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Effects of High-Intensity Light Curing Devices and Resin Adhesive System on Repair Strength of Amalgam with Resin Composite

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This study aims to evaluate the effects of the new generation light curing devices and different adhesive systems on the shear repair strength between amalgam and resin composite. Ninety-six square-shaped amalgam (Cavex Non Gamma-2; Cavex Holland BV, Haarlem, the Netherlands) samples were prepared. The amalgam surfaces were polished with 600-grit abrasive paper. The prepared amalgam samples were divided into four groups (Single Bond Universal, 3M ESPE; Adper Easy One, 3M ESPE; Prebond SE, President Dental; OptiBond All-in-One, Kerr) according to the adhesive brand. Each adhesive group was divided into two subgroups according to the 3rd generation light curing devices (Elipar DeepCure-S [3M ESPE, USA], VALO Cordless [Ultradent, USA]) ($n = 12$). Microhybrid composite cylinders of 3 mm height and 2 mm diameter were placed on the amalgam surfaces by layered method with a silicone mold (Dynamic Plus; President Dental, Germany). Each layer was polymerized with a group specific light curing device. The samples were incubated in distilled water at 37 °C for 24 h before the shear-bond-strength test. The shear bond strength test was accomplished using a universal testing device. Statistical analyzes were made with two-way ANOVA and Tukey HSD tests. Two-way ANOVA revealed a significant effect of the adhesive system brand on bond strength ($p < 0.00$). Prebound SE provided the lowest bond strength between both light curing devices groups. There was no significant difference between the two light-curing devices groups among Single Bond Universal, Adper Easy One and OptiBond All-in-One resin adhesive systems. It has been revealed that the high-intensity LED light curing device brand does not have a significant effect on the amalgam-resin composite repair strength, and the repair strength may be more affected by the brand of the adhesive system used.
Keywords: amalgam repair, adhesion, adhesive systems, 3rd generation LCD.

1. INTRODUCTION

As a reaction to the dramatic increase in the use of composite resins, light-curing attracted considerable scientific interest. Light curing devices (LCD) are an important factor in the polymerization of composite resins sufficiently. The light at the correct wavelength must be delivered to the target in sufficient amount to ensure sufficient polymerization [1]. It has been reported that the inhomogeneity of the light emitted from the LCD may prevent the homogeneous polymerization of the surface of the composite under the light guide tip [2]. Incomplete polymerization of the material results in a deterioration in the biocompatibility and mechanical properties of the material, resulting in a decrease in its clinical performance. Therefore, the LCD has an important role in the clinical success of resin-based materials together with the technique used [3].

It is always preferred to shorten the curing time without impairing the polymerization quality. To date, different light-curing devices have been developed for photo-polymerization of the resin materials under different clinical conditions [4]. While Quartz-tungsten-halogen (QTH) LCDs were in widespread use, today light-emitting diode (LED) LCDs have come into routine use in dentistry practice due to their advantages such as less heat generation, being more ergonomic and having a longer service life [5]. While the curing time was 40 seconds with WTH LCDs, the curing time was reduced to 20 seconds with LED LCDs. However, with the latest third generation high intensity LED LCDs, the curing time has been reduced to down to 10 seconds [6].

Dental amalgam has been used as a restoration material in dentistry for nearly 200 years because of its acceptable wear resistance, low cost, and easy manipulation [7]. Although the average clinical service life of amalgam restorations is acceptable, amalgam restorations may fail for some reason. These reasons may be secondary caries formation and marginal defects, fractures in amalgam or tubercules [8]. In such cases, clinicians have two options; the first is to completely remove the existing amalgam restoration and replace it, the second option is to repair the existing amalgam restoration. However, in recent years, amalgam repair has taken first place among the minimally invasive treatment options [9].

Repairing an amalgam restoration is a less invasive option than removing the existing restoration completely and placing a new one [10]. Repairing defects preserves both dental tissues and restorative material [11]. Replacing the existing restoration may cause the restoration to grow by causing loss of substance in healthy adjacent tooth tissues [12, 13]. Since repairing the restoration causes less destruction than the replacement of the existing restoration, it also reduces the risk of pulp damage and tooth fracture [14].

