The Effects of Argon Laser Irradiation on Shear Bond Strength of Orthodontic Brackets: An In Vitro Study

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Purpose: Argon lasers, because of their significant time savings over conventional curing lights and their ability to confer demineralization resistance on enamel, have been investigated for use in orthodontics. The purpose of this study was to assess their effect on the shear bond strength of brackets.

Materials and Methods: Fifty intact human premolars were randomly divided in to 5 groups. In groups 1 and 2, the brackets were bonded with conventional light (600 mW) and argon laser (200 mW), respectively. In groups 3 and 4, the enamel was prelased, and then brackets were bonded as in groups 1 and 2, respectively. Brackets in group 5 were bonded conventionally, and after 2 days of immersion in artificial caries solution, laser was applied. Then all of the samples immersed in Ten Cate solution for 10 days. The shear bond strength was subsequently measured automatically using an Instron machine. One-way ANOVA, Dunnett's t-test and Tukey's test were used for data analysis. The adhesive remnants were also evaluated.

Results: The mean shear bond strength of groups 2 and 5 were significantly lower than group 1 ($p = 0.02$, $p = 0.01$ respectively). There were no statistically significant differences between any laser treated groups ($p > 0.05$). The adhesive remnant index analysis revealed no statistically significant difference between all 5 groups ($p > 0.05$).

Conclusion: Lasing the enamel before bracket bonding had no effect on bond strength. Laser application, during or after bracket bonding, may lead to lower bond strength.

Keywords: orthodontics, argon laser, composite curing system, bond strength.

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The use of light-cured adhesives has become the most popular method of bracket bonding, because of their ease of application and the extended time they allow for bracket placement.[1] Since lasers were introduced to dentistry in the 1960s, many uses have been found for them,[2] including applications in orthodontics.[3]

The argon laser was introduced in the 1990s.[3] The argon laser produces a limited number of very specific wavelengths of light energy, with 476 nm, 488 nm and 514.5 nm being the most important.[4] This coincides with the peak activity centered around 480 nm for the activation of most dental composites.[5]

Many general practitioners have used the argon laser for polymerization of restorative materials.[6] In contrast to conventional visible light, the argon laser is collimated and provides more consistent power density over distance.[4,7] Visible light curing (VLC) units use bulbs, reflectors, and filters which can impair curing efficiency.[7] Recent research has focused on the argon laser's ability to cure composite resins used in bonding orthodontic appliances rapidly.[7,8] Using argon laser, the orthodontist could decrease the total curing time to 10-16 minutes per patient.[9]

Argon laser's ability to confer demineralization resistance on enamel is also an important aspect of clinical success. Although many orthodontists use the argon laser because of these properties, not all aspects of its efficacy for curing orthodontic adhesives have been fully investigated.[5]

A review of the literature reveals that laser-cured restorative composites have bond strengths comparable with that produced by conventional halogen lights.[5,8,10-15] Argon laser polymerization has demonstrated the potential to improve shear bond strengths in both enamel and dentin. Another study found no significant difference between bond strengths using argon laser and halogen lamp curing units.[8] Shanthala and Munshi[16] have demonstrated equal or higher shear bond strength with a 10-s argon laser exposure compared with conventional visible light exposure for 40 s. A recent study by Talbot et al[7] showed that when orthodontic brackets were bonded with an argon laser or a VLC unit, shear bond strengths were equal.

The purpose of the present in-vitro study was to determine whether argon laser irradiation of enamel, before, during, or after bracket bonding would affect bond strength. The adhesive remnant index (ARI) was scored for each tooth after debonding. This study was designed in concordance with another study, performed simultaneously and reported in the second part, which evaluated the demineralization resistance effect of argon laser. The samples of these two studies were the same.

MATERIALS AND METHODS

In this experimental in vitro study, 50 extracted caries-free human premolars were collected and stored in a solution of 10% formalin. The buccal enamel surface of collected teeth had no developmental defects, cracks, caries, or white spots. The teeth had not been exposured to any pretreatment with chemical agents such as hydrogen peroxide. The remaining visible soft tissue having been debrided with a razor blade, the teeth were cleansed and polished with nonfluoridated pumice and rubber prophylactic cups. The teeth were mounted in acrylic placed in phenolic rings with the facial surfaces of the teeth perpendicular to the bottom of the mold.

