Content available at: https://www.ipinnovative.com/open-access-journals

IP Indian Journal of Orthodontics and Dentofacial Research

Journal homepage: www.ipinnovative.com

Original Research Article

A comparitive evaluation of the shear bond strength of Er:YAG laser ablation on enamel at 3 different power outputs with that of onventional acid etching technique - An invitro study

Anjana S Nair[1,*], Anil Kumar P[1], Amal S Nair[1]

[1] *Dept. of Orthodontics, Shree Mookambika Institute of Dental Science, Kanyakumari, Tamil Nadu, India*

A R T I C L E I N F O

Article history:
Received 22-07-2020
Accepted 04-08-2020
Available online 04-09-2020

Keywords:
Lasers
erbium: yttrium - aluminum garnet (Er: YAG)
acid etching
Shear bond strength (SBS)
Universal Testing Machine (Instron)

A B S T R A C T

Background: The aim of this study is to determine whether bonding of stainless steel orthodontic brackets to tooth enamel prepared by laser etching would result in a similar bonding capability as those prepared by acid etching using 37 % phosphoric acid; and also to compare the shear bond strength.

Materials and Methods: Eighty four samples were prepared for the study. The 4 groups were Group 1- The enamel was etched with 37 % phosphoric acid, Group 2- Er: YAG laser etching was done at 1W power output, Group 3- Er: YAG laser etching was done at 2W power output and Group 4- Er:YAG laser etching was done at 3W power output. All groups have 20 teeth for shear bond strength testing and one tooth for SEM evaluation. Shear bond strength testing was performed on all teeth using Instron universal testing machine.

Results: Analysis of the variance indicated a significant difference ($P < 0.005$) among the groups. Maximum shear bond strength was shown by laser etching at 2 W to the tooth surface for 15 seconds in compared to conventional acid etching. In this study the highest shear bond strength was found in the 2-W laser etched group (16.09 ± 0.42) MPa, followed by the 1-W laser etched group (12.62 ± 0.35) MPa, 3-W laser etched group(12.01 ± 0.31) MPa and acid etched group.(6.42 ± 0.32)MPa.

Conclusion: The results showed that at that laser etching at 2 W to the tooth surface for 15 seconds had statistically significant higher shear bond strength in comparison to conventional 37% phosphoric acid technique. The use of increasing the laser power output more than 2 W did not significantly increase the bond strength. The shear bond strength of all the three Laser etched groups was clinically acceptable. Enamel etching with Er: YAG Laser (2W for 15 seconds) produced maximum bond strength than acid etching and could be a viable alternative method.

1. Introduction

It has been widely recognized for many years that accurate bracket positioning and durable bonding is of much importance in the efficient application of biomechanics and in realizing the full potential of any appliance. In orthodontic practice the bond strength between the enamel surface and bracket base must be enough to withstand the mechanical and thermal effects of the oral environment. Bonding can be accomplished with various enamel conditioning procedures which can either be chemical or mechanical.

Since the report of Buonocuore[1] in 1955, the standard protocol to treat enamel for successful bonding has been acid etching with 37% phosphoric acid. Phosphoric acid etching has been used for tooth enamel preparation and for resin bonding and also for orthodontic attachment. An irregular surface of enamel is created mostly by dissolving hydroxyapatite which allows the flow of fluid adhesive components which locks the adhesive, leading to micromechanical retention. One potential disadvantage of acid etching is the demineralization of the most superficial

* *Corresponding author*.
E-mail address: anjananair843@gmail.com (A. S. Nair).

https://doi.org/10.18231/j.ijodr.2020.028

layer, which makes the enamel surface more susceptible to long-term acid attack and caries, especially around orthodontic attachments.

