The effect of curing mode of dual-cure resin cements on bonding performance of universal adhesives to enamel, dentin and various restorative materials

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The effect of curing mode of dual-cure resin cements on the tensile bond strength (TBS) of universal adhesives to enamel, dentin, zirconia, lithium disilicate ceramics (LDS), feldspathic porcelain (FP), and a Pd-Au alloy was evaluated. The substrates were bonded using Tokuyama Universal Bond (TUB) or Scotchbond Universal Adhesive (SBU), followed by luting with Estecem II (ECII) or Rely-X Ultimate (RXU), respectively, which were used either in light-curing or self-curing mode. The TBS test was performed after 24 h or 5,000 thermal cycles. Light-curing significantly improved the 24-h TBS of TUB/ECII to enamel, dentin and FP, as well as the TBS of SBU/RXU to all substrates except LDS. After thermal cycling, light-curing significantly increased the TBS of both adhesives/cements to dentin, but significant differences between curing modes were seldom observed for other substrates. This suggested that light-curing is essential for the hydrophilic dentin, but self-curing might be sufficient for other substrates.

Keywords: Adhesives, Resin cements, Light-curing, Tensile strength, Durability

INTRODUCTION

Resin cements are commonly used for the cementation of indirect restorations, which is a crucial step in the process of ensuring retention, adequate marginal adaptation, and durability of the restorations. Except for veneers, most restorations require the use of self-cure or dual-cure resin cements, because the opacity and thickness of the restorative material do not allow for efficient photopolymerization. Dual-cure materials have become very popular as they combine the benefits of light-curing with the ability to polymerize chemically under insufficient irradiation. Nevertheless, it was reported that light exposure is necessary for the resin cements to reach the maximal degree of conversion (DC). This is important, because the deficiency of polymerization in the self-curing mode also results in lower mechanical properties and higher solubility of dual-cure resin cements.

The bonding performance of resin cements is largely dependent on the adhesive system employed. Lower bond strength values in the self-curing mode compared with the light-curing mode were obtained in previous studies, and another study revealed that even the addition of a chemical initiator to an adhesive system did not lead to sufficient polymerization without light-curing. Moreover, it was reported that simplified adhesives were incompatible with self-cure and dual-cure resin composite materials due to the reaction of acidic monomers with basic tertiary amines which are used as co-initiators. As a consequence of the incompatibility, unexpected debonding of restorations was commonly observed. Later, it was revealed that the incompatibility can be prevented by the use of sulfinic acid salts.

In recent years, a new type of adhesive systems categorized as “universal” has been introduced. Universal adhesives are one-step systems that can be applied to dentin and enamel in the total-etching, self-etching, or selective-etching mode depending on the specific clinical situation. Furthermore, they can be used for bonding to restorative materials such as zirconia, precious and non-precious metals, and various silica-based ceramics without the application of an additional priming agent. To prevent the aforementioned incompatibility with dual-cure and self-cure composites, it is necessary to use most universal adhesives with separate polymerization activators containing sulfinic acid salts. On the other hand, some products incorporate initiators which allow for chemical polymerization after contact with a corresponding dual-cure resin cement even without the use of an activator. Such systems are also called “touch and cure” or “contact cure” and they can improve the bond strength in situations where light irradiation may be insufficient.

More recently, a new two-bottle universal adhesive, Tokuyama Universal Bond (Tokuyama Dental, Tokyo, Japan) with an innovative polymerization technology...
was introduced. Upon mixing the two solutions, an aryl borate catalyst reacts with an acidic three-dimensional self-reinforcing (3D-SR) monomer, forming a borane compound. The borane is then oxidized by the contained peroxide, generating polymerizable radicals which serve as highly active initiators of chemical polymerization\textsuperscript{22,23). The manufacturer claims that there is no compromise in the bonding effectiveness even in the absence of light irradiation. However, there is a limited amount of independent research on the bonding performance of new universal adhesives and dual-cure resin cements to various substrates under different conditions of light irradiation.

Therefore, the present study examined the tensile bond strength (TBS) of two universal adhesives to bovine enamel, dentin, and indirect restorative materials including zirconia, lithium disilicate ceramics (LDS), feldspathic porcelain (FP), and a Pd-Au alloy. The effect of curing mode of the subsequently applied corresponding resin cements on TBS was evaluated after 24 h and thermal cycling. The null hypotheses were (1) that the curing mode of resin cements would not affect TBS to enamel, dentin, and restorative materials, and (2) that TBS would not be influenced by thermal cycling.

