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Effect of Nd:YAG and 980nm Diode laser irradiation as a hypersensitivity treatment on shear bond strength of metal orthodontic brackets to enamel

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ABSTRACT

Lasers are one of the tooth hypersensitivity treatments. This study aimed to determine the effect of irradiation of Nd:YAG 1064nm and 980nm Diode lasers, used for hypersensitivity treatment, on the shear bond strength (SBS) of metal orthodontic brackets to enamel. Ethylenediaminetetraacetic acid (EDTA) was used to simulate sensitivity in 70 extracted human premolars. The teeth were radiated with 1w Nd:YAG, 1.5w Nd:YAG, 1w Diode, or 1.5w Diode. All samples were incubated at 37° for 24 hours, after bonding the metal brackets. SBS values and adhesive remnant index (ARI) for each tooth was recorded. One-way analysis of variance (ANOVA) and Kruskal-Wallis test were used to compare the mean SBS and the distribution of ARI scores between the study groups, respectively. The SBS mean from the highest to the lowest were in 1w Diode (25.71Mpa), 1w Nd:YAG (24.66Mpa), 1.5w Diode (23.08Mpa), control (21.68Mpa) and 1.5w Nd:YAG (21.53Mpa) groups. No statistically significant difference existed between different groups, in terms of SBS (p=0.211) and ARI distribution (p=0.066). The application of Nd:YAG and 980nm Diode lasers to treat tooth hypersensitivity did not change the SBS of metal orthodontic brackets to the enamel and thus, are harmless to use for orthodontic patients.

Key words: dentin sensitivity; shear strength; lasers; orthodontic brackets; dental bonding.

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Introduction

Dentin hypersensitivity (DH) is a common chronic discomfort, which poses a challenge to dental practitioners.[1,2] The closest estimate and the average prevalence of DH based on the literature are about 11.5% and 33.5%, respectively.[2] It is a sudden sharp pain that originates from the effect of thermal, tactile, osmotic, or chemical stimuli on exposed dentin, which is not associated with dental defects or pathological factors.[3,4]

There are several potential causes of tooth hypersensitivity. Coronal enamel loss or root cementum removal results in dentinal tubule opening, which is directly associated with hypersensitivity pain.[5] In addition to attrition, erosion, abrasion, abfraction, gingival recession, and physiological changes (like aging), some dental treatments may also lead to DH.[5,6] For instance, surface treatment with 30-40% phosphoric acid, which is required for proper bracket bonding, eliminates the smear layer and may lead to DH.[7-9]

A widely accepted mechanism to explain this phenomenon is the movement of fluid within the exposed dentinal tubules due to physical stimuli, known as hydrodynamic theory.[10,11] Based on this theory, procedures that result in the occlusion of permeable dentinal tubules seem to be effective in pain control.[12,13]

The ideal treatment ceases pain immediately after a single application and has a long-lasting effect. On the other hand, it doesn't cause pulp irritation, tooth discoloration, and surface properties' alteration.[14] Up to now, there is no definitive or ideal DH treatment, and each patient is treated according to the etiology of his DH, using non-invasive and invasive methods.[15] Various chemical products including fluorides,[16] oxalates,[17] or arginine,[18,19] in addition to physical methods such as adhesives[20] or laser therapies[21] are applicable for this purpose.

Lasers act on tooth hypersensitivity via different mechanisms, as they have various intensities. Nd:YAG (Neodymium-doped yttrium aluminum garnet), Er:YAG (Erbium-doped yttrium aluminum garnet), Er, Cr:YSGG (Erbium, chromium-doped yttrium, scandium, gallium, and garnet), and CO2 are high-intensity lasers and treat DH by obliterating dentinal tubules,[22] while GaAlAs and He Ne are low-intensity lasers and reduce pain symptoms by blocking the transmission of pain stimuli.[23]

Among the near-infrared lasers, Diode and Nd:YAG lasers are commonly used in dentistry due to their cost-effectiveness and versatility.[24] Radiation of Nd:YAG and 980 nanometer (nm) Diode lasers on the tooth transfers heat so that a layer of melted mineral is placed on the surface of dentinal tubules and leads to narrowing or blockage of them.[25-34] Since the efficiency of adhesive systems depends on the diameter of the dentinal tubules[35] and the formation of a uniform hybrid layer on the tooth surface, laser irradiation can weaken the bond strength.[36,37]

