CO2 Laser Effects on Shear Bond Strength of Orthodontic Brackets and Enamel Demineralization

Nasrin Farhadian[a] ,Amirfarhang Miresmaeili[a],Loghman Rezaei Soufi: Fahimeh Baghaei[b] Ehsan Shahvali[c]

Abstract

Aim: of this in vitro study was to evaluate the effects of Co2 laser irradiation on demineralization adjacent to orthodontic brackets and their shear bond strength in human premolar teeth. Enamel demineralization adjacent to orthodontic brackets is a major problem that requires new professional method independent to patient cooperation.

Materials and methods Sixty human premolars were randomly divided to two groups (n=30). Group1, enamel surface irradiated with Co2 laser. Group2 without any enamel surface treatment. In both groups, a bracket at buccal surface was bonded with Transbond XT and cured with conventional light cure. Demineralization in all sample induced with artificial caries solutions. A universal testing machine was used to determine shear bond strengths. The teeth were sectioned bucco-lingually and were evaluated under polarized light microscope. Average lesion depths were calculated from three depth measurements. The Two independent sample T- tests were used to compare the study type group in detail.

Results: The mean of shear bond strengths in the group1 and 2 were 13.90±5.01and 15.84 ±3.68 Mpa respectively, but not statistically significant (P=0.102).The mean lesion depth in group1and 2 was 72.29±58.09 µm 120.01±76.49µm respectively, which was significant (P=0.018)

Conclusion: Co2 laser irradiation can reduce enamel demineralization while not affecting the shear bond strengths significantly.

Keywords: CO2 laser, Shear bond strength, Enamel demineralization

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Enamel decalcification with white spot formation on buccal surfaces of teeth adjacent to orthodontic brackets is a relatively common side effect of fixed orthodontic appliances.[1-3] These appliances make conventional plaque removal more difficult, thus increasing the risk of decalcification on surfaces that normally show a low prevalence of dental caries.[4]

[a]Associated Professor, Hamadan Dental Faculty, Department of Orthodontics
Hamadan Dental Faculty, Department of Orthodontics,
[b]Assistant Professor, Hamadan Dental Faculty, Department of Restorative Dentistry
[c]Postgraduate Student, Hamadan Dental Faculty, Department of Orthodontic
Corresponding author:
Dr Amirfarhang Miresmaeili,
e-mail: miresmaeili@gmail.com

These early carious lesions can be seen as early as 4 weeks after band or bracket placement.[4-7] The prevalence of white spot lesions in orthodontic patients has been reported between 2% and 96%.[1,8-10] These lesions can occur on all teeth but are most frequently seen on the facial surfaces of maxillary lateral incisors, mandibular canines, and first premolars in the cervical and middle thirds of the teeth. [3, 11] These lesions compromise the esthetic results at the end of orthodontic treatment.[12]

Several methods for prevention of this lesions may include: good oral hygiene, nutritional counseling, and treatment with topical fluoride13, enamel sealants, modified appliance designs 4, 14 and laser therapy around the bracket15. Most of these methods, however; rely on patient compliance, which is unreliable, and could be seen effective only in 13% of orthodontic patients. In this way, compliance-free methods must be developed for more efficient patient care. [16] It was reported that CO2 laser irradiation can decrease enamel decalcification more than 98% .[17] Although CO2 laser have not been applied for composite curing, it may probably affect the bond strength, via etching effect on enamel surfaces [18] and these lased surfaces may have superior bond strength than acid-etched enamel ones.[19]

Present study evaluates the combination effects of CO2 laser on enamel demineralization and shear bond strength of orthodontic brackets.