**MATERIALS AND METHODS**

Two commercially available self-etch universal adhesive systems, Scotchbond Universal Adhesive (SBU; 3M Oral Care, St Paul, MN, USA) and Tokuyama Universal Bond (TUB; Tokuyama Dental, Tokyo, Japan), and two dual-cure resin cements, Rely X Ultimate (RXU; 3M Oral Care) and Estecem II (ECII; Tokuyama Dental) were used in this study. The composition of the adhesive systems and the resin cements are presented in Table 1 together with manufacturers’ instructions for use. Restorative materials included yttria-stabilized zirconia blocks (TZ-3Y-E; Tosoh, Tokyo, Japan), LDS blocks (IPS e-max CAD; Ivoclar Vivadent, Schaan, Liechtenstein), FP blocks (AAA, Kuraray Noritake Dental, Tokyo, Japan), and a Pd-Au alloy (Castmaster 12S; IDS, Tokyo, Japan). Their compositions are summarized in Table 2.

**Specimen preparation**

One hundred twenty-eight bovine teeth were used in this study. The teeth were stored in periodically changed distilled water at 4°C until their usage within 1 month of extraction. Labial sides of the crowns were ground using 600-grit silicon carbide (SiC) paper (DCCS, Sankyo Fuji Star, Saitama, Japan) under running water to expose enamel (n=64) and dentin (n=64) surfaces with a standardized smear layer. For each restorative material, sixty-four custom-made blocks (10 mm length, 10 mm width, 2 mm thickness) were used and their surfaces were ground with 600-grit SiC paper. The Pd-Au alloy and zirconia blocks were additionally air-abraded with...
Table 2  Composition of restorative materials used in this study

| Restorative materials       | Product (manufacturer)                  | Composition                                      |
|-----------------------------|-----------------------------------------|-------------------------------------------------|
| Feldspathic porcelain (FP)  | Super Porcelain AAA                     | SiO$_2$, Al$_2$O$_3$, K$_2$O, CaO, MgO, Li$_2$O |
| Lithium disilicate ceramics (LDS) | IPS e-max CAD (Ivoclar Vivadent, Schaan, Liechtenstein) | SiO$_2$, Li$_2$O, K$_2$O, P$_2$O$_5$, ZrO$_2$, ZnO, Al$_2$O$_3$, MgO, coloring oxides |
| Precious metal (Pd-Au alloy) | Castmaster 12S (IDS, Tokyo Japan)        | Au 12%, Pd 20%, Ag 54%, Cu 12%, additives       |
| Zirconia                    | TZ-3Y-E (Tosoh, Tokyo, Japan)            | ZrO$_2$, Y$_2$O$_3$, HfO$_2$, Al$_2$O$_3$        |

Fig. 1 A schematic illustration of specimen preparation for the tensile bond strength test. FP: feldspathic porcelain; LDS: lithium disilicate ceramics.

50 µm Al$_2$O$_3$ particles from a 10 mm distance for 20 s at 0.4 MPa and 0.2 MPa pressure, respectively, using a blasting machine (Basic Master, Renfert, Hilzingen, Germany). After preparation, all restorative materials were ultrasonically cleaned in distilled water for 5 min, dried with oil-free compressed air, and a polyethylene tape of a 100 µm thickness with a circular hole (diameter 4 mm) was placed on the surface. The adhesive (SBU or TUB) was applied to the substrate (n=32) according to the manufacturer’s instructions, and immediately followed by the application of the corresponding resin cement (RXU or ECII) without light-curing. A stainless-steel metal rod previously treated with the respective adhesive was then carefully vertically pressed against the paste, and excess cement was removed from the bonding margins using cotton pellets. The specimens were either light-cured (n=16) for 40 s from four sides using a quartz-tungsten halogen unit (Optilux 501, 600 mW/cm², Demetron, Danbury, CT, USA) or left undisturbed in darkness for 30 min to self-cure (n=16). After the 30-min setting time, half of the specimens (n=8) were stored in distilled water at 37°C for 24 h (24h), and the other half (n=8) were subjected to 5,000 thermal cycles (TC5,000) in distilled water between 5 and 55°C. The dwell time in each bath was 30 s and the transfer time was 2 s (thermal-cycling machine K178-08, Tokyo Giken, Tokyo, Japan). A schematic illustration of the specimen preparation is shown in Fig. 1.