Proper bonding of the bracket to the tooth surface is a major issue in fixed orthodontic procedures, as it affects the duration and outcome of the treatment. The bond should be strong enough that the brackets will not detach from the tooth during treatment, but can be removed at the end of treatment without damaging the enamel.[38] Adhesive type, bracket properties, tooth surface characteristics, and preparation technique prior to bonding have an impact on bond strength.[39]

Due to the prevalence of tooth hypersensitivity, the risk of DH at the beginning of orthodontic treatments, and the importance of proper bracket bonding to teeth, researchers are seeking to find the effect of each hypersensitivity treatment method on the bond strength of brackets. To the best of our knowledge, there is scant information about the effect of lasers in DH treatment, on the bond strength of brackets. The present study aimed to determine the effect of Nd:YAG and 980 nm Diode laser irradiation as a hypersensitivity treatment on shear bond strength of metal orthodontic brackets to enamel and to compare the adhesive remnant on the tooth surface.

Materials and Methods

This *in-vitro* study was conducted in March 2022, after approval of the Research Ethics Committee of the Tehran University of Medical Sciences (IR.TUMS.DENTISTRY.REC.1400.126).

Selection and preparation of samples

A total of seventy extracted human upper premolars were collected, immersed in 0.2% thymol for 24 hours,[40] and stored in saline at room temperature until the start of the study. The teeth were carries free, with no enamel cracks, defects, or hypoplasia. They were extracted for reasons not related to the purpose of this study. The periodontal tissue at the root surfaces was removed with a periodontal curette. Each tooth was placed separately in-side auto polymerizing acrylic blocks (Acropars, Tehran, Iran) so that the long axis of the tooth was perpendicular to the resin block and the cemento-enamel junction was 1-2 millimeter (mm) above the acrylic surface. Teeth were polished with a rubber cup, non-fluoridated pumice, and water for 10 seconds at a low speed. To simulate hypersensitive teeth, cotton balls containing 0.5 M ethylenediaminetetraacetic acid (EDTA) were placed in contact with the buccal surface of the crown of each tooth for 2 minutes, washed with water for 30 seconds and air dried.[41] Eventually, samples were randomly divided into five groups of 14. Study groups were as follows: i) G1: received Nd:YAG laser (LightWalker, Fotona, Slovenia) treatment (1 W and 10 Hz); ii) G2: received Nd:YAG laser treatment (1.5 W and 10 Hz); the first and second groups got irradiated in a pulsed manner (pulse width=300 microsecond), through a quartz fiber optic of 320 micrometer (μm) for 10 seconds. The fiber optic headpiece was 1 mm away from the tooth surface on the bracket bonding area; iii) G3: received 980 nm Diode laser (Simpler, DoctorSmile, Italy) treatment (1 W); iv) G4: received 980 nm Diode laser treatment (1.5 W); the third and fourth groups got irradiated in continuous emission form, through an optical fiber of 320 μm for 10 seconds. The fiber optic headpiece was 1 mm away from the tooth surface on the bracket bonding area; v) G5: did not receive any laser treatment.

Etching and bonding procedure

As an etchant, 37% phosphoric acid (Morvabon, Tabriz, Iran) was applied to buccal surfaces for 30 seconds. Acid was wiped away by gentle water flow and the enamel surface was dried by oil- and moisture-free air to reach an opaque white appearance. A thin layer of Transbond XT primer (3M Unitek, California, USA) was applied to the surfaces and dried thoroughly with mild airflow. Each metal bracket (American Orthodontics, Wisconsin, USA), fabricated for maxillary premolars, with the proper amount of Transbond XT light cure adhesive (3M Unitek, California, USA) on its base area, was placed in the middle of the buccal surface and pressed firmly onto it. Eventually, the excess composite was removed and cured for 20 seconds using LED light cure (Woodpecker, Guangxi, China), 10 seconds at each mesial and distal side of the bracket. One researcher (M.K.) performed the conditioning steps and another researcher (A.B.) bonded the bracket in all samples.

Samples were stored in distilled water for 24 hours in a 37°C incubator, before measuring SBS.

