Enhancement of dentin bond strength of resin cement using new resin coating materials

Sae AKEHASHI¹, Rena TAKAHASHI¹, Toru NIKAIDO¹,², Michael F. BURROW³ and Junji TAGAMI¹

¹ Department of Cariology and Operative Dentistry, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University (TMDU), 1-5-45, Yushima, Bunkyo-ku, Tokyo 113-8549, Japan
² Department of Operative Dentistry, Division of Oral Functional Science and Rehabilitation, School of Dentistry, Asahi University, 1851 Hozumi, Mizuho, Gifu 501-0296, Japan
³ Faculty of Dentistry, University of Hong Kong, Pokfulam, Hong Kong SAR, China

Corresponding author, Rena TAKAHASHI; E-mail: renatakahashi@hotmail.com

The purpose of this study was to investigate combinations of resin coating materials with a dual-cure resin cement for indirect restorations by evaluating microtensile bond strengths (µTBS). Dentin surfaces of human molars were bonded with either a direct or an indirect resin composite with/without the resin coating technique. For the resin coating material, Clearfil SE Bond 2 and either one of Clearfil Protect Liner F, Clearfil Majesty LV, Panavia V5 or an experimental light-cure coating material were used. For the dual-cure resin cement, either Panavia V5 or Panavia F2.0 were used with Panavia V5 Tooth Primer or ED Primer II. Resin coating does not always contribute to the enhancement of µTBS. The highest µTBS was obtained with the resin coating combination of Clearfil SE Bond 2 and Panavia V5, and cementation with Panavia F2.0, which was identical to that of the direct resin composite bonded with Clearfil SE Bond 2.

Keywords: Resin coating, Microtensile bond strength, Dual-cure resin cement, Indirect restoration, Dentin bonding agent

INTRODUCTION

Indirect esthetic restorations and subsequent cementation with resin cements have become more popular in recent years with the improvement of restorative materials and resin luting cement adhesion. Tooth preparation for indirect restorations in vital teeth causes significant exposure of the dentin which may result in postoperative sensitivity that can be exacerbated by the colonization of microorganisms⁹. In order to minimize such problems, the resin coating technique was introduced in the early 1990’s⁸. Several clinical techniques were promulgated to create a seal on the prepared dentin⁹ as well as enhance bonding of resin cements to the prepared dentin. The recommended resin coating technique included the immediate application and polymerization of a combination of a dentin bonding agent and flowable resin composite to the freshly cut dentin that was able to provide improved dentin bonding performance than the commonly used technique according to the manufacturers’ instructions for a resin cement⁴-⁶. Magne⁷ proposed the “immediate dentin sealing” technique to create a hybrid layer by interpenetration of monomers into the prepared hard tissues, which is believed to follow the same concept as the “resin coating technique”⁸⁻¹⁰.

However, the dentin bond strength of indirect restorations with the resin coating technique was reported to be lower than that of direct restorations, even when the same dentin bonding agent was applied to the dentin substrate¹¹. In previous studies, a low-viscosity resin composite, Clearfil Protect Liner F (PLF, Kuraray Noritake Dental, Tokyo, Japan), was routinely used as a representative flowable resin composite because of its good handling properties¹¹,¹². However, currently many flowable resin composites with different filler loads and viscosities are commercially available. Some of the flowable resin composites have demonstrated mechanical properties for use as a posterior restorative material¹³.

To achieve success of indirect restorations, adequate polymerization of the resin cement is one of the crucial factors¹⁴. For cementation of an indirect esthetic restoration, dual-cure resin cements are commonly used, which can polymerize with photo- and self-cure modes. In order to obtain good bonding performance of the dual-cure resin cement to dentin, optimal polymerization of the cement with adequate light transmission through the restorative material is essential¹⁵. Tagami et al.¹⁶ reported that a newly-developed dual-cure resin cement, Panavia V5 (V5, Kuraray Noritake Dental) demonstrated an enhanced dentin bonding performance in both the dual- and self-cure modes. However, there is no information about the dentin bonding performance of V5 when used in conjunction with the resin coating technique.