Materials and methods

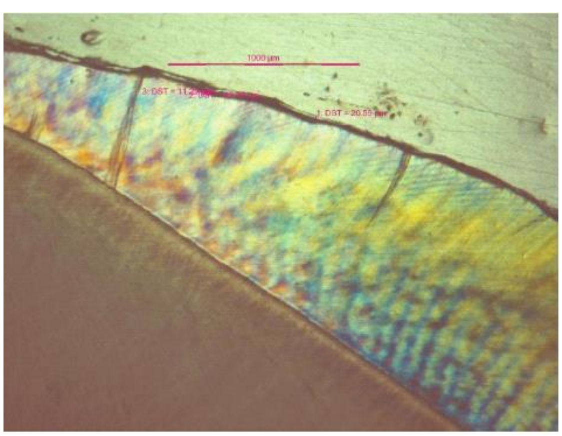
Sample size was determined based on following formula:

$$\frac{(Z_{1-\alpha/2}+Z_{1-\beta})(\sigma_1^2-\sigma_2^2)}{(\mu_1-\mu_2)^2} = \frac{(1.96+1.28)(9.3^2+8.7^2)}{(15.93-6.45)^2} \approx 20$$

In which μi and σi (i=1,2) were obtained from previous study.15 In this study, the type I error (α) was less than 0.05. So a minimum of 20 subjects in each group was adequate .Teeth with enamel cracks , visible white spots or other stains were excluded. For compensating the probable sample loss sixty intact human premolars immediately after extraction were placed in a solution of 10% formalin. Visible soft tissue removed with a razor blade, and then the teeth were cleansed and polished with non fluoridated pumice and prophylactic rubber cups. Root of teeth was mounted in cold-cure acrylic resin and then teeth were randomly assigned to the following equal groups: Group 1, enamel surface was exposed to Co2 laser unit, Smart US-20 D (Deka, Calenzano, Italy).Water used as coolant during lasing process. The unit was set up on level 2 and pulse mode with following parameters : wave length 10.6 µm, pulse repetition Rate 20HZ , 1 milliseconds per pulse and output power of 1 J. We irradiated brackets position area, a surface about 7 mm by 7mm.The focal spot of the laser was 0.2 mm in diameter. The irradiation was carried out in swabbing motion and precisely irradiated this area. Group 2, enamel surface had not received any laser irradiation. Brackets were bonded to all samples as follows: the buccal surfaces were acid etched for 15 seconds with 37% phosphoric acid, rinsed with water for 30 seconds and dried with an oil free air stream for 20 seconds, giving the enamel a chalky appearance. All brackets(S.S Standard 018 Slot, Dentarum , Germany) were bonded with Transbond XT (3M/ Unitek , Monrovia, California), according to the manufacturer's instruction ,

using a total 40 seconds (10 seconds from each side of the bracket) conventional light(Optilux 501, kerr, orange, calif,USA) with approximat power of 820mW/cm2. Then, all teeth were painted with a thin coat of acid resistance varnish covering all surfaces of the teeth except the buccal surface. The teeth were immersed in a standard tenCate demineralizing solution, (consisting of 2.20 mmol/L calcium,2.20 mmol/L phosphate,0.05 mol/L acetic acid, and 0.025 ppm fluoride) at room temperature. 20 After a 10 days exposure to the artificial caries solution, the presence or absence of demineralization were judged by visual inspection of the teeth .The appearance of frosty white enamel when dried was assigned as the presence of demineralization. Tensile debonding forces were applied at 0.5 mm/second on the testing machine (SANTAM, STM-20, Tehran, Iran) with wire loop occluso-gingivally. Shear bond strength values were calculated based on the peak load at failure divided by the bracket surface area .The mean bond strength values for two studied groups was compared using two independent sample t-test. Then bracket bases and the enamel surfaces were examined with a stereomicroscope at 10 times magnification to evaluate the amount of adhesive remaining on the teeth. The adhesive remnant index (ARI) was used to assess the quantity of adhesive remaining on the enamel surface. The ARI scores ranged from 0 to 3 according to Årtun .21For comparing the two groups Mann whitney U-test was used.