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There is no study in the literature on how third generation high-intensity LED LCDs affect the effects of different resin adhesive systems on the repair strength of amalgam restorations with resin composite. Considering the important differences between the chemical ingredients of current resin adhesive systems in the market, it may be important to evaluate the potential effects of new generation high-intensity LED LCDs on amalgam repair strength. Therefore, in this study, it was aimed to test two null hypotheses: high-intensity LED LCD brand does not affect amalgam-resin composite repair strength and adhesive system brand does not affect amalgam-resin composite repair strength, with the shear bond strength test.

2. EXPERIMENTAL DETAILS

2.1. Specimen preparation

Ninety-six square-shaped amalgam (Cavex Non Gamma-2; Cavex Holland BV, Haarlem, the Netherlands) samples were prepared. Modelling wax pieces of 5 × 5 × 2 mm were used as a template for amalgam samples. First, the modelling wax pieces were embedded in the plaster with the help of double-sided adhesive tape and a silicone mould. After the wax was removed with hot water, the amalgam was condensed into the cavities created by the wax fragments according to the manufacturer's instructions. While the amalgam was being condensed, the surface was smoothed with a glass slide. The amalgam samples were allowed to harden for 24 hours in water. To preserve the flatness of the amalgam surfaces, the amalgam surfaces were polished with 600-grit abrasive paper, which prepares a surface similar to the surface roughness created by the medium diamond bur for 30 s under water-cooling [15].

2.2. Experiment groups

The prepared amalgam samples were divided into four groups according to the adhesive brand. Each adhesive group was divided into two subgroups according to the LCD (*n* = 12). All adhesive systems were applied strictly following the manufacturer's instructions (Table 1). VALO Cordless (Ultradent Products, South Jordan, Utah, USA) LCD was used in standard mode at 1000 mW/cm^2 power for 15 seconds. Elipar DeepCure-S (3M ESPE, St.Paul, MN, USA) LCD was used in standard mode for 10 seconds at 1470 mW/cm^2.

2.3. Repair composite application

Microhybrid composite cylinders of 3 mm height and 2 mm diameter were placed on the amalgam surfaces by layered method with a silicone mold (Dynamic Plus; President Dental, Germany). Each layer was polymerized with a group specific LCD. The same operator (H.G.D.) performed all procedures in the experiment.

2.4. Shear bond strength test

Bonded samples were subjected to a shear bond strength test after being kept in water for 24 hours. Shear bond strength test was carried out in a Universal Testing Machine (Besmak BMT-E, BESMAK, Ankara, Turkey) at a cross-head speed of 1 mm/minute. The same operator (Ö.Y.) performed all the mechanical tests in the experiment. Shear bond strength values were calculated in MPa. After the bonding test, the failure mode was determined at 10^x magnification with a stereo microscope (Meade Bresser Biolux, Meade Bresser, Rhede, Germany). The type of failure was classified as "adhesive failure" if the composite was not visible at all on the bonding surface, "cohesive failure" if it was in the composite or enamel, or "mixed failure" if it contained both structures.