In 1964 lasers was applied in dentistry by Stern and Sognnaes.[2] The lasers were used to inhibit caries by increasing the resistance of enamel to demineralization. Later on, four-ruby lasers,[3] Carbon dioxide (CO2) and Neodymium: Yttrium- Aluminium-Garnet (Nd: YAG) lasers, have been used in dental practice.[4] The reported application of lasers to a variety of dental procedures has prompted a great deal of interest particularly for soft tissue surgery, etching of dental enamel and to facilitate debonding of orthodontic brackets. Lasers were also demonstrated to vaporize and crater enamel surface with a high Energy beam. As a result the attention has been focused on the treatment of soft and hard tissue lesions. In the recent years there has been a growing interest and advancements in the application of lasers. Thus different laser systems evolved for different needs. One of the most commonly used lasers in dentistry is the Er: YAG lasers (Erbium doped yttrium aluminium garnet) on all the biological tissues that contain water molecules. Compared with other lasers the Er: YAG lasers[5] can more effectively alter enamel and dentin surfaces because of its 2.94 nm wavelength emission. Er: YAG laser has a greater ability to handle dental hard tissue with high efficiency and the ability of laser irradiation to remove the smear layer has been also reported.

The development of the erbium: yttrium-aluminium-garnet (Er: YAG) laser and more recently, the erbium, chromium: yttrium-scandium-gallium-garnet (Er, Cr: YSGG) laser permit ablation in both soft and hard tissues without any thermal side effects. These lasers can ablate enamel and dentin effectively because their light is highly and efficiently absorbed by both water and hydroxyapatite. Histological studies have revealed no pulpal inflammatory responses in dental hard tissue irradiated with the Er, Cr: YSGG laser.[6]

Laser radiation in particular causes thermally induced changes on the enamel surface. It causes surface roughening and irregularity similar to acid etching to a depth of 10 μ to 20 μ, depending on the type of laser and the energy applied to the surface .In hard-tissue procedures, the water vapour production induces an increase of the internal pressure within the tissue, resulting in an explosive expansion called a micro explosion which produces changes in the morphology of the enamel, including effects that have been described as craters and cracks.

With laser etching procedural errors can be reduced and does not involve heat, making it attractive for daily use. Furthermore laser etching of enamel and dentin has been reported to yield micro cracks or uneven surface making it less prone to caries attack. It has also been suggested that laser etching might create remineralisation of micro spaces that trap free ions. Thus laser induced caries resistance would of great importance in orthodontics. Because of this property laser etching holds a lot of promise as an alternative to acid etching procedure. This suggests that the Er: YAG laser may etch enamel suitably for orthodontic purposes. Therefore, the present study was conducted to test the shear bond strength, surface characteristics, and fracture mode of brackets bonded to enamel etched with an Er: YAG laser operated at different power outputs and to compare them with conventional acid etching.

The aim of this study is to determine whether bonding of stainless steel orthodontic brackets to tooth enamel prepared by laser etching would result in a similar bonding capability as those prepared by acid etching using 37 % phosphoric acid; and also to compare the shear bond strength.

2. Materials and Methods

The following study was done at Department of Orthodontics, Sree Mookambika Institute of Dental Sciences, Kulashekaram, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Biomedical Technology Wing, Poojappura, Thiruvananthapuram and also at National Institute of Interdisciplinary Science And Technology, Thiruvananthapuram.

A total of 84 sound extracted human premolars for orthodontic purpose were randomly divided into four groups of 21 samples each. Teeth were mounted vertically in self-cure acrylic resin block so that the crown portion alone was exposed. The teeth were mounted on acrylic blocks such that the roots were completely embedded in the acrylic up to the cement enamel junction leaving the crown portion exposed. The blocks were color coded for easy identification.

The buccal enamel surfaces of the teeth were pumiced, washed for 30 seconds and dried for 10 seconds with a moisture free air spray. All groups have 20 teeth for shear bond strength testing and one tooth for SEM evaluation and ARI index score.

The group were as follows

1. Group I - enamel was etched with 37 % phosphoric acid.
2. Group II - Er: YAG laser etching was done at 1W power output.
3. Group III - Er: YAG laser etching was done at 2 W power output.
4. Group IV - Er: YAG laser etching was done at 3W power output.