Shear bond strength test

SBS was measured by a universal testing machine (Zwick Roel, Ulm, Germany). A knife-edge blade was placed parallel to the tooth axis, between the bracket wings and the contact area of the base. The SBS force was applied at a crosshead speed of 0.5 mm/min and values were recorded in Newton units. To convert them to Megapascal (MPa), the values were divided by the area under the brackets.

Adhesive remnant index

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After performing the SBS test, each sample was examined at 10x magnification under a stereomicroscope (EZ4D, LEICA, Germany). Two members of the research team scored the adhesive residue on each tooth, according to the adhesive remnant index (ARI),[42] to reduce operator error. In case of disagreement between two people, the opinion of a third party was used.

Statistical analysis

IBM SPSS Statistics version 21 for windows (IBM Corp., Armonk, N.Y., USA) served for statistical analysis. Means and standard deviations (SD) served to describe SBS. One-way analysis of variance (ANOVA) served to compare the mean SBS among groups. Counts and percentages served to describe ARI scores distribution in different groups. Kruskal-Wallis test served to compare the distribution of ARI scores among groups.

Results

SBS

The mean (SD) SBS of each study group is reported in Table 1. The maximum and minimum mean values belonged to the 980 nm Diode 1 w and the Nd:YAG 1.5 w groups, respectively. Homogeneity of variance between the SBS in different groups was confirmed (Levene test p-value=0.124) and no statistical difference existed between the groups in terms of SBS (ANOVA p-value=0.211).

Figure 1 depicts SBS mean and 95% confidence interval in each group.

ARI

Less than 50% of the adhesive remained on the tooth surface in 72.9% of all samples after the SBS test. Table 2 demonstrates the detailed distribution of ARI scores in different groups. No statistical difference existed between the groups in terms of ARI score distribution (p-value=0.066).

Discussion

There is a variety of hypersensitivity treatments from chemical to physical methods, decreasing pain by blocking neurotransmitters or occluding dentinal tubules.[13] Due to the advancement of treatment methods and instruments, lasers have been introduced in many branches of dentistry.[43] The literature supports the immediate and long-term analgesic effect of laser treatments on tooth hypersensitivity.[44] However, the side effects of these treatments on the enamel are unclear and require further investigation. The present study aimed to evaluate the SBS of metal orthodontic brackets to enamel, after irradiation of two near infra-red lasers, used in DH treatments. We found out that the application of Nd:YAG and 980 nm Diode lasers on hypersensitive enamel did not alter the SBS of metal orthodontic brackets to the tooth surface.

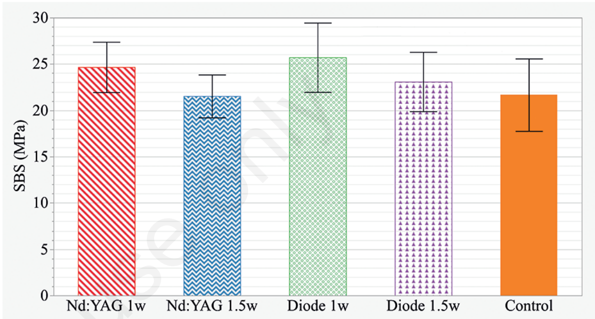

Figure 1. SBS mean and 95% confidence interval in study groups.

Table 1. Mean (SD), maximum, and minimum of SBS* in study groups.

Group	Mean (SD)	Minimum	Maximum
Nd:YAG 1w	24.66 (4.72)	13.70	31.97
Nd:YAG 1.5w	21.53 (4.00)	13.37	28.05
Diode 1w	25.71 (6.48)	16.86	36.96
Diode 1.5w	23.08 (5.55)	11.11	30.93
Control	21.68 (6.77)	12.64	35.99
Total	24.66 (4.72)	11.11	36.96

**Megapascal.*

Table 2. ARI score distribution among groups by counts (percentages).

Groups	ARI score (%)			
	0	1	2	3
G1	2 (14.3)	8 (57.1)	3 (21.4)	1 (7.1)
G2	4 (28.6)	6 (42.9)	4 (28.6)	0 (0)
G3	0 (0)	8 (57.1)	6 (42.9)	0 (0)
G4	6 (42.9)	7 (50)	1 (7.1)	0 (0)
G5	4 (28.6)	6 (42.9)	4 (28.6%	0 (0)
Total	16 (22.9)	35 (50)	18 (25.7)	1 (1.4)

G1, Nd:Yag 1W; G2, Nd:Yag 1.5W; G3, Diode 1W; G4, Diode 1.5W; G5, No laser. ARI Score: 0, all the adhesive remnant on bracket; 1, less than 50% adhesive remnant on tooth; 2, more than 50% adhesive remnant on tooth; 3, all the adhesive remnant on tooth.

