



Original article

Effects of different bonding systems with various polymerization modes and root canal region on the bond strength of core build-up resin composite

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Abstract

Purpose: The aim of this study was to clarify the effects of different bonding systems (BSs) with various polymerization modes and root canal regions on the bond strength of core build-up resin composite to dentin.

Methods: Post cavities were prepared in the roots of 54 bovine teeth. Three types of BS with various polymerization modes (light, chemical, and dual-cure) were applied to the walls of the cavities, which were subsequently filled with core build-up resin composite, and stored in 37°C water for 7 days. Each tooth was then sectioned perpendicular to the long axis of the tooth into 9-disk from the coronal to the apical side. Bond strengths were measured on two-thirds of the disks, while dye penetration was examined in the remaining third.

Results: Statistical analysis revealed significant differences between the bond strengths of BSs with different polymerization modes, indicating chemical-cured BS had higher bond strength than light-cured BS. The chemical-cured BS group showed cohesive failure in both resin composite and dentin regardless of the root canal region, while adhesive failure was observed in the coronal region for dual-cured BS and in the apical region for light-cured BS. Dye penetration was significantly more at the bonding interface at the apical region of the light-cured BS.

Conclusions: Chemical-cured BS displayed a greater bond strength than light-cured BS. Cohesive failure was observed in both core build-up resin and dentin, indicating that the integration of tooth structure with resin composite was effective for retaining the resin core and sealing the root canal.

Keywords: Polymerization, Bonding system, Push-out, Bond strength, Root canal dentin

Received 23 October 2020, Accepted 7 January 2021, Available online 25 March 2021

1. Introduction

When the crown of a tooth is destroyed due to caries or trauma, the roots can successfully be preserved with proper endodontic treatment and abutment construction. The occlusal function can also be restored with the fabrication of a prosthetic crown. The survival of endodontically treated teeth depends on many factors, such as the type of prosthetic procedure, abutment construction, and appropriate disinfection of root canals. The rubber dam isolation technique, which ensures moisture control and infection prevention is essential for successful endodontic treatment [1]. Because proper adhesion between the abutment and root dentin prevents bacterial re-infection of endodontically treated teeth, sealing of root canals is vital to ensure a good prognosis. A study has shown that the survival rate of teeth declines significantly after 6 years when cast cores are used for abutment construction [2]. The data show that the 15-year survival rate of teeth was 55% for cast cores and 79% for resin cores. This suggests that successful preservation of teeth after endodontic treatment not only depends on proper root canal treatment but also on the materials used for core build-up and final crown restoration [3–5].

Endodontic treatment is important to remove the pathogen causing infection and prepare the root canal so that it can retain the post and core

structure required for the final prosthetic device. There are two methods for core build-up: the indirect method in which the post and core complex is fabricated on a model that is then bonded to the dentin using resin cement, and the direct method where the post and core build-up resin composite is directly filled in the root canal using a bonding system (BS). In the direct method, post and core complexes are constructed using core build-up resin, and a BS is used to retain the prosthetic device and to seal gaps to prevent bacterial infection. Prostheses, such as onlays and crowns, can be retained adequately without the use of fiber posts so long as there are two or more residual tooth walls with thicknesses and heights greater than 1 mm and 2 mm, respectively [6, 7]. However, detachment of the resin core structures due to poor adhesion has been frequently reported [8]. Therefore, BSs are very important during core build-up in order to sufficiently bond the resin composite to the root canal dentin.

Previous studies have reported the effects of residual endodontic treatment agents and root canal region on the bond strengths of resin cements and core-build-up resin [9–12]. Proper irrigation of the root canal with sodium hypochlorite improved the bond strength between the dentin and the resin composite during abutment construction [9], while a prolonged treatment period reduced the bond strength [10]. Root canal irrigants have also been shown to reduce the bond strength between the dentin and the resin cement [11].

The structures of the dentin, such as the direction, number, and width of dentinal tubules, vary according to region. The bond strength decreases when the dentinal tubules run perpendicular to the bonding surface [12]. The density of dentinal tubules decreased toward the apex, which resulted in less resin tag formation corresponding to bonding strength [13]. Therefore, the adhesion of bonding materials on endodontically treated

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teeth is presumed to be inadequate due to factors such as residual irrigating agents in the cavity or the direction of the dentinal tubules. In addition, there is a risk of marginal leakage due to polymerization shrinkage or insufficient curing of the resin composite in the deep areas of the cavity on endodontically treated teeth [14]. Adequate bonding in deeper regions of the cavity is important to prevent the risk of re-infection; however, there are still very few studies on the adhesion of dentin in deep regions of the root canal.