Therefore, the purpose of this study was to investigate whether dentin bond strengths of various combinations of resin coating materials and dual-cure resin cements are able to achieve bond strengths similar to those recorded for direct resin composites. The null hypotheses tested were that (i) selection of resin coating material and resin cement does not affect the bond strength to dentin, and (ii) there are no differences in dentin bond strength between indirect and direct restorative materials when the same adhesive system is used.
MATERIALS AND METHODS

Materials used in this study
The protocol for this study was approved by the Ethics Committee of the Graduate School and Hospital, Tokyo Medical and Dental University (No. D2013-022) for the use of extracted human teeth. The occlusal surfaces of fifty-two intact human molars were wet ground on a model trimmer (Y-230, Yoshida, Tokyo, Japan) to expose flat superficial dentin, and were finished ground with 600-grit silicon carbide paper under running water to create uniform surfaces and smear layers. The dentin surfaces were randomly divided into three groups; direct resin composite restoration, indirect restoration without resin coating and indirect restoration with resin coating.

The resin coating materials and dual-cure resin cements used in this study are listed in Tables 1 and 2, respectively. The combinations of resin coating material, primer and dual-cure resin cement are shown in Table 3. Four teeth were used per each group.

Table 1  Resin coating materials and others used in this study

| Code  | Material       | Batch No. | Compositions                                                                 | Procedure                                                                 |
|-------|----------------|-----------|------------------------------------------------------------------------------|---------------------------------------------------------------------------|
|       | Dentin bonding system |           |                                                                              |                                                                            |
| SE2   | Clearfil SE Bond 2 | 000022    | Primer:10-MDP, HEMA, hydrophilic aliphatic dimethacrylate, di-camphorquinone, water Bond:10-MDP, Bis-GMA, HEMA, hydrophilic aliphatic dimethacrylate, di-camphorquinone, initiators, Accelerators, silanated colloidal silica | Apply and leave primer for 20 s, air-dry. Apply bond, air-dry, light cure for 10 s. |
|       | Flowable resin composite |           |                                                                              |                                                                            |
| PLF   | Clearfil Protect Liner F | BB0003    | Bis-GMA, TEGDMA, fluoro-methyl methacrylate, camphorquinone, silanated colloidal silica, organic filler Filler contents/ 42 wt% TEGDMA, hydrophobic aromatic dimethacrylate, camphorquinone, Silanated barium glass filler, Silanated colloidal silica Filler contents/ 81 wt% | Apply on the cured dentin bonding system, light cure for 20 s. |
| MJ    | Clearfil Majesty LV  | 9R0013    | Bis-GMA, TEGDMA, aromatic multifunctional monomer, aliphatic multifunctional monomer, new chemical polymerization accelerator, dl-camphorquinone, photopolymerization accelerator, surface treated barium glass, fluoroalumino-silicate glass, fine particulate filler |                                                                            |
| V5/DC | Panavia V5       | 1U0001    | Bis-GMA, TEGDMA, aromatic multifunctional monomer, aliphatic multifunctional monomer, dl-camphor quinone, photopolymerization accelerator, surface treated barium glass, fluoroalumino-silicate glass, fine particulate filler |                                                                            |
| V5/LC | Panavia V5 (light-cure only) | 160520  |                                                                              |                                                                            |

Manufacturer: Kuraray Noritake Dental, Tokyo, Japan; 10-MDP: 10-methacryloyloxydecyl dihydrogen phosphate; HEMA: 2-hydroxyethyl methacrylate; Bis-GMA: bisphenol-A-diglycidyl methacrylate; TEGDMA: triethyleneglycol dimethacrylate
Table 2  Dual-cure resin cements used in this study