Each set of 10 teeth was randomly assigned to one of the following five groups:

1. In the control group, brackets (S.S Standard 018 Slot, Dentarum, Germany) were bonded to buccal surface of each tooth using a Quartz Tungsten Halogen curing unit (Faraz Dentin halogen light, Faraz Mehr, Isfahan, Iran).
2. An argon laser (593 AP Line tunable system, Mellas Griot, USA) was used to bond brackets to teeth.
3. The buccal surfaces of the teeth were irradiated with argon laser before etching, then the brackets were bonded conventionally.
4. The same as group 3, except that bonding of brackets was also done by argon laser.
5. Brackets were bonded conventionally and after 2 days' immersion in artificial caries solution, teeth were lased.

The brackets were bonded to the teeth by the following methods: the buccal surfaces were acid etched for 15 s with 37% phopsphoric acid (3M/Unitek, Monrovia, CA, USA), rinsed with water for 30 s, and dried with an oil free air stream for 20 s, giving the enamel a chalky white appearance. Transbond XT (3M/Unitek) primer was painted onto the etched surface. All brackets were bonded with Transbond XTt (3M/Unitek), following the manufacturer's instructions, using either a visible-light curing unit or an argon laser. The curing time was 40 s for the visible light (20 s mesially and 20 s distally) and 10 s for the laser (5 s mesially and 5 s distally).

An argon laser at approximately 200 mW, 5 mm beam size, power density of approximately 1020 mW/cm^2 and a conventional visible light at approximately 600 mW, 13 mm beam size, power density of approximately 900 mW/cm^2, were used to polymerize the composite.

Finally, all bonded samples were immersed in an artificial caries solution (Ten Cate solution) consisting of 2.2 mM/L Ca^{2+}, 2.2 mM/L $po4^{-}$, 0.05 M acetic acid, 0.50 ppm fluoride at a pH of 4.3 at room temperature with constant circulation for 10 days. Following that, the samples were stressed by thermocycling for 24 consecutive hours. Each thermocycle consisted of immersing the bonded samples in water for 30 s at 5°C immediately followed by a 30-s immersion at 55°C for a total of 1500 successive cycles.

Table 1 Mean, SD and range of shear bond strength of each group in MPa

Groups	Mean	Standard deviation	Range	Number
1	10.80	3.34	8.40-13.19	10
2	6.85	3.02	4.68- 9.021	10
3	9.87	3.45	7.40-12.33	10
4	8.92	3.55	6.38-11.46	10
5	8.59	3.39	5.38- 7.65	10

Table 2 Mean of bond strength difference in treated groups vs control group using Dunnett test

Groups		Mean deference	Standard error	Number	p-value
2	1	- 3.94	1.37	10	0.02*
3	1	- 0.93	1.37	10	0.90
4	1	- 1.88	1.37	10	0.46
5	1	- 4.28	1.37	10	0.01*

All teeth were then stored in deionized water for 1 week before debonding. A Zwick Universal Test Machine (Zwick; Ulm, Germany) was used to test the shear bond strength of each sample. An occlusogingival load was applied to each bracket producing a shear force at the bracket-tooth interface. This was accomplished by utilizing the flattened end of a steel rod attached to the crosshead of the machine. A computer electronically connected to the Zwick test machine recorded the result of each test in Megapascals (MPa). Shear bond strengths were measured at a crosshead speed of 0.5 mm/min.

Debonded specimens were examined under 7X magnification with an optical microscope (stereomicroscope SR, Zeiss; Oberkochen, Germany) in a blind situation. The amount of residual adhesive left on the teeth was assessed according to the adhesive remnant index (ARI).[17] An ARI score of 0 indicated that no adhesive was left on the tooth in the bonded area, 1 indicated that less than half of the adhesive was left on the tooth, 2 indicated that more than half was left on the tooth and 3 indicated that all the adhesive remained on the tooth, along with the impression of the bracket base. Statistical analysis was performed using one-way ANOVA, Dunnett's t-test, and the Kruskal-Wallis test. P-values < 0.05 were considered statistically significant.

RESULTS

Mean shear bond strengths and standard deviations for the 4 treated groups and the control group are listed in Table 1. Based on the 1-way ANOVA, the mean shear bond strength between 5 groups was statistically significant ($p = 0.01$). Data analysis using Dunnett's t-test showed that groups 2 and 5 had significantly lower bond strengths compared with the control group ($p < 0.05$), as shown in Table 2 .

The Kruskal-Wallis test revealed that there were no significant differences in the ARI scores between groups ($p = 0.39$) (Table 3).

