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Effect of phototherapy on dentin bond strength and microleakage when bonded to resin with different conditioning regimes

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ABSTRACT

Aim: To assess the efficacy of phototherapy on bond strength and microleakage of bulk fill composites in comparison to conventional dentin surface treatments.

Materials and Methods: Ninety human third molars were divided into 3 groups (n = 30 each) according to surface conditioning treatment. Group 1 (Etch and Bond) EB, group 2 was treated with Er,Cr: YSGG (ECL) and group 3 was treated with a diode laser (DL). Based on the type of bulk fill resin composite, samples were divided into six sub-groups. In sub-group 1, 2 and 3 (n = 15) build-up was done using ZirconCore (ZC) and these subgroups were named as EB-ZC, ECL-ZC and DL-ZC. In subgroup 4,5,6 (n = 15) MulticCore Flow (MC) was used for core build-up and these subgroups were named as EB-MC, ECL-MC, DL-MC. For shear bond strength (SBS) all the samples were exposed to loads using a universal testing machine. Five samples each from all subgroups were immersed in methylene blue dye for 24 h prior to microleakage testing. Data were assessed using analysis of variance and Tukey multiple comparisons test.

Results: Among all the groups the lowest bond strength was achieved in DL-ZC [10.45(0.459)]. Similarly, the highest bond strength was attained in EB-MC[17.84(0.925)]. The highest microleakage scores amongst different group was exhibited in DL-ZC [82.45(39.459)] whereas, the lowest microleakage scores were displayed in EB-MC [31.21(15.92)].

Conclusion: Phototherapy in the form of Er,Cr:YSGG laser showed comparable adhesive bond outcomes to conventional etch and bond dentin conditioning techniques. Moreover, Multicore bulk fill material showed better bond strength and microleakage scores than zirconium particle infiltrated bulk fill composite in the presence of dentin phototherapy.

1. Introduction

Obtaining a reliable bond between dentin and resin composite determines clinical success of the restoration. The complex nature of dentin influences the adhesive bond, making dentin bonding more challenging when compared to enamel [1]. Methods are continuously developing to find techniques and materials, which can provide reliable and predictable bonding with minimum steps and technique sensitivity [2]. Conventionally, dentin is treated with phosphoric acid, which is rinsed off, followed by the application of dentin bonding agents (DBA) [3]. However, phosphoric acid has a disadvantage of being technique sensitive and its overuse may cause irreversible demineralization [4].

Recently, contemporary phototherapy strategy in the form of diode laser, working at a wavelength of (810–1064 nm) in soft tissue surgeries and other dental procedures have gained popularity due to their convenient size, cost-effectiveness, durability and safety [5,6]. Use of diode laser in dental bleaching procedures, treatment of dentin hypersensitivity and its effects with different DBA have shown encouraging but conflicting results [7–9]. Similarly, Erbium, chromium-doped yttrium, scandium, gallium and garnet (Er, Cr:YSGG) at wavelength 2760 nm is found to be minimally invasive and exhibits precise structural removal of both soft and hard tissues [9,10]. Erbium laser shows the potential of thermomechanical damage to hard tissues due to increase in temperature. However, evidence recommends that this rise in temperature improves bond strength by eliminating free radicals [11]. The effect of Er,Cr:YSGG phototherapy on enamel surface is efficacious [9,12,13], however, its effect on dentinal surfaces as a surface conditioner alternate is limited [14]. Moreover, an additional advantage of using laser on the dentinal surface is includes removal of smear layer, improvement in micro retention, unlocking of dentinal tubules and surface sterilization. All these factors are advantageous when bulk fill resin composites are used as restorative material [15].

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Long-term clinical success of resin bulk fill composite is dependent upon multiple factors. A prerequisite for predictable bonding is to prevent microleakage and secondary caries [16,17]. Compared to conventional silica and barium-based micro and macro filler composite, zirconium-based filler particles in composite resin have unveiled better mechanical properties including less microleakage and better bond strength scores [10,18].