| Code | Material       | Batch No. | Compositions                                                                 | Procedure                                      |
|------|----------------|-----------|-----------------------------------------------------------------------------|------------------------------------------------|
| TP   | Panavia V5     | 1W0001    | pH2.0 10-MDP, original multifunctional monomer, new polymerization accelerator, HEMA, water, stabilizer | Apply and leave primer for 20 s, air-dry.     |
|      | Tooth primer   |           | Bis-GMA, TEGDMA, aromatic multifunctional monomer, aliphatic multifunctional monomer, new chemical polymerization accelerator, dl-camphor quinone, photopolymerization accelerator, surface treated barium glass, fluoroaluminosilicate glass, fine particulate filler |                                               |
| V5   | Panavia V5     | 1U0001    | pH 2.4 10-MDP, 5-NMSA, HEMA, accelerators, water, Liquid B:5-NMSA, accelerators, catalysts, water, Paste-A: 10-MDP, hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated silica filler, silanated colloidal silica, dl-camphorquinone, catalysts, initiators | Apply and leave primer for 30 s, air-dry.     |
|      | ED Primer II   | 5C0022    | pH 2.4 10-MDP, hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated silica filler, silanated colloidal silica, dl-camphorquinone, catalysts, initiators | Place auto-mixed pastes, light cure for 20 s. |
|      |                | 5F0022    |                                                                                       |                                                |
|      |                | 5M0103    |                                                                                       |                                                |
|      | Panavia F2.0   | 5R0016    | pH 2.4 Paste-B: hydrophobic aromatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophilic aliphatic dimethacrylate, silanated barium glass filler, surface treated sodium fluoride, catalysts, accelerators, pigments | Place hand-mixed pastes, light cure for 20 s. |

Manufacturer: Kuraray Noritake Dental, Tokyo, Japan; 10-MDP: 10-methacryloyloxydecyl dihydrogen phosphate; HEMA: 2-hydroxyethyl methacrylate; Bis-GMA: bisphenol-A-diglycidyl methacrylate; TEGDMA: triethyleneglycol dimethacrylate; 5-NMSA: N-methacrylic-5-aminosalicylic acid

Table 3  The combinations of resin coating, primer and resin cements used in this study

| Coating | Primer | Resin cement |
|---------|--------|--------------|
| None    | TP     | V5           |
| SE2+PLF |        |              |
| SE2+MJ  |        |              |
| SE2+V5/DC|       |              |
| Experiment 1 |
| None    | ED     | F2.0         |
| SE2+PLF |        |              |
| SE2+MJ  |        |              |
| SE2+V5/DC|       |              |
| SE2+V5/DC|       |              |
| SE2+V5/LC|      |              |
| SE2+V5/LC|      |              |
| Experiment 2 |

Primer Plus (Kuraray Noritake Dental) was applied to the surface of the resin composite disks and gently air-dried.

Experiment 1
For the direct restoration group, dentin surfaces were treated with Clearfil SE Bond 2 (SE2, Kuraray Noritake Dental) according to the manufacturer’s instructions. A 1 mm thick layer of direct resin composite (Clearfil
AP-X, shade A2, Kuraray Noritake Dental) was placed and light-cured for 20 s using the light curing unit (Optilux 501).

For the indirect restoration without resin coating, dentin surfaces were conditioned with either Panavia V5 Tooth Primer (TP, Kuraray Noritake Dental) or ED Primer II (ED, Kuraray Noritake Dental) according to the manufacturer’s instructions (Table 2). The silane coated resin composite disks were placed on the dentin surfaces using the one of two resin cements, namely V5 or Panavia F2.0 (F2.0, Kuraray Noritake Dental). A load of 0.5 kg was applied to extrude the excess resin cement which was wiped with a cotton pellet. The seating force was removed and the specimens were light-cured from an occlusal direction for 20 s using the halogen light curing unit (Optilux 501).

