Original Article

Comparative evaluation of bond strength of diode and neodymium-doped:Yttrium aluminum garnet-assisted bleached enamel with nanofilled composite: An *in vitro* study

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Abstract

Background: The world of esthetic dentistry is constantly making efforts toward the management of tooth staining. Laser-assisted bleaching is needed before adhesive restorations and has become common and advantageous as it accelerates bleaching action, reduces postoperative sensitivity, and promotes recrystallization of enamel.

Aim: The study aimed to evaluate and compare the bond strength of diode (Biolace: EpicX) and neodymium-doped:yttrium aluminum garnet (Nd:YAG) (LightWalker, Fotona, Slovenia) assisted bleached (Pola Office, SDI) enamel with nanofilled composite (GC Solare Sculpt).

Materials and Methods: The samples were divided into three groups (n = 11): Group A – Conventionally bleached enamel, Group B – Diode laser-assisted bleached enamel, Group C – Nd:YAG laser-assisted bleached enamel. After storing samples in Artificial Saliva for 2 weeks, bonding was performed, and nanofilled composite resin was applied through an incremental method. Samples were subjected to shear bond strength (SBS) analysis.

Conclusion: The use of Nd:YAG laser on bleached enamel significantly increases the bond strength with nanofilled composite resin.

Keywords: Bond strength; composite resin; diode laser; neodymium-doped:yttrium aluminum garnet laser; tooth bleaching

INTRODUCTION

The demand for esthetic dentistry is driving toward conservative management of tooth discoloration caused due to extrinsic and/or intrinsic staining. Extrinsic stains can be easily removed by polishing the stained surfaces with polishing pastes and rubber cups, whereas direct and indirect restorations are required for managing aggressive intrinsic stains. The outcomes of esthetic treatments can be enhanced by combinative therapy of bleaching with direct restorations, such as direct composite veneering, to meet the patient's expectations effectively.[1,2]

The most enamel-conservative treatment modality for such discoloration is tooth bleaching which is preferred choice for both dentists and patients.[2,3] It consists of coating the stained teeth with a chemical, which then oxidizes the organic pigments which causes the discoloration. Various bleaching agents that can be used include oxalic acid, carbamide peroxide, hydrogen peroxide, chlorine dioxide, and sodium perborate.[4]

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Vital bleaching can be achieved by two methods – in-office bleaching (IOB) or at-home bleaching techniques. These results can also be accelerated by the application of heat/light.[3,4] The present IOB technique customarily uses varying concentrations of hydrogen peroxide in the range of 15%–40%, with/without light source.[3,4]

Recently, various lasers have been employed as light sources to expedite chemical reactions. These include diode lasers with wavelengths of 810 and 980 nm, neodymium-doped:yttrium aluminum garnet (Nd:YAG) lasers at 1064 nm, erbium:yttrium aluminum garnet lasers at 2940 nm, and Kalium-Titanyl-Phosphate lasers at 532 nm.[4,5]

The Nd:YAG produces the heat necessary for the activation of hydrogen peroxide, reducing the marginal microleakage while promoting recrystallization of mineralized tissue, thus increasing the bond strength.[6,7] Whereas using the diode laser in IOB produces low hypersensitivity in teeth as well as decreases the working time. This makes it a preferred conservative esthetic correction.[2,6,7]

Various studies have assessed the action of laser-assisted bleaching and its bond strength.[8] To the best of our knowledge, no study has directly compared the influences of Nd:YAG and diode laser-assisted bleaching on the shear bond strength (SBS) of nanofilled composite restorations.

Thus, this study aimed to evaluate and compare the bond strength of diode (Biolase: EpicX) and Nd:YAG (LightWalker, Fotona, Slovenia) laser-assisted bleached enamel (Pola Office, SDI) using nanofilled composite (GC Solare Sculpt).

MATERIALS AND METHODS

Preparation and selection of teeth

Twenty teeth were collected based on the inclusion and extrusion [Figure 1]. Inclusion criteria included teeth with sound enamel, with no history of bleaching, and teeth extracted for orthodontic purposes, whereas exclusion criteria included carious teeth, cracked teeth, teeth undergone prior bleaching, hypocalcified teeth, teeth with erosion and developmental anomalies, teeth with carious lesions, and deciduous teeth.

The teeth were then cleaned using an ultrasonic scaler, autoclaved, and stored in 0.5% thymol solution.

All the teeth were thoroughly examined under the microscope (EXTARO 300, Carl Zeiss, United States) for cracks and a total of 40 enamel samples were obtained.

Each sectioned tooth was embedded in cold cure resin cylinders (DPI RR) (1.5 cm wide by 1.5 cm high) with the enamel exposed. On secondary examination, 33 intact samples were included in the study. This sample size was calculated and obtained using “Open-Epi Software”.