TBS test

After 24 h or TC5,000, the specimens were positioned in a testing apparatus with the bonded interface oriented perpendicularly to the tensile load and subjected to the TBS test at a crosshead speed of 2 mm/min (Autograph AGS-J, Shimadzu, Kyoto, Japan). After testing, the debonded areas of all the specimens were observed under a light microscope (Nikon SMZ1000, Nikon, Tokyo, Japan) at a 10× magnification for failure mode determination. Failure modes were classified as adhesive failure between the substrate and the resin cement, cohesive failure within the resin cement, and mixed failure.

Statistical analysis

The number of specimens per group (n) was calculated...
using the sample size determination method for two tailed t-test as follows: \(n=\frac{2 (Z_{\alpha/2}+Z_{\beta})^2 \times \text{SD}^2}{\Delta^2}\). Confidence level was set to 95% (\(Z_{\alpha/2}=1.96\)) and statistical power level to 90% (\(Z_{\beta}=1.282\)). Standard deviation (SD) and the difference between mean TBS (\(\Delta\)) of self-cured and light-cured groups was obtained from the pilot study where 24-h TBS (\(n=5\)) to enamel (\(\Delta=5\text{MPa}, \text{SD}=3\text{MPa}\)) and FP (\(\Delta=12\text{MPa}, \text{SD}=7\text{MPa}\)) was measured. The calculated sample size was 7.57 for enamel and 7.15 for FP, so the number of specimens per group was set to 8.

Shapiro-Wilk test indicated that the TBS data were normally distributed (\(p>0.05\)). The TBS data were analyzed separately for each substrate using a three-way ANOVA (factors adhesive/cement, curing mode, thermal cycling) followed by t-tests with Bonferroni correction for pairwise comparisons. The analyses were performed at a significance level of 0.05 (SPSS Statistics 22, IBM, Chicago, IL, USA).

### RESULTS

Means and standard deviations of TBS to enamel, dentin and the tested restorative materials are presented in Table 3. Three-way ANOVAs revealed that curing mode had a significant influence on TBS to enamel, dentin, and FP (\(p<0.001\)), whereas its effect on TBS to other restorative materials was not significant (\(p>0.05\)). Thermal cycling was a significant factor for LDS, FP, and the Pd-Au alloy (\(p<0.001\)), but not for enamel, dentin, and zirconia (\(p>0.05\)). A significant effect of adhesive/cement was disclosed for enamel, zirconia, LDS, FP, and the Pd-Au alloy (\(p<0.001\)), but not for dentin (\(p>0.05\)).

### TBS after 24 h

Light irradiation significantly increased the bond strength of SBU/RXU to all substrates, except for LDS, where no significant difference from the self-curing mode was revealed. With TUB/ECII, TBS to enamel, dentin, and FP was significantly higher in the light-cured groups. On the other hand, TBS to LDS was significantly higher in the self-curing mode. There was no significant difference between the curing modes for zirconia and the Pd-Au alloy.

### The effect of TC5,000

With SBU/RXU, all LDS specimens failed during TC5,000 irrespective of the curing mode, and they were assigned zero bond strengths. A significant decrease in TBS after TC5,000 was also observed with FP and the Pd-Au alloy, while a significant increase in TBS was observed for enamel in both curing modes. No significant effect of TC5,000 was revealed in both curing modes for dentin and zirconia. TUB/ECII exhibited a significantly decreased TBS to LDS, FP in both curing modes, and to enamel and zirconia in the light-curing mode after TC5,000. No significant difference in TBS was disclosed for dentin and the Pd-Au alloy in both curing modes, and for enamel and zirconia in the self-curing mode.

### TBS after TC5,000

SBU/RXU exhibited significantly higher TBS to dentin in the light-curing mode than in the self-curing mode. No significant difference between the curing modes was revealed for enamel, zirconia, LDS, FP, and the Pd-Au alloy. The TBS of TUB/ECII to dentin and FP was significantly improved by light-curing, while significantly higher TBS to zirconia was obtained in the self-curing mode. The curing mode did not significantly affect TBS to enamel, LDS, and the Pd-Au alloy.

### Failure mode analysis

Failure mode distributions of de-bonded specimens after the TBS test are shown in Fig. 2 (SBU/RXU) and Fig. 3 (TUB/ECII). For SBU/RXU, the predominant failure mode was debonding at the interface between the adhesive and the substrate. For TUB/ECII, the predominant failure mode was cohesive failure within the adhesive.

