Original Article

The Effect of Argon Laser Irradiation on Demineralization Resistance of Human Enamel Adjacent to Orthodontic Brackets: An In Vitro Study

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Abstract: Argon lasers, because of their significant timesavings over conventional curing lights, have been investigated for use in bonding orthodontic brackets. They are also being investigated for their ability to confer demineralization resistance on enamel, which is of great interest in orthodontics. A two-part in vitro study on 86 human posterior teeth was conducted to determine the effects of a five-second argon laser exposure on shear bond strength and to evaluate the effects of a five- and 10-second argon laser exposure (250 mW) on demineralization of enamel surrounding orthodontic brackets after exposure to an artificial caries bath. Brackets cured with the argon laser for five seconds yielded mean bond strengths similar to those attained with a 40-second conventional light-cured control ($n = 13$ per group, 20.4 vs 17.8 MPa). Brackets cured with the argon laser for 10 seconds resulted in significantly lower mean lesion depth when compared with a visible light control ($n = 20$ per group, 107.8 vs 137.2 μm, $P = .038$). There were no statistically significant differences in lesion depth between the five-second argon laser and the visible light control groups. Overall, there was a 15% and 22% reduction in lesion depths for the five- and 10-second group, respectively. Poor correlations were found between the clinical appearance of decalcifications and their lesion depth. Argon lasers used for bonding orthodontic brackets would save a significant amount of chair time while possibly conferring demineralization resistance upon the enamel. (*Angle Orthod* 2003;73:249–258.)

Key Words: Argon laser curing system; White spot lesions; Demineralization resistance; Demineralization lesion depth

INTRODUCTION

In 1991, the Food and Drug Association approved the argon laser for polymerization of dental restorative materials. Since this time, mainly general practitioners have used the argon laser for polymerization of restorative materials and bleaching teeth. Recent research has mainly focused on the argon laser's ability to cure composite resins used in bonding orthodontic appliances rapidly.[1,2] Using the argon laser for this purpose in itself equates to a tremendous timesavings for the practitioner compared with the standard visible light–curing (VLC) methods. But perhaps a more interesting application of the argon laser in orthodontics involves its ability to alter enamel, rendering it less susceptible to demineralization, which is a relatively common side effect from treatment with fixed appliances.[3–5]

As early as 1965, investigators showed that exposure of enamel to laser irradiation imparts some degree of protection against demineralization under acid attack.[6] Yamamoto and Sato[7] embedded small pieces of lased enamel into several parts of human dentures. After three months, the unlased area of the enamel showed a chalky white lesion, whereas no detectable visible change was observed in the lased area. More recent studies have focused on the effects of laser irradiation on demineralization of human enamel. Using quantitative microradiography, argon laser irradiation of enamel reduces the amount of demineralization by 30–50%.[8–10] Fox et al[11] found that, in addition to decreasing enamel demineralization and loss of tooth structure, laser treatment can reduce the threshold pH at which dissolution occurs by about a factor of five. Westerman et al[12] showed that argon laser treatment at low fluences could considerably alter the surface morphology while maintaining an in-

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TABLE 1. Groups Used in This Two-Part Study

	Study Groups
Part I Shear Bond Strength	5-second Argon Laser (250 mW) n = 13 Visible Light Control n = 13
Part II Demineralization Study	5-second Argon Laser (250 mW) n = 20 10-second Argon Laser (250 mW) n = 20 Visible Light Control n = 20

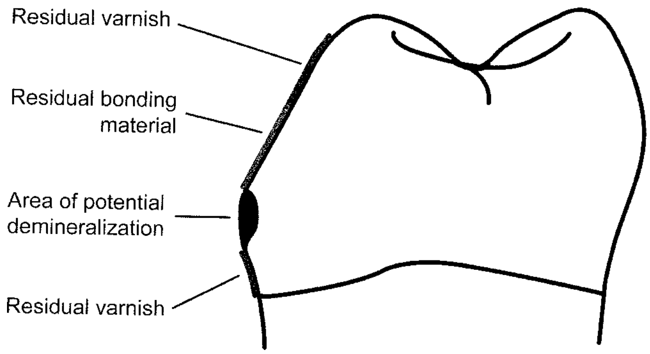

FIGURE 1. View of buccolingual section of a crown depicting areas of potential demineralization of buccal surface.

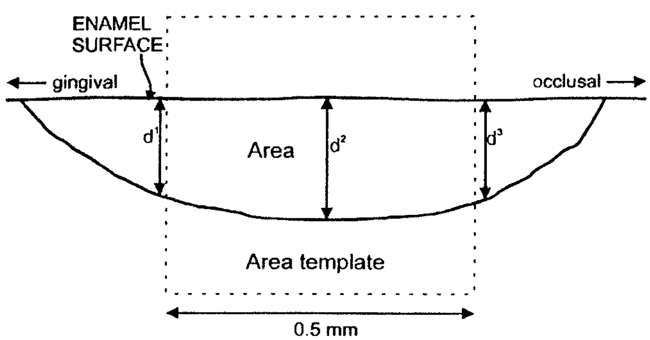

FIGURE 2. Magnified view of longitudinal section of demineralized lesion demonstrating how depth and area measurements were taken. Box outline represents template used to measure area.

tact enamel surface. A number of studies have also shown that combining laser irradiation with fluoride treatment can have a synergistic effect on acid resistance.[13–18]