For the indirect restoration with resin coating groups, a combination of the two-step self-etch adhesive; SE2, and a flowable resin composite; PLF or Clearfil Majesty LV (MJ, Kuraray Noritake Dental), or a dual-cure resin cement; V5/DC, were used as the resin coating (Table 1). The dentin surface was treated with SE2 according to the manufacturer’s instructions, following this, one of the three coating materials; PLF, MJ or V5/DC was applied with a brush and light-cured using a halogen light curing unit (Optilux 501). The specimens were stored in distilled water at 37°C for 24 h. They were then treated with 40% phosphoric acid (K-Etchant) for 10 s, rinsed with water and air-dried, either TP or ED was applied to the treated dentin surfaces according to the manufacturer’s instructions. The fabricated resin composite disks were placed on the dentin surfaces using either V5 or F2.0 resin cement pastes. A load of 0.5 kg was applied to extrude the excess resin cement which was wiped off with a cotton pellet. Then seating force was removed and the specimens were light-cured for 10 s using the halogen light curing unit (Optilux 501) from an occlusal direction.

Experiment 2
In order to elucidate the effect of the initiator system of the coating material on dentin bond strength in resin coating groups, an experimental light-cure coating material (V5/LC) was prepared. In the V5/LC coating material, the self-curing chemical initiator was removed from the compositions of V5/DC. The specimen preparation for experiment 2 were carried out in the same manner described in experiment 1. The microtensile bond strength (μTBS) test values were compared in the various combinations listed in Table 3.

μTBS test
All specimens were stored in distilled water at 37°C for 24 h. Before the specimens were subjected to the μTBS test, the top surfaces were cleaned with 40% phosphoric acid (K-Etchant) for 10 s, rinsed with water and air-dried. A silane coupling agent (Clearfil Ceramic Primer Plus) was applied to the surface of the indirect resin composite disks and gently air-dried. SE2 bond was applied to the surface, gently air-dried, and light-cured for 10 s, then a direct resin composite (Clearfil AP-X) was built up to create a block approximately 3 mm high for the μTBS test.

Each tooth was cross-sectioned longitudinally using a low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) to obtain beam-shaped specimens with an approximate bonded surface area of 1×1 mm². Before the μTBS test, the dimensions of each beam were checked with digital calipers (Mitutoyo CD-15C, Mitutoyo, Kanagawa, Japan), after which each specimen was attached to a customized microtensile jig with a cyanoacrylate adhesive (Model Repair II Blue, Dentsply-Sankin, Tokyo, Japan) and placed in the testing apparatus (EZ-SX, Shimadzu, Kyoto, Japan) for the μTBS test at a crosshead speed of 1 mm/min.

Failure modes analysis
After debonding, the fractured specimens were gold sputter-coated and observed with a scanning electron microscope (SEM; JSM-5310LV, JEOL, Tokyo, Japan) at ×100 magnification. The failure modes were classified into the following seven categories as illustrated in Fig. 1. Type A: cohesive failure in direct/indirect resin composite; Type B: adhesive failure between indirect resin composite and resin cement; Type C: cohesive failure in resin cement; Type D: adhesive failure between resin cement and flowable resin composite; Type E: adhesive failure along the dentin surface; Type F: cohesive failure in dentin; and Type G: mixed failure.

Statistical analysis
As the distribution of data fitted the presumption of normality (Kolmogorov-Smirnov test), the μTBS test data for experiments 1 and 2 were separately analyzed by one-way ANOVA followed by the post-hoc Tukey’s multiple comparison test. All the statistical procedures were performed at the 95% confidence level using PASW Statistic 18 (IBM, Armonk, NY, USA).

RESULTS
Experiment 1
The results of μTBS test and failure mode analysis are summarized in Table 4. The direct restoration group yielded the highest mean μTBS (94.5 MPa) among all the groups. The distribution of failure modes of the direct restoration group was cohesive failure in resin composite (Type A=56%), adhesive failure along the dentin surface (Type E=3%), cohesive failure in dentin (Type F=22%) and mixed failure (Type G=19%).

For the indirect restoration without resin coating group, the mean μTBS of V5 to dentin was 33.6 MPa, which was statistically higher than that of F2.0 (25.2 MPa, p<0.05). As for the predominant failure mode in the without resin coating groups, V5 was cohesive failure in the resin cement (Type C), while F2.0 was cohesive failure in the resin cement (Type C) and adhesive failure along the dentin surface (Type E).