For acid etching, 37% phosphoric acid was applied to the enamel surface, rinsed with running water and gently dried with dryer. Each procedure was done for 30 seconds, bonding agent was applied on the tooth using the applicator tip, left for 20 seconds, air blown, and the adhesive (Trans bond XT 3M) was then applied and light cured for 40 seconds on the surface.

For hard tissue procedures it utilizes advanced lasers and water atomization methods to safely and efficiently perform tissue cutting, contouring, etching and resection. It provides optical energy to a user controlled distribution of atomized water droplets. The water droplets absorb the optical energy in hydro photonic cutting effects.

The hydro photonic process refers to the removal of tissue with high energized water particles. Strong absorption of laser energy by atomized water droplets results in intense yet controlled water particle excitation and micro expansions. The resulting forces induce mechanical separation of surface material quickly and cleanly removing hard tissue. The optical power output and atomized water spray can be adjusted to use. It generates precise hard tissue cuts by laser energy interaction with water above and at the enamel surface.

The laser used here is Er: YAG Laser (Waterlase MD,Biolase Technology Inc. Irvine, California, U.S.A) and the device operates at a wavelength of 2780 nm, a Turbo hand piece was used with pulse duration of 25 pulses/second(25 Hz) were used. The average power output can be varied from 0.1 to 8 W. Three power settings (1W, 2W, 3W) were used. The air and water levels were 60 and 30 % respectively. The laser beam was perpendicular to the enamel at a distance of 0.5 to 3mm. The diameter of the treated spot was about 1.2 mm

After etching stainless steel standard premolar brackets (0.018 inch, 3M Gemini) were bonded. These brackets had a bonding area of 12.66mm^2. A thin uniform coat of adhesive was applied to the etched surface. After the application of bonding material (Trans bond XT, 3M Unitek) the bracket was placed on the tooth surface, adjusted to its final position and pressed firmly. Excessive sealant and adhesive were removed from the periphery of the bracket base to keep each bond area uniform. Each side of the tooth (mesial, distal, occlusal and gingival) was light cured using a curing light for 10 seconds a total of 40 seconds. After that the specimens were stored in deionized water for 24 hours before debonding.

2.1. *Shear Bond Strength Testing*

Once the bonding protocols were completed the specimens were then subjected to shear bond strength test using Universal Testing machine. The machine basically contains two jigs. The upper jig was attached to the moving element of the machine cross load element. The immovable part was attached to the lower jig. The crosshead elements were connected to the plotter and the monitor. The teeth were carefully oriented in the jig in order to maintain distance and parallel orientation of the labial surface of the tooth and the shear die. The shear force at a crosshead speed of 0.5mm/minute was transmitted to the bracket by a shear blade, the same size as the bracket. The force required to shear the bracket causing bonding failure was recorded in Newton's and the bond strengths were calculated in megapascals (MPa).

The test was repeated on all the samples and the values obtained were recorded.The data was stored on PC using the software Origin 6.1 (Origin Lab, California, USA) The values obtained were recorded. The samples were tested for shear bond strength on Universal Testing machine at a cross head speed of 0. 5 mm/minute and the readings of shear bond strengths were recorded in Newton and converted into Megapascals by following equation:

Shear bond strength in Megapascals = $\frac{Debonding\ force\ in\ Newton's}{Bracket\ base\ area\ (12.6mm^2)}$

2.2. *SEM (Scanning electron microscopy)*

One specimen in each group was selected, whose surface was conditioned with 37% phosphoric acid and Er: YAG Laser with 1W, 2W and 3 W. The crowns were sectioned from the roots with a carborandum disc using water spray at the labial cemento-enamel junction. Each crown was sectioned vertically in labial-lingual direction. The sections of tooth were cleaned with water and dried with compressed air. The specimens were then examined in JSM-840 scanning electron microscope (JEOL Ltd, Tokyo, Japan) operated at 20 KV. Photographs were taken at the magnification of 500× and 1000 × to analyse the surface roughness and etching pattern

2.3. *Modified Adhesive Remnant Index*

After the brackets were debonded, the enamel surface of each tooth was examined under 10 times magnification stereomicroscope (Discovery V20, Stereo). The teeth were mounted on the mounting table one by one and the microscope was adjusted to view the enamel surface. A modified adhesive remnant index (ARI) score was used to quantify the amount of remaining adhesive on each tooth.