Several mechanisms for the enhanced caries resistance of enamel after laser irradiation have been proposed, although the exact mechanism is not known.[8,12,13,15–17] Several factors may act together to achieve this reduction in caries susceptibility. The most likely mechanism for caries resistance is through the creation of microspaces within lased enamel. During demineralization, acid solutions penetrate into the enamel and result in release of calcium, phosphorus and fluoride ions. In sound enamel, these ions diffuse into the acid solutions and are released into the oral environment. With lased enamel, the microspaces created by laser irradiation, trap the released ions and act as sites for mineral reprecipitation within the enamel structure. Thus, lased enamel has an increased affinity for calcium, phosphate and fluoride ions.[9,11] A number of in vitro studies by Powell and Hicks[8–10,12,13,15,16] have looked at irradiation of enamel with an argon laser at various low energy levels (11.5–120 J/cm^2). Results have shown marked resistance (30–60%) to demineralization in artificial caries systems and decreased enamel solubility.

Applying these principles to orthodontics, laser irradiation has promising potential, in that it may be effective in reducing enamel decalcification that is often seen during fixed appliance treatment. Orthodontic brackets bonded to-

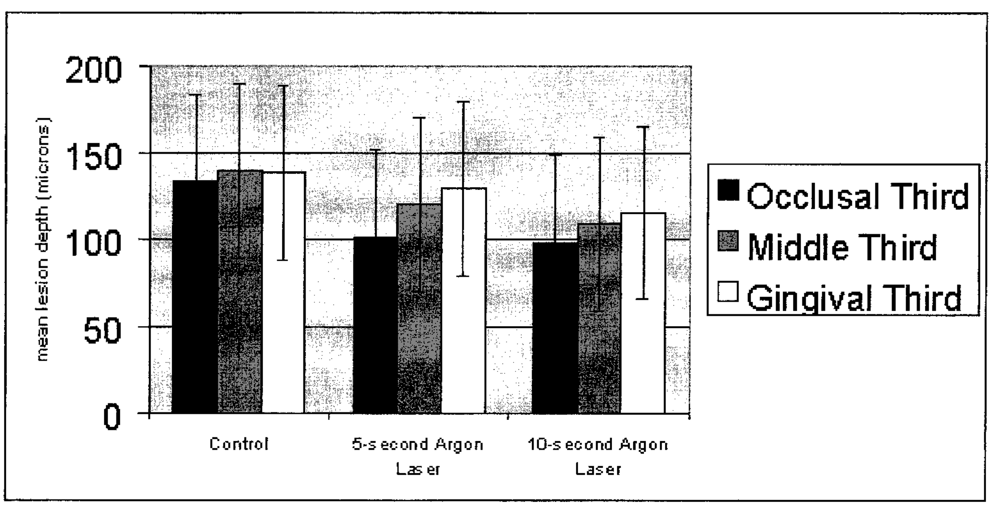

FIGURE 3. Plot of lesion depth (μm) based on occlusogingival location.

the surface of the enamel trap plaque around the bracket pads, allowing bacterial acids long periods of time to dissolve the inorganic portion of the enamel. As the enamel loses its mineral content, it appears chalky white, which is esthetically displeasing and may eventually progress to frank decay. Lasing the enamel surface at the time of bracket placement may significantly reduce the prevalence of decalcification associated with poor oral hygiene during orthodontic treatment. In previous studies, the percentage of patients who experience some degree of white spot formation during orthodontic treatment ranged from 49.6% to 64%.[19–22]

In orthodontics, the argon laser has been studied as an alternative to the VLC systems. Because laser light is intense, monochromatic, coherent, and collimated, it is a superior light source for photopolymerization of dental composite materials. Cobb et al[23] and Shanthala and Munshi[24] have demonstrated equal or higher shear bond strengths with argon laser polymerization exposed for 10 seconds compared with conventional visible light exposure for 40 seconds of polymerization. Recent work by Talbot et al[1] where orthodontic brackets were bonded with an argon laser and a VLC unit, has shown that shear bond strengths for a 10-second argon exposure were equal to those obtained with a 40-second VLC exposure.

The review of the literature reveals that researchers have tested from 250 to 2000 mW of argon laser irradiation and its effect on demineralization resistance.[8–10,15–17] All these energy levels have proven to be effective in producing statistically significant caries resistance as compared with a visible light control, ranging from a 31% to a 60% reduction in the amount of demineralization. But currently, the argon lasers manufactured for the purpose of composite polymerization have an energy range of 100–250 mW that cannot be adjusted to increase energy. Testing energies out of the range of in-office argon lasers would serve no purpose for the practicing clinician. Hicks et al[16,17] evaluated demineralization resistance after argon laser irradiation, using energy levels within the range of an in-office argon laser. The results of studies with a 10-second exposure at 250 mW energy level showed a 31–35% reduction in the demineralization compared with a visible light control.

The most recent data available report that approximately 93% of orthodontic brackets are bonded directly, and of those, more than 50% are bonded using a VLC unit.[25] Typically for a full appliance case, 20 brackets are cured for 40–60 seconds each for a total of 13.5–20 minutes of curing time per patient. Using argon laser polymerization, the orthodontist could decrease the total curing time to 3.5 minutes or by 10–16.5 minutes per patient. If it were possible to apply patients' orthodontic brackets with clinically acceptable bond strength and achieve a 30% reduction in demineralization while reducing overall chair time for the patient and the orthodontist, laser irradiation would certainly be a valuable tool to all orthodontists and patients.