Randomization sequence generation

Each sample was given a unique number. The allocation of the sample in each group was done using a computer-generated random sequence table. This was done using sequentially numbered, opaque, sealed envelope technique, and concealed. The samples were then randomly divided into three groups ($n = 11$).

Group A (Conventionally bleached enamel): (n = 11)

According to the manufacturer’s instructions, the contents of bleaching gel (SDI Pola Office) were mixed and applied on clean dried enamel using a brush applicator till it reached a uniform consistency, after which a generous layer of the gel was placed and kept undisturbed for 8 min. Then, the bleaching agent was removed through suction. This constituted 1 bleaching cycle. This cycle was repeated twice for 20 min. Following the final application, the gel was removed with a suction and then rinsed using distilled water.

Group B (Bleaching with diode laser): (n = 11)

Similar to Group A, bleaching gel was applied. The gel was activated using a diode laser (Biolase, EpicX, USA). The bleaching process involved attaching the handpiece to the fiber shaft and setting the function of whitening mode. This mode had power set at 1.5 W for 30 s. After 8 min, the bleaching agent was removed through suction. This marked 1 cycle, and this process was repeated twice for 20 min.[9]

Group C (Bleaching with neodymium-doped:yttrium aluminum garnet laser): (n = 11)

The bleaching protocol was similar to the previous groups. The gel was activated using Nd:YAG laser (LightWalker, Fotona, Slovenia, 1064 nm) at a setting of 2.5w and 25 Hz in VLP mode. The R24 handpiece was kept at a working distance of 2 cm for 6 mm spot size diameter. The laser was activated 5 times with 4 s interval (20 s per sample). After 8 min, the gel was suctioned and this constituted one bleaching cycle. This was repeated twice for 20 min.[9]

After the intervention, the samples were collected and stored in three different containers containing Artificial Saliva (Wet Mouth Liquid, ICPA HEALTH PRODUCTS LTD) for a period of 2 weeks.

Bonding procedure

After 2 weeks, the samples were rinsed and dried followed by etching using 37% phosphoric acid (PRIME Dental, Pvt. Ltd.) for 15 s. The bonding agent (Single Bond Universal Adhesive, 3M ESPE, Germany) was applied to the samples according to the guidelines of the manufacturer. Plastic cylindrical tubes (3 mm × 4 mm) were placed on each sample followed by the application of composite resin in increments and cured for 20 s at 850 mW/cm^2 (WOODPECKER). The plastic tubes were delicately extracted from the samples with the help of tweezers. These samples were subjected to SBS testing using a knife-edge shear blade in a universal testing machine (UTM) (Instron, LLOYD instruments LRX, UK) at a crosshead speed of 0.5 mm per minute.

Statistical analysis

SBS analysis was performed, and the descriptive statistics for each group were presented as the mean along with the standard deviation (SD). The software used was SPSS (Statistical Product and Service Solutions) version 19 (By IBM SPSS Statistics). For comparison, the statistical tests employed included one-way analysis of variance and the *post hoc* Kruskal–Wallis Test. Multiple group comparisons were conducted using the Dunn's multiple comparison test. All statistical analyses were performed at a significance level of $P < 0.05$.

RESULTS

The SBS assessment was carried out utilizing the UTM (UNITEST 10, ACME Engineers, India). Shear forces were applied at the junction between the adhesive and enamel, employing a crosshead speed of 0.5 mm per minute until the point of debonding occurred. The maximum force required for debonding was quantified in Newtons and subsequently converted into Megapascals (MPa).

The maximum and minimum values, mean values, and the SD of SBS for Group A were 13.55 ± 1.85 Mpa, Group B was 14.79 ± 1.65 Mpa, and Group C was 15.20 ± 0.61 Mpa [Table 1 and Figure 2].

On intergroup comparison, a significant difference was noted between Group A (Only bleaching) and Group C (Bleaching + Nd:YAG laser) ($P < 0.005$) [Table 2].

DISCUSSION

The bloom of minimally invasive dentistry directs for an alternative approach in the management of intrinsic tooth staining. Combination therapy of tooth bleaching followed by composite restoration allows a conservative management with added economic benefit.[10]

In this study, 35% hydrogen peroxide was used to bleach the enamel surface which was activated using diode and Nd:YAG lasers.

Hydrogen peroxide is known for its potency as a robust oxidizing agent. When in contact with enamel, it breaks down into reactive oxygen and free radicals, which subsequently infiltrate the dental tissues and oxidize pigments. Its concentrations can range from 15% to 40%, and at higher concentrations, such as 35%–40%, its potency is notably increased.[11-13]

Numerous studies recommend that resin bonding to the bleached enamel should be performed after 1–2 weeks postbleaching.[11-16] This is done to ensure the removal of oxygen-free radicals that are produced during bleaching, which are suspected to interfere with the photopolymerization reaction of composite restorations.[11-16] Hence, in the present study, the bonding procedure was performed after 2 weeks.

