Laser Versus Conventional Acid Etching Technique on BondStrength of Orthodontic Brackets (An in Vitro Study)

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ABSTRACT

Aims: This *in vitro* study was undertaken to evaluate and compare the effect of acid etching and/or diode laser (1064 nm) irradiation on shear bond strength of orthodontic brackets. **Materials and Methods:** Thirty freshly extracted human premolars were included in this study. Laser irradiation was done by using the new 1064 nm diode laser with output power of 2.5 Watt in continues mode, also use stainless steel orthodontic brackets (Roth, 22–slot size), and use orthodontic flowable composite resin which needs no bonding fluid. The 30 human teeth were divided into 3 groups (each group consist of 10 teeth): Group A–use acid etching (37% phosphoric acid) for 1 minute to bond bracket to tooth surface (control group), group B–use laser irradiation for 30 seconds with Indian ink (coated on teeth). Group C–use laser irradiation for 30 seconds with Indian ink after that use acid etching for 1 minute. Shear bond strength measured by using unconfined shear testing machine at a cross head speed of 5 mm/min. **Results:** The shear bond strength means were as follows: Group A: 11.27 MPa, group B: 6.21 MPa, group C: 14.04 MPa. The acid etching after 1064 nm diode laser irradiation (group C) has significantly higher bond strength ($p \leq 0.05$) than remaining groups. In group B, orthodontic brackets had significantly lower shear bond strength ($p \leq 0.05$) than remaining groups. **Conclusions:** These results indicate that acid etching after laser irradiation enhances and improves the bonding of orthodontic composite resin to human enamel. In the same time 1064 nm diode laser irradiation with ink coating is not consider as a replacement to acid etching in bonding of orthodontic brackets to human enamel.

Key words: Diode laser 1064 nm, shear bond strength, acid etching.

Bonding of composite resin on tooth surface is based on the mechanical locking of the adhesive to irregularities in the enamel surfaces of the tooth and to mechanical locks formed in the base of the orthodontic attachment. Successful bonding in orthodontics, therefore, requires careful attention to the three components of the system: The tooth surface and its preparation, the design of the attachment base and the bonding material itself.[1]

Total etching with 30–40% orthophosphoric acid is accepted to be one step in adhesive techniques that use acid etching as a separated procedures.(2) Acid etching agents are capable of removing several microns of superficial enamel and creates a porous surface, resin tags form within this porous surface, providing micromechanical interlocking of resin and enamel.(3) Resin tags that form between enamel rod peripheries are called macrotags. A much finer network of thousands of smaller tags form across the end of each rod where individual hydroxyl apatite crystals have been dissolved, leaving crypts outlined by residual organic material. These fine tags are called microtags. Macrotags and microtags are the basis for enamel micromechanical bonding.(4)

Laser radiation of 1064 nm wavelength is well established in dental lasers, but previously only available from the Nd:YAG crystal as the lasing medium. Currently, with the new technology a semiconductor medium (diode) can produce laser with the same wavelength (1064 nm) and same properties which is dramatically smaller, more efficient, longer pulse duration and more control output power.

Hard tooth structure contains inorganic (hydroxyapatite), organic (primarily collagen), and water components. By volume, enamel contains approximately 96% hydroxyapatite and 4% protein and water. Each of these tissue components absorbs laser energy at different wavelengths. Enamel surface changes characterized by etching, cracking, melting, pitting, and frank cratering. Some chemical changes can also occur, including loss of carbonate, sintering, recrystallization, and formation of calcium phosphate. Like the physical alterations, chemical changes are temperature dependent and It is not clear whether chemical changes in the enamel would affect resin bonding.(3, 5)

Several characteristics of lased dental hard tissue have been considered advantageous: Microscopically rough surfaces without demineralization, open dentinal tubules without smear layer production and tooth surface sterilization.(6)

It has been proved that the laser irradiation with the wavelength 1064 nm (which was represented by Nd:YAG laser) is capable of producing irregularities of enamel surface look like those resulting from the use of conventional acid etching technique.(7–9) Also it has been reported that short term etching after irradiation with Nd:YAG laser (1064 nm) enhances the bonding of composite resin to human enamel.(10)

MATERIALS AND METHODS

The samples consist of thirty extracted human premolars of normal shape, size which were extracted for orthodontic treatment purposes.