Root of teeth cut 2 mm apically from cementoenamel junction. Two cut approximately 2mm apart in buccolingual direction placed on each tooth at the middle of the crown with a water-cooled diamond disk along the long axis of the tooth by a handpiece. Then the thickness of sections reduced to 90-100 micro meters with progressively finer grades of silica carbide grinding paper then the sections were imbibed with water (refractive index 1.33) for evaluation under polarized light microscope (LX400,Labo America, Fremont, USA) (Fig 1 a,b) with 10 x magnification. A trained operator in blind situation measured the lesion depth 1mm far from cervical of bracket site at the 3 level as shown in schematic figure (Fig 2).The average of three representative measurements from the surface in 3 zone (coronal, middle, gingival)to the depth of the lesion was calculated. Measuring repeated after 10 day by the same operator.



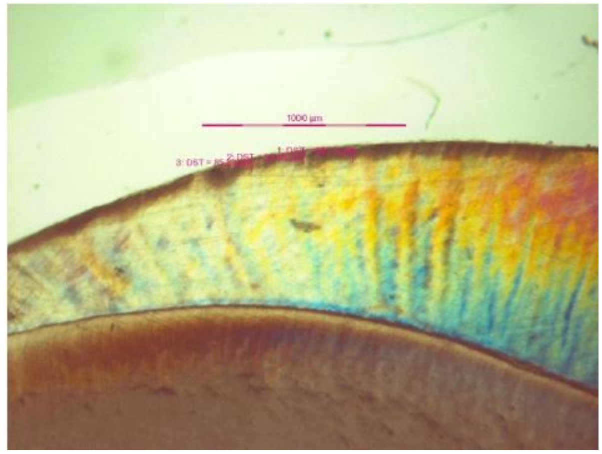


Figure 1: Polarized light micrograph of demineralized enamel lesion in A; laser group and B; control group

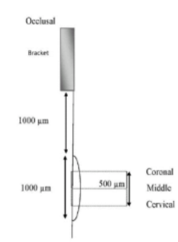


Figure 2: The schematic figure that showed a standardized area for measurements in each

Figure 2: The schematic figure that showed a standardized area for measurements in each specimen

Intra-class correlation was calculated for random error. Data analysis was performed using SPSS 16.0. ARI and shear bond strength was compared using Spearman's Correlation Coefficient test.

Result

At the end of study 7 teeth in control and 5 ones in laser group were lost. The shear bond strength and demineralization depth were normally distributed according to the Kolmogorov-Smirnov test. Mean shear bond strength in control and laser group was 15.29± 3.56Mpa, 13.41± 4.83 MPa respectively. Student T-test analysis showed that there is no significant difference in shear bond strength between two groups (P=0.102) (Table 1).

Mann-Whitney U Test showed significant differences in ARI between two groups (P=0.001) Mean ranks in group1 and 2 was 0.96 and1.79 respectively. (Table 2). Spearman correlation coefficient (r=0.2) didn't show any significant correlation between ARI and shear bond strength (P=0.133).

Mean lesion depth in control and laser groups were 120.01±76.49 µm and 72.29±58.09 µm respectively. Independent Samples T-test showed significant differences between two groups (P=0.018) (Table 3). Intra-class Correlation Coefficient was equal to 0.97.

Table 1: Shear Bond Strength in laser(1) and control(2) group

	Group	N	Mean	Std. Deviation	Std. Error Mean	P.Value
Shear bond strength	1	28	13.419	4.837	.914	0.102
	2	29	15.297	3.560	.661	

Table 2: ARI scores in laser(1) and control(2) group

P.Value	Mean Rank	ARI Score				N	Group
0.001		3	2	1	0		
	.96	1	4	16	7	28	1
	1.79	7	11	9	2	29	2

Table 3: Depth of demineralized lesion in µm

	Group	N	Mean	SD	SE. Mean
Mean lesion Depth	*1*	*25*	*72.296*	*58.099*	*11.619*
	2	*23*	*120.011*	*76.494*	*15.950*