The resin core build-up using the direct method is more advantageous in that less tooth reduction is required, patient visitation is reduced, and treatment can be performed in isolation when the rubber dam isolation technique is used. The direct method involves core build-up using a resin composite and a BS. There are three types of dental BS: light-cured, chemical-cured, and dual-cured. Studies have shown that in light-cured BS where polymerization is accelerated by light irradiation, polymerization of the bonding material affects the bond strength between the core and the tooth structure [15–17]. However, the effects of polymerization modes of different BS on the retention of core build-up material in endodontically treated dentin remain unclear.

The purpose of this study was to clarify the effects of BS using different polymerization modes and of the root canal region on the bond strength of core build-up resin to dentin. Three types of BSs were applied to endodontically created bovine tooth roots, and resin composite was used to fill the cavities. The bond strength of core build-up resin on dentin was examined as well as the fracture mode on the adhesive interface. The null hypothesis was that the BS and root canal region have no effect on the bond strength between the resin composite and root canal dentin.

2. Materials and Methods

2.1. Specimen preparation

Fifty-four bovine anterior teeth were prepared. The crown was removed at the cement–enamel junction using a diamond disk. Each root was fixed in an acrylic ring with cold-cured acrylic resin in a direction parallel to the tooth axis. A 14-mm deep and 3-mm wide cavity was prepared in the root canal using a 3-mm drill. The cavity was washed with 18% EDTA (Ultradent EDTA 18%, ULTRADENT JAPAN, Tokyo, Japan), 3% NaOCl (ChlorCid, ULTRADENT JAPAN), and distilled water for 1 min each. The prepared roots were stored in water at 37°C. After 1 week, roots were dried using an air blow and paper points. The cavities were treated with one of three BSs with different polymerization modes (light-cured, chemical-cured, and dual-cured). The BS used and their instructions are listed in Table 1. Light-cured and dual-cured BSs were used on three types of BS to 6 roots each, and chemical-cured BS was applied to two types of BS to 9 roots each. For light- and dual-cured BSs, irradiation was performed using a light source (PEN Bright, Shofu, Kyoto, Japan) upon application of the bonding agent. For each system used, the cavities were first half-filled with a core build-up resin composite (BeautiCore LC Post paste, Shofu) and irradiated for 20 s. Following this, the remaining cavity was filled and irradiated again. The roots were stored in an incubator at 37°C for 1 week. After 1 week, a cutting machine (ISOMET, Buehler, USA) was used to section the coronal 14-mm of each root into 9 specimens (1-mm thick). Three specimens were prepared for each of the three groups, that were divided according to the region (coronal, middle, and apical). The surface of each specimen was polished with 2,000 grit water-resistant abrasive paper, and a uniform thickness was established by measuring each specimen with a micrometer (Mitutoyo, Kanagawa, Japan). Two specimens from each region were used for bond tests and the remaining specimen was used for the dye penetration test. This study was approved by the Ethics Committee for animal experiments of Iwate Medical University (Permission number: 02-004). The schematic of the experimental design is shown in Figure 1.

2.2. Bond strength

The bond strength between the core build-up resin composite and root canal dentin using various BSs were measured by means of the push-

out and modified biaxial tests using a universal testing machine (EZ-LX: SHIMADZU, Kyoto, Japan). The apical side of each specimen was supported on three steel balls, and a load was applied with an indenter at the center of the resin portion of the specimen at a cross-head speed of 0.5 mm/min. The bond strength was calculated from the maximum load.

2.3. Fracture mode

The surfaces of the fractured specimens were observed under a digital microscope (UM12, MicroLinks Technology, Kaohsiung, Taiwan). The fracture modes were classified into four categories (Fig. 2): adhesive failure between resin composite and root canal dentin (Category 1), cohesive failure of resin composite (Category 2), mixture of both adhesive failure (between resin composite and root canal dentin) and cohesive failure of root canal dentin (Category 3), and cohesive failure of both the resin composite and root canal dentin (Category 4).