The criteria for tooth selection included intact buccal surface with no caries, cracks, restorations and not subjected to any pretreatment with chemical agents, the teeth were stored in distilled water at room temperature.(11, 12)

The teeth were randomly divided into 3 groups (each group consisted of 10 teeth):

Group A–control group: Use acid etching (37% phosphoric acid), coated on tooth surface for 1 minute, apply orthodontic composite resin which need no fluid bonding agent (Vivadent Heliosit flowable orthodontic composite) on orthodontic bracket base then attached on etched, dry tooth surface, composite resin then polymerized using light cure unit (wavelength 400–500 nm, intensity 400 mw/c^2).

Group B: Use diode laser irradiation (1064 nm wavelength) applied on black Indian ink coated on buccal surface of tooth sample for 30 seconds. Laser radiation is used for conditioning of tooth surface prior of bracket attachment. The laser radiation strongly reacts with pigmented tissue causing an increase of the laser energy absorption, the enamel surface can be melted and vaporized in a more efficient way by the use of black India ink.(7)

Group C: Use combination of former 2 groups above, after diode laser irradiation on tooth surface coated with Indian ink for 30 seconds, apply acid etching (37% phosphoric acid) on tooth surface then fix brackets using orthodontic composite resin on dry tooth surface.

Laser irradiation was performed by using diode laser (FOX™, ARCLASER–Germany) (Figure 1), with wave length of 1064nm and output power of 2.5 watt for 30 seconds in continues mode by direct contact with continues movement of the tip of the fiber every tooth receive about 75 j.

Figure (1): Diode laser radiation device (FOX™, ARCLASER–Germany)

A new class of low viscosity resin composites, commonly called "flowable composites", has become established in dentistry. Flowability is regarded as a desirable handling property which allows the material to be injected through small–gauge dispensers, thus simplifying the placement procedure and amplifying the range of possible clinical applications. However, composites with a lower filler–content and/or elastic modulus have shown better marginal sealing compared to composites with a higher filler–content.(13)

For mounting of teeth, plastic rings were used (20 mm outside diameter, 18 mm inside diameter and 26 mm height) the rings were filled with dental stone to half of its height, after stone setting, the teeth were fixed by sticky wax on the stone surface, so the tooth would be in centre and perpendicular to the base,(14) the ring were placed on the base of the surveyor in a manner that long axis of the tooth was parallel to the long axis of the analyzing rode of the surveyor (Figure 2), then we started to fill the ring with cold cure acrylic resin till cement–enamel junction.(15)

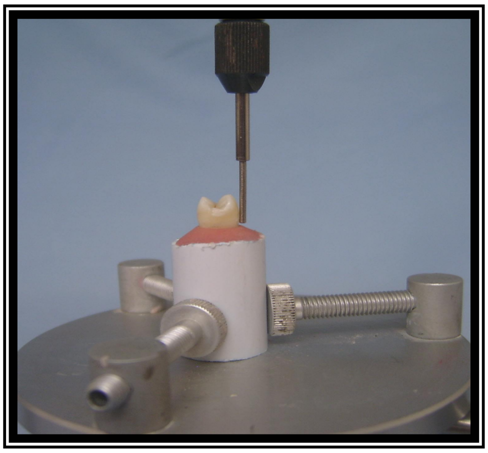

Figure (2): Long axis of the tooth parallel to the long axis of the analyzing rode of the surveyor

After conditioning of tooth surface either by acid etching and/or diode laser irradiation with Indian ink, the orthodontic bracket was hold by clamping tweezers, the orthodontic composite resin was applied on the base of the bracket and the bracket was transferred to the centre of the buccal surface of the crown of the premolar tooth at a distance of 4.5 mm from the occlusal surface.(16) A load of 200 gm was directed at a right angle to the bracket according to the pressure standardizing procedures. Then curing was started by using halogen light curing unit,(17) the curing light was applied for 1 minute in all direction and the distance between the curing tip and the bracket was within the accepted range (0–5 mm) and was adjusted to about 2 mm.(18)

To standardize the pressure the sample was placed on the surveyor table which already positioned in a parallel plane with the floor, the bracket was loaded under 200 gm (100 gm load + 100 gm weight of the surveyor shaft) which placed on the top of the surveying arm in which the chisel of the surveyor was inserted, the surveying arm was adjusted so that the chisel was just fitting in the bracket slot(19) (Figure 3). The shear bond strength was measured by using the unconfined shear testing machine (Figure 4).