Discussion

The aim of this study was to evaluate the effects of CO2 laser on enamel demineralization and shear bond strength of orthodontic brackets. According to previous studies CO2 laser with 10.6 µm wavelength that is commercially available in medical field was selected. 22 Present study showed an approximately 42% reduction in demineralization depth in laser group. Kantorowitz et al. with the same wavelength CO2 laser reported 48% reduction in demineralization.[23] Featherstone et al. in their study on CO2 laser with 10.6 µm wavelength and different energy per pulse, reported 45-85% reduction in enamel demineralization. [24] Hsu et al. reported up to 98% decrease in enamel demineralization. 17 As the small changes in laser parameters could lead to significant changes in laser effects, the different results of studies may be explained. [24]

According to Hsu et al. in a pilot study 17, if the energy density of CO2 laser irradiation on enamel be more than 3 J/cm2, crater formation, surface melting and surface flaking will be observed. Also it is reported if the temperature reaches to 400 ˚C the majority of enamel structures became positively briefringent. [25, 26] In present study, laser parameters were selected in such a way to minimize the adverse effects of CO2 laser on teeth (preventing pulp temperature increase, crater formation and enamel flaking).[17] As sections in the laser group showed relatively negative birefringence, it seems that the laser-induced surface temperature did not reach 400°C. Fowler et al. and Holcomb et al., reported that enamel proteins decompose between 300 - 400°C and reduction of enamel demineralization are maximum in this range. [27-28]

The exact effect of CO2 laser on enamel that results in enamel resistance to demineralization still not clearly understood. Several mechanisms proposed for this effect including: the combination of reduced enamel permeability with a reduced solubility with melting, fusion and sealing the enamel surface [29-30], ultra-structural crystallographic effects such as different shape and larger size of apatite crystals, and loss of prismatic structure[31]. Also conversion of acid phosphate to pyrophosphate 28 and partial decomposition of the organic matrix 17 are responsible for producing of acid resistant layer on enamel surface. [32]

Considering the effect of laser on enamel surface and structural changes that influence the acid resistance of enamel may possibly affect the shear bond strength of orthodontic brackets. In present study, shear bond strength of two groups had no statistically significant differences, so it could be used successfully for orthodontic clinical purposes. [33] Several studies reported use of CO2 laser as enamel etchant. CO2 laser induced physical changes such as melting, recrystallization, formation of numerous porosity and small bubbles like lesions, which is similar to Type III pattern of etching with phosphoric acid. This increased level of roughness and irregularities, provides micro-mechanical retention for the adhesive materials.[34-35] In spite of the surface roughness, some researchers reported that shear bond strength in laser etched samples was lower than acid etched samples [36-37] and some others reported comparable bond strength. [38] Walsh and colleagues reported greater shear bond strength than acid etched with this laser parameter (power density 2380 W/cm2, energy density 23.8 J/cm2) but with this power the adverse effects on enamel could be expected .[17, 39]

In present study, according to the selected laser parameters (less than 3J/cm2), photothermal phenomena seems to be occurred and this changes merely reduces the solubility of enamel and enamel demineralization process and has not the negative impact on acid etching process and resulted bond strength.

ARI scores characterize the type of bond failure. High ARI scores in control group show that failure occurs at adhesive/bracket interface 40 and more adhesive remained on enamel surface relative to laser group. In present study in spite of significant difference in ARI between two groups there is no correlation with shear bond strength value. It may be the advantage of laser that permits orthodontist to clean remained adhesives at debonding stage more easily.

Conclusion

Apply CO2 laser on enamel surface considerably reduces enamel demineralization and it didn't show negative impact on the shear bond strength of orthodontic brackets. In spite of its favorable effect on enamel, cost of this method is a limiting factor to make it popular.

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