To take advantage of the argon laser's ability to reduce decalcification during orthodontic treatment, the shortest exposure time necessary to impart demineralization resistance to enamel while providing adequate clinical bond strengths can be determined. If brackets cured for only five or 10 seconds reduce demineralization or white spot lesion (WSL) formation when compared with a visible light control and still have adequate bond strength, the argon laser has the potential to increase practice efficiency and quality of patient care in orthodontics.

The purpose of this in vitro study was to: (1) determine and compare the average shear bond strength of orthodontic brackets placed using a five-second argon laser curing time and brackets placed using a 40-second VLC time, (2) evaluate the ability of the argon laser at five- and 10-second exposures to inhibit demineralization of enamel surrounding orthodontic brackets when exposed to an artificial caries challenge by comparing lesion depth, surface zone, and WSL scale measurements, and (3) evaluate the correlation between a categorical scale to assess extent of WSL development and lesion depth measurements.

MATERIALS AND METHODS

Sample studied

A total of 86 extracted caries-free human premolars and molars were obtained immediately after extraction for this in vitro study. After debridement of remaining visible soft tissue with a scaler and a razor blade, the teeth were placed in a solution of 0.1% (weight/volume) thymol and stored in a refrigerator. The criteria for tooth selection included intact buccal enamel with no developmental defects, not subjected to any pretreatment chemical agents such as hydrogen peroxide, no cracks caused by pressure of the extraction forceps and no caries or WSLs. The study teeth were obtained from a collection of extracted teeth that lacked patient identifiers. Therefore, teeth were statistically analyzed as independent observations ignoring any correlation between teeth from the same patient. The teeth were randomly assigned into two equal groups of 13 each for Part I and into three equal groups of 20 each for Part II (Table 1).

Part I

To determine and compare the average shear bond strength of orthodontic brackets placed using a five-second argon laser curing time and brackets placed using a 40-second VLC time, a total of 26 human posterior teeth were mounted in acrylic that were placed in phenolic rings (Buehler Ltd, Lake Bluff, Ill), with the facial surfaces of the teeth perpendicular to the bottom of the mold. The teeth were then cleansed and polished with nonfluoridated pumice and rubber prophylactic cups for 10 seconds. The buccal surfaces were acid etched for 30 seconds with 37% phos-

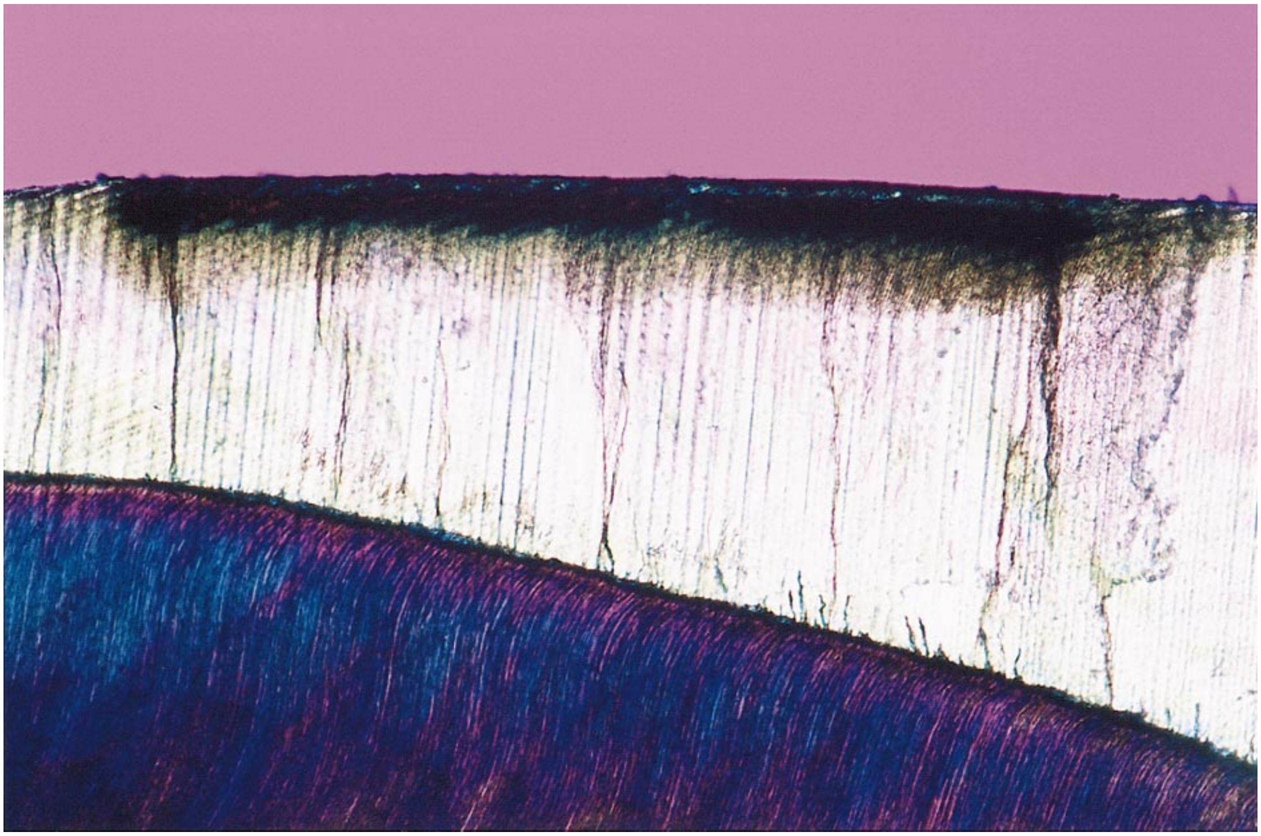

FIGURE 4. Polarized light micrograph of enamel lesion representing the 10-second laser group.