Table 1. Materials used in the present study

Material, manufacturer, batch number	Composition	Instructions for Use
Single Bond Universal, (3M ESPE, St.Paul, MN, USA), (6806583)	MDP phosphate monomer, dimethacrylate resins,HEMA, Vitrebond Copolymer, filler, ethanol, water, initiators, silane	1. Apply the adhesive to the entire preparation with a microbrush and rub it in for 20 s. 2. Direct a gentle stream of air over the liquid for about 5 s until it no longer moves and the solvent has evaporated completely. 3. Light polymerize for 10 s.
Adper Easy One, (3M ESPE, St Paul, MN, USA), (4747900)	HEMA, bis-GMA, methacrylated phosphoric esters, 1, 6 hexanediol methacrylate, vitrebond copolymer, finely dispersed bonded silica with 7 nm filler particles, ethanol, water, initiators based on camphorquinone and stabilizers	1. Apply the adhesive to the entire preparation with a microbrush and rub it in for 20 s. 2. Air dry for 5 s. 3. Light polymerize for 10 s.
Prebond SE, (President Dental, Germany), (177976)	MDP phosphate monomer, methacrylate, photoinitiators, ethanol, water	1. Apply an ample amount, leave undisturbed for at least 20 s. 2. Remove solvent with an air syringe for at least 5 s. 3. Light polymerize for at least 10 s.
OptiBond All-in-One, (Kerr, Orange, CA, USA), (7496568)	Glycerol phosphate dimethacrylate mono and difunctional methacrylate monomers, water, acetone, ethanol, camphorquinone, three nano-sized fillers, sodium hexafluorosilicate and ytterbium fluoride	1. Scrub the surface with a brushing motion for 20 s. 2. Apply a second application of OptiBond All-In-One adhesive with a brushing motion for 20 s. 3. Dry the adhesive with gentle air first and then medium air for at least 5 s with oil-free air. 4. Light cure for 10 s.
MDP, 10-methacryloyloxydecyl dihydrogen phosphate; HEMA, 2-hydroxyethyl methacrylate; Bis-GMA, bisphenol A-glycidyl methacrylate		

2.5. Statistical analysis

The findings were analyzed by calculating the mean shear bond strength (MPa) and standard deviations for each group. The differences between the shear bond strength means were evaluated statistically by two-way analysis of variance (ANOVA; adhesive brand vs LCD) and Tukey test. The statistical evaluation of the failure mode distribution was performed with the use of the chi-squared test with contingency tables. The bond strength of the five systems was analyzed using Kaplan–Meier survival analysis and a log-rank test. All tests were done using SPSS 16.0 (SPSS Inc., Chicago, IL, USA) at a significance of 0.05.

3. RESULTS

Two-way ANOVA showed that only adhesive system brands had a significant effect on bond strength. Two-way ANOVA also showed that LCD brand had no significant effect on bond strength and there was no significant interaction between adhesive brand and LCD brand. In Valo LCD groups and Elipar LCD groups, the lowest SBS values were detected in Prebond groups (7.74 ± 2.4 and 6.99 ± 2.7 respectively). The highest SBS value was found in the Optibond group (10.36 ± 1.9)) in Elipar LCD groups, and the Single Bond Universal group (9.53 ± 2.3)) in Valo LCD groups. In both LCD groups, no significant differences were found between Single Bond Universal and Optibond groups. In both LCD groups, EasyOne showed similar bond strengths with Optibond and Single Bond Universal adhesives. Adhesive failure mode was predominantly seen in all groups, independent of LCD and adhesive systems. No cohesive failure mode was observed in any group. It has been revealed that the 3rd generation LCD device type does not have a significant effect on the amalgam-resin composite repair strength, and the repair strength may be more affected by the brand of the adhesive system used (Table 2).

4. DISCUSSION

Although the preference of amalgam in material selection for the new restoration has decreased considerably, many amalgam restorations still exist. Therefore, the most appropriate repair method for the repair of old amalgam restorations is still one of the most researched topics. Therefore, in this study, the effects of different adhesive systems and high-intensity LCDs on amalgam-resin composite repair strength were investigated. The first null hypothesis that the high-intensity LED LCD brand has no effect on amalgam-resin repair strength was rejected as both high-intensity LED LCDs showed similar bond strength in all adhesive systems. On the other hand, the second null hypothesis, that the adhesive system brand affects the amalgam-resin composite repair strength, was not rejected because there was a significant difference between the bond strengths provided by the adhesive systems in both high-intensity LCD groups.

Previous studies report that repairing the existing restoration improves the quality of the restoration and extends the clinical service life compared to the replacement of the restoration [16, 17]. Since the repair of marginal defects allows cleaning of areas that patients cannot easily clean, it protects the remaining healthy tooth tissues from tooth decay and extends the clinical service period of the restoration [18]. The cost of replacing an existing restoration is as much as the cost of making a new restoration, and if indirect restoration is required, the cost will increase further. The application of such restorations is time consuming and technically difficult [19]. On the other hand, repair of the existing restoration is a less costly and easier treatment option [20].

