ORIGINAL ARTICLE

# Effect of laser preparation on bond strength of a self-adhesive flowable resin

A. Rüya Yazici · Ishita Agarwal · Marc Campillo-Funollet ·
Carlos Munoz-Viveros · Sibel A. Antonson ·
Donald E. Antonson · Thomas Mang

**Abstract** The aim of this in vitro study was to evaluate the effect of laser treatment on shear bond strength of a self-adhesive flowable resin composite to human dentin. Eighty extracted sound human molar teeth were used for the study. The teeth were sectioned mesiodistally and embedded in acrylic blocks. The dentin surfaces were ground wet with 600-grit silicon carbide (SiC) paper. They were randomly divided into two preparation groups: laser (Er:YAG laser, with 12 Hz, 350 mJ energy) and control (SiC). Each group was then divided into two subgroups according to the flowable resin composite type ($n=20$). A self-adhesive flowable (Vertise Flow) and a conventional flowable resin (Premise Flow) were used. Flowable resin composites were applied according to the manufacturer's recommendations using the Ultradent shear bond Teflon mold system. The bonded specimens were stored in water at 37 °C for 24 h. Shear bond strength was tested at 1 mm/min. The data were logarithmically transformed and analyzed using two-way analysis of variance and Student–Newman–Keul's test at a significance level of 0.05. The self-adhesive flowable resin showed significantly higher bond strength values to laser-prepared surfaces than to SiC-prepared surfaces ($p<0.001$). The conventional flowable resin did not show such differences ($p=0.224$). While there was a significant difference between the two flowable resin composites in SiC-prepared surfaces ($p<0.001$), no significant difference was detected in laser-prepared surfaces ($p=0.053$). The bond strength of a self-adhesive flowable resin composite differs according to the type of dentin surface preparation. Laser treatment increased the dentin bonding values of the self-adhesive flowable resin.

**Keywords** Laser · Flowable resin · Dentin · Bond strength

## Introduction

Patients' concerns over the use of amalgam have prompted clinicians to seek alternative restorative materials and easier methods for their placement. This desire continues for treatment modalities that are more comfortable, interceptive, and conserving of healthy tooth structure. With the introduction of adhesive restorative materials and techniques, less removal of healthy tissue has been promoted. In minimally invasive dentistry, smaller preparations can be completed and flowable resin composites could be one of the most popular materials of choice due to their flow characteristics and ease of application. Flowable resin composites were introduced in late 1996 with a wide range of applications [1]. They have two desirable clinical handling properties: fluid injectability and non-stickiness [1]. Recently, new self-adhering flowable resins have been developed. According to the manufacturers, these resins bond to tooth substrate without the use of adhesive systems due to their acidic monomer composition. One of the problems related to using complicated adhesive systems to treat dentin is the time required for various steps and the associated technique sensitivity. These new self-adhesive flowable resins are even more useful when a patient may be uncooperative during treatment.

Adhesive dental materials and bonding systems have revolutionized dentistry by opening several new alternative preparation techniques. One aspect of patient discomfort frequently noted during treatment with conventional high-

A. R. Yazici (✉)
Faculty of Dentistry, Hacettepe University,
Ankara, Turkey
e-mail: ruyay@hacettepe.edu.tr

I. Agarwal · M. Campillo-Funollet · C. Munoz-Viveros ·
S. A. Antonson · D. E. Antonson · T. Mang
School of Dental Medicine Buffalo, University at Buffalo,
State University of New York,
Buffalo, NY, USA

speed rotary instrumentation is the bone-conducted noise, pressure, and vibration. Erbium lasers provide several advantages, such as no vibration, pressure, or noise that patients feel with high- or low-speed preparation and reduced need for local anesthesia [2–4]. Dental hard tissues can be effectively removed with the ablation process that involves microexplosions. Lasers allow for minimally invasive caries removal and tooth preparation [5–7]. With the wide range of bonded materials, these smaller preparations can be restored effectively. However, bond strengths to laser-prepared dental hard tissues in the literature are often contradictory [8–12]. For the success of a restoration, durable bonding should be achieved. The types of adhesive systems, restorative materials, and the method of cavity preparation affect the bond strength of resins to tooth structure [13–15]. There have been many laboratory studies concerning surface characteristics and bond strength to enamel and dentin following laser irradiation. To our knowledge, the literature contains no studies that specifically compared the bond strength of a self-adhesive flowable resin to laser-prepared dentin surfaces. Therefore, the aim of the present study was to compare the shear bond strength of a self-adhesive and a conventional flowable resin to laser and silicon carbide (SiC) paper-prepared dentin.