phoric acid, rinsed with water for 30 seconds and dried in an oil-free air stream for 20 seconds, giving the enamel a chalky white appearance. The 26 teeth were randomly assigned to one of the two groups (Table 1). One group had the brackets bonded according to the manufacturer's instructions, using an argon laser set at 250 mW for five seconds (AccuCure 1000™, LaserMed, Inc, Salt Lake City, Utah). The second group served as a control and had the brackets bonded using a 40-second exposure to a conventional visible light-curing unit (XL 3000, 3M/Unitek).

American Orthodontics® (Sheboygan, Wis) preangulated stainless steel brackets with 80-gauge meshscreen backing, assembly reorder numbers 993-548C and 390-0302 (premolar and molar brackets) were used in this study. All brackets were applied with Transbond XT® (3M/Unitek, Monrovia, California), according to the manufacturer's instructions, using either a VLC unit or an argon laser, as discussed above. Curing time was 40 seconds for the visible light and five seconds for the laser. The visible light was applied for 10 seconds each from the coronal, mesial, distal, and gingival surfaces. The laser was applied for five seconds from the gingival surface only. All samples were then stored in deionized water for one week before debonding.

The MTS® (MTS Systems Corp, Minneapolis, Minn) Universal Testing Machine was used to measure the shear bond strength to remove the bracket from each tooth. The phenolic rings were mounted on a universal joint to ensure that the applied force was parallel to the tooth surface. The force was applied with a beveled flat-end steel rod at the bracket-tooth interface with a crosshead speed of 0.5 mm per minute. The force values at the point of failure of the bracket were recorded in Newtons and divided by the area of the bracket base in mm^2. A two-sided two-sample *t*-test at a type I error level of 5% was used to assess whether the mean shear bond strength was significantly different between the group irradiated with argon and control group exposed to visible light.

Part II

To evaluate the ability of the argon laser in inhibiting demineralization of enamel surrounding orthodontic brackets, a total of 60 human molars were prepared for bonding as in Part I. The entire buccal surface was used, instead of limiting the etching area, to mimic the clinical situation better and to standardize the demineralization caused by etching.

A set of 20 teeth were randomly assigned to one of three groups: (1) 250 mW of argon laser irradiation for 10 seconds, (2) 250 mW of argon laser irradiation for five seconds, or (3) 40 seconds of VLC exposure serving as the control (Table 1). To avoid the introduction of a bias be-