### Table 3  Tensile bond strength to various substrates: Mean (S.D.) in MPa

| Adhesive/Cement | Curing mode | Enamel 24 h | TC 5,000 | Dentin 24 h | TC 5,000 | Zirconia 24 h | TC 5,000 | PD-Au alloy 24 h | TC 5,000 | FP 24 h | TC 5,000 | LDS 24 h | TC 5,000 |
|-----------------|-------------|-------------|-----------|-------------|-----------|---------------|-----------|-----------------|-----------|---------|-----------|----------|-----------|
| Self-curing     | 7.2±0.9     | 11.9±2.4    | 5.2±1.6   | 6.0±3.9     | 31.1±5.3  | 30.8±6.2      | 15.7±1.9  | 1.1±0.2         | 15.1±3.2  | 10.2±3.2| 15.0±7.0  | 0.0±0.0  |
| Light-curing    | 12.5±3.2    | 14.7±3.0    | 13.7±2.9  | 14.1±3.4    | 36.8±6.7  | 33.8±7.5      | 18.0±2.2  | 1.0±0.2         | 27.4±6.9  | 13.7±3.5| 13.7±4.0  | 0.0±0.0  |
| SBU/RXU         | Self-curing | 15.9±6.7    | 13.1±3.6  | 5.4±1.6     | 4.9±2.1   | 21.1±4.6      | 21.9±5.2  | 21.8±4.8        | 19.1±5.0  | 21.7±5.0| 15.1±6.5  | 30.8±10.6| 16.9±5.7 |
| Light-curing    | 21.4±5.6    | 13.7±3.5    | 13.8±3.7  | 12.6±3.4    | 22.3±5.2  | 16.8±5.5      | 23.8±5.1  | 21.8±3.4        | 40.6±10.6| 21.2±5.5| 24.7±6.3  | 16.9±5.7 |
| TUB/ECII        | Self-curing | 21.5±6.0    | 13.1±3.6  | 5.4±1.6     | 4.9±2.1   | 21.1±4.6      | 21.9±5.2  | 21.8±4.8        | 19.1±5.0  | 21.7±5.0| 15.1±6.5  | 30.8±10.6| 16.9±5.7 |
| Light-curing    | 21.4±5.6    | 13.7±3.5    | 13.8±3.7  | 12.6±3.4    | 22.3±5.2  | 16.8±5.5      | 23.8±5.1  | 21.8±3.4        | 40.6±10.6| 21.2±5.5| 24.7±6.3  | 16.9±5.7 |

Different superscript letters indicate significant differences (\(p<0.05\)); uppercase letters in columns, lowercase letters in rows (between 24 h and TC5,000 in each group).

SBU/RXU: Scotchbond Universal Adhesive/Rely X Ultimate; TUB/ECII: Tokuyama Universal Bond/Estecem II; TC5,000: 5,000 thermal cycles; FP: feldspathic porcelain; LDS: lithium disilicate ceramics.
mode was adhesive failure between the substrate and the resin cement, especially after TC5,000. However, it could be noted that mixed failures were more frequent in light-curing groups compared with self-curing groups at dentin, zirconia, FP, and the Pd-Au alloy. Pre-testing failures of all LDS specimens bonded with SBU/RXU in both curing modes were observed after TC5,000. For TUB/ECII, failures were predominantly mixed, followed by adhesive failures at the substrate-cement interface. It could be noted that the proportion of adhesive failures tended to increase after TC5,000. Cohesive failures in the resin cement were prevailing for FP after 24 h, but they were scarce in other groups.
DISCUSSION
Dual-cure resin cements have been recommended for the luting of indirect restorations, because they can compensate for insufficient light irradiation24. However, previous studies showed that the polymerization of dual-cure resin cements is not optimal in the absence of light-curing25,26 which may result in decreased mechanical properties4-9, postoperative sensitivity30, microleakage and recurrent caries26. Self-curing was also reported to result in lower bond strengths of adhesives to dentin11,12, so some recent materials incorporate novel polymerization accelerators which initiate polymerization upon contact between the adhesive and the corresponding resin cement. In this study, the TBS test after 24 h and TC5,000 was used to evaluate the effect of light-curing on two of these modern universal adhesives and corresponding resin cements.

