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Original Article

Influence of Diode Laser Irradiation on Shear Bond Strength of Activa and Composite Resin Restorations in Primary Molars: An In-Vitro Study

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Abstract

Aim: This study aims to evaluate Microshear bond strength of two esthetic restorative materials; Activa bioactive restoration and composite resin after irradiating tooth surface with laser diode. **Materials and Methods**: 104 primary molars were collected and divided into two main groups (n=52) (Laser and No laser). Acrylic molds were prepared to mount the teeth where the enamel and dentin surfaces were exposed. Samples of each group were randomly distributed into 4 subgroups: Activa + enamel, Activa + dentin, composite + enamel and composite + dentin. Enamel samples were etched, while universal adhesive was used for Activa and composite samples in dentin. Diode laser irradiation (980nm wavelength, 1W power, continuous mode) was applied after adhesive application and before polymerization. After thermocycling for 500 cycle, microshear bond strength was measured using a universal testing machine in MPs. Statistical analysis was done using three ways ANOVA. **Results:** Mean bond strength of enamel samples were significantly higher than dentin samples ($p<0.05$). In Activa bioactive restoration samples, diode laser irradiation significantly reduced microshear bond strength in enamel and dentin. Irradiation with diode laser did not significantly improve the mean microshear bond strength enamel and dentin composite samples. **Conclusion:** Diode laser irradiation did not improve bond strength of composite restorations when applied before adhesive polymerization of primary teeth and had negative effect on bond strength of Activa bioactive restorations.

Keywords: Laser Irradiation, Bond strength, Deciduous Teeth, Diode Laser.

I. INTRODUCTION

One of the key issues in adhesive dentistry is achieving a reliable bond between composite restorations and the tooth surface. The effectiveness of the different adhesive systems is dependent on the hybrid layer interface formation. Unfortunately, most of the commonly used bonding systems usually don’t fully penetrate into the microtags. Therefore, microgaps are usually formed between the composite restoration and dentin surface (Hardan et al., 2021). Recently, a novel technique was proposed to improve adhesion to dentin using lasers.

Earlier research proposed that laser irradiation helps the infiltration of different bonding agents into dentin, before their polymerization. (Zhang & Jiang, 2020; Silva et al., 2019). In dentistry, bioactive restorative materials are a relatively recent approach. It has been reported that bioactive materials release fluoride more than glass ionomers. As well as they respond to fluctuations in pH levels within the oral environment by absorbing calcium, phosphate, and fluoride ions thereby preserving the chemical integrity of the tooth structure.

Activa bioactive restoration (Pulpdent, USA) is a restorative material that is composed of Embrace resin matrix (a bioactive shock- absorbing rubberized ionic-resin) which contains a small amount of water mechanically (Alkhudhairy et al., 2019). According to manufacturer instructions Activa bioactive restoration can be used with or without a bonding system; but recently, the manufacturer recommendation is to use any type of bonding agent (Kaushik and Yadav, 2017). Also, research has indicated that the use of adhesive resin in conjunction with Activa bioactive restoration resulted in enhanced dentine bond strength and improved marginal seal (Benetti et al., 2019; Tohidkhah et al., 2022).

Bonding to dentin have been extremely studied due to its difficulty as this presents a great challenge for the operator. Although many articlesstudied the effect of diode laser irradiation on bondstrength to dentin, few studies evaluated the effectof diode laser irradiation on bonding restorations to primary teeth. Thus, This research was conducted to highlight the impact of diode laser irradiation on micro shear bond strength of Activa bioactive restorative materials and composite resin to primary teeth (enamel and dentin).

II. MATERIALS AND METHODS

The study design was invitro study. This experimental study was conducted on discarded natural primary molars. Teeth were indicated for extraction due to normal shedding, orthodontic reasons and over-retention. Primary molars were cleaned with pumice without fluoride to remove any surface debris or contaminants and disinfected using 0.01% Thymol for one week. Teeth were then examined under magnification to ensure the molars were free from cracks, fractures or any defects and were stored at room temperature in isotonic salinesolution till use (Alkhudhairy et al., 2019).

According to sample size calculations, the sample size was chosen to be a total of 104 teeth, splitted equally into eight subgroups, each had 13 teeth. This was based on minimum detectable difference in mean bond strength and that the minimum value recommended for bond strength to dentin in primary teeth was 17.6 MPa. This sample size would be able to reject the null hypothesis with probability (power) 0.8. The Type I error probability associated with the test of this null hypothesis is 0.05.