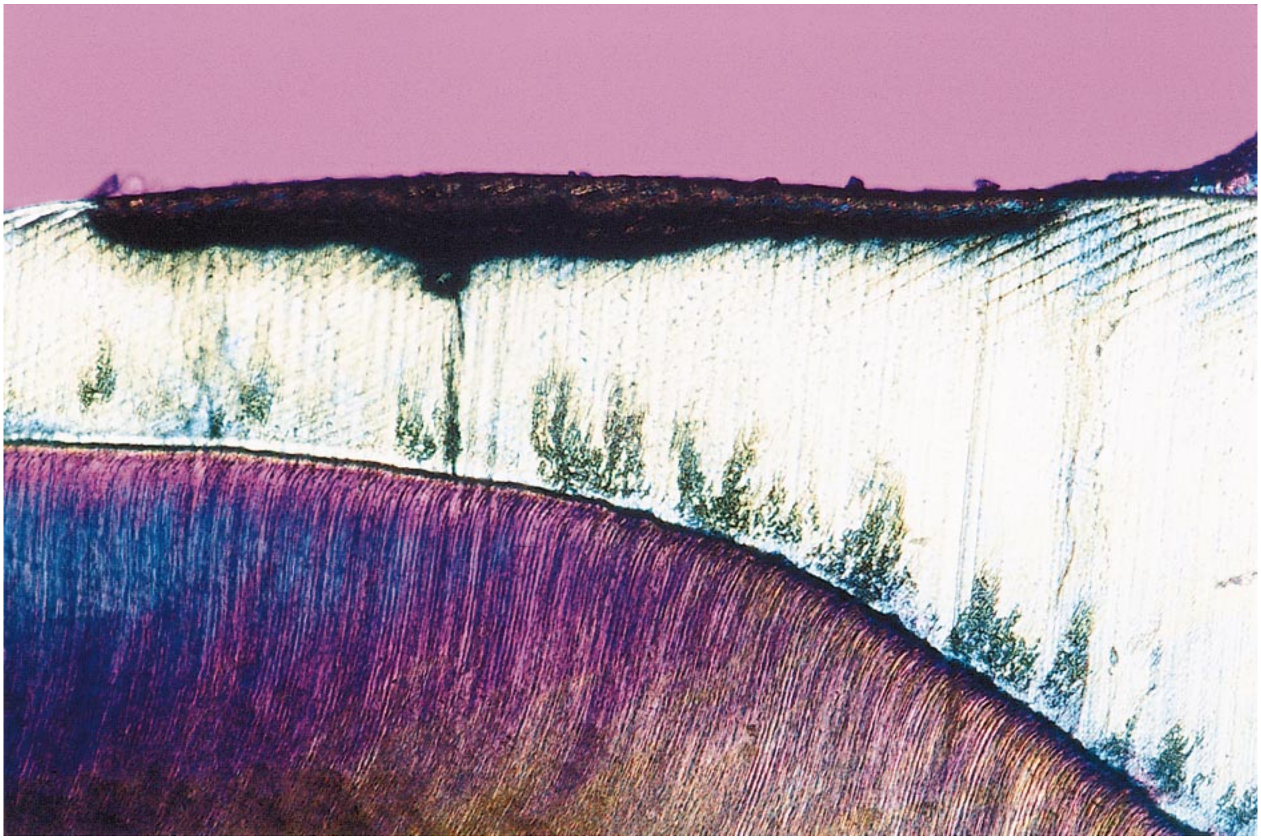

FIGURE 5. Polarized light micrograph of enamel lesion representing the five-second laser group.

cause of a learning or practice effect, the order in which the teeth were bracketed and lased was randomized. American Orthodontics® (Sheboygan) preangulated stainless steel brackets with 80-gauge mesh-screen backing, assembly reorder number 993-548C (molar brackets only) were used in this study. All brackets were applied with Transbond XT® (3M/Unitek), according to the manufacturer's instructions, using either a visible light-curing unit or an argon laser, as discussed above. The brackets were positioned on the facial surface at the height of contour mesiodistally, in the middle one-third occluso-gingivally and parallel to the long axis of the tooth. The cement was applied in thin layers on the mesh pads of the brackets with a plastic instrument. The brackets were positioned and pressed on the enamel surface until they were fully seated. Excess cement was removed with an explorer before either argon or light curing.

Curing time was 40 seconds for the visible light and either five or 10 seconds for the laser. The visible light was applied for 10 seconds each from the coronal, mesial, distal, and gingival surfaces. The laser was applied for either five or 10 seconds from the gingival surface only. The argon irradiation was focused at the gingival margin of the bracket because this area is most susceptible to demineralization during orthodontic treatment.[20–23] After bonding of the brackets, all teeth were painted with a thin coat of acid-resistant varnish covering all surfaces of the teeth except a two-mm area directly gingival to the bracket. This enabled isolation of an area of demineralization and standardization of the demineralization caused by etching. All samples were then stored in deionized water until they were subjected to the demineralization process.

Without removing the brackets, the teeth were challenged by submerging in an artificial caries solution (Ten Cate Demineralizing Solution[26]) consisting of 2.2 mM/L Ca^{2+}, 2.2 mM/L PO_4^-, 0.05 M acetic acid, and 0.50 ppm fluoride at a pH of 4.3 at room temperature with constant circulation. After a one-week exposure to the artificial caries solution, the presence or absence of demineralization was judged by visual inspection of the teeth. The appearance of frosty white enamel when dried was scored as the presence of demineralization.

Brackets were removed with a 3M/Unitek Lift off Debracketing Instrument (3M/Unitek), and the teeth were sectioned buccolingually with a water-cooled diamond disk along the long axis of the tooth by a Series 1000 Deluxe Hard Tissue Microtome (Scientific Fabrication, Littleton, Colo).

Sections were carefully washed and placed in prelabeled petri dishes. The 90–100 μm thick sections were oriented longitudinally on glass cover slides. The sections were then imbibed with water (refractive index 1.33) for evaluation under polarized light microscopy using an Olympus dual stage polarized light microscope (model BH-2, Dualmont Corporation, Minneapolis, Minn). Sections were oriented, and the stage was rotated to allow maximum illumination. The areas of demineralization were centered in the field of view, and the sections were photographed with maximum illumination. Resulting photomicrographs were evaluated at 20× magnification for differences among the various groups. Figure 1 illustrates a magnified tooth section with demineralization.

Images from the photomicrograph slides were projected with 10× magnification. The demineralized areas were then traced on paper, and both depth and area were quantitatively measured with a GP6-50 sonic digitizer (Science Accessories Corporation, Stratford, Conn). One examiner performed all the measurements. Lesion depth for each section was taken as the average of three representative measurements from the surface of the lesion to the depth of the lesion (ie, occlusal, middle, and gingival). A template was constructed to measure a standardized area of each lesion. The template, illustrated in Figure 2, was positioned over the deepest portion of each lesion to accurately measure an occlusogingival width of 0.5 mm. Depth was measured in micrometers and the area was measured in micrometers squared.

A visual analysis was also completed before sectioning the teeth. A standardized WSL scale developed by Geiger[21] was used. This ordinal numerical scale scores lesions into one of four stages on the basis of visual inspection of white spots and evidence of roughness or cavitation: (1) no white spot formation, (2) slight white spot formation, (3) severe white spot formation, and (4) excessive white spot formation including cavitation.