To our knowledge from indexed literature evidence on zirconia particle in bulk fill composite is limited. Moreover, controversial evidence exists on the effect of different laser treatments on dentin and bonding of conditioned surface, with different bulk-fill materials. It is hypothesized that dentin conditioned with Er,Cr;YSGG at (4.5 W and 30 Hz) and diode laser (2 W at 10 Hz for 40 s at 10 µs pulse) bonded with zirconium particle bulk fill resin would exhibit comparable bond strength and microleakage scores in comparison to conventional 37% phosphoric acid and bulk fill composite material. Therefore, the aim of the present study was to assess microleakage and bond strength between dissimilar bulk fill composites in combination with different surface treatment on dentin.

2. Material and method

Prior to dentin preparation, ninety human third molars free from carious lesion, cracks, restorations and endodontic treatment were stored in 0.01% thymol at 4C for a month. Tissue remnants and debris were removed with the help of periodontal scaler (Sonic flex 2000, Biberach, Germany). All the specimens were initially rinsed and then mounted vertically within the segments of polyvinyl pipes (8 mm diameter) in acrylic resin up to cemento-enamel junction (CEJ) only revealing the clinical crown. To standardize the dentinal depth the buccal surface of all molars was ground to flat surface (2 × 2 mm) and occlusal surface were exposed to a depth of 1.5 mm (Isomet saw, Buehler, Illinois, USA) followed by polishing with a carbide paper 300–600 on a polishing machine (Aropol 2 V, Arotec) at 250 rpm under irrigation for 10 s (s). The present in-vitro research follows the general guidelines as described in the CRIS (checklist for Reporting In-vitro Studies)

Specimens were randomly divided into 3 groups (n = 30 each) according to surface conditioning treatment. Group 1 (Etch and Bond) EB, group 2 treated with Er,Cr: YSGG (ECL) and group 3 treated with diode laser (DL). The following treatment protocol was performed for these groups

Group 1 (EB): Dentinal surface was etched using 37% phosphoric acid for 20 s (Harward Etch) and washed for 30s A Harvard bond TE bonding agent (Harvard Dental International, GmbH, Hoppegarten, Germany) with agitation was applied on moist dentin for 30 s and air dried 20 s forming a uniform layer. Another layer of TE bonding agent was applied in accordance with manufacturer instructions for 30 s and air dried for 15 s. The bonding agent was light-cured for 20 s with an intensity of 650 mW cm^{-2} (Bluephase® C8, Ivoclar Vivadent, Schaan, Liechenstein).

Group 2 (ECL): Specimens exposed to Er,Cr:YSGG laser (Biolase-Waterlase I-Plus) with power 4.5 W and frequency 30 Hz in a non-contact mode at 2 mm using (MZ = 8) for 60 s. The samples were rinsed with artificial saliva (NeutraSal) for 30 s after laser procedure. A bonding agent TE (Harvard Dental International, GmbH, Hoppegarten, Germany) was applied on moist dentin for 30 s, air dried 15 s and light cured for 20 s (Bluephase C8, Ivoclar Vivadent, Schaan, Liechenstein) at an intensity of 650 mW cm^{-2}.

Group 3 (DL): Samples exposed to diode laser (SIROLaser Advance, Sirona wavelength 940 nm) (2 W at 10 Hz for 40 s at 10 µs pulse) using a fibre-optic tip with a diameter of 200 mm with an incidence angle of 90°, 1.5 mm from the dentinal surface. The surface of the dentin was irradiated for 60 s. The lased specimens were rinsed with artificial saliva (NeutraSal) for 30 s after procedure. A bonding agent TE (Harvard Dental International, GmbH, Hoppegarten, Germany) was applied on moist dentin for 30 s, air dried for 15 s and light-cured for 20 s (Bluephase® C8, Ivoclar Vivadent, Schaan, Liechenstein) at an intensity of 650 mW cm^{-2}.