2.4. Dye penetration test at adhesive interface

The bonding interface between the resin composite and root canal dentin was examined via the dye penetration test using a 0.2% fuchsin solution (Fuchsin Basic, FUJIFILM Wako Pure Chemical, Osaka, Japan). On the cervical side of the specimen, 100 μ L of fuchsin solution was placed for 1 min and washed with water for 10 s. The surface was polished with 2000 grit abrasive paper to remove excess dye, and the bonding interface was observed using a digital microscope (UM12, MicroLinks Technology). The proportion of dye penetration at the interface between the resin composite and the root canal dentin was calculated using the Image J software (NIH, USA).

2.5. SEM observation

Fractured surfaces were observed under a field emission scanning electron microscope (SEM; SU8010, Hitachi High Technologies, Tokyo, Japan). Prior to observation, the specimens were coated with 50 nm of OsO₄ using a coater (OSMIUM PLAZMA COATER OPC 60A, Filgen, Aichi, Japan). SEM observations were performed at an accelerating voltage of 10 kV.

2.6. Statistical analysis

First, the bond strength of each bonding agent among bonding systems was analyzed using the Shapiro-Wilk test for normality. Subsequently, this test was used to analyze the bond strengths and dye penetration area by classifying the BS and dentin regions (Region) into 9 groups. Bond strengths and dye penetration areas were statistically analyzed using two-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test. The ratio of fracture modes was analyzed using the χ^2 test and residual analysis. The significance level was set at 95% ($\alpha=0.05$; SPSS statistics ver. 22; IBM, Cary, NC, USA).

3. Results

3.1. Bond strength

The bond strengths of each bonding agent are listed in Table 2. These varied widely among the brands of bonding agents. However, all the bond strengths in bonding system including three or two bonding agents were statistically confirmed the normality. The results of the two-way ANOVA among BSs and root canal regions are shown in Table 3. Significant differences were observed between the bond strengths for different BSs; however, no significant differences in bond strengths were observed among different regions. There were no significant differences between the interaction of BS and dentin regions. Figure 3 displays the bond strength of BS at each dentin region. The bond strengths of light-cured, chemical-cured, and dual-cured BSs on the root canal dentin were 5.3 \pm 3.0, 6.7 \pm 2.7, and 5.8 \pm 2.9 MPa, respectively. A significant difference in bond strengths was observed between light-cured and chemical-cured BS.

Table 1. Bonding systems and resin composite for build-up used in the present study

Code	Product name	Composition of materials ¹⁾	Lot. No.	Manufacturer
Light cured type bonding system				
GPB	G-Premio BOND	4-META, Phosphate monomer, thiophosphate monomer, Acetone, Water, Photoinitiator	1708081	GC
SB	Scotchbond Universal Adhesive	Phosphate monomer, Dimethacrylate, Ethanol, Water, Photoinitiator	71130E	3M
AU	Adhese Universal	Methacrylates, Ethanol, Water, Highly dispersed silicon dioxide, Initiators and stabilizers	Y02992	Ivoclar Vivadent
Chemical cure type bonding system				
CLF	CLEARFIL NEW BOND	Catalyst liquid: Bis-GMA, HEMA, MDP Universal liquid: Ethanol, Water	250013	Kuraray Noritake Dental
BL	BONDMER Lightless	Bond A: Acetone, Phosphate monomer, Bis-GMA, TEGDMA, HEMA, MTU-6 Bond B: Acetone, Isopropyl alcohol, Water, Borate catalyst, γ -MPTS, Peroxide	020, 504	Tokuyama Dental
Dual cure type bonding system				
BDB	Beauti Dual Bond EX	Bond A: Water, Acetone, Bond B: Acetone, Bis-GMA, Carboxylic acid monomer, TEGDMA	071814, 091817	Shofu
LB	i-TFC LUMINOUS BOND	Liquid: 4-META, Acetone, Water Brush: Aromatic amine, Aromatic sulfonate	SR1 SW11	Sun Medical
UFC	UniFil Core Self Etching Bond	Bond A: Water, Ethanol, 4-META, Methacrylic ester Bond B: Water, Polymerization accelerator	Bond A: 1903011 Bond B: 1903051	GC
Resin composite for build-up				
BC	Beauticore LC post paste	Glass powder, Bis-GMA, TEGDMA, UDMA	071813	Shofu