## Materials and methods

Eighty freshly extracted non-carious human molars were used in this study. Teeth were stored in a solution of 0.5 wt% chloramine-T and used within one month after extraction.

The teeth were sectioned mesiodistally and mounted in blocks of self-polymerized acrylic resin (Fastray, HJ Bosworth, Skokie IL, USA). Samples were ground to expose a flat area of dentin using a diamond wheel (WhipMix, Louisville KY, USA). The dentin surfaces were wet ground with 600-grit SiC paper to create a standardized surface.

The teeth were randomly divided into two treatment groups: laser (Er:YAG laser, with 12 Hz and 350 mJ energy) and control (600-git SiC). Surface preparation was performed using an Er:YAG laser, wavelength 2,940 nm (model Opus 20, Opus Dent; Tel Aviv, Israel) with 12 Hz and 350 mJ energy in dentin. This model possesses air–water spray cooling (25 ml/min), focused mode 2 mm from the target surface. The irradiation distance was standardized using a custom-made apparatus consisting of a holder that positioned the handpiece in such a way that the laser beam was delivered perpendicular to the sample surface at a constant working distance from the target site.

Each group was then divided into two subgroups according to the flowable resin composite type: a self-adhesive flowable, (Vertise Flow, Kerr Corp, Orange CA, USA) and a conventional flowable resin (Premise Flow, Kerr Corp) ($n=$ 20/group). Table 1 summarizes the composition and recommended application mode of each of the materials used in the study. Self-adhesive flowable resin composites were applied according to the manufacturer's recommendations.

For the Premise Flow group, Optibond Solo Plus adhesive was applied onto the dentin surface according to the manufacturer's instructions, and the resin composite was condensed into the Ultradent Teflon mold and cured for 40 s. For all of the preparations, the specimens were clamped in the Ultradent Bonding Jig (Ultradent Products Inc., South Jordan, UT, USA), and Teflon molds (2.38 mm in internal diameter, 2 mm in height) were used to form and hold the resin composite specimen on the dentin surface. The finished specimens were transferred to distilled water and stored at 37 °C for 24 h.

**Table 1** Composition, batch numbers, and the application modes of the materials used in the study

| Material | Composition | Application mode |
| --- | --- | --- |
| Gel Etchant (Kerr, Orange, CA, USA), Batch# 3538466 | 37.5 % ortophosphoric acid, silica thickener | Etch with 37.5 % phosphoric acid (15 s), rinse (15 s) and dry (5 s) |
| Optibond Solo Plus (Kerr, Orange, CA, USA), Batch# 3474069 | Bis-GMA, HEMA, GDMA, GPDM, ethanol, CQ, ODMAB, BHT, filler (fumed $SiO_2$, barium aluminobarosilicate, $Na_2 SiF_6$), Coupling factor A174 (15 wt% filled) | Apply the adhesive and rub for 15 s. Dry for 3 s, light cure for 20 s |
| Premise flowable (Kerr, Orange, CA, USA), Batch# 3626622 | PPF, barium glass, silica filler, ethoxylated bis-DMA, TEGDMA, light-cure initiators and stabilizers, organophoshate dispersant | Apply 2 mm thick layer; light cure for 20 s |
| Vertise Flow (Kerr, Orange, CA, USA), Batch# 3607923 | GPDM, PPF, 1-micron barium glass filler, nano-sized colloidal silica, nano-sized ytterbium fluoride | Dispense first layer less than 0.5 mm thick; brush with moderate pressure for 15–20 s; light cure for 20 s; apply additional layer 1.5 mm thick; light cure for 20 s |

*HEMA* hydroxyethylmethacrylate, *GPDM* glyceroldimethacrylate dihydrogen phosphate, *PAMM* phthalic acid monoethyl methacrylate, *TEGDMA* triethylene glycol dimethacrylate, *UDMA* urethane dimethacrylate, *bis-GMA* bisphenol-glycidyl methacrylate, *PPF* prepolymerized filler, *bis-DMA* bisphenol-A-dimethacrylate, *CQ* camphorquinone, *BHT* butylhydroxytoluene, *GDMA* glycerol dimethacrylate, *GPDM* glycerol phosphate dimethacrylate, *HEMA* 2-hydroxyethyl methacrylate, *ODMAB* 2-(ethylhexyl)-4-(dimethylamino)benzoate, *TEGDMA* triethylene glycol dimethacrylate

Twenty specimens per group were tested in the shear mode using a notched-edge testing apparatus (Ultradent Products Inc., South Jordan UT) in a testing machine (Ultra tester, Ultradent Products Inc., South Jordan UT) at a crosshead speed of 1.0 mm/min. The shear bond strength values (in megapascals) were calculated from the peak load at failure divided by the specimen surface area. Logarithmic transformation of the data was performed and two-way analysis of variance (ANOVA) was used to compare the groups.

