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ORIGINAL ARTICLE

Evaluation of the effects of CO_2 laser on debonding of orthodontics porcelain brackets vs. the conventional method

Azita Tehranchi · Reza Fekrazad · Morvarid Zafar · Behnam Eslami · Katayoun A. M. Kalhori · Norbert Gutknecht

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Abstract Debonding of ceramic brackets due to their high bond strength and low fracture toughness is one of the clinician's complications. The purpose of this study is to evaluate the effect of a laser on shear bond strength, site of debonding, and ARI index during debonding of ceramic brackets and then compare it to the conventional method used for this procedure. Thirty polycrystalline alumina (G & H Series, Germany) brackets were bonded to 30 intact extracted first and second maxillary premolars and stored in a 1% thymol solution. A chemically cured orthodontic composite resin (No-mix, Unitek, USA) was used for bonding the brackets to the enamel surface on all teeth. All brackets were positioned 4 mm from the incisal edge of the teeth with an orthodontic bracket-positioning device. Then the teeth with bonded brackets were embedded in auto-polymerized polymethylmethacrylate (2.2.3 cm) blocks using a special device to make their slots horizontally parallel. These 30 teeth were then divided into two subgroups: control or no-lased (n=15) and super pulse CO_2 laser (n=15). To characterize the peak of SBS in two groups, we used an Instron machine while its blade was moving at a constant speed of 1 mm/min. For evaluating the site of debonding and the adhesive remnant index (ARI index), a light microscope and the Photoshop program were used. Means and standard deviations of the SBS in two subgroups shows that in the control group, the teeth have definitely higher values in comparison to the experimental group. The results of the two groups drew no substantial differences with respect to the surface of debonding, which was mostly within the adhesive. However, observing the results of ARI presented a significant distinction between the control and experimental group. This index denoted that the debonding site in the control group was closer to the enamel adhesive interface and, consequently, the rate of enamel damage in this group would be greater. The present study shows that a CO_2 laser has the potential to replace the conventional method for debonding ceramic brackets due to less debonding force and more adhesive remnant index on the tooth surface.

Keywords Porcelain brackets · Lasers · Debonding

A. Tehranchi · M. Zafar · B. Eslami · K. A. M. Kalhori
Iran Center for Dental Research, Dept of Orthodontics,
Dental School, Shahid Beheshti University of Medical Sciences,
Tehran, Iran

R. Fekrazad (✉)
Dental Department, AJA University of Medical Sciences,
Tehran, Iran
e-mail: dr_rfekrazad@yahoo.com

R. Fekrazad
Laser Research Center, Dental Faculty,
Tehran University of Medical Sciences,
Tehran, Iran

N. Gutknecht
Department of Conservative Dentistry,
Periodontology and Preventive Dentistry,
University Hospital Aachen,
Aachen, Germany
e-mail: ngutknecht@post.klinikon.rwth-aachen.de

Introduction

Ceramic brackets are esthetic, strong, and resistant to chemical degradation. However, the atomic structure that imparts these advantages also accounts for the most obvious fault of ceramics, namely their brittleness and low fracture toughness [1, 2].

Fig. 1 Special device designed to make the bracket slots horizontally parallel

The composite-enamel high bond strength and brittleness, which are major concerns during bracket removal, sometimes result in damage to the tooth enamel, existing restorations, and brackets.

Various forms of thermal debonding devices are documented in other publications, using electrical heating elements or laser energy to soften the adhesive at the bracket–resin interface to facilitate removal of orthodontic brackets. Despite the expedition gained through these devices, the lack of quantitative control over the amount of thermal energy delivered to ceramic brackets may cause overheating of the tooth during bracket removal, creating a temperature increase at the dentin–pulp interface [3–5].

One of the ways to deliver a controlled amount of thermal energy is by using lasers [6–8]. In previous experiments, CO_2 lasers were the most favorite candidates. The energy of the incident laser is converted into heat on the bracket surface and goes deeper to the bracket–resin interface, softening the adhesive resin [6, 8, 9]. Strobl et al. investigated the in vitro removal of ceramic brackets with CO_2 and Nd:YAG lasers and concluded that laser-aided debondings significantly reduce both the debonding force and the risk of enamel damage [7].