Scoring	Description
5	All of adhesive remained on the bracket
4	More than 90% of adhesive remained on the bracket
3	More than 10% or less than 90% of adhesive remained on the bracket
2	Less than 10% of adhesive remained on the bracket
1	No adhesive remained on the bracket

2.4. *Statistical analysis*

Statistical analysis was done using SPSS 20.0 version. Descriptive statistics including mean and standard deviations were calculated for each group. Comparisons of shear bond strengths of different surface treatments were performed using ANOVA test.

3. Results

Shear bond strength of four different groups was compared. The mean shear bond strength in Group-I was found to be 6.42±0.32. It increased to 12.62±0.35 in Group-II. In Group III it increased to16.09±0.42 and in group IV it decreased to 12.01±0.31. Group II has significant difference compared with group-I and III but not with group-IV. Group-IV has no significant difference compared with Group-II. There was a significant difference shear bond strength MPa values compared group-IV with group-I and III. In this study the highest shear bond strength was found in the 2-W laser etched group (16.09±0.42) MPa, followed by the 1-W laser etched group (12.62±0.35) MPa, 3-W laser etched group (12.01±0.31) MPa and acid etched group. (6.42±0.32)MPa.

The highest values for SBS were measured in group Ib (20.21±0.94 MPa). The lowest values for SBS were measured in group IIIc (7.22±2.15 MPa). Mean values of shear bond strengths of different group are given in table II. Multiple comparisons of mean value of SBS (MPa) of different groups are illustrated.

3.1. Scanning Electron Microscopic Study

Group I (Etched with 37 % phosphoric acid for 30 seconds) regular rough surface and spaces that of Type I acid etching. Group II (1W) Laser irradiation shows an irregular & uneven surface with slight grooves. Group III (2W) Laser irradiation shows uniform concentrated circles accompanied by the appearance of micro cracks. Group IV (3W) Laser irradiation shows more micro cracks and the surface destruction was more prominent.

Table 1:

	Groups	Color coding
Group-I	37 % phosphoric acid	Blue
Group-II	Laser etching at 1W	White
Group-III	Laser etching at 2W	Yellow
Group IV	Laser etching at 4W	Pink

Table 2:

Groups	Type of etching	Shear bond strength (MPa) (MEAN±SD)
Group-I	Conventional method	6.42±0.32
Group-II	Laser etching at 1W	12.62±0.35
Group-III	Laser etching at 2W	16.09±0.42
Group-IV	Laser etching at 3W	12.01±0.31

4. Discussion

The direct bonding of orthodontic brackets has revolutionized the practice of Orthodontics. However

Fig. 1: 80 Extracted Human Premolars (For Shear Bond Strength Testing)

Fig. 2: Group II Samples (20) For Laser Etching 1 W

Fig. 3: Group III Samples (20) For Laser Etching 2 W

Fig. 4: Group IV Samples (20) For Laser Etching 3 W

Table 3:

S. No	Group-I: Conventional Method (CM)	Group-II: Laser Etching 1W (LE1W)	Group-III: Laser Etching 2W (LE2W)	Group-IV: Laser Etching 3W (LE3W)
1.	6.45	12.89	15.90	12.05
2.	6.03	11.94	16.39	12.13
3.	5.98	12.78	16.56	11.56
4.	6.85	12.65	15.28	12.05
5.	6.23	11.95	16.73	12.19
6.	6.56	12.56	16.40	12.07
7.	5.89	12.80	16.29	11.93
8.	6.45	12.95	15.89	12.03
9.	6.95	12.48	15.90	12.34
10.	6.34	12.83	15.82	12.60
11.	6.67	12.91	16.05	12.34
12.	5.87	12.84	16.23	11.56
13.	6.34	11.75	16.38	12.29
14.	6.89	12.74	16.29	11.74
15.	6.34	12.56	15.03	12.04
16.	6.29	12.60	16.29	11.63
17.	6.56	12.95	16.43	11.89
18.	6.84	12.63	16.04	12.05
19.	6.57	12.80	15.79	12.18
20.	6.34	12.73	16.08	11.34
Mean± SD	6.42±0.32	12.62±0.35	16.09±0.42	12.01±0.31

Table 4: IV

Groups	Type of etching	Shear Bond Strength (MPa) (MEAN±SD)
Group-I	Conventional Method (CM)	6.42±0.32
Group-II	Laser Etching 1W (LE1W)	12.62±0.35
Group-III	Laser Etching 2W (LE2W)	16.09±0.42
Group-IV	Laser Etching 3W (LE3W)	12.01±0.31

Fig. 5: Armamentarium

there is a need to improve the bonding procedures to save time as well as to minimize the enamel loss without jeopardizing the ability to maintain clinically successful bond strength. 37% Phosphoric acid etching is one of the common methods to bond resin to enamel. One disadvantage of enamel etching is the complete removal of the smear layer and exposure of dentinal tubules. Acid etching results in chemical changes that may modify the organic matter and decalcify the inorganic component.[7]

White spot lesions have been a regular finding in cases where conventional acid etching was used. Thus enamel etching with phosphoric acid creates an etch pattern by creating surface irregularities and demineralised areas, making it more prone to enamel caries especially around orthodontic attachments.

The Er: YAG laser was introduced in 1974 by Zharikov et al as a solid-state laser[8] that generates a pulsed laser with a wavelength 2,940 nm. Of all lasers emitting in the near- and mid-infrared spectral range, the absorption of the Er: YAG laser8in water is the greatest because its 2,940 nm wavelength coincides with the large absorption band for water. The absorption coefficient of water of the Er: YAG laser is theoretically 10,000 and 15,000 - 20,000 times higher than that of the CO2 and the Nd: YAG lasers, respectively.

In our study, the Er: YAG laser was selected because; it appears to have lesser thermal effects than other lasers. Er: YAG laser at 2 W showed increased ARI score and thus decreased the risk of enamel fracture, and they are thus effective in reducing shear bond strength of orthodontic brackets. The idea to use Er: YAG laser for bracket bonding

Fig. 6: Er:YAG Laser Unit

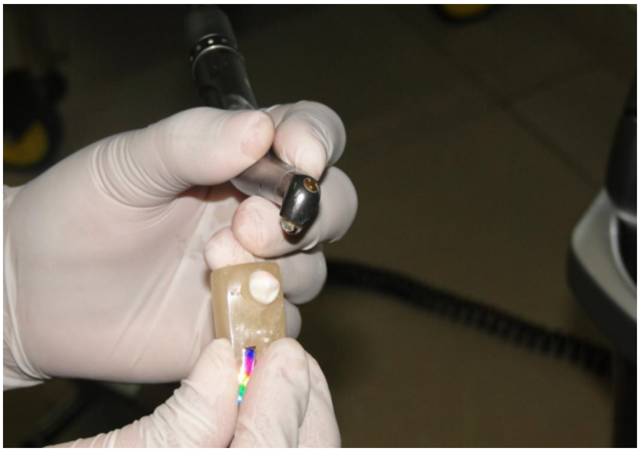

Fig. 7: Laser Etching At 1 W

is quite new and only few references are found in the literature.