1) Based on manufacturer's data

4-META: 4-Methacryloyloxy trimellitate anhydride, Bis-GMA: bisphenol A-glycidyl methacrylate, HEMA: 2-Hydroxyethyl methacrylate, MDP: 10-methacryloyloxydecyl dihydrogen phosphate, TEGDMA: Triethyleneglycole dimethacrylate, MTU-6: Methacrylic acid 6-[[[(2-thioxo-4-oxo-1,2,3,4-tetrahydropyrimidine)-5-ylcarbonyl]oxy]hexyl ester, γ -MPTS: γ -methacryloxy propyltrimethoxysilane, UDMA: Urethane dimethacrylate

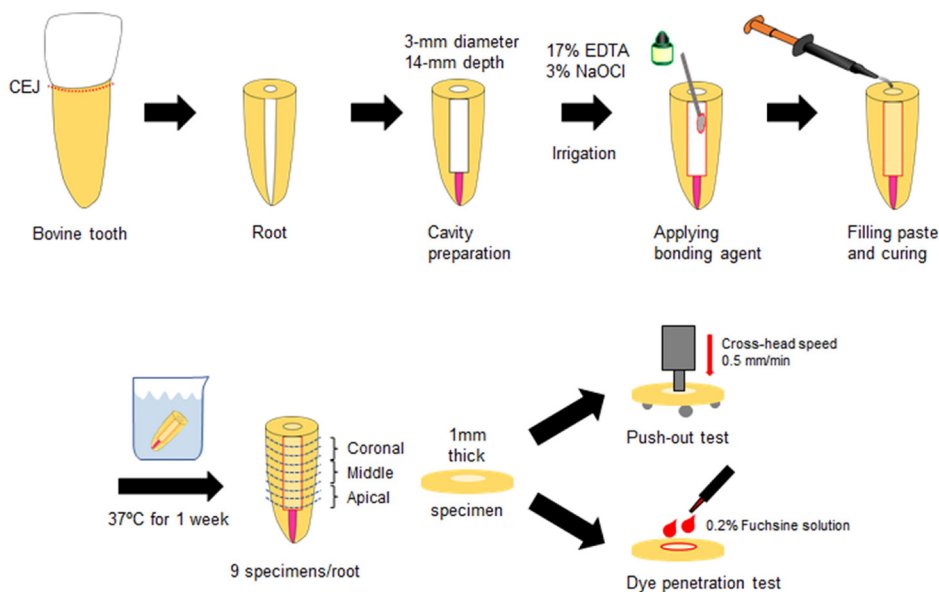


Fig. 1. Schema in experimental design. Specimen preparation: specimens were cut at the CEJ, cavity preparation, applying bonding agent, and filled with resin composite. The specimens were then sectioned perpendicularly to the long axis of the root. Nine disks of 1 mm thickness were cut in order to obtain three specimens in coronal middle and apical side per root. Bond strength were measured on two thirds of the disks, while dye penetration was examined on the remaining third.

3.2. Fracture mode

Figure 4 shows the fracture modes of the specimens in each BS according to the region after the push-out test. The χ^2 test and residual analysis revealed that chemical-cured BS had higher ratio of Category 4 regardless of region. Category 1 was most often observed for dual-cured and light-cured BSs in the coronal and apical regions, respectively ($P < 0.05$).

3.3. SEM observation

Figure 5 shows the representative SEM images of fractured surfaces in Category 1 (Fig. 5(a) coronal and (b) apical region with light-cured BS), root canal cavity after endodontic treatment (Fig. 5(c)), and fractured surfaces in Category 4 for chemical-cured BS (Fig. 5(d) and (e)). Compared to dentinal tubules after endodontic treatment, dentinal tubules in fractured surfaces (Fig. 5(a) and (b)) were obstructed due to resin tags (Fig. 5(c)). Resin tags were observed in all regions of the root canal due