Based on the type of bulk fill resin composite, samples were divided into six sub-groups. In sub-group 1, 2 and 3 (n = 15) build-up was done using ZirconCore (ZC) (Harvard Dental International, GmbH, Hoppegarten, Germany) and these subgroups were named as EB-ZC, ECL-ZC and DL-ZC. In subgroup 4,5,6 (n = 15) MulticCore Flow (MC) (Ivoclar Vivadent Schaan Liechtenstein) was used for core build-up and these subgroups were named as EB-MC, ECL-MC, DL-MC. This resulted in 6 experimental groups. Resin core build-up was done using standardized split moulds cylinder having dimensions of 3 mm diameter and 3 mm height. Excess material was removed with the help of hand instruments and the composite build-up was light cured (Bluephase C8, Ivoclar Vivadent, Schaan, Liechenstein) at intensity of 650 mW cm^{-2}. After the procedure, all specimens were kept in artificial saliva (NeutraSal) at 37C for 24 h and thermocycled (TC) between 5 and 55°C for 5000 cycles for 30 s before shear bond strength testing.

3. Shear bond strength (sbs) testing

For shear bond strength (SBS) the samples were exposed to increasing load with a transversal velocity of 1 ml/min on a universal testing machine (Instron Model 4400 Universal Testing System, Instron Corporation) on a dentin-resin interface.

4. Microleakage testing

Five samples each from all subgroups were immersed in methylene blue dye for 24 h prior to microleakage testing. Isomet disc was used to section the samples without dislodgement of restoration. The cut surfaces were further smoothened using a polishing machine (Buehler Polishing Machine type: 49-5100-230, No 620-PXB-22061, Buehler, Germany). The samples were cleaned with distilled water (Pure Steam Distilled H2O - 1100 ml by Innovative Naturopathics) and air dried. The microleakage scores was calculated by a single operator using an Image analysis software (DPsoft, Olympus Optical, Middlesex) on a digital microscope (Hirox-KH7700). All specimens were measured at 50-X magnification.

5. Statistical analysis

The data were assessed for normality using Kolmogorov Smirnov test and the data was found to be normally distributed. The influence of different surface treatment with different core build-up material was analyzed using statistical program for social sciences (SPSS). Means and standard deviations of bond strength and microleakage was compared among the experimental groups using analysis of variance (one-way-ANOVA) and post hoc Tukey multiple comparisons test. The statistical significance among the study groups was determined at $p < 0.05$.

6. Results

6.1. Shear bond strength

Among all the groups the lowest bond strength was achieved in diode laser-zirconcore (DL-ZC) [10.45(0.459)]. Similarly, the highest bond strength was attained in etch and bond multicore (EB-MC) [17.84(0.925)]. Specimens treated with EB-MC [17.84(0.925)] and Er.Cr:YSGG laser multicore (ECL-MC) [17.13(2.012)] showed comparable bond strength values. Furthermore, samples treated with etch and bond zirconcore (EB-ZC) [15.21(1.123)] and Er,Cr: YSGG zirconcore (ECL-ZC) [15.17(1.102)] exhibited comparable bond scores. Moreover, the bond strength scores among diode laser multicore (DL-MC) [10.96(0.611)] and specimens treated diode laser zirconcore (DL-ZC) [10.45(0.459)] were comparable. For bond strength values, analysis of variance (ANOVA) showed significant difference among the study

Table 1
Means and SD for shear bond strength values among study groups using ANOVA and Tukey multiple comparisons test.