All the debonded tooth surfaces were examined with an optical microscope at ×40 magnification to determine the failure mode. Failure modes were categorized into one of the three types: A—100 % adhesive failure between tooth substrate and adhesive resin; C—100 % cohesive failure in tooth substrate; AC—mixed failure with adhesive failure (A) and cohesive failure in tooth substrate (C). All statistical tests were conducted at $\alpha = 0.05$.

## Results

The mean shear bond strength and standard deviations in megapascals and failure modes are shown in Table 2. The ANOVA indicated that there was statistically significant difference among the mean bond strength values and significant interactions between the flowable resin composites and preparation techniques (two-way ANOVA; flowable composites, $F = 23.021$, $p < 0.05$; preparation techniques, $F = 14.105$, $p < 0.001$; flowable resin composites vs preparation techniques $F = 4.082$, $p = 0.047$).

While there was a significant difference between flowable resins for the SiC-prepared surfaces ($p < 0.001$), no difference was observed in laser-prepared surfaces ($p = 0.053$). Vertise Flow showed significantly higher bond strength values to laser-prepared surfaces than SiC-prepared surfaces ($p < 0.001$). Premise Flowable resin produced similar bond strength values for SiC- and laser-prepared surfaces, which ranged from 14.64 to 16.81 MPa. Regarding the types of failure in fractured specimens, adhesive failure was the predominant failure mode for all the groups.

**Table 2** Results of shear bond strength test ($n = 20$)

| Preparation | Material | Bond strength Mean ± SD (MPa) | Failure mode A | AC | C |
|---|---|---|---|---|---|
| SiC | Premise flowable | 14.64±6.75 | 19 | – | 1 |
| | Vertise Flow | 7.92±2.91 | 20 | – | – |
| Laser | Premise flowable | 16.81±6.76 | 18 | 2 | – |
| | Vertise Flow | 12.61±3.49 | 17 | – | 3 |

## Discussion

The reliability and durability of the adhesively bonded interface still needs to be improved at least concerning the dentin. The use of laser has been recommended to increase the adhesion of resin to tooth structures. It was also reported to be used for etching or modifying the surface of teeth as a substitute for acid etching. However the effectiveness of this technique is controversial; while some researchers support the preparation or etching ability of laser to dentin [16–18], others deny its efficacy [19–21]. When tooth surfaces are treated by rotary instruments, an amorphous layer of organic and inorganic debris is deposited on the surface. This smear layer is resistant to mechanical removal and can only be removed by chemical means [22]. The smear layer can prevent the diffusion of monomers into the dentin structure. Therefore, in order to obtain an adequate bond to dentin, this smear layer must be removed or modified/treated prior to the placement of the adhesive restoration. In the present study, the blockage of dentin tubules with the smear layer that occurred after SiC preparation may account for the improper penetration of Vertise Flow. This might be the reason why self-adhering flowable resin showed lower bond strength values to SiC-prepared dentin than conventional flowable resin, which used phosphoric acid etching prior to bonding. Vertise Flow has the self-etching/self-adhering acidic monomer glyceroldimethacrylate dihydrogen phosphate which is also included in the OptiBond Solo Plus adhesive used for the conventional flowable composite. However, the acidity of this monomer might not be enough to modify the smear layer and allow penetration to occur. On the other hand, Vertise Flow showed higher bond strength values to laser-prepared surfaces than to SiC-prepared ones. Irradiation of dentin produces a rough surface, without smear layer, with opened dentinal tubules and protruding peritubular dentin [23–27]. These surface characteristics might account for the improvement on adhesion observed on Vertise Flow over the SiC-prepared surface. Moreover, according to the manufacturer, the acidic phosphate group etches the tooth structure and creates chemical bonds with the calcium. In the absence of a smear layer, this process might have been enhanced.

da Silva et al. [9] evaluated the shear bond strength of a total-etch adhesive system and a self-etch adhesive system to dentin, prepared conventionally or with an Er:YAG laser. They obtained similar bond strength values whether the dentin was prepared with a diamond bur or an Er:YAG laser. Adebayo et al. [28] compared bonding effectiveness of different self-etch adhesives to dentin surfaces that had been prepared with different instruments: steel, diamond and ceramic bur, SiC paper, and laser. They found no difference between different types of preparation methods in terms of adhesive systems' bond strength. They revealed that the

effectiveness of some self-etching primer adhesive systems was not significantly affected by the mode of rotary instrumentation used in dentin preparation.