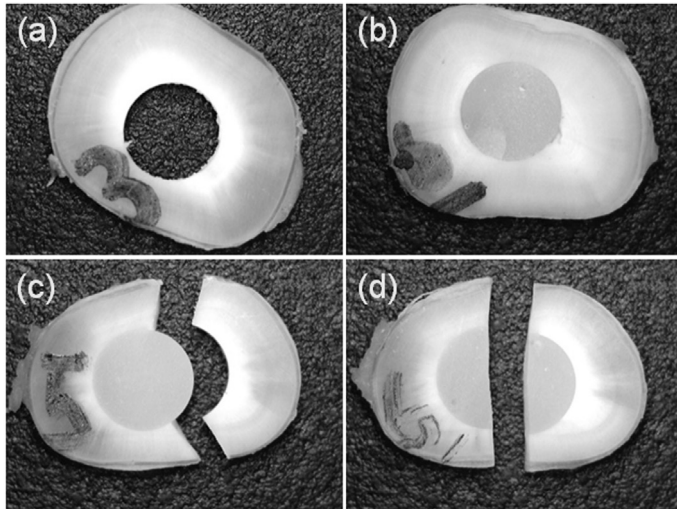


Fig. 2. Fractured mode after push-out test. (a) Category 1: Adhesive failure between resin composite and root canal dentin, (b) Category 2: Cohesive failure of resin composite, (c) Category 3: Mixture of both adhesive failure (between resin composite and root canal dentin) and cohesive failure of root canal dentin, (d) Category 4: Cohesive failure of both resin composite and root canal dentin

Table 2. Bond strength of specimens adhered by each BS at region of root canal dentin

Bonding system		Coronal	Middle	Apical	Total at brand
Light-cured	GPB	3.2±2.2	2.1±1.7	2.8±1.0	2.7±1.7
	SB	5.6±3.5	4.8±3.5	4.6±3.0	5.0±3.3
	AU	7.5±1.5	8.8±1.5	8.3±1.9	8.2±1.6
Light-cured total		5.4±3.1	5.0±3.7	5.2±3.0	5.3±3.0
Chemical-cured	CLF	8.0±2.1	7.6±1.7	7.1±1.9	7.6±2.0
	BL	5.9±3.0	5.7±3.7	6.0±2.2	5.9±3.0
Chemical-cured total		7.0±2.8	6.7±3.0	6.6±2.2	6.7±2.7
Dual-cured	BDB	3.0±1.7	6.0±2.4	5.2±1.6	4.7±2.3
	iLB	7.9±4.0	7.6±2.9	7.0±3.1	7.5±3.3
	UFC	4.4±1.1	5.5±2.5	5.6±2.3	5.2±2.1
Dual-cured total		5.1±3.3	6.4±2.7	5.9±2.5	5.8±2.9
Total in dentin region		5.8±3.2	6.1±3.2	5.9±2.6	

(mean ± standard deviation)

Table 3. Result of two-way ANOVA of bond strength

Factor	Sum of squares	DF	Mean of squares	F value	P value	Judge
Bonding system (A)	112.8166	2	56.4083	6.4801	<0.0017	**
Dentin region (B)	3.5245	2	1.7622	0.2024	0.8168	
Factor A * Factor B	31.3501	4	7.8375	0.9003	0.4639	
Error	2742.0178	315	8.704			
Total	2889.7090	323				

** : P<0.01

to bonding agents remaining in the dentinal tubules. Figure 5(d) shows cohesive fractures with unclear margins between the resin composite and the dentin on the surfaces in Category 4. At the interface, the resin tag remained on the dentinal tubules and the resin composite layer was integrated with dentin alongside the bonding agents.

3.4. Dyed areas at adhesive interface

Figure 6 shows the proportion of dye penetration at the bonding interface for each BS. Regardless of the BS, the proportion of dye penetration

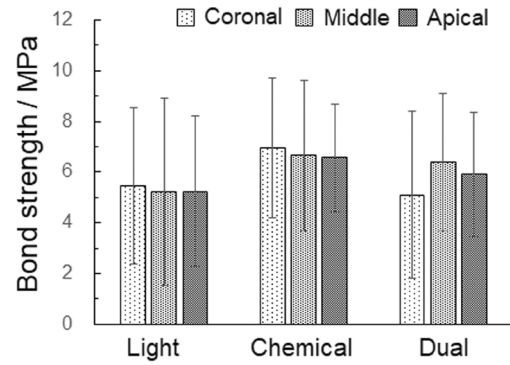


Fig. 3. The bond strength of specimens adhered with BSs at each region of root canal dentin.