Surface treatment/ Type of bulk fill material	Mean (Mpa)	SD (Mpa)	**P value**[!]
EB-MC[†] (Control)	**17.84**	0.925	< 0.001
EB-ZC[*] (Control)	15.21	1.123	
ECL-MC[†]	17.13	2.012	
ECL-ZC[*]	15.17	1.102	
DL-MC[¶]	10.96	0.611	
DL-ZC[¶]	**10.45**	0.459	

ZC: Zirconcore, MC: Multicore, EB: Etch and bond, ECL: Er, Cr: YSGG, DL: Diode laser.
The highest and lowest SBS values are in bold.
[†] Significantly different from groups- EB-ZC, ECL-ZC, DL-MC, DL-ZC ($p < 0.05$).
[*] Significantly different from groups- EB-MC,ECL-MC, DL-MC, DL-ZC ($p < 0.05$).
[¶] Significantly different from groups- EB-MC, EB-ZC,ECL-MC,ECL-ZC (Tukey multiple comparison test).
[!] Showing significant difference among study group (ANOVA).

groups ($p < 0.001$). EB-MC and ECL-MC was found to be highly significant from group EB-ZC, ECL-ZC, DL-MC, DL-ZC ($p < 0.001$). Similarly, EB-ZC and ECL-ZC was found to be statistically significant from groups EB-MC, ECL-MC, DL-MC, DL-ZC ($p < 0.001$) Table 1.

6.2. Microleakage outcomes

A Significant difference with respect to microleakage was demonstrated in Table 2 ($p < 0.001$). The highest microleakage scores amongst different group were exhibited in DL-ZC [82.45(39.459)] whereas, the lowest microleakage scores were displayed in EB-MC [31.21(15.92)]. For microleakage values, analysis of variance (ANOVA) showed significant difference among the study groups ($p < 0.001$). Diode lased specimen displayed comparable microleakage scores when bonded with bulk fill material multicore and zirconcore. Similarly, microleakage scores in ECL-ZC was significantly different from groups EB-MC, ECL-MC, DL-MC, DL-ZC. Samples treated with EB-MC [31.21(15.92)] and ECL-MC [29.78(13.01)] showed comparable microleakage.

7. Discussion

In the present study, dentin was conditioned using different surface treatments and bonded with two dissimilar bulk fill composite materials across different groups. The bonding efficacy was evaluated using shear bond strength values whereas microleakage scores were assessed using dye penetration test. In the current study, it was hypothesized that dentin, when treated with phototherapy by two different laser prototypes (Er: Cr, YSGG and diode laser) and bonded with zirconium bulk fill composite, will exhibit comparable bond strength and microleakage scores compared to conventional dentinal surface etched with 37% phosphoric acid and bonded with bulk fill composite material. Intriguingly, one part of the hypothesis was accepted as bond strength and microleakage scores were found to be comparable to specimens treated with Er,Cr:YSGG, to samples treated with conventional 37% phosphoric acid and bonded with two dissimilar bulk fill composites simultaneously.

Table 2
Means and SD for microleakage values among study groups using ANOVA and Tukey multiple comparisons test.

Surface treatment/ Type of bulk fill material	Mean (nm)	SD (nm)	P value[!]
EB-MC[†] (Control)	**31.21**	15.92	< 0.001
EB-ZC[*] (Control)	48.61	23.123	
ECL-MC[†]	29.78	13.01	
ECL-ZC[*]	46.57	21.102	
DL-MC[¶]	78.18	33.611	
DL-ZC[¶]	**82.45**	39.459	

ZC: Zirconcore, MC: Multicore, EB: Etch and bond, ECL: Er, Cr: YSGG, DL: Diode laser.
The highest and lowest microleakage values are in bold.
[†] Significantly different from groups- EB-ZC, ECL-ZC, DL-MC, DL-ZC ($p < 0.05$).
[*] Significantly different from groups- EB-MC,ECL-MC, DL-MC, DL-ZC ($p < 0.05$).
[¶] Significantly different from groups- EB-MC, EB-ZC,ECL-MC,ECL-ZC (Tukey multiple comparison test).
[!] Showing significant difference among study group (ANOVA).