The ability of Er: YAG laser[9] to effectively ablate dental hard tissues at 2940nm wavelength emission is coincident with the absorption band of water and hydroxyapatite of enamel. This study was designed to determine whether laser systems can be used in orthodontics with minimal tooth structure destruction and optimal bracket retention.

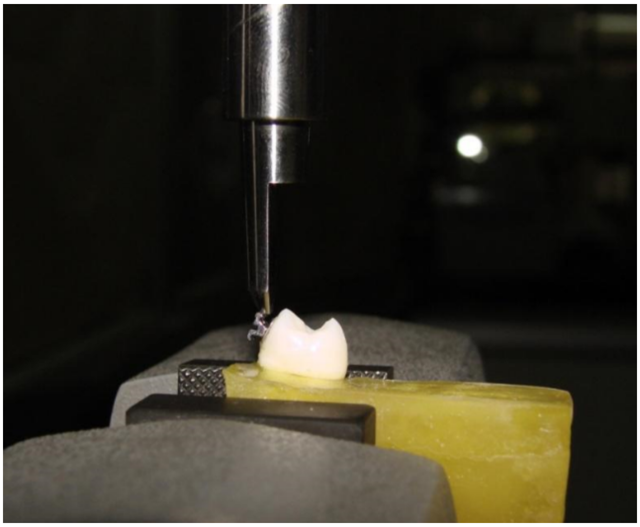

Fig. 8: Shear bond Strength Testing usingInstron machine

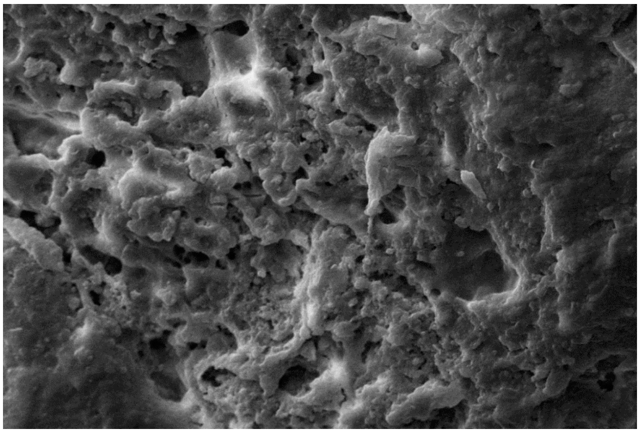

Fig. 9: SEM showingLaser Etched Enamel Surface -1W(2000X)

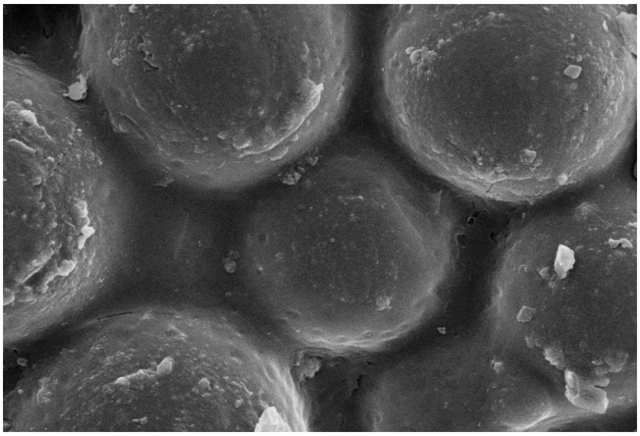

Fig. 10: SEM showingLaser Etched Enamel Surface -2W (2000X)

In this present study the influence of all factors were negated by the use of same curing light (Woodpecker LED Light), same adhesive thickness over the bracket base by pressing the bracket firmly against the tooth surface for all the samples by the same operator. Each side of the tooth (mesial, distal, occlusal and gingival) was light cured using Woodpecker LED curing light for 10 seconds for a total of 40 seconds.