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Although Nd:YAG laser irradiation leads to a morphologically changed and acid-resistant surface,[25,45] irregularities in the tooth occur due to melting and recrystallization of the surface which increases the micromechanical bond.[46] Furthermore, prior studies have shown that Nd:YAG laser irradiation raises the concentration of calcium and phosphorus in dentinal tubules, which ultimately strengthens the bond between dentin and adhesive.[47,48] Laser radiation on enamel might cause changes similar to those on dentin.

In the present study, laser irradiation for purpose of tooth hypersensitivity treatment, compared to the control group, did not significantly change the SBS of brackets to the enamel. Also, there was no significant difference in the SBS of brackets to enamel, between the groups treated with Nd:YAG and 980 nm diode lasers with powers of 1 and 1.5 w.

In line with the present study, in Yazıcı et al.'s study, the shear bond strength of two types of self-etch adhesives with dentin samples did not decrease after Nd:YAG and Er:YAG lasers irradiation, for the treatment of tooth sensitivity.[49] Also, Nd:YAG laser radiation did not affect the shear bond strength of dentin with resin cement used to bond ceramic restorations.[50] In addition, the 1096 nm Nd:YAG laser, which was applied to reduce the permeability and block the dentinal tubules, did not affect the shear bond strength of the resin composite to dentin.[51] There is another interesting finding that shows that Nd:YAG laser irradiation for the treatment of tooth sensitivity of simulated sensitive samples, before restoration with composite, even strengthens the micro tensile bond.[52] In contrast to these findings, in the study of Akca *et al.*,[53] the micro tensile bond strength of composite to dentin was significantly reduced following Nd:YAG laser irradiation, as a DH treatment. The lack of a standard methodology in using the laser to treat dental sensitivity and as a result, intervention with various techniques and parameters that are incompletely reported in studies, can lead to conflicting results. It should also be noted that these studies were conducted on dentin samples and the difference between the results of them and enamel studies is possible.

In line with the present study, Can-Karabulut[54] showed that the SBS of composite to dentin after laser irradiation in the red wavelength region (Diode 650nm) is not significantly different from the bond strength of the control group. In addition, a study of composite restorations in non-carious cervical lesions that have been subjected to diode laser irradiation demonstrated that tooth sensitivity decreased, but the durability of the restoration remained the same.[55] Meanwhile, Aranha *et al.*[56] concluded that samples that were exposed to 660nm Diode laser for the treatment of DH had significantly lower mean dentin bond strength than the control group. Although a diode laser was used in the previous study, the variation of wavelength and power, used for the intervention, may have caused the difference in the results. Also, the previous study was conducted on dentin samples, while the present study investigated the strength of the enamel bond.

Pumice paste, sodium bicarbonate, hydroxyapatite, bioglasses, glass ionomers, dentin bonding, and resin restorations, physically and using fluoride, oxalate, glutaraldehyde-based agents, and calcium compounds chemically block the dentin tubules; thereby reduce tooth sensitivity.[57] The application of these materials can cause changes in the surface characteristics of the tooth, including bond strength.

The study of Khoroushi and Ghazalgoo[58] showed that the use of a desensitizing agent containing potassium nitrate, fluoride, and amorphous calcium phosphate (ACP), as a tooth hypersensitivity treatment caused by bleaching, does not weaken the SBS of composite to enamel; This is in line with the current study that showed no weakening of the SBS of orthodontic metal bracket to tooth enamel, following the use of laser for the same reason. Similarly, another study found no significant difference in the micro SBS of two self-etching primer adhesive and total-etching primer adhesive systems to teeth, after bleaching and tooth sensitivity treatment with casein phosphopeptide-amorphous calcium phosphate (CPP-ACP).[59] In addition to treating tooth sensitivity, CPP-ACP paste is also used for remineralization with the same application method. Studies on CPP-ACP used for remineralization have shown that the use of this paste does not significantly alter the SBS between composite and enamel in the etch and rinse adhesive system.[60]