The results of μTBS test and failure mode analysis were different according to the resin cement. As for V5,
Fig. 1 Illustration of each failure mode. (a): direct resin composite restoration; (b): indirect restoration without resin coating; (c): indirect restoration with resin coating. Type A: cohesive failure in direct/indirect resin composite; Type B: adhesive failure between indirect resin composite and resin cement; Type C: cohesive failure in resin cement; Type D: adhesive failure between resin cement and flowable resin composite; Type E: adhesive failure along the dentin surface; Type F: cohesive failure in dentin; and Type G: mixed failure.

| Coating | Primer | Resin cement | Microtensile bond strength (MPa) | Fracture modes (%) |
|---------|--------|--------------|---------------------------------|-------------------|
|         |        |              |                                 | A     B     C   D   E   F   G |
| Direct  |        |              |                                  | 56    | 33.6 (8.6)<sup>a</sup> | 0   0   92   —  5   0   3 |
|         |        | V5           |                                  |       | 33.7 (9.4)<sup>b</sup> | 0   0   86   0   0   0   0 |
|         |        | TP           |                                  |       | 38.7 (9.2)<sup>c</sup> | 0   0   89   0   0   0   0 |
|         |        | SE2+V5/DC    |                                  |       | 49.2 (12.2)<sup>d</sup>| 0   100 0   0   0   0   0 |
| Indirect| None   |              |                                  | 25.2  | 55.7 (11.6)<sup>e</sup> | 0   0   92   0   0   0   0 |
|         |        | F2.0         |                                  |       | 49.0 (14.7)<sup>f</sup> | 0   0   86   0   0   0   14|
|         |        | ED           |                                  | 79.5  | 79.5 (22.5)<sup>g</sup>| 0   89   11  0   0   0   0 |

All values are the mean (SD). Within the same small superscript letter are not statistically different (p>0.05). Type A: cohesive failure in direct/indirect resin composite; Type B: adhesive failure between indirect resin composite and resin cement; Type C: cohesive failure in resin cement; Type D: adhesive failure between resin cement and flowable resin composite; Type E: adhesive failure along the dentin surface; Type F: cohesive failure in dentin; and Type G: mixed failure.

There were no statistical differences among without resin coating, resin coating with SE2+PLF and resin coating with SE2+MJ groups (p>0.05). The predominant failure mode of the three groups was cohesive failure in the resin cement (Type C). The resin coating with SE2+V5/DC group demonstrated significantly higher mean $\mu$TBS value (49.2 MPa) than the three groups. All specimens were fractured between indirect resin composite and resin cement (Type B) in the resin coating with SE2+V5/DC group.

As for F2.0, the $\mu$TBS of indirect restoration with resin coating groups were significantly higher than that of without resin coating group (p<0.05). There were no statistical differences in $\mu$TBS between resin coating with SE2+PLF and resin coating with SE2+MJ groups (p>0.05). The mean $\mu$TBS value of SE2+V5/DC (79.5 MPa) was significantly higher than those of resin coating with SE2+PLF and resin coating with SE2+MJ groups (p>0.05). There were no statistical differences in $\mu$TBS between the direct restoration group and resin coating with SE2+V5/DC and cementation with F2.0 group (p>0.05). The fracture mode of SE2+V5/DC was mainly adhesive failure between indirect resin composite and resin cement (Type B).
The results of μTBS test and failure mode analysis are summarized in Table 5. There were no statistical differences among the test groups except for resin coating with SE2+V5/DC, pretreated with ED and cementation with F2.0 group (p>0.05). The mean μTBS of resin coating with SE2+V5/DC, treated with ED and cementation with F2.0 group was the highest among the groups. However, the failure mode tendency after debonding was different. Adhesive failure between indirect resin composite and resin cement (Type B) was mainly observed in resin coating with SE2+V5/DC, treated with TP and cementation with V5 and treated with ED and cementation with F2.0 groups. However, the predominant failure mode was cohesive failure in the resin cement (Type C) in the other groups.