Instron universal testing machine was used to apply forces of uniform nature in shear Mode to all samples at crosshead speed of 0.5mm2/minute. Here the conventional acid etching for 15 seconds provided lower shear bond strength for bracket bonding. The Laser wavelength was kept constant (2780 nm). The laser power outputs were varied because the main purpose of the present study was to determine the shear bond Strengths and surface characteristics of brackets bonded to enamel etched with an Er: YAG laser operated at 3 different power outputs.

The usage of 3 different power outputs causes different effects. The hand piece of the Er: YAG laser system is light and useful. Ease of handling aids in the use of this apparatus and prevents unnecessary etching of the enamel. Nevertheless, even when using liquid acid etchants, there is always a shift of acid on the enamel surface.

Er: YAG laser systems create precise hard tissue cuts by the virtue of laser[12] energy interacting with water at the tissue surface called a hydrokinetic system. However low power outputs that would probably etch enamel (1W, 2W, 3W) were used only with a constant distance of 3mm. The usage of three different outputs can cause different effects. The varying power outputs and duration of laser irradiation make different etching patterns. In this study the highest shear bond strength was found in the 2-W laser etched group (16.09 ± 0.42) MPa, followed by the 1-W laser etched group (12.62 ± 0.35) MPa, 3-W laser etched group (12.01 ± 0.31) MPa and acid etched group. (6.42 ± 0.32)MPa.

These four etching modalities were clinically acceptable. Group II with 1-W laser irradiation had showed lower shear bond strength whereas 2-W Group III has superior bond strength than 1-W and 3-W. Laser irradiation with 2-W is superior to all other laser etched groups and showed increased shear bond strength than phosphoric acid etching. Laser etching at 2-W (Group III) showed significant higher shear bond strength when compared to conventional acid etching. There were no significant shear bond strength differences between 1-W and 3-W laser etching. It was observed an increase in power during laser etching more than 2-W will decrease the bond strength.

Laser irradiation with 1-W and 3-W was almost similar. Reynolds (1975)[10]reported that 6 to 8 Mpa were clinically acceptable bond strength were as Maijer[8] andSmith (1986) found 8 MPa to be adequate.The shear bond strength of 3-W laser was found to be more than acid etching but inscanning electron microscope, it was noticed that there is more destruction of theenamel, with more micro cracks. Hence, the ideal power setting for etching the enamelto attain acceptable shear bond strength would be of 2-W.

The Scanning electron microscope analysis evaluation helped us to inspect the amount of destruction on the etched enamel surfaces. In Group I the enamel surface was acid etched with 37% phosphoric acid. Here a regular rough surface and spaces (Type III acid etching) can be seen as described by Silverstone et al. The hydroxyapatite dissolved by phosphoric acid produced resin tags and rough surfaces that provided the mechanical locks for the resin. There is a presence of the keyhole pattern of enamel observed.

In Group II the laser irradiation was done at 1W for 15 seconds and shows an uneven surface, numerous coarse scratches and slight grooves. Slot-type pattern of enamel ablation is seen in the 2,000x magnification indicating selective ablation of the enamel prisms occurring over the lased surface.[10] The lased surface shows a definite micro-retentive surface with presence of elevations and depressions. A micro roughened surface was observed at this low energy output level of 1 W however the depth of the roughened areas seemed lesser as compared to the higher energy output of 2-W.

In Group III the enamel surface laser irradiated with 2-W showed Uniform concentrated circles accompanied by the appearance of micro cracks that aided in the penetration of the resin. This shows a uniform micro-retentive surface over the etched area. This maybe the reason for maximum shear bond strength. In Group IV the enamel surface was irradiated with 3W and showed more micro cracks and saucer-like cavitation is seen on the surface. The surface destruction was more prominent with coarse scratches, wide grooves, which might be the reason for decreased shear bond strength seen in Group IV.