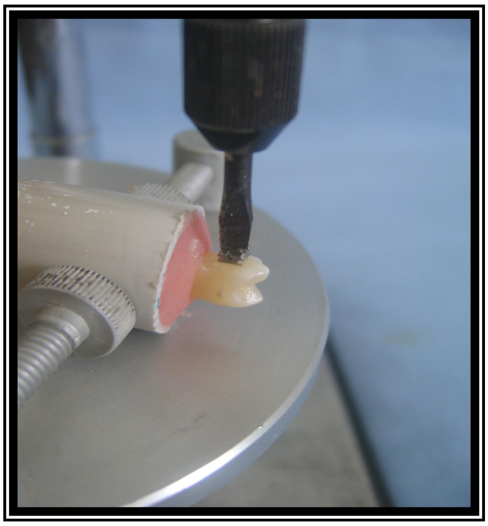

Figure (3): Brackets loaded under 200 gm in which the chisel just fit in bracket slots.

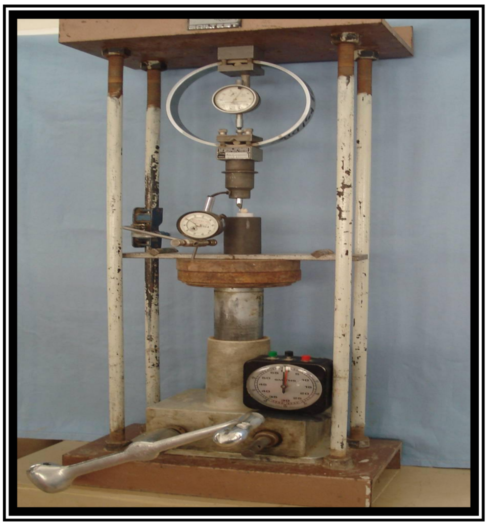

Figure (4): The unconfined shear testing machine.

Each bonded bracket was positioned parallel to the direction of load application, a custom made chisel shaped rod (knife edge rod) was directed toward the composite–enamel interface, so the force was exerted adjacent and parallel to the bracket base and applied to the bond interface in an occluso–gingival direction. A cross head speed of 5 mm/min was used(20, 21) (Figure 5).

The maximum shear bond strength necessary to debond the bracket was recorded in Newton unit and converted to megapascal (MPa) unit by dividing the fracture load in Newton unit to the surface area of the bonded bracket base,(22) the surface area of the bracket was found to be equal to 8.75 mm^2, so the shear bond strength was calculated and expressed in MPa according to the following equation(23):

Shear Bond Strength (MPa)= Force (Newton)/Surface Area (mm^2)

Figure (5): Shear bond strength measurement.

RESULLTS

The descriptive analysis that includes mean, standard deviations, standard error minimum and maximum values of shear bond strength in MPa of all three groups are listed in Table (1).

The descriptive statistics shows that group B reflect smallest mean of shear bond strength (6.219 MPa), and group C shows highest shear bond strength mean (14.048 MPa), while group A reflect intermediate value of shear bond strength (11.279).

Table (1): Descriptive analysis of shear bond strength in MPa for all groups

Groups	No.	Minimum	Maximum	Mean	$\pm$ SD	SE Mean
A	10	8.43	13.79	11.279	1.768	0.5593
B	10	4.55	8.56	6.219	1.328	0.42
C	10	11.44	16.53	14.048	1.77	0.5597

The analysis of variance (ANOVA) was used to compare the shear bond strength of the 3 groups. This test showed significant difference between the three groups studied at $p \leq 0.05$ as in Table (2).

The results of Duncan's Multiple Range Tests showed that group C had the highest mean of shear bond strength value in regard to other groups, and had significant difference at $p \leq 0.05$ with other groups. While group B had the lowest mean value with significant difference at $p \leq 0.05$ from other groups. The remaining group (group A) was distributed on statistical level between the highest and the lowest mean value with a significant difference between them at $p \leq 0.05$, as in Table (3).