After 24 h, the TBS of SBU/RXU to all tested substrates except LDS was significantly higher in the light-curing mode compared with the self-curing mode. The light-cured groups also exhibited more mixed failures and fewer adhesive failures than the self-cured groups. These findings are in agreement with previous studies11,12, and they can be attributed to the higher DC of both the adhesive and resin cement after light irradiation23,28. With TUB/ECII, light-curing significantly improved TBS only to enamel, dentin and FP, but not to zirconia and the Pd-Au alloy. Moreover, TBS to LDS was significantly higher in the self-curing mode. These results suggest that the polymerization accelerator of TUB/ECII consisting of a tetraphenyl borate sodium salt and a peroxide might be more efficient than the dual-cure activator in SBU/RXU. The higher DC of TUB could also contribute to the fact that fewer adhesive failures were observed compared with SBU.

While immediate testing has limited clinical relevance, the data gathered after in vitro aging appear to be indicative of long-term clinical performance27. In this study, the bonding durability was evaluated after TC5,000, a widely-used artificial aging procedure which simulates thermal changes occurring in the oral cavity28,29. The comparison between curing modes revealed fewer significant differences than after 24 h. Light-curing resulted in significantly higher TBS of both adhesives/cements to dentin and the TBS of TUB/ECII to FP. On the other hand, a higher TBS to zirconia was obtained with TUB/ECII in the self-curing mode. Based on these results, the first null hypothesis that the curing mode would not affect TBS had to be partially rejected.

In most groups, TBS after TC5,000 was lower compared with 24-h values and accordingly, more adhesive failures were observed. The decrease in TBS was significant for both adhesives/cements to LDS and FP, for SBU/RXU to the Pd-Au alloy in both curing modes, and for TUB/ECII to enamel and zirconia in the light-curing mode. This can be attributed to water sorption, resulting in decreased mechanical properties of the adhesives and resin cements28,30,31 and hydrolytic degradation at the resin-substrate interface32, as well as mechanical stress induced by different thermal expansion coefficients of the adherends33. In contrast, a significant increase in the TBS of SBU/RXU to enamel was observed after TC5,000, especially in the self-curing mode. Presumably, the early exposure to heat in the warm bath (55°C) could accelerate chemical polymerization and lead to an increase in DC, thus enhancing the mechanical properties of the adhesive and resin cement33,34. Therefore, the second null hypothesis had to be rejected.

For the reason that universal adhesives enable bonding to hard dental tissues as well as most restorative materials, bonding to several substrates was examined in this study. TUB/ECII exhibited significantly higher 24-h TBS to enamel and more mixed failures than SBU/RXU. Presumably, the lower pH of TUB (2.2) compared to SBU (2.7) could contribute to this result. Moreover, the DC of SBU/RXU was probably not final after 24 h, because significantly higher TBS was obtained after TC5,000. Consequently, there were no significant differences between the adhesives regardless of the curing mode. The good performance of SBU/RXU after TC5,000 could also be supported by the content of 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) which forms very stable chemical bonds with hydroxyapatite35.

Dentin was the only substrate which benefited from light-curing with both adhesives/cements after 24 h as well as after TC5,000; the self-cured groups exhibited low TBS and predominantly adhesive failures. While the other substrates are mainly inorganic and hydrophobic, dentin also contains an organic phase and is naturally hydrophilic. Previous studies revealed that moisture can adversely affect the bond strength of one-step self-etch adhesives30 to dentin, so we presume that faster polymerization in the light-curing mode could prevent this effect. The present result corroborates previous studies which found significantly lower micro-tensile bond strength of touch-curing adhesives to dentin in the absence of light-irradiation23,27, and indicates that light-curing is indispensable for obtaining a sufficient bonding performance to dentin.

Both adhesives/cements exhibited high TBS to zirconia which also resulted in fewer adhesive and more mixed failures. However, the TBS of SBU/RXU was significantly higher than that of TUB/ECII and it was not significantly affected by TC5,000. This might be due to the content of 10-MDP in SBU which is able to form a strong chemical bond with zirconia36,37. A recent review revealed that the combination of air abrasion and 10-MDP based agents resulted in the highest bond strength and the most durable adhesion to zirconia36. TUB contains a different phosphoric acid monomer, 3D-SR, and the results of this study suggested that its interaction with zirconia was weaker than that of 10-MDP. Moreover, the TBS of TUB/ECII decreased significantly after TC5,000 in the light-curing mode, indicating that the adhesion was also less durable. No such decrease was observed in the self-curing mode where it could possibly be balanced by an increase in the DC of TUB/ECII during TC5,000.
lower polymerization rate in the self-curing mode might have also enabled a better compensation of the cement contraction stress, attributing to the significantly higher TBS after TC5,000 in the self-curing mode compared with the light-curing mode.