From a clinical standpoint, saving chair side time also improves adhesion because it reduces the risk of salivary contamination[8] the required time for acid etching varies from 15 to 60 seconds. Osorio et al reported that 15 seconds of enamel etching with phosphoric acid is longer than necessary for successful orthodontic bonding. Fifteen seconds of water spraying and 15 seconds of air drying are also necessary in phosphoric-acid etching. A total of 45 seconds for each tooth is needed with phosphoric acid. The required time is shorter with laser systems. The time needed for laser systems is only 15 seconds, which is shorter than that required time for phosphoric acid.

Laser system is at least 30 seconds faster than phosphoric-acid etching.[9] Thirty seconds of chair-time saving for each tooth equates to at least 5 minutes of chair-time saving for a full-mouth bonding. Here the required time was not recorded, but it was evident that laser saves chair time. The Er: YAG laser has also been shown to have anti-bacterial properties.[10]The taste of phosphoric acid may also not be well accepted by the patients hence laser etching would be a better option.

The results of the study indicate that laser has the potential to successfully bond orthodontic brackets with clinically acceptable bond strength or even more compared with acid etching. Further in vivo studies are needed to assess the clinical efficiency of laser etching.

5. Conclusions

Based on the results of the study, the shear bond strength of all the three Laser etched groups was clinically acceptable. The mean shear bond strength obtained with an Er: YAG laser (operated at 1W, 2W and 3W for 15 seconds) is an alternative to acid etching. Enamel etching with Er: YAG Laser (2 W for 15 seconds) produced maximum Shear bond strength than acid etching and could be a viable alternative method. More preferred etching pattern was seen with 2 W Er: YAG Lasers (Group III).

6. Source of Funding

None.

7. Conflict of Interest

None.

References

1. Buonocore MG. A Simple Method of Increasing the Adhesion of Acrylic Filling Materials to Enamel Surfaces. *J Dent Res*. 1955;34(6):849–53.
2. Stern RH, Sognnaes RF. Laser effect on dental hard tissues. A preliminary report. *J South Calif Dent Assoc*. 1965;33(1):17–9.
3. Maiman TH. Stimulated Optical Radiation in Ruby. *Nat*. 1960;187(4736):493–4.
4. Keller U, Hibst R. Ultrastructural changes of enamel and dentin following Er: YAG laser radiation on teeth Laser Surgery: Advanced Characterization, Therapeutics, and Systems II. *Int Soc Optics Photonics*. 1990;1200:408–15.
5. Fraunhofer JAPV, Allen DJ. Thermal effects associated with the Nd/YAG dental laser. *Angle Orthod*. 1993;63(4):299–304.
6. Iglesias A, Flores T, Moyano J, Artés M, Gil FJ, Puigdollers A, et al. In Vitro Study of Shear Bond Strength in Direct and Indirect Bonding with Three Types of Adhesive Systems. *Mater*. 2020;13(11):2644.
7. Maijer R, Smith DC. A new surface treatment for bonding. *J Biomed Mater Res*. 1979;13(6):975–85.
8. Zharikov EV, Zhekov VI, Kulevskii LA, Murina TM, Osiko VV, Prokhorov AM, et al. Stimulated emission from Er3+ions in yttrium aluminum garnet crystals at $\lambda = 2.94\ \mu$. *Soviet J Quantum Electronics*. 1975;4(8):1039–40.
9. Reynolds IR. A Review of Direct Orthodontic Bonding. *Br J Orthod*. 1975;2(3):171–8.
10. Lee BS, Hsieh TT, Lee YL, Lan WH, Hsu YJ, Wen PH, et al. Bond strengths of orthodontic bracket after acid-etched, Er: YAG laser-irradiated and combined treatment on enamel surface. *Angle Orthod*. 2003;73(5):565–70.

Author biography

Anjana S Nair Reader

Anil Kumar P Professor and HOD

Amal S Nair Professor

Cite this article: Nair AS, Kumar P A, Nair AS. **A comparitive evaluation of the shear bond strength of Er:YAG laser ablation on enamel at 3 different power outputs with that of onventional acid etching technique - An invitro study**. *IP Indian J Orthod Dentofacial Res* 2020;6(3):137-144.