Lesion depth and surface zone area measurements for the two groups irradiated with argon and the control group exposed to visual light were summarized with means and standard deviations (SD). An overall F test from a one-way analysis of variance (ANOVA) model was used to determine whether mean lesion depth and surface zone area were significantly different between the three study groups. The four-point WSL scale was summarized by frequencies and percentages, as well as means and standard deviations. Comparison of the WSL scale between the three groups was made using the Kruskal-Wallis test. If there was evidence of statistically significant differences in lesion depth, surface zone area, or WSL scale between the three groups, pair-wise differences were assessed. A Bonferroni correction was applied to the *P* values obtained for the three pairwise group comparisons (ie, each of the *P* values was multiplied by three). The correlation between lesion depth and the WSL scale, both overall and by study group was evaluated using the Spearman rank correlation coefficient. All calculated *P* values were two-sided, and *P* values less than .05 were considered statistically significant.

TABLE 2. Shear Bond Strength by Study Group

Study Group	Shear Bond Strength (MPa)[a] Mean (SD) Range
5-second Argon Laser n = 13	20.4 (4.4) 10.8–25.8
Visible Light Control n = 13	17.8 (6.5) 7.1–27.3

[a] Mean shear bond strength was not significantly different between study groups ($P = 24$).

TABLE 3. Lesion Depth and Surface Zone by Study Group

	Mean (SD) Range	
Study Group	Lesion Depth (μm)[a]	Surface Zone Area (μm²)[b]
5-second Argon Laser n = 20	117.2 (43.6) 47.8–188.7	54,849 (27,166) 11,748–100,447
10-second Argon Laser n = 20	107.8 (33.3) 48.9–178.2	53,159 (18,084) 26,287–86,868
Visible Light Control n = 20	137.2 (37.5) 73.9–227.8	64,008 (19,042) 31,350–107,598

[a] Mean lesion depth was not significantly different between the three groups ($P = .055$). Pairwise comparisons revealed that teeth cured with the 10-second argon laser had a significantly lower mean lesion depth than did the control group ($P = .038$).

[b] There was no significant difference in the mean surface zone area between the argon-treated and control groups ($P = .25$).

RESULTS

Part I

Shear bond strengths for the argon-treated and visible light control groups are summarized in Table 2. Bond strength was not significantly different between the two groups ($P = .24$). The lower one-sided 99% confidence limit for mean bond strength of the argon-treated group was 17.2 MPa. This lower limit exceeded the suggested minimum bond strength (6–8 MPa) for clinical orthodontic treatment.[27]

Part II

Lesion depth and surface zone measurements for the three study groups are summarized in Table 3. Figures 4 through 6 illustrate representative lesions from each group. Mean lesion depths for the control, five-, and 10-second groups were 137.2, 117.2, and 107.8 μm, respectively. This equates to a 22% reduction in the 10-second group and a 15% reduction in the five-second group compared with the VLC. On the basis of the overall F test from an ANOVA model, differences just missed being statistically significant in mean lesion depth between the argon-treated groups and control group ($P = .055$). Because these differences approached statistical significance, exploratory analysis was carried out to investigate this relationship. The pair-wise group comparisons revealed that the teeth cured with the

10-second argon laser had a significantly lower mean lesion depth than did the control group (107.8 vs 137.2 μm, $P = .038$). But there were no statistically significant differences in lesion depth between the teeth cured with the five-second argon laser compared with the visible light control or between the five- and 10-second argon-treated groups. No statistically significant differences were detected in mean surface zone area among the argon-treated and control groups (ANOVA, $P = .25$).

Individual lesion depth measurements for the three study groups based on their location (occlusal, middle, and gingival) within the lesion are summarized in Table 4 and Figure 3. In the occlusal third, there was evidence of a difference in mean lesion depth between the argon-treated groups and the control (ANOVA, $P = .016$). The teeth cured with the 10-second laser had a significantly lower mean lesion depth than the control ($P = .015$). The difference in lesion depth for the middle and gingival third measurements among the argon-treated groups and the control group was not statistically significant (ANOVA, $P = .089$ and $P = .19$, respectively).

The WSL scale is summarized by study group in Table 5. The data suggest that the WSL scale distribution differed among the three groups ($P = .013$). The teeth irradiated with argon for five seconds had significantly lower WSL scale scores than did the control ($P = .018$). Neither was there difference between the teeth irradiated with argon for 10 seconds and those cured with the visible light control was not statistically significant ($P = .089$) nor was there difference in WSL scale scores between the five- and 10-second argon-treated groups.

The correlation between lesion depth and the WSL scale for the three study groups was examined. The Spearman rank correlation coefficient was $r = 0.26$, indicating a poor positive relationship between the two measurements ($P = .044$). There was also poor correlation within each study group: $r = 0.31$ ($P = .19$) for five-second argon-treated group, $r = 0.04$ ($P = .85$) for 10-second argon-treated group, and $r = 0.15$ ($P = .52$) for visible light control.

DISCUSSION

The ideal orthodontic bracket bonding method should be fast, provide adequate bond strengths to satisfactorily retain orthodontic brackets and, if possible, help prevent or reduce the amount of demineralization during treatment. For these reasons, the argon laser has received much attention. The argon laser has the ability to cure composite resins quickly and at the same time potentially confer demineralization resistance upon the enamel. Research to date, has independently examined the ability of the argon laser to cure composite resin and its effect on enamel in reducing demineralization. This is the first study to investigate the effects of the argon laser on demineralization resistance when used for bonding of orthodontic brackets and to attempt correlating the visual appearance of a demineralization lesion with its corresponding lesion depth.