The erbium family consists of two different lasers; Er,Cr:YSGG and Er:YAG. Both lasers work on different wavelengths, are well absorbed by the dental hard tissues and produce minimal thermal effect on surrounding oral tissues [19]. Er,Cr:YSGG is known for its painless, conservative and bactericidal nature [20]. In addition, it makes dentin more resistant to acid attack [21]. In the present study, dentin lasered with Er,Cr:YSGG displayed comparable bond strength to specimen etched with 37% phosphoric acid. A possible explanation to these findings is that Er,Cr:YSGG produces scaly, irregular rugged appearance, free from smear layer [22]. Moreover, laser ablation results in loss of inter tubular dentin, roughened surface and forms huge crater making bonding for the bulk composite more advantageous and viable [23]. But there are also studies by Hasoon [14]; Ansari et al. [24], who claim that phototherapy exposed dentinal surface by Er,Cr:YSGG have low bond strength. In the authors' opinion, diversity in results is due to different laser parameters, frequency, power, irrigation system and types of material used. In the current study Er,Cr:YSGG was used at 4.5 W and 30 Hz showed comparable outcome. Similarly, bond strength of dentin treated with diode laser displayed lowest bond strength scores. Since in the present study diode laser was used at power 2 W and frequency10 Hz for 40 s, the author speculates that at this frequency, power and duration dentin is more prone to cracks and narrowing of dentinal tubules. These findings are found to be concurrent with studies by Malekipour et al. [7], and Umana et al [25].

In the current study, the bond strength was measured using universal testing machine to maintain standardization and consistency. It is an in-vitro qualitative method which provides precise and swift data on specific parameters [26].Two different types of bulk fill composites were used i.e. zirconcore (ZC) and multicore (MC). Based on the type of bulk fill material, MC showed better bond strength scores over all among different experimental groups. There are multiple factors that have been reported previously that affect resin bond strength i.e. curing methods, type of material, quality of dentin, aging process, bonding regime and curing time [27]. This is the first study which evaluates ZC and MC used as bulk fill composite on surface conditioned with two different lasers (Er,Cr:YSGG and diode laser). Conventionally, to form a bulk fill material the inorganic part of filler and organic resin is linked together with silane coupling agent. In the authors' opinion in case of ZC poor coupling of resin (urethane dimethacrylate) with zirconia fillers may be associated to poor bond strength when compared to MC (micro-hybrid and urethane dimethacrylate) [10]

Microleakage scores were lowest in groups conditioned with diode laser and comparable in groups treated with Er,Cr:YSGG and etch and bond. In the present study microleakage scores were assessed using a dye penetration test. The method is homogenized, standardized and widely used to detect microleakage [28]. There are multiple factors that influence microleakage i.e. quality of dentin, coefficient of thermal expansion, polymerization shrinkage, thermo cycling and location of margins [29]. In the present study lowest microleakage scores in diode laser may be attributed to poor absorption of diode laser at 940 nm wavelength by hard tissues causing incomplete removal of smear layer [29,30]. Furthermore, dentin is a complex structure and water between collagen may prevent resin to penetrate forming weak bond, resulting in high microleakage score [24]. From our understanding, Er,Cr:YSGG at 2760 nm wavelength has better absorbing capability by dentin due to higher water content. This presents a strong thermomechanical interaction which results in higher temperature, water evaporation and smear layer removal which result in decrease microleakage [31,32]. A possible clinical implication of these results indicates that use of phototherapy (Er,Cr:YSGG) for conditioning of dentinal surface is a potential alternative to conventional EB.

Findings of the present study suggest the use of phototherapy in dentin bonding, however, more clinical studies are required to extrapolate the findings of the present study. The study has limitations based on its in-vitro study design. These results are applicable only on the methods of phototherapy used, applied bonding agent, quality of dentin and bulk fill material. Furthermore, surface profilometry of the dentin surface should be investigated along, with the topographic analysis by scanning electron microscope (SEM) so that further findings from the present study can be established.

8. Conclusion

Phototherapy in the form of Er,Cr:YSGG laser showed comparable adhesive bond outcomes to conventional etch and bond dentin conditioning techniques. Moreover, Multicore bulk fill material showed better bond strength and microleakage scores than zirconium particle infiltrated bulk fill composite in the presence of dentin phototherapy.

Conflict of interest

There is no conflict of Interest declared by the authors.

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