Since adding new amalgam to the existing amalgam restoration is not a successful repair method, the method using resin adhesives is more preferred when repairing amalgam [21]. The method of preparation of the amalgam surface, the adhesive system used and the restorative material has a significant effect on the repair of amalgam restoration with resin composite. The long-term success of the repair material depends on its strong repair strength [22]. It is realized that the large variety of values reported for the same products was due to the different design protocols implemented by different authors, including different types of cement, methodology, storage time, and thermocycling duration. Previous studies reported Amalgambond Plus with HPA to have some of the highest bond strengths. In addition, OptiBond was reported to have the highest or second highest (to Amalgambond Plus with HPA) bond strength to dentin.

Out of all the resin adhesive systems bonded to dentin tested by different studies, Amalgambond Plus with HPA and OptiBond generally gave the highest or second highest bond strengths [23]. Differences in the chemical structures of different adhesive systems may explain the different effects of adhesive on amalgam repair strength.

Table 2. Repair strength means and distribution of failure modes according to adhesive system brand and 3rd generation LCD brand ($n = 12$)

Light curing devices/adhesive system	Elipar deep cure-S (3M ESPE, St.Paul, MN, USA)				VALO Cordless (Ultradent, South Jordan, UT, USA)			
	Repair strength, MPa	Failure modes, %			Repair strength, MPa	Failure modes, %		
		A	M	C		A	M	
Adper easy one	7.93 ± 2.2^{abc}	9	3	0	8.7 ± 2.3^{ab}	10	2	0
Prebond SE	6.99 ± 2.7^{ab}	11	1	0	7.74 ± 2.4^{ab}	12	0	0
Optibond all-in-one	10.36 ± 1.9^{ac}	10	2	0	9.53 ± 2.3^{ac}	9	3	0
Single bond universal	9.47 ± 2.2^{ac}	9	3	0	10.82 ± 2.3^{ac}	9	3	0

Different superscripts indicate significant differences in the same column ($p < 0.05$).
A: adhesive failure, M: mix failure, C: cohesive failure nor in resin composite or amalgam.

Since the conventional adhesives required time-consuming additional surface procedures to repair fractured amalgam restorations, in the repair protocol of amalgam restorations, using universal adhesives may be useful to increase the bond strength of composite resins to amalgam surfaces. The manufacturers claim that universal adhesives can be bonded to any substrate such as zirconia, noble and nonprecious metals, composite resins, and various silica-based ceramics without the need for a separate silane or primer application [24]. However, there was no significant difference between universal adhesive (Single Bond Universal) and conventional adhesive (Adper Easy One) from the same manufacturer (3M ESPE) in the present study as similar findings were reported in the literature [25].

In the current dental literature, there is not enough information about the effects of new generation LCDs on the amalgam repair strength of different adhesives. In this study, the total energy applied by two different high-intensity LED light sources in the polymerization of resin adhesive systems and resin composite was standardized as approximately 1500 mW/cm^2. It has been determined that both high-intensity LED light sources provide similar bond strength when used in the polymerization of different adhesives with this total energy.

A major concern with high-intensity LED light sources is the possible effect of the high temperature they generate during polymerization on pulp vitality. An increase in intrapulpal temperature of more than 5.5 °C can cause pulpal damage. However, the total light energy of the Valo LCD device is at a level that will not cause serious temperature increases [23, 26]. In the literature, it has been reported that high-intensity plasma light sources cause less tooth temperature increase than halogen light sources [23, 26, 27]. This is probably due to the short polymerization times of high-intensity light sources.

5. CONCLUSIONS

The amalgam repair shear bond strength means of all adhesive systems cured with Elipar DeepCure-S are not statistically different from those achieved by curing with the VALO Cordless. However, amalgam repair strength was affected by adhesive system brands. Prebond SE exhibited significantly lower bond strength when compared to those of other adhesive systems regardless of light curing device. Therefore, it can be concluded that the repair strength may be more affected by the brand of the adhesive system used than high-intensity LED light curing device.

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