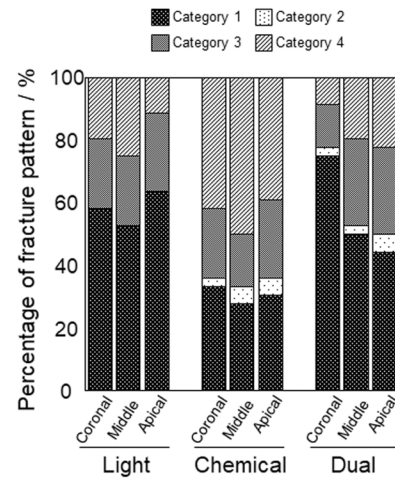


Fig. 4. The fracture modes of specimens with BS according to region of root canal dentin after the push-out test.

in the coronal and middle region of root dentin was 6–18% and 16%, respectively. The proportion of dye penetration in the apical region was 30% for light-cured BS. Table 4 shows the two-way ANOVA results for dye penetration according to the dentin region for each BS. The results illustrated significant differences in dye penetration among dentin regions, and interactions were observed between the BS and dentin region. The Tukey multiple-comparison test indicated a significant difference between the apical of light-cured BS and the coronal of light- and chemical-cured BSs and apical of chemical-cured BS, indicating that the apical region for light-cured BS displayed the largest amount of dye penetration among the tested specimens.

4. Discussion

4.1. Push-out and dye penetration tests

In this study, various BSs were applied to the post cavity prepared in the roots, and the bond strengths of core build-ups on resin in different regions of dentin were evaluated using the push-out and dye penetration tests. Specimens were made from bovine mandibular anterior teeth with root lengths that ranged between 20–21 mm from the cement–enamel junction. Since the structure of bovine teeth is similar to that of human teeth, bovine teeth are often used to evaluate the bond strength of dental materials [18, 19]. However, since bovine teeth are larger than human teeth, the root lengths of selected teeth for this study were limited to 20–21 mm, and root preparation was performed on the coronal 2/3 (14 mm). A total of 9 specimens were prepared from each bovine tooth, and each specimen had a

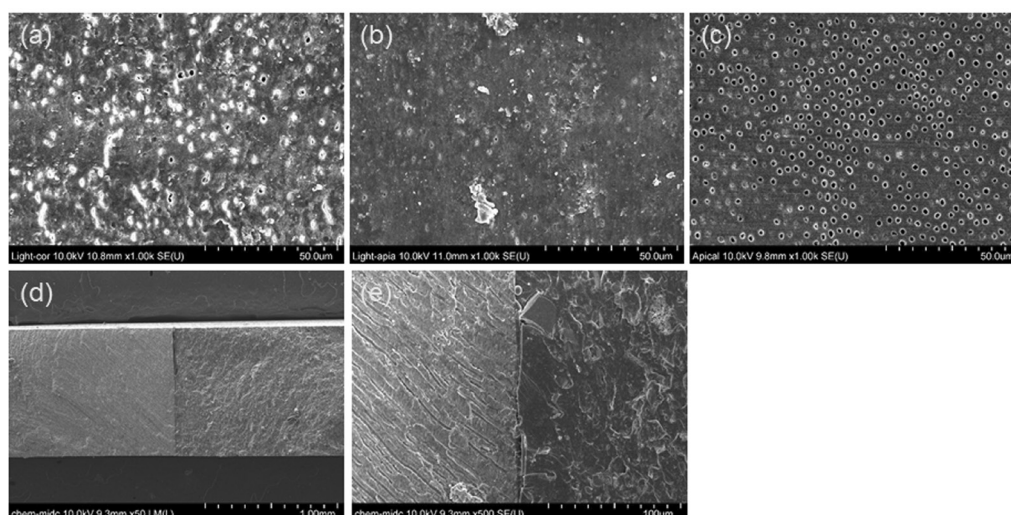


Fig. 5. Typical SEM images of fractured surface of dentin. (a) Adhesive failure at coronal region with light-cured BS, (b) adhesive failure at apical region with light-cured BS, (c) apical region with pre-treated with 17% EDTA and 3% NaOCl, (d) cohesive failure at middle region of chemical-cured BS (low magnification), (e) high magnification in “(d)” image.