Table (2): One–Way ANOVA test for all groups

	Sum of Squares	df	Mean Square	F–value	Significance
Between Groups	315.223	2	157.611	58.915	0.000*
Within Groups	72.231	27	2.675		
Total	387.454	29			

*Significant difference existed at $p \leq 0.001$.

Table(3): Duncan' multiple range test for all groups

Groups	No.	Mean* ± SE	Duncan's Group**
A	10	11.279 ± 0.559	A
B	10	6.219 ± 0 .42	B
C	10	14.048 ± 0.5597	C

*Mean measure unit in MPa.

**Different letters mean significant difference at $p \leq 0.05$.

DISCUSSION

This study was conducted to evaluate and compare the etching of enamel by the new diode 1064 nm laser and/or the conventional method by using acid etching agent for bonding orthodontic brackets on tooth surface. The use of diode laser irradiation alone with black Indian ink in order to increase the absorption of laser light by enamel surface for bonding orthodontic bracket (group B) had shown a significantly lower bond strength than that achieved by using acid etching technique, which can be explain that acid etching the surface has clean enamel prism without melted and carbonized structure and this may disturb the adhesion of composite to enamel.(7, 10, 24)

Static laser exposures produced central craters surrounded by areas of damaged enamel. The damage was characterized by melting, pitting, cracking, and general roughening. The effects of laser energy on enamel surfaces are related not only to absorption of that energy by specific enamel components, but also by reflectance of light by the surface. As energy is absorbed, the tissue is heated. At relatively low temperatures, water is lost. Various mineral phase changes and melting occur as the temperature rises. Rapid development of heat (and subsequent rapid cooling when the exposure ceases) causes stresses in the enamel that can lead to flaking and ejection of material. Thermal shock is likely to be greatest at the area of beam focus.(3, 5)

Concerning the different distribution of phosphorus and calcium between the lased and unlased enamel surface, it was observed that the organic substances were evaporated with laser energy, this was explained by the melted and recrystalizes enamel surface so the irradiated enamel surface was melted and homogeneous like lava.(7)

Also it is found that after laser irradiation, carbonized materials and layer remain on the tooth surface and this would disturb the adhesion of composite resin (agreed with results of group B), and it had been hypothesized that acid etching after laser irradiation would be effective to remove these materials and improve the bond strength.(10)

The laser irradiated enamel surface produced surface fissuring and a union or blending of the distinctive etch pattern normally seen in acid etched enamel, this blending effect likely prevented the penetration of resin into the enamel resulting in lower enamel bond strength values (as group B results), the subsequent addition of acid etchant to laser ablated enamel created delicate etch pattern that assumed the appearance of a more retentive surface than that created by laser etching alone (agreed with group C results), the subsequent use of phosphoric acid after laser irradiation eliminates the surface scaling and flaking on enamel surface.(25)

CONCLUSIONS

The results of this study indicate that acid etching after laser irradiation enhances and improves the bonding of orthodontic composite resin to human enamel. In the same time 1064 diode laser irradiation with ink coating is not consider as a replacement to acid etching in bonding of orthodontic brackets to human enamel.