### DISCUSSION

Based on the current results, the first null hypothesis was rejected, which means that the selection of resin coating material and resin cement was the important factor influencing bond strength of resin cements to dentin. The second null hypothesis was partially accepted, meaning that the resin coating with SE2+V5/DC, primer with ED and resin cement with F2.0 group was able to achieve an equivalent bond strength as the direct restoration adhesion.

SE2 was used as a dentin bonding system for a direct resin composite and also for the first applied material for the resin coating technique. SE2 is regarded as a gold standard material for dentin bonding systems, which contains the functional monomer, 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) in both the SE2 primer and SE2 bond. 10-MDP plays several important roles to dissolve the smear layer, promote monomer penetration and chemically bond to hydroxyapatite. SE2 contributes to the high quality of the hybrid layer and acid-base resistant zone at resin-dentin interface.

As for indirect restoration without resin coating, V5 yielded higher μTBS than F2.0. In previous μTBS test studies, the predominant failure mode without resin coating was complete or partial adhesive failure along the dentin surface. In the present study, F2.0 showed 36% of adhesive failure along the dentin surface, while V5 showed only 5% of adhesive failure along the dentin surface. These findings suggest that a strong bond exists at the interface between dentin and V5. The results corresponded to that of previous studies. The self-curing interaction between the primer, which contains co-initiators, and the resin cement, which contains an initiator, may initiate conversion when they are in contact without light curing. This unique curing system is called “touch-cure”. The primer also improves surface wettability and promotes interfacial polymerization. Tagami et al. reported that V5 showed superior dentin bonding performance compared with F2.0 with or without light curing.

Resin coating dramatically improved dentin bond strength in the groups that used F2.0. Applying a flowable resin composite on the cured adhesive will polymerize the oxygen inhibition layer. The uncurd resin of the oxygen inhibition layer may subsequently polymerize with the diffusion of free radicals from the flowable resin composite.

The cement paste of V5 was used as not only a resin luting agent but also as a resin coating material in this study, because it does not contain functional monomers. No statistically significant difference was found between direct restoration group and resin coating with SE2+V5/DC and cementation with the F2.0 group. The similar elastic modulus between the cements and the coating materials could be related to the high bond strength for resin coating with SE2+V5/DC and cementation with F2.0 group. It was that the difference in elasticity changed stress distributions elsewhere in the structure. Contrary to our expectations, some resin coating materials i.e. SE2+PLF and SE2+MJ did not improve the bond strength in the cementation with V5 groups. However, resin coating with SE2+V5/DC improved dentin bond strength when V5 is the luting...
agent. In addition, only adhesive failure between indirect resin composite and resin cement (Type B) was observed in resin coating with SE2+V5/DC and cementation with V5 group. This result was most likely caused by relatively weak bond between indirect resin composite and V5 in the bonded assembly.

The cement paste of F2.0 contains 10-MDP. An interaction between the hydroxyl groups of 10-MDP in F2.0 and the cationic surface of resin block was able to form a strong bond between resin cement and resin block. Previous studies have suggested that while V5 has good dentin bonding ability16), V5 shows inferior bonding performance to prosthetic materials when comparing V5 to F2.020).

The manufacturer stipulates the correct primer-resin cement combination for both V5 and F2.0 to ensure the best adhesion and polymerization can be achieved. From the result of experiment 2, it was revealed that the proper use of a primer-resin cement combination is mandatory. When using F2.0 with ED, V5/LC was inferior to V5/DC as a coating material. This result indicated that V5/LC may have reduced mechanical properties than that of V5/DC. Tsujimoto et al.25) reported that V5 was not influenced by the curing mode in terms of simulated localized wear. V5/DC can be activated by both photo- and chemical-initiators. It is speculated that V5/DC greatly depends on the chemical initiator.