The mean shear bond strengths of both groups in this study were significantly higher than those attained by Olsen et al[28] and Lalani et al,[2] and very similar to those by Talbot et al.[1] All studies used the same adhesive (Transbond XT). Both the five-second argon laser group and the visible light–cured control produced similar shear bond strengths and far exceeded the suggested minimum bond strength (6–8 MPa) for clinical orthodontic treatment.[27] At the time this study was undertaken, no studies had examined the shear bond strength of orthodontic brackets after a five-second exposure to the argon laser. Recently, however, Lalani et al[2] reported that a five-second laser-curing time was comparable to a 40-second visible light–cured control. Lalani et al also found increasing the argon laser curing exposure beyond five seconds did not result in significantly greater bond strengths.[2] Our findings corroborate those of Lalani et al,[2] that it requires 87.5% less time to cure composite used for orthodontic bonding with the argon laser. A five-second exposure from the argon laser provides shear bond strengths similar to those obtained by the standard 40-second exposure from the visible light, representing considerable timesavings.

In previous studies, Hicks et al[16,17] reported that a 10-second exposure to the argon laser at an energy level of 250 mW resulted in a 31–35% reduction in enamel demineralization compared with a visible light control. These studies did not incorporate orthodontic brackets into their investigation, making comparisons with our study difficult. We found a 15% and 22% reduction in lesion depth, respectively, with a five- and a 10-second exposure of 250 mW. Differences with previous reports might be attributed to less actual exposure to the enamel from the argon laser. Presence of brackets at the time of argon exposure in this study may have resulted in reduced exposure to the area tested because of some scattering of the laser energy from the bracket. The previous studies isolated a specific area where the argon laser could be localized for the exposure time. This may have caused a more intense exposure possibly accounting for a higher percentage of demineralization reduction.

Our results show that teeth cured with a 10-second argon laser had a significantly lower mean lesion depth than did the control group ($P = .038$). No significant difference was detected in lesion depth between the five-second argon laser group and the control. The results equate to a 15% reduction for the five-second group and a 22% reduction for the 10-second group for this in vitro study. What percent reduction in lesion depth would be clinically significant during the course of routine orthodontic therapy? Currently this is a question that warrants further investigation with well-controlled clinical trials. Quite possibly, demineralization resistance imparted by the argon laser might prevent a

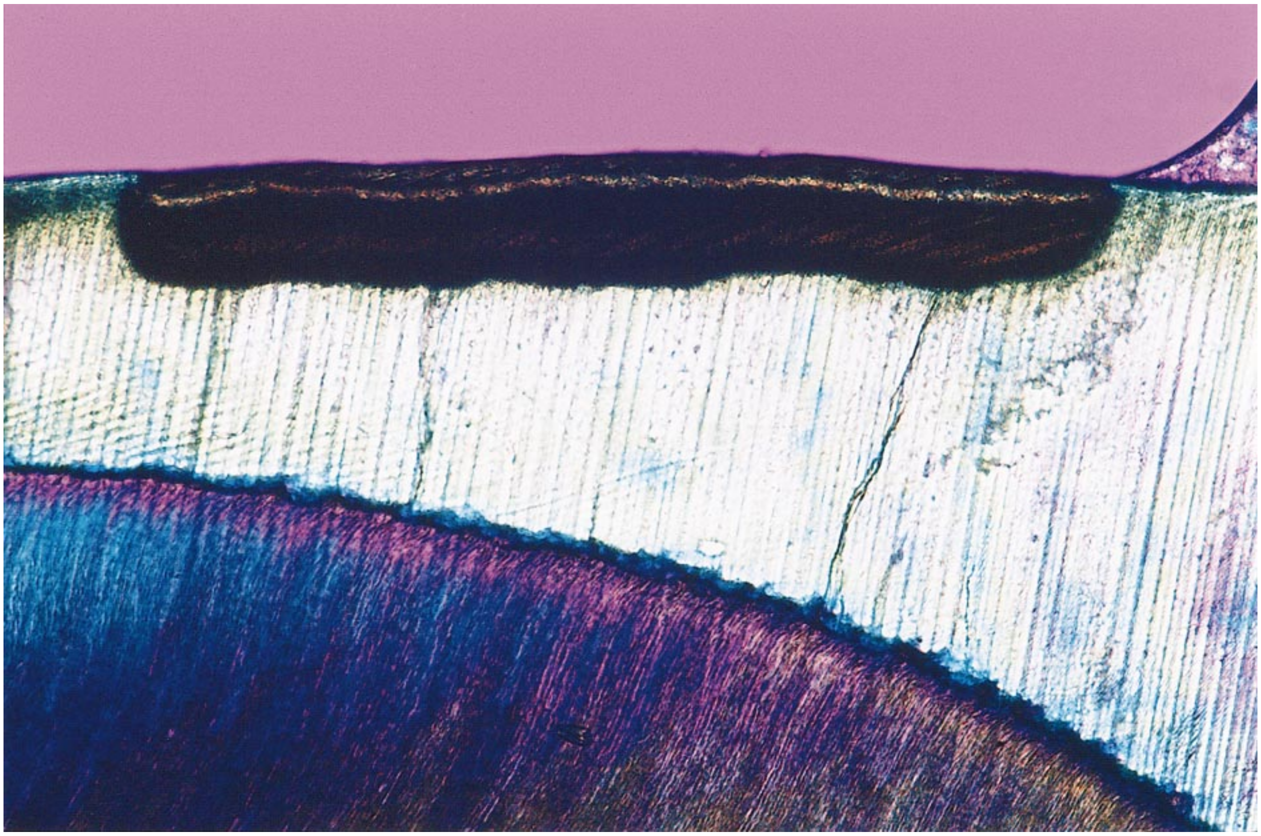

FIGURE 6. Polarized light micrograph of enamel lesion representing the control group.