REFERENCES

1. Proffit WR, Fields HW, Ackerman JL. Contemporary Orthodontics. 3rd ed. Mosby. St Louis. 2000; Pp: 397–398.
2. Carmona VB, Lopez SG, Lujan TB, Munoz CDH, De La Macorra JC. Effect of etching time of primary dentine on interface morphology and microtensile bond strength. *J Dent Mater*. 2006; 22: 1121–1129.
3. Swift EJ, Edwards GS, Perdigao J, Thompson JY, Nunes MF, Ruddell DE, Negishi A. Free–electron laser etching of dental enamel. *J Dent*. 2001; 29: 347 –353.
4. Bayne SC, Thompson JY, Taylor DF. Dental Materials. Cited in: Sturdevant CM, Roberson TM, Heymann HO, Swift EJ. Art and Science of Operative Dentistry. 4th ed. Mosby. St Louis. 2002; p: 237.
5. Fowler B, Kuroda S. Changes in heated and laser–irradiated human tooth enamel. *Calcified Tiss Inter*. 1986; 38: 197–208.
6. Ceballos L, Osorio R, Toledano M, Marshall GW. Microleakage of composite restoration after acid or Er–YAG laser cavity treatment. *J Dent Mater*. 2001; 17: 340–346.
7. Eduardo CP, Cecchini RCM, Marques JLL, Matsumoto K. Scanning electron microscopy study on enamel etching with Nd:YAG laser and phosphoric acid. *J Clin Laser Med Surg*. 1995;13(2): 81–85.
8. Roberrts–Harry DP. Laser etching of teeth for orthodontic bracket placement: A preliminary clinical study. *Lasers Surg Med*. 1992; 12(5): 467–470.
9. Ariyaratnam MT, Wilson MA, Makie IC, Blinkhorn AS. A comparison of surface roughness and composite/ enamel bond strength of human enamel following the application of the Nd:YAG laser and etching with phosphoric acid. *Dent Mater*. 1997; 13(1): 51–55.
10. Tanase S, Takada Y, Tamura Y. Shear bond strength of Nd:YAG laser–irradiated versus acid–etched human enamel. *Inter Cong Series*. 2003; 1248: 171–173.
11. Romano FL, Tavares SW, Nouer DF, Consani S, Magnani DA. Shear bond strength of metallic orthodontic brackets bonded to enamel prepared with self–etching primer. *Angle Orthod*. 2005; 75(5): 849–853.
12. Coreil MN, Ledoux PM, Ledoux WR, Weinberg R. Shear bond strength of four orthodontic bonding systems. *Am J Orthod Dentfac Orthop*. 1990; 97(2): 126–129.
13. Irie M, Hatanaka K, Suzuki K, Wastts DC. Immediate versus water–storage performance of Class V flowable composite restoration. *J Dent Mater*. 2006; 22: 875–883.
14. Farquhar RB. Direct bonding comparing a polyacrylic acid and a phosphoric acid technique. *Am J Orthod Dentfac Orthop*. 1986; 90(3): 187–194.
15. Cacciafesta V, Sfondrini MF, Scribante A, Angelis MD, Klersy C, Effect of blood contamination on shear bond strength of brackets bonded with a self etching primer combined with a resin modified glass ionomer. *Am J Orthod Dentfac Orthop*. 2004; 126(6): 703–708.
16. Mclaughlin RP, Bennett JC, Trevisi HJ. Systemized Orthodontic Treatment Mechanics. 1st ed. Mosby International Ltd. Spain. 2001; p: 63.
17. Signorelli MD, Kao E, Ngan PW, Gladwin MA. Comparison of bond strength between orthodontic brackets bonded with halogen and plasma arc curing lights: An *in vitro* and *in vivo* study. *Am J Orthod Dentofac Orthop*. 2006; 129(2): 277–282.
18. Oyama N, Komori A, Nakahara R. Evaluation of light curing units used for polymerization of orthodontic bonding agents. *Angle Orthod*. 2004; 74(6): 810–815.
19. Al–Khayyat NA. Shear bond strength of bonded buccal and lingual brackets for three orthodontic composites: An *in vitro* study. MSc thesis. College of Dentistry. University of Mosul. 2000.
20. Bishara SE, Soliman MMA, Oonsombat C, Laffon JF, Ajlouni R. The effect of variation in mesh–base design on the shear bond strength of orthodontic brackets. *Angle Orthod*. 2004; 74(3): 400–404.
21. Bishara SE, Ostby AW, Laffoon JF, Warrenc JJ. The effect of modifying the self–etchant bonding protocol on the shear bond strength of orthodontic brackets. *Angle Orthod*. 2007; 77(3): 504–508.
22. Elvebak BS, Rossouw PE, Miller BH, Buschang P, Ceen R. Orthodontic bonding with varying curing time and light power using an argon laser. *Angle Orthod*. 2006; 76(5): 837– 844.
23. Rajagopal R, Padmamabham P, Gnanamani J. A comparison of shear bond strength and debonding characteristics of conventional, moisture–insensitive, and self–etching primers *in vitro*. *Angle Orthod*. 2004; 74(2): 264–268.
24. Barbakow F, Peters O, Havranek L. Effects of Nd:YAG lasers on root canal walls: A light and scanning electron microscopic study. *Quintessence Int*. 1999; 12: 837–845.
25. Dunn WJ, Davis JT, Bush AC. Shear bond strength and SEM evaluation of composite bonded to Er–YAG laser–prepared dentine and enamel. *J Dent Mater*. 2005; 21: 616–624.