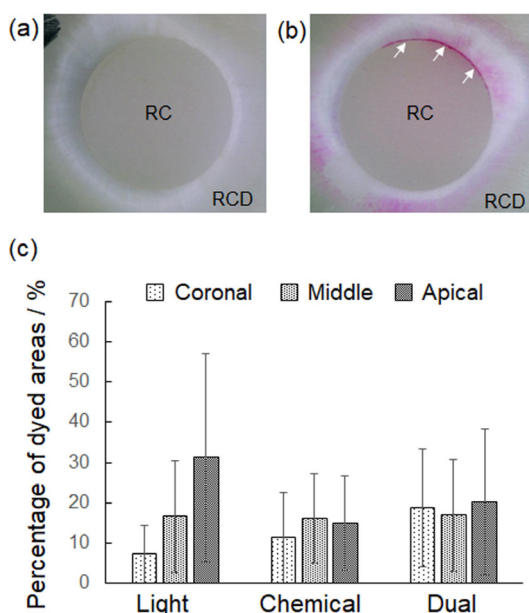


Fig. 6. The images of penetration test (a, b) and the proportion of dye penetration at the bonding interface for each BS (c). (a) No dye penetration at interface, (b) Partial dye penetration (white arrows) at interface, (c) Percentage of dye penetration at the bonding interface. “RC” and “RCD” in (a) and (b) are resin composite and root canal dentin, respectively.

final thickness of 1.0 mm.

During resin core build-up via the direct method, the addition of a fiber post is generally recommended because of its similar elastic modulus to dentin and its resistance against vertical stress. However, some studies have suggested that fiber posts are not always necessary when there is sufficient tooth structure remaining following endodontic treatment [6, 7]. Methods to investigate post retention include the pull-out and push-out tests [16, 20]. The pull-out test is suitable for measuring the retention force of the entire post, and the push-out test is suitable for measuring the bond strength at specific regions.

Push-out tests have been conducted to determine the effects of pretreatments on the retention of the fiber post with resin core build-up

Table 4. Result of two-way ANOVA of dye penetration at adhesive interface

Factor	Sum of squares	DF	Mean of squares	F value	P value	Judge
Bonding system (A)	679.5131	2	339.7565	1.4484	0.2382	
Dentin region (B)	2600.0220	2	1300.0110	5.5419	0.0047 **	
Factor A * Factor B	2994.3135	4	748.5784	3.1912	0.0150 *	
Error	35890.4118	153	234.5779			
Total	42164.2603	161				

** : $P < 0.01$, * : $P < 0.05$

on different regions of endodontically treated dentin [21]. Bond strength varied depending on the region of the root canal, and 80% of fractures occurred at the interface between the resin cement and dentin. These results revealed the necessity of evaluating the bond strength in the deeper areas of the root canal when performing resin core build-up via the direct method.

In the present study, the push-out method was used to evaluate bond strength. The bond strength was evaluated by microtensile test, shear bond test, and push-out test. Compared to the microtensile test, the push-out method and shear bond test are more reliable and clinically appropriate [22]. The thickness of the specimens (approximately 1 mm) in the push-out test allows for a more even distribution of stress during loading [22]. In addition, the bond strength on human and bovine dentins via the push-out method was reported that there were no significant differences between the two types of dentin [23]. The push-out method was used because this study also examined bond strengths at specific regions of dentin.

The dye penetration test is used in dentistry to determine fracture lines and gaps and to evaluate marginal fit. During resin composite restoration, a gap forms around the cavity due to polymerization shrinkage. When composite restorations were stained from the crown side, SEM and micro-CT images confirmed the presence of gaps in the stained regions [24]. In this study, the roots were cut perpendicularly to the root canal and also stained from the crown side to evaluate the gaps between the dentin and resin composite.

4.2. Bond strength

Based on the results of the two-way ANOVA, significant differences in bond strengths were found only between the BSs. The Tukey’s multiple comparison test as a post-hoc test also indicated significant differences in bond strengths between light-cured and chemical-cured BSs. The push-out test was used to examine the differences in the bond strengths of

various resin cements to an abutment cavity 10 mm in depth, with and without using a BS, and the results suggested that the dentin area had no effect on the bond strength of the resin cement [25]. However, the effects of pre-treatment on the bond strength of root canal build-up with composite and fiber posts were reported that bond strengths significantly differed according to the root canal region [21]. The bond strength of the root dentin treated with dual-cured BS significantly differed between the coronal and apical regions of the root canal [26]. In this study, the bond strength did not significantly differ with the region of the root canal dentin. These results were consistent with those of studies conducted by Oskoe et al. [25]. Therefore, when the root canal length of the bovine tooth was approximately 21 mm and the cavity depth was two-thirds (14 mm) of the root length, data showed that the dentin region did not influence the bond strength of the resin composite to dentin.

