved after recementation with Panavia F2.0 and surface cleaning with a carbide bur.

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