For the resin coating groups, adhesive failure along the dentin surface (Type E) was not observed at all in the present study. It can be inferred that application of resin coating on the exposed cut dentin can avoid or reduce effects from irrigation or other physical, chemical, and/or bacterial stimuli if a restoration debonds or fails, as well as during the period of temporization. A cavity preparation for an indirect inlay/onlay restoration is much more aggressive than that of direct resin composite restoration. When indirect restorations are selected, it can be said that resin coating technique minimizes pulp irritation and postoperative sensitivity.

In previous studies, the weakest interface was the resin coating-resin cement interface11,12). However, in this study, adhesive failure between resin cement and flowable resin composite (Type D) was not observed. The probable reason for this result was that the surface of light-cured flowable resin composite was not cleaned with alcohol-soaked cotton pellets to remove the unpolymerized air-inhibited layer. This situation replicated the scenario of a single-visit treatment with CAD/CAM technology. With the exception of a single-visit treatment, the use of temporary sealing materials are mandatory. In addition, the unpolymerized air-inhibited layer limited the polymerization reaction of impression materials26). However, intraoral digital impression of single-visit treatment does not contact with the resin coating layer. Thus, the unpolymerized air-inhibited layer could be remained and utilized for enhancement of dentin bond strength.

A halogen light curing unit used in this study has a radiant emittance of about 800 mW/cm². Light-emitting diode (LED) curing units which are currently most common light curing unit that reach irradiances of more than 1,000 mW/cm². The spectral emission range and spectral radiant power are different between a halogen and LED light curing units27). Newly developed light activated materials may demonstrate different properties with the different light curing sources. Thus, further study should be conducted to investigate the effect of selection of the light curing unit on bonding performance using the resin coating technique in any way.

CONCLUSION

Dentin bond strength of the dual-cure resin cement, Panavia F2.0 with the resin coating technique using the combination of a two-step self-etch adhesive, Clearfil SE Bond 2 and a dual-cure resin composite, Panavia V5 achieved identical dentin bond strengths as that of a direct resin composite using Clearfil SE Bond 2.

ACKNOWLEDGMENTS

The authors are thankful to NIKKISO Co., Ltd. Hakusan Factory for its assistance to measure the light irradiance of the light curing unit. This study was supported by a Grant-in-Aid for Scientific Research (No. 17K17122) from the Ministry of Education, Science, Sports, Culture, and Technology, Japan.

REFERENCES

1) Cagidiaco MC, Ferrari M, Garberoglio R, Davidson CL. Dentin contamination protection after mechanical preparation for veneering. Am J Dent 1996; 9: 57-60.
2) Christensen GJ. Resin cements and postoperative sensitivity. J Am Dent Assoc 2000; 131: 1197-1199.
3) Peters MC, McLean ME. Minimally invasive operative care. 1. Minimal intervention and concepts for minimally invasive cavity preparations. J Adhes Dent 2001; 3: 7-16.
4) Sultana S, Nikaido T, Matin K, Ogata M, Foxton RM, Tagami J. Effect of resin coating on dentin bonding of resin cement in Class II cavities. Dent Mater J 2007; 26: 506-513.
5) Nikaido T, Inoue G, Takagaki T, Takahashi R, Sadr A, Tagami J. Resin coating technique for protection of pulp and increasing bonding in indirect restoration. Curr Oral Health Rep 2015; 2: 81-86.
6) Nikaido T, Tagami J, Yatani H, Ohkubo C, Nihei T, Koizumi H, et al. Concept and clinical application of the resin-coating technique for indirect restorations. Dent Mater J 2018; 37: 192-196.
7) Magne P, IDS: Immediate Dentin Sealing (IDS) for tooth preparations. J Adhes Dent 2014; 16: 594.
8) Murata T, Maseki T, Nara Y. Effect of immediate dentin sealing applications on bonding of CAD/CAM ceramic onlay restoration. Dent Mater J 2018; 37: 928-939.
9) Ishii N, Maseki T, Nara Y. Bonding state of metal-free CAD/CAM onlay restoration after cyclic loading with and without immediate dentin sealing. Dent Mater J 2017; 36: 357-367.
10) Qamungo A, Aras MA, Chitre V, Mysore A, Amin B, Daswani SR. Immediate dentin sealing for indirect bonded restorations. J Prosthodont Res 2016; 60: 240-249.
11) Okuda M, Nikaido T, Maruoka R, Foxton RM, Tagami J. Microtensile bond strengths to cavity floor dentin in indirect composite restorations using resin coating. J Esthet Restor Dent 2007; 19: 38-46.
12) Udo T, Nikaido T, Ikeda M, Weerasinghe DS, Harada N, Foxton RM, et al. Enhancement of adhesion between resin coating materials and resin cements. Dent Mater J 2007; 26: 519-525.