Teeth were randomly divided into two groups (n=52); Group I: Laser & Group II: No Laser. Each group was subdivided into two equal subgroups according to type of substrate: Subgroup E: Enamel substrate & Subgroup D: Dentin substrate. Each subgroup was divided into two equal suborders according to type of restoration: Suborder A: Activa bioactive restoration (Pulpdent, USA) & Suborder C: Composite resin Filtek Z350XT (3M ESPE, USA).

For enamel samples, primary molars with intact buccal or lingual surface were selected. Roots were cut at the cemento-enamel junction roots for easier placement of sample in the mold. Enamel samples were mounted horizontally (buccal or lingual surface facing up) in cylindrical-shaped mold filled with self-cured acrylic resin. In dentin samples, teeth were mounted in the acrylic resin within the mold in a vertical direction revealing 1-2 mm of the crown. Then the occlusal enamel of the teeth was removed perpendicular to the long axis of teeth with model trimmer to reveal the flat mid-coronal dentin under water cooling Morresi et al. (2014). All surfaces were subjected to wet grinding using 800-grit abrasive paper until a uniform surface with a minimum diameter of 3 mm of the tooth dentin was revealed. The generated smear layer was not removed. (Figure 1).

Enamel samples were etched with 37% phosphoric acid (Meta Biomed Co., Korea) for 20 seconds, followed by proper rinsing, with excess water was suctioned by high volume suction for 1 - 2 seconds, resulting in a visibly moist preparation (AlHabdan et al., 2021). Two layers of All- Bond universal adhesive (Bisco, USA) were applied, using a microbrush with scrubbing action for 10 - 15 sec per layer. Air-drying with an air syringe for a minimum of 10 seconds was used to remove any excess solvent (Ramachandruni et al., 2019). Dentin samples were not acid etched, a universal adhesive was applied in self-etch mode, following the same procedural steps universal adhesive was used in self-etch mode following the same steps mentioned for enamel samples. After universal adhesive application, diode laser treatment was conducted on the substrate surface maintaining a distance of approximately 1 mm perpendicular to the surface. Diode laser irradiation with wavelength 980 nm (Photon plus, Zolar Technology, Canada), power of 1 W and continuous wave mode along with 300 µm optical fiber tip was used in the study(Zabeu et al., 2019). The diode laser energy was delivered by a hand-piece at a speed of 1mm/second, testing area was scanned for 10 seconds in circular motion from thecenter outward and then inward (Figure 2) (Zabeu et al, 2019). Laser irradiation was followed by 10 seconds of light-curing with output power of 2300 mW/cm2. In the second group (No laser) all specimen preparations and bonding procedures were the same as group I except that universal adhesive was light cured without laser irradiation.

To create a clear plastic mold for Activa bioactive restorations and composite (Filtek 350XT) restorations, a size 6 FG urology catheter was used. Plastic catheter was cut with lancet to obtain cylindrical mold; with a diameter of 1 mm, and length of 1.5 mm. Plastic mold was held securely and immobilized using cotton pliers on the indicated substrate (enamel or dentin) after applying adhesive system and after diode laser irradiation in laser subgroups. Activa bioactive material was injected in molds using automix tips with bendable 20-gauge metal cannula and light cured for 20 seconds in Activa subgroups. Composite samples were packed with FiltekZ350XT composite resin that is cured for 20 seconds.

Thermocycling was conducted in accordance with ISO guidelines, utilizing a total of 500 cycles. Dwell times of 25 seconds in the respective water baths, with a lag time of 10 seconds. The low-temperature threshold was 5°C, while the high-temperature threshold reached 55°C.

Micro-shear bond strength test was carried out with universal testing machine (Model 3345, Instron Industrial Products, USA) and wire loop debonding. A shearing load was applied with a loadcell of 5 kN at a crosshead speed of 0.5 mm/min. After microshear bond strength test, specimens were viewed using a USB digital- microscope (U500x Digital Microscope, Guangdong, China) (magnification x45) to determine failure mode pattern according to the following categorization; adhesive (Interfacial), cohesive (within tooth only or restoration only) and mixed.

Comparisons between groups with respect to normally distributed numeric variables were performed by independent t test. Three ways ANOVA was used to study the significance of interaction of variables. All p-values are two-sided. P-values ≤ 0.05 were considered significant and confidence interval 95% (CI=95%).