Bonding performance to two types of glass ceramics, FP and LDS, was also evaluated in this study. In general, hydrofluoric acid etching and the application of a silane coupling agent are recommended as pretreatments for silica-based materials to obtain a strong and durable adhesion. However, manufacturers of some silane-containing universal adhesives including TUB claim that these pretreatments are not necessary, so the surfaces of FP and LDS were only mechanically roughened in this study. To standardize the preparation procedure and to obtain comparable results with both adhesives, SBU was also used without hydrofluoric acid etching in spite of the manufacturer’s recommendation. It was revealed that the adhesion was unstable, the TBS of both adhesives/cements decreased significantly after TC5,000 irrespective of the curing mode. The decrease in the TBS of TUB/ECII to LDS was accompanied by an increased frequency of adhesive failures, and all LDS specimens bonded with SBU/RXU failed prior to testing. This demonstrated that hydrofluoric acid etching is indispensable to achieve durable bonding to glass ceramics, especially for SBU. Besides that, durability could be adversely affected by the presence of water and 2-hydroxyethyl methacrylate (HEMA) in the composition of SBU and TUB. Previous investigations reported that HEMA and residual water contributed to the hydrolytic degradation of bonding to feldspathic porcelain blocks. Nevertheless, the one-bottle adhesive SBU performed significantly worse than the two-bottle TUB. It was reported that 3-methacryloxypropyl trimethoxysilane (MPTES), which is also contained in SBU, is unstable in acidic conditions. Therefore, when stored with silanes (MPTS), which is also contained in SBU, it undergoes premature hydrolysis and self-condensation, thus losing its ability to bond with the glass ceramics and resulting in the pre-testing failures observed in this study. In contrast, TUB consists of two bottles, so the silane coupling agent is separated from water and acidic monomers, and they are mixed just before the application on the ceramic surface, thus providing a stronger and more durable adhesion.

The Pd-Au alloy was the last substrate examined herein, and significantly higher TBS was obtained with TUB/ECII compared with SBU/RXU. The difference was more pronounced after TC5,000 which did not significantly affect the TBS of TUB/ECII but dramatically decreased the TBS of SBU/RXU. Accordingly, all SBU/RXU failed adhesively after TC5,000 while there was no marked change in the failure mode distribution of TUB/ECII. Previous studies reported that monomers with a thiol structure were efficient in bonding to precious metals, especially when combined with acidic monomers like 10-MDP. Therefore, we assume that the strong and stable bond of TUB/ECII to the Pd-Au alloy was achieved due to the content of 6-methacryloyloxyhexyl 2-thiouracil 5-carboxylate (MTU-6) and the 3-D-SR monomer in TUB. In contrast, the TBS of the 10-MDP-based SBU/RXU decreased significantly after TC5,000. Although 10-MDP can chemically bond to metals such as titanium or chromium oxide, the presented result suggests that it does not form a durable bond with precious metals and that the use of a suitable metal primer might be necessary to obtain clinically acceptable bonding with SBU.

A great progress has been achieved in the versatility of adhesives and the simplification of their application procedures. This study revealed that novel initiators of chemical polymerization which are activated upon contact between corresponding adhesives and resin cements were effective in compensating the absence of light-curing for all substrates except for dentin, where self-curing resulted in significantly lower TBS. This was presumably caused by its hydrophilicity which remains a challenge for the future adhesive development. The results also confirmed that designing a truly universal adhesive which could form a durable bond with any substrate without any pretreatment is difficult. Most contemporary universal adhesives are based on 10-MDP which is very versatile, but the addition of a thiol monomer might be necessary to improve bonding to noble metals. However, universal adhesives are intricate mixtures, so any additional components might lead to undesired side-effects. This issue could be partly overcome by splitting the components into two bottles, but the need to mix two solutions just before application might be regarded as a step back by clinicians.

CONCLUSION

Within the limitations of this in vitro study, it was concluded that light-curing improved the immediate bond strength of the tested adhesives and resin cements to most substrates. However, after TC5,000 which decreased the bond strength in most groups, the performance in both curing modes was similar except for dentin which benefited from light-curing. The one-bottle adhesive SBU exhibited a stronger adhesion to zirconia, but it underperformed the two-bottle adhesive TUB when applied to LDS, FP, and a Pd-Au alloy.

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CONFLICT OF INTEREST

None.

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