13) Sumino N, Tsuubota K, Takamizawa T, Shiratsuchi K, Miyazaki M, Latta MA. Comparison of the wear and flexural characteristics of flowable resin composites for posterior lesions. Acta Odontol Scand 2013; 71: 820-827.

14) Takahashi R, Nikaido T, Ariyoshi M, Foxton RM, Tagami J. Microtensile bond strengths of a dual-cure resin cement to dentin resin-coated with an all-in-one adhesive system using two curing modes. Dent Mater J 2010; 29: 268-276.

15) Moraes RR, Correr-Sobrinho L, Sinhoreti MA, Puppin-Rontani RM, Ogliari FA, Fiva E. Light-activation of resin cement through ceramic: relationship between irradiance intensity and bond strength to dentin. J Biomed Mater Res B Appl Biomater 2008; 85: 160-165.

16) Tagami A, Takahashi R, Nikaido T, Tagami J. The effect of curing conditions on the dentin bond strength of two dual-cure resin cements. J Prosthodont Res 2017; 61: 412-418.

17) Sato K, Hosaka K, Takahashi M, Ikeda M, Tian F, Komada W, et al. Dentin bonding durability of two-step self-etch adhesives with improved of degree of conversion of adhesive resins. J Adhes Dent 2017; 19: 31-37.

18) Yoshida Y, Nagakane K, Fukuda R, Nakayama Y, Okazaki M, Shintani H, et al. Comparative study on adhesive performance of functional monomers. J Dent Res 2004; 83: 454-458.

19) Guan R, Takagaki T, Matsui N, Sato T, Burrow MF, Palamara J, et al. Dentin bonding performance using Weibull statistics and evaluation of acid-base resistant zone formation of recently introduced adhesives. Dent Mater J 2016; 35: 684-693.

20) D’Arcangelo C, De Angelis F, D’Amario M, Zazzaroni S, Ciampoli C, Caputi S. The influence of luting systems on the microtensile bond strength of dentin to indirect resin-based composite and ceramic restorations. Oper Dent 2009; 34: 328-336.

21) Rohr N, Fischer J. Tooth surface treatment strategies for adhesive cementation. J Adv Prosthodont 2017; 9: 85-92.

22) Foxton RM, Nakajima M, Tagami J, Miura H. Adhesion to root canal dentine using one and two-step adhesives with dual-cure composite core materials. J Oral Rehabil 2005; 32: 97-104.

23) Kelly JR. Perspectives on strength. Dent Mater 1995; 11: 103-110.

24) Rohr N, Brunner S, Martin S, Fischer J. Influence of cement type and ceramic primer on retention of polymer-infiltrated ceramic crowns to a one-piece zirconia implant. J Prostheth Dent 2018; 119: 138-145.

25) Tsujimoto A, Barkmeier WW, Takamizawa T, Watanabe H, Johnson WW, Latta MA, et al. Simulated localized wear of resin luting cements for universal adhesive systems with different curing mode. J Oral Sci 2018; 60: 29-36.

26) Ghiggi PC, Steiger AK, Marcondes ML, Mota EG, Burnett LHJ, Spohr AM. Does immediate dentin sealing influence the polymerization of impression materials? Eur J Dent 2014; 8: 366-372.

27) Harlow JE, Sullivan B, Shortall AC, Labrie D, Price RB. Characterizing the output settings of dental curing lights. J Dent 2016; 44: 20-26.