III. RESULTS

Mean values of micro-shear bond strength test and standard deviations of Activa and composite restorations bonded to enamel and dentin with and without diode laser irradiation were summarized in Table 1. Statistical analysis of comparison between groups revealed that bond strength of Activa restorations bonded to both substrates (enamel and dentin) with diode laser irradiation was significantlyreduced compared with no laser group (p=002 & p=0.003 for enamel and dentin respectively). On the other hand, diode laser irradiation showed no statistically significant difference in bond strength of composite restorations bonded to both enamel and dentin.

As for comparison between restoration types, composite restorations showed significantly higher bond strength to enamel compared to Activarestorations when no laser irradiation was performed(p=0.002). However, Activa restoration had significantly higher mean bond strength than composite restorations when bonded to dentin withdiode laser irradiation (0.00001). Mean micro-shear bond strength of Activa and composite restorations bonded to enamel was significantly higher that dentin.

Regarding failure mode, most of the subgroups had more adhesive failure as compared to mixed failure. A higher percentage of adhesive failure wasfound in (dentin-no laser-Activa) subgroup (76.9%) group followed by (Laser-dentin-composite) subgroup (75%). In comparison, (Laser-enamel- Activa) showed the lowest percentage of adhesive failure with (18%).

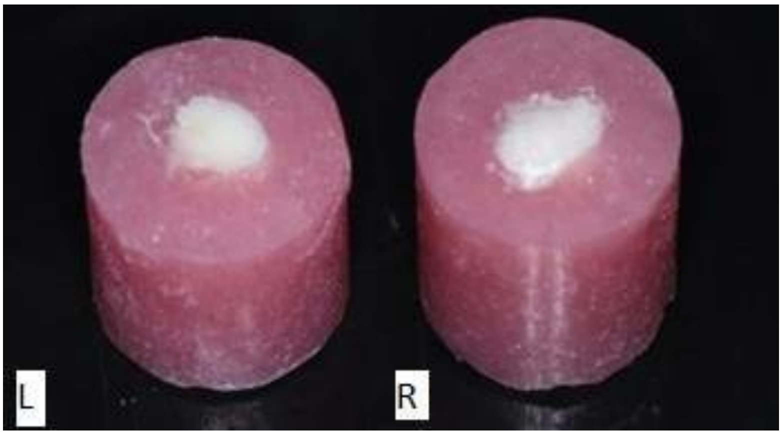

Figure (1): Photograph showing dentin sample after removal of occlusal enamel (Left), Enamel sample (Right).

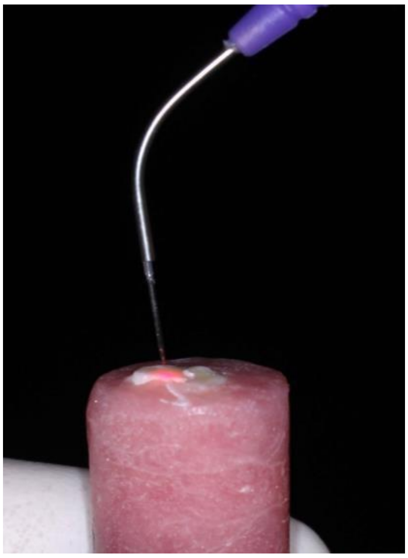

Figure (2): Diode laser irradiation after adhesive application and before light curing.

Table (1): Comparison between swabs from two groups during follow up time

Subgroup	Suborder	Group	Mean ± SD	P value
Subgroup E (Enamel)	Suborder A (Activa)	GP I (Laser)	19.68 ± 3.65	0.002*
		Gp II (No laser)	24.70 ± 2.92	
	Suborder C (Resin composite)	GP I (Laser)	18.44 ± 7.49	0.477 ns
		Gp II (No laser)	20.25 ± 3.68	
Subgroup D (Dentin)	Suborder A (Activa)	GP I (Laser)	13.61 ± 3.07	0.003*
		Gp II (No laser)	17.88 ± 3.46	
	Suborder C (Resin composite)	GP I (Laser)	19.74 ± 3.64	0.119 ns
		Gp II (No laser)	17.63 ± 2.63	

Significance level p≤0.05, * significant, ns=non-significantC.I.= 95% confidence interval

IV. DISCUSSION

Diode lasers have a wide range of clinical applications in the field of dentistry because of their adaptability, effectiveness, small size, and low cost. So, expanding the field of its application can give major benefits (Malekipour et al., 2015). Strong dentin bond is the cornerstone in long-term successful tooth restoration so, many techniques have been proposed to improve the dentin bonding strength. To achieve a fully infiltrated hybrid layer, combination between lasers and dentin bonding systems has been proposed and investigated as well. Understanding the different bonding strategies and how it affects the mechanical properties of whole restoration is crucial for appropriate clinical decision making.