TABLE 4. Lesion Depth Based on Occlusogingival Location

Study Group	Lesion Depth (μm) by Location: Occlusal Third[a] Mean (SD)	Middle Third[b] Mean (SD)	Gingival Third[c] Mean (SD)
5-second Argon Laser n = 20	101.7 (47.7)	120.3 (50.0)	129.6 (43.2)
10-second Argon Laser n = 20	98.7 (33.7)	109.1 (37.5)	115.6 (39.6)
Visible Light Control n = 20	133.7 (40.1)	139.4 (41.9)	138.6 (35.7)

[a] For the lesions in the occlusal third, there was evidence of a statistically significant difference in mean lesion depth between the three study groups ($P = .016$). In particular, the teeth curved with the 10-second laser had a significantly lower lesion depth than did the control group ($P = .015$).

[b] For the lesions in the middle third, there was no statistically significant difference in mean lesion depth between the three study groups ($P = .089$).

[c] For the lesions in the gingival third, there was no statistically significant difference in mean lesion depth between the three study groups ($P = .19$).

TABLE 5. Geiger White Spot Lesion (WSL) Scale by Study Group

Study Group	WSL Scale[a] N(%) 1	2	3	4	Mean (SD)
5-second Argon Laser n = 20	2 (10.0)	11 (55.0)	7 (35.0)	0 (0.0)	2.25 (0.64)
10-second Argon Laser n = 20	1 (5.0)	10 (50.0)	9 (45.0)	0 (0.0)	2.40 (0.60)
Visible Light Control n = 20	0 (0.0)	5 (25.0)	13 (65.0)	2 (10.0)	2.85 (0.59)

[a] WSL scale scores were significantly different among the three groups ($P = .013$). In particular, the 5-second argon-treated group had significantly lower WSL scale scores compared with the control ($P = .018$).

large percentage of WSLs during the course of orthodontic treatment.

An attempt was made to correlate the depth of lesions with that of their clinical appearance based on the WSL scale developed by Geiger.[20] If one could determine the extent of demineralization on the basis of the clinical appearance, a practitioner could then make better decisions about treatment of the lesions (ie, fluoride treatment with continued treatment or possibly early removal of appliances).

The WSL scale used in this study is a fairly gross visual examination. It is fairly easy to identify lesions that have cavitation (WSL = 4) by gross visual examination. But there is very little correlation between the WSL scale scores and lesion depth. Some of the teeth scored as WSL = 1 (ie, no white spot formation) had deeper lesions than some scored as WSL = 2 or even WSL = 3. This clearly points to the fact that the clinical appearance of WSLs is not the best indicator of their depth. This makes a good argument for further research and development in laser technology to prevent WSL from the very start, by imparting demineralization resistance to enamel. At the very least, better diagnostic methods or techniques should be developed to help the orthodontist identify demineralization lesions when they may be at a reversible stage.

Recent research by Al-Khateeb et al, in the area of in vivo monitoring of mineral changes in incipient enamel lesions looks very promising.[29] They used a caries diagnostic technique called quantitative laser fluorescence. This method uses an argon laser light–induced fluorescence to determine the amount of demineralization in enamel. This technique seems suitable for in vivo monitoring of mineral changes in incipient enamel lesions and useful for the evaluation for preventive measures in caries-prone persons, such as orthodontic patients. A well-controlled clinical trial using this technique would enable close monitoring and measurements of the argon-treated and control groups.

The argon laser has promising potential in orthodontics. With the ability to bond brackets in just five seconds, the potential chair-time savings would be significant to the practitioner. This savings of 35 seconds per tooth during a full-mouth bond-up would result in 12 minutes per patient of chair-time saved. Depending on the number of new cases per year a practitioner starts, the savings would quickly justify the increased cost of the laser. More importantly, this research also confirms the argon laser's ability to make enamel significantly more resistant to decalcification. Further research will be needed to determine at what energy level significant differences will be seen during the course of orthodontic treatment. The percentage of patients who experience some degree of white spot formation during orthodontic treatment ranges from 49.6% to 64% when last studied.[20–23] Being able to have some control on the formation of WSLs would be a great advance in the area of orthodontics. Knowing this, the argon laser could become the ideal orthodontic bonding tool in the near future.

CONCLUSIONS

On the basis of this in vitro study, the following conclusions were made.

- Brackets cured with the argon laser for five seconds yielded bond strengths similar to a 40-second conventional light-cured control group.
- Brackets cured with the argon laser for 10 seconds resulted in significantly lower mean lesion depth when compared with a visible light control.
- Clinical appearance of decalcification is not a good indicator of lesion depth.
- Argon lasers used for bonding orthodontic brackets would save a significant amount of chair time while conferring some demineralization resistance upon the enamel.
- Well-controlled randomized clinical trials are needed to investigate the argon laser's efficacy in reducing white spot demineralization during orthodontic treatment.
- Further research into the correlation between lesion depths and clinical appearance as well as in vivo monitoring of demineralization would have great importance in orthodontics.

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