The bond strength of adhesive to dentin treated with laser has been reported to be similar to the bond strength resulting from conventional preparation [29]. A comparison of adhesives' bond strength to laser-prepared cavities and those prepared with a bur showed no significant difference between the treatment methods [8]. These findings are in line with the present study's result as the bond strength of Premise Flow to laser-prepared dentin was not different from SiC-prepared dentin surfaces. The reason why Premise Flow showed that similar bond strength values might be related with the bonding procedure. Premise Flow was used according to the manufacturers' recommendations. Therefore, acid etching was performed after the surface was laser prepared. To obtain optimum results, subsequent etching of enamel and dentin with phosphoric acid following laser treatment has been advocated by several authors as it has been demonstrated that laser irradiation does not eliminate the need of acid etching [25, 30–32]. As acid etching was applied to the lased surfaces, it is not surprising to obtain similar bond strength values.

Contrary to our findings, Moretto et al. [33] found that morphological alterations produced by Er,Cr:YSGG laser irradiation adversely influenced the bonding effectiveness of adhesives to dentin. Esteves-Oliveira et al. [34] compared bond strength of a self-etch primer to laser- and bur-prepared dentin. They found that bond strength to laser-irradiated dentin was lower than for the bur-prepared group. Ramos et al. [35] reported that Er:YAG laser irradiation severely undermined the formation of consistent resin–dentin hybridization zones and yielded lower bond strengths. Studies reporting SEM observations of laser-treated enamel and dentin surfaces showed that surface roughness increases; however, the characteristics of lased tooth structure were much different from those prepared with conventional cavity preparation or from those treated with phosphoric acid etching. Van Meerbeek et al. [36] compared the bond strengths of etch-and-rinse and self-etch adhesives to enamel and dentin that have been prepared with SiC paper, diamond bur, sonoabrasion, laser irradiation, and air abrasion. Bonding to Er:YAG-irradiated dentin surfaces resulted in significantly lower bonding effectiveness when compared to SiC paper- or diamond bur-prepared surfaces. They attributed this result to the subsurface damage caused by Er:YAG irradiation that also compromised the hybridization effectiveness. In their Fe-SEM observation, they have examined altered dentin subsurface beneath which collagen fibrils had lost cross-banding and fused together, thus eliminating interfibriller spaces, impeding hybridization. In another study, the shear bond strength of a self-etch adhesive (Clearfil SE Bond) to surfaces prepared using an Er:YAG laser or a bur were compared [37]. Without intrapulpal pressure, the shear bond strengths of the Er:YAG laser-prepared surfaces were lower than those seen on bur-prepared surfaces. With pressure, the shear bond strength of the bur-prepared surfaces and the laser-prepared surfaces were not statistically significantly different. They concluded that the absence of smear layer formation during the preparation of the dentine by the Er:YAG laser did not improve the adhesion values of self-etching adhesive systems. Supporting this result, Er:YAG laser ablation to dentin was found to be adversely affected the micro tensile bond strength and the sealing ability of SE Bond [38].

It is hard to compare our results with other studies, as different laser application parameters, output, and distance can alter the laser–tissue interaction. The conflicting results observed in the literature are generally related to the large number of laser variables and also preparation design and adhesive/restorative material. It is important to select proper parameters to ablate the tooth tissue otherwise, undesirable modifications in dentin collagen after laser irradiation can occur, which would affect bond strength between restorative materials and the tooth negatively [39]. Additional studies are required to confirm the benefits of laser preparation on the bond strength of conventional and self-adhesive resins. Therefore, extrapolation of the findings of the current study to the clinical situation remains to be further investigated.

## Conclusion

The bond strength of a self-adhesive flowable resin composite differs according to the type of dentin surface preparation. Laser treatment increased the dentin bonding values of the self-adhesive flowable resin.

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