This study showed that differences in BS had an effect on the bond strength between core build-up resin and bovine dentin. Factors that affect bond strength for light-cured and dual-cured resin composites and resin cement include the distance from the light source, the composite shade [27, 28], and the use of a light transmitting post [29]. For dual-cured type resin cements and bonding materials, light irradiation enhances the kinetics of polymerization; however, adequate polymerization will not occur without sufficient light irradiation (only chemical-cured) [30]. Aziz et al. studied the bond strengths of resin cement and endodontically treated dentin after removing excess bonding agents and reported that 62.5% of fractures occurred at the interface between the resin cement and the dentin [16]. In this study, adhesive fractures (Category 1) were the most common in light-cured BS, whereas cohesive fractures (Category 4) were most common in chemical-cured BS (Fig. 4). These results suggest that the bond strength of chemical-cured BS is dependent on the cohesive strength between root canal dentin and core build-up resin. Therefore, the true value of bond strength between the root canal dentin and the core build-up resin with chemical-cured BS can be larger than the measured value.

All BSs tested in this study were of a one-step type system. Bonding between the root canal dentin and BS occurs through the formation of a hybrid layer and a resin tag. Bond strength may also be affected by the acidic monomers (carboxylic acid-based and phosphoric acid-based monomers), organic resin components, and silica in the BS because these components may contribute to the strength of the BS itself. In this study, since only one type of dual-cured type resin composite for core-build-up was used, the bond strength between different types of resin composite and bonding agents should be examined in the future.

Coronal seal after endodontic treatment and core build-up is important for the prevention of re-infection as well as retention of the final restoration. In this study, the dye was permeated into the specimens that were cut perpendicular to the tooth axis to determine the amount of gap between the tooth structure and the core build-up resin. The largest gap was observed in the apical region of the light-cured BS, and the proportion of dye penetration increased with cavity depth. The gap that formed at the bottom of the cavity when the composite resin was light-cured from the surface revealed that gaps formed from stress due to polymerization shrinkage and poor adhesion of the bonding agents to the resin composite [24]. Gap formation was reduced when the bonding area was increased by etching dentin [31]. In this study, no differences in bond strength were observed depending on the tooth region, even for light-cured BS; however, the proportion of adhesive fracture and dye penetration was significantly higher in the apical region, suggesting inadequate adhesion of the BS.

4.3. Clinical Implication

In this study, the effects of various BSs on the bond strengths between endodontically treated dentin and core build-up resin was investigated. As a result, significant differences in bond strengths were observed only between the BSs only. During the dye penetration test, significant differences were observed between dentin regions and among interactions between BSs and dentin regions. Therefore, the null hypothesis that the BS and root canal region have no effect on the bond strength between the resin composite and the dentin was rejected. Endodontic treatment is important to treat the infection in the root canal, prevent re-infection, and retain the

final prosthetic device. Although bovine teeth are much longer than human teeth, they are structurally very similar. The bond strengths for the BS did not change in the cavity in areas as deep as 14 mm. However, when light-cured BS was used, the level of seal differed between the apical and coronal regions. Chemical- and dual-cured BSs showed uniform bonding along the root canal; no difference in the level of seal was observed between the different dentin regions. In addition, the fracture mode of chemical-cured BS demonstrated integration of the core build-up resin to dentin. These results suggest that the strength of the roots can be improved when the core build-up resin is integrated with the tooth structure.

5. Conclusion

This study investigated the bond strength of core build-up resin to bovine root canals using various BSs, and the following results were obtained:

1. The bond strength of the resin composite for core build-up to the endodontically treated dentin was significantly higher in the application of chemical-cured BS compared to light-cured BS.
2. Adhesive fracture in the apical region was observed in the light-cured BS, whereas adhesive fracture in the coronal region was observed in the dual-cured BS.
3. Cohesive fractures in core build-up resin and dentin were observed in the chemical-cured BS, demonstrating an effective bond.
4. A large gap ratio was observed in the apical region between the core build-up resin and dentin in the light-cured BS.

Acknowledgments

S.T. acknowledges the partial supports of a JSPS KAKENHI, Grant-in-Aid for Scientific Research (C), Grant Number JP17K11809 and 20K10015.

Conflict of interest statement

We have no conflict of interest.

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