There are similar findings regarding the SBS of orthodontic brackets to enamel after the application of CPP-ACP paste for purpose of remineralization, indicating that SBS remains the same.[61] In contrast, a significant decrease in the bond strength of orthodontic adhesives, used to bond brackets to etched enamel surfaces, has occurred after the use of Gluma Desensitizer™.[62]

Just as laser application to treat tooth sensitivity did

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not reduce SBS, a clinical study (*in-vivo*) showed that a desensitizer containing potassium nitrate and fluoride, used after bleaching, did not significantly alter the SBS of the composite to enamel.[63] On the other hand, Türkkahraman and Adanir[64] showed that by using a combination of potassium nitrate with fluoride or using oxalate, the bracket-to-enamel SBS decreased. In addition, following the treatment of tooth sensitivity with oxalate desensitizers, calcium oxalate crystals are deposited on the dentin surface and, by forming an impermeable layer, limit the formation of resin tags in the collagen matrix; For this reason, the SBS of composite to dentin decreases significantly.[65] On the other hand, the formation of calcium oxalate crystals has also been observed in the enamel margin of dentin samples, treated with oxalate, which can interfere with the formation of resin-enamel junctions[65,66] and lead to bond weakening. In another study, the shear bond strength of resin cement to dentin was significantly reduced in the presence of desensitizer agents containing resin.[67]

In the present study, no comparison was made between different methods of tooth sensitivity treatment. However, by putting together the results of other studies in this field, it seems that potassium nitrate, fluoride, ACP, or CPP-ACP don't have much negative effect on enamel bond strength. On the other hand, the use of compounds containing oxalate, glutaraldehyde, or resin has shown the potential to reduce bond strength. Considering these findings, Nd:YAG and 980nm Diode lasers, in terms of effect on SBS, seem to have similar, and in some cases better outcome than conventional desensitizers.

To evaluate the adhesive remaining on the teeth, we reported the ARI score of each sample. The absence of a significant difference between the intervention groups and the control group confirmed the equality of SBS. On the other hand, the uniformity of this index between the groups assures the dentists that removing the adhesive residue and polishing the tooth to restore a smooth and polished surface does not lead to damage to the tooth and is easily possible.

There are several studies in the literature on the effects of DH treatments, including lasers, on the dentin-adhesives bond strength.[36,49,51,52,68] These studies prepared valuable data for treating patients with exposed dentin. But not all patients who suffer from DH have completely lost their enamel or dentin lining. One of the strengths of the current study is that instead of using dentin blocks, the specimens were prepared more similarly to what dentists, especially orthodontists, encounter. On the other hand, only little research on enamel samples after laser irradiation is available. Hence, the present study is novel in evaluating laser irradiation effects on enamel SBS.

In our study, tooth sensitivity was simulated on the samples by mechanical and chemical methods, but it is unclear to what extent the prepared teeth represent clinical dental sensitivity and how severe it is. Although this *in-vitro* study has provided valuable information, it should be noted that the oral cavity is a complex environment, full of stress, tension, temperature changes, acid challenges, humidity, and plaque.[69] Considering the lack of saliva and dentinal fluid that directly affect the bond strength, it must be admitted that it is difficult to predict clinical performance. Therefore, it is necessary to conduct additional *in-vivo* studies in this field.

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Conclusions

Within the limitations of this *in-vitro* study, the authors concluded that the application of Nd:YAG and 980 nm Diode lasers as tooth hypersensitivity treatment do not alter the shear bond strength of orthodontic brackets to tooth enamel and can be used as an effective DH treatment in orthodontic treatment candidates.

Contributions: NC, SS and MK contributed to the investigation, supervision, writing, review, and editing of the study. The study was conceptualized by SS, and NC, Data curation, data visualization, and formal analysis were carried out by MK and AB. All authors read and approved the final manuscript.

Conflict of interest: the authors declare no potential conflict of interest, and all authors confirm accuracy.

Ethics approval and consent to participate: the study was approved by Tehran University of Medical Sciences ethics committee (approval ID: IR.TUMS.DENTISTRY.REC.1400.126).

Informed consent: not applicable.

Patient consent for publication: not applicable.

Availability of data and materials: all data generated or analyzed during this study are included in this published article.

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