For the bonding procedure, etch-and-rinse method was used. This is in accordance with several studies, suggesting that the restorations to enamel with etch-and-rinse method are more predictable and give better bond strength to composites, than dentin.[17-19]

SBS values of Group C showed a significant difference when compared to Group A.

The application of Nd:YAG laser increases substrate temperature and induces changes in the structure of enamel. These structural changes manifest as microcavities resembling honeycombs.[19] Enamel bleaching with 35% HP also increases the depth of enamel irregularities and works synergistically with laser. These features followed by 37% phosphoric acid etching provide miniscule spaces that can be utilized for the adherence of sealants or composites.[19-24]

Recrystallization occurs due to increased energy density by the laser. The calcium and phosphorous loss of enamel, leading to the shift of organic matrix and its subsequent re-mineralization could result in greater bond strengths.[19-23]

This observation is consistent with the results by Basir *et al*., which indicated that the microtensile bond strength of specimens to Nd:YAG laser irradiation was notably superior to that of the other subgroups.[24]

Table 1: Descriptive statistics and the results of shear bond strength (MPa) in all study groups

Groups	Number of samples	Minimum	Maximum	Mean±SD
Group A - Control (only bleaching)	11	9.84	17.68	13.55±1.85
Group B – Bleaching + diode	11	11.60	16.20	14.79±1.65
Group C – Bleaching + ND:YAG	11	14.29	16.20	15.20±0.61

SD: Standard deviation, Nd:YAG: Neodymium-doped:yttrium aluminum garnet

Figure 1: (a) Armamentarium used; (b) Extracted teeth collected according to inclusion criteria; (c) Samples in each group (n = 11); (d and e) Dispensing and application of bleaching gel for each group; (f) Suctioning of the gel in between application; (g and h) Diode laser and its application, respectively; (i and j) neodymium-doped:yttrium aluminum garnet laser and its application, respectively; (k) Incremental composite buildup following bonding protocol; (l) Shear bond strength analysis using universal testing machine

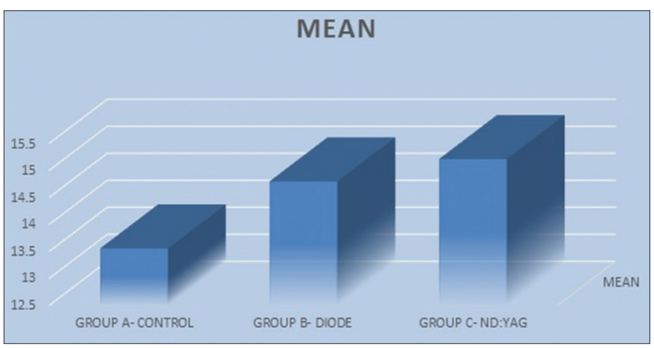

Figure 2: Bar graph showing mean shear bond strength of each group

In a similar vein, Rocha Gomes Torres *et al*. in 2012 discovered that Nd:YAG laser-assisted bleached enamel, the bond strength exhibited a value that was five times greater compared to the conventional method.[25]

Diode-assisted bleached enamel showed no significant difference in SBS values compared to only bleaching and Nd:YAG-assisted bleaching groups. This may be due to insufficient energy density by the diode laser to elicit adequate recrystallization of enamel.[9,26]

Mirzaie *et al*., in 2016, evaluated the surface roughness of enamel after diode and Nd:YAG laser-assisted bleaching. Their results showed that the most substantial increase in microroughness was observed after using conventional bleaching when compared to diode and Nd:YAG-assisted bleaching. In this study, the samples were stored in artificial saliva for 2 weeks postbleaching. This could considerably alter the bleached enamel surface in terms of remineralization and result in the outcome of SBS values.[27,28]

Table 2: Intergroup comparison by Dunn's multiple comparisons test

Comparison	Difference	P
Group A (control) versus Group B (bleaching + diode)	9.318 (NS)	>0.05
Group A (control) versus Group C (bleaching + Nd:YAG)	10.864*	<0.05
Group B (bleaching + diode) versus Group C (bleaching + Nd:YAG)	1.545 (NS)	>0.05

*Significance at $P<0.05$. NS: Not significant, Nd:YAG: Neodymium-doped: yttrium aluminum garnet

Further studies using Nd:YAG laser-assisted bleaching are necessary in this regard. Although this study could not fully simulate the complex oral environment, these results could pave way for further research on the use of Nd:YAG laser-assisted bleaching in cases of direct composite veneering postbleaching.

CONCLUSION

Within the limitation of this study, it was concluded that

Nd:YAG laser-assisted bleaching increases the SBS of nanofilled composite resin to bleached enamel. Lower SBS is obtained with diode laser-assisted bleaching when compared with Nd:YAG laser-assisted bleaching, though not statistically significant. In addition, no statistically significant difference was observed between nonassisted bleaching and bleaching with diode laser assistance.

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Conflicts of interest

There are no conflicts of interest.

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