DISCUSSION

The most widely used light sources for photoactivating resin-based materials are conventional QTH light units. In orthodontics, the argon laser has been investigated as an alternative to the visible light curing (VLC) systems for rapid and effective polymerizing of composite resins.[5,9] Laser has also been shown to be safe for the intraoral polymerization of composite materials.[8] Lasing the enamel may be effective in reducing enamel decalcification that is often seen during fixed appliance therapy.[9]

Table 3 ARI scores in 5 groups using the Kruskal-Wallis test

Group	Mean rank	Number	p-value
1	32.4	10	0.46
2	23.6	10	
3	33.33	10	
4	30.9	10	
5	27.1	10	

1. Control, bonding with Halogen light; 2. Bonding with argon laser; 3. Prelasing, then bonding as in group 1; 4. Prelasing, then bonding as in group 2; 5. Bonding with light, lasing after 2 days immersion in Ten Cate solution.

The aim of the present study was to evaluate the effect of argon laser on orthodontic bracket's shear bond strength in 3 different stages; before, during and after bonding.

All teeth used were premolars with same anatomy and contour; in order to mimic clinical conditions Ten Cate solution and thermocycling were used, because the long duration of orthodontic treatment (about 2 years) makes oral conditions favorable for caries extension.

In the present study, the mean shear bond strengths were lower than those obtained by Lalani et al[8] and Talbot et al,[7] but were nevertheless within the range of clinically sufficient bond strengths (5.89-7.85 MPa)[18] in all groups of this study. All studies used the same adhesive (Transbond XT), but these differences could be the result of thermocycling and also etching time. Samples in Talbot et al's study were not thermocycled.[7] Studies in restorative dentistry have shown that thermocycling of samples can decrease the bond strength by 20% to 70%.[19,20] The etching time in the study by Lalani et al[8] was longer than the etching time in present study. Some studies have reported that increased etching time up to 30 s caused increased bond strength.[21] Ten Cate solution may also effect bond strength.

The results of this study showed a higher mean shear bond strength compared to those of James et al.[5] In James' study, the brackets were debonded with a lower crosshead speed (0.1 mm/min) than used in our study. Lower crosshead speed might better remove the influence of the material's strain rate sensitivity, which might be expected to decrease bond strength.[5]

Significant differences were found between bond strengths of brackets in the control group, which were placed with a conventional halogen light (40 s), and those placed with an argon laser (10 s). Even though the narrower wavelength and collimation are beneficial for argon laser, the total light energy (intensity of the light times the duration of exposure) appears to be a more important factor when determining the degree of polymerization. Greater total light energy generally results in greater bond strength. Because the argon laser cures composites at a considerably lower intensity than the halogen light, it might require curing times longer than the recommended 10 s to provide comparable total light energy. This result corroborates those of James et al.[5]

Bond strengths were significantly lower in group 5, the samples of which were lased after bracket bonding with a conventional halogen light. Samples were immersed in Ten Cate solution for 48 h before laser application to ensure complete composite polymerization. It seems the laser imparts some structural changes to the composite surface when the polymerization is completed, compromising the bond strength. Lower bond strength may also be explained by longer immersion in Ten Cate solution. Recently, however, Talbot et al reported that argon laser application after bracket placement with a delay time of 24 h may lead to further polymerization of composites and improve bond strength.[7]

Although shear bond strength in group 4 was higher than in group 2, this increase was not statistically significant, so the results indicate that lasing the enamel before bracket placement with either conventional curing light or argon laser did not significantly affect bond strength. Perhaps the acid-etch procedure obliterates all microstructural changes in the enamel surface imparted by laser treatment. Another possibility is that laser application alters the enamel structure, but not by an amount sufficient to affect bond strength. This finding is similar to those obtained by Talbot et al.[7]

There were no statistically significant differences in the ARI between the 4 groups and the control group. In spite of sufficient bond strengths, the majority of the composite was left on the bracket base in all groups. This result may be clinically interesting.

Research is currently under way to investigate the effective usage, capability, and limitations of the argon laser. Further studies are needed to confirm the argon laser's ability to make enamel significantly more resistant to demineralization, a benefit that might justify the application of such an expensive piece of dental equipment.

CONCLUSION

According to the present study, lasing the enamel before bracket bonding has no effect on subsequent shear bond strength. Argon laser, when used during or after bracket placement, may lead to significant reduction of shear bond strength.

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