The null hypothesis was adopted. For composite restorations, either for enamel ordentin. Laser and no laser subgroups showed no statistically significant difference in microshear bond strength, while for Activa bioactive restoration, either for dentin or enamel substrates, no laser subgroups showed higher microshear bond strength than laser subgroups.

It was also found that microshear bond strength of Activa restorations to enamel was significantly higher than composite restorations bonded to enamel when no diode laser irradiation was used. (p=0.002). This could be due to high calcium/mineral content in enamel. As Activa restorative develops a chemo-mechanical bond with the calcium and mineral composition of the tooth structure (Carvalhoet al., 2011). So variation in the adhesion values in this study It may be attributed to variation in the mineral/calcium content.

There was a statistically significant reduction in microshear bond strength of Activa bioactive restoration when substrates (enamel and dentin) where irradiated with diode laser after application of universal adhesive and before photopolymerization (p=.002 & p=.003 in enamel & dentin groups respectively). This could be attributed to the thermal denaturation of collagen fibers caused by laser irradiation. Besides high temperatures can cause chemical alterations due to crystal liquefaction of the tooth. This liquefaction process could be responsible for obliterating the microporous surface and reduction in bond strength (Nijhawan et al., 2019; De-Melo et al., 2011). In general, diode laser irradiation did not improve bond strength of composite or Activa restorations in this investigation.

The results of present study were in agreement with (Malekipour et al., 2015) who reported that 808nm diode laser decreased bond strength of composite resin restoration to dentin. Where laser application results in heating the tooth surface, with alteration of the dentin's morphology, and reduction of the bonding agent's penetration. Subsequently it causes morphological disruption and lack of adaptation between the composite and dentin, thus gab formation. On the other hand the control group (non-lased) had a higher values of bond strength which may be attributed to partial clogging of the dentinal tubules and lack of re-hydration of the laser radiated surface.

In line with the current study, (Zabeu et al., 2019) stated that 970nm diode laser treatment did not improve bond strength of non- simplified adhesive systems (4th and 6th generations). Scanning Electron Microscope (SEM) images showed a slight increase in resin tags length when diode laser was applied after primer in three-step etch-and-rinse adhesive system.

In contrast to earlier research, Maenosono et al., 2015) discovered that irradiation with a 970 nm diode laser enhanced the microtensile bond strength of two simplified adhesives. The author proposed that near-infrared lasers aid in the evaporation of solvents and the penetration of adhesives. Additionally, Kasraei et al. (2019) who stated that bond strength to dentin can be considerably increased by applying 940 nm diode laser irradiation following bond application.

Ramachandruni et al., 2019 described opposite results to our present study as well. He proposed that in the laser radiated group there is a creation of a new layer in which the adhesive and dentin are fused, improving the bond strength.

Many factors could explain the inconsistent results between authors who investigated the effect of diode laser irradiation on the bond strength. First, diode laser wavelengths and parameters were not the same in all these studies. 808, 810, 940 and 970nm wavelengths were used in different investigations which could affect the amount of energy emitted to substrate. Also, power parameters, time of irradiation and diameter of fiber delivery tip were changed among studies. Using larger tip diameters would deliver less laser energy to the target tissue and vice versa. The efficacy of diode laser irradiation is dependent on the amount of laser radiation absorption by hard dental tissues, which is dependent on target tissue optical quality. Besides laser characteristics; the emission mode (continuous or pulsed), the wavelength, and energy density (Verma et al., 2012; Malekipour et al., 2015).

V. CONCLUSIONS

Within the limitations of this in-vitro study, it can be concluded that diode laser irradiation improved the microshear bond strength of composite restoration to dentin to a certain limit that was statistically insignificant. On the other hand, diode laser irradiation did not improve microshear bond strength of composite restorations to enamel when applied before adhesive polymerization. In addition to the fact that diode laser is expensive, and its application needs certain safety precautions, it had negative effect on bond strength of Activa bioactive restoration to enamel and dentin.

Conflict of Interest:

The authors declare no conflict of interest.

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Ethics:

This study protocol was approved by the ethical committee of the Faculty of Dentistry- Cairo University on: 26-1-2021 approval number: 4-1-21

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