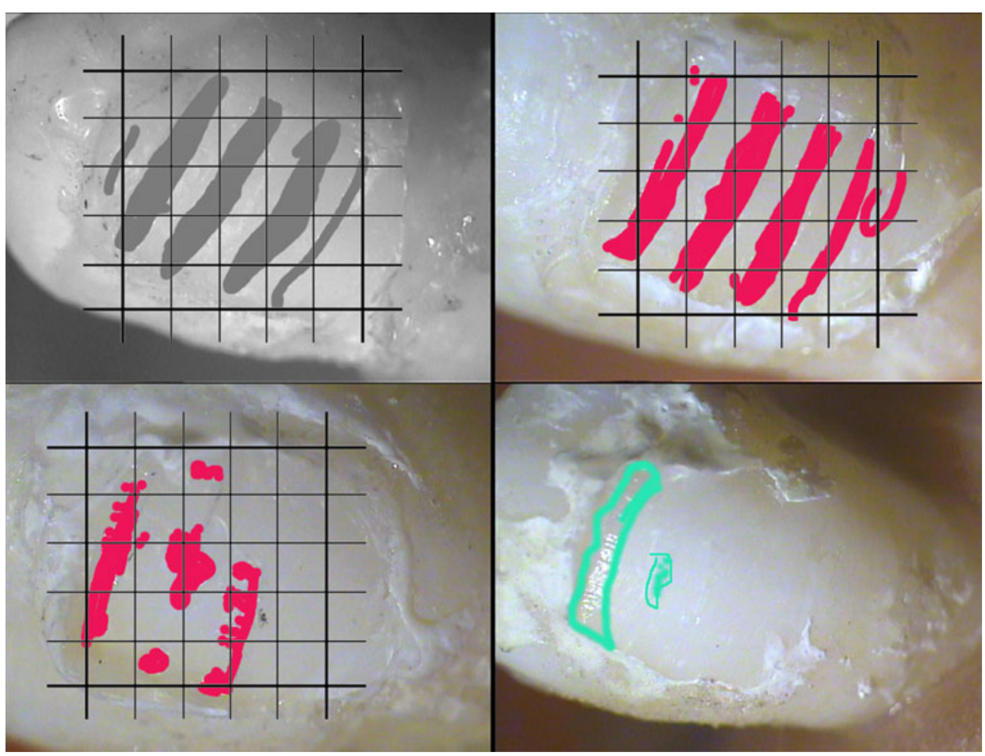
Ma and Marangoni evaluated different criteria in debonding ceramic brackets by CO_2 laser and recognized that laser use facilitates debonding while the interpulpal temperature is within the pulp's physiologic tolerance [6]. In another report, Obata reported the same results in using a super pulse CO_2 laser in debonding ceramic brackets. Previous reports found no significant differences between the debonding forces of brackets on the first premolars and on the second premolars.

The aim of this in vitro investigation is to determine the effects of super pulse CO_2 laser on shear bond strength, on site of debonding, and on Adhesive Remnant Index (ARI), to debond ceramic brackets in comparison with those variables in the conventional method.

Materials and methods

Among all popular brackets, polycrystalline alumina (G & H Series, Germany) is recommended for laser-assisted debonding because of its resistance, therefore it was

Fig. 2 Observing the exact percentage of adhesive resin on the enamel surface after debonding by taking the advantage of a computerized grid shield (Photoshop software, Adobe Systems, USA)



selected for this study. Thirty brackets were bonded to 30 intact extracted first and second maxillary premolars and stored in a 1% thymol solution. The teeth were washed with tap water before scaling and root planning. The enamel surfaces were polished with non-fluoridated pumice paste and again rinsed and dried with an air–water spray. In the next step, according to Pramid et al., the teeth were etched with a 37% ortho-phosphoric acid solution for 30 s [10], rinsed with water for 20 s, and completely dried with an air–water spray. A chemically cured orthodontic composite resin (No–mix, Unitek, USA) was used for bonding the brackets to the enamel surface on all teeth. All brackets were positioned 4 mm from the incisal edge of the teeth with an orthodontic bracket-positioning device.

Excess composite was removed from the edge of the brackets with a dental explorer before polymerization. The ceramic brackets were attached to each specimen by using bonding resin in a controlled thickness. The teeth were stored in water at 37°C for more than 48 h to ensure complete polymerization.

Finally, the teeth with bonded brackets were embedded in auto-polymerized polymethylmethacrylate (2*2*3 cm) blocks using a special device to make their slots horizontally parallel (Fig. 1).

These 30 teeth were then divided into two subgroups: control or no-lased (n=15) and super pulse CO_2 laser (n=15).

They were separately placed in a holding ring positioned in the lower jaw of the Instron machine so that the bracket base of each one would be parallel. The application of shearing force was perpendicular to the bracket interface.

The super pulse CO_2 laser was selected in this study and had a power density of 50 W, an exposure time of 5 s, and a duration pulse of 500 µs separated by sufficient time to allow the tissue to cool between pulses (interval time: 2,000 µs), thus limiting thermal damage. The frequency of the laser was 400 Hz and it was placed at a convenient distance point to the center of the brackets with a spot size of 1 mm. To characterize the peak of SBS in two groups, we used an Instron machine with the blade moving at a constant speed of 1 mm/min. The blade reached the tooth bracket interface as soon as the beam of the laser was stopped. The peak shearing bond strength in both groups was determined.

Table 1 Bond failure of two groups

Failure place group	Adhesive	Dentin/adhesive	Total
Control	13 (43.3%)	2 (6.7%)	15 (50%)
Super pulse	15 (50%)	0 (%0)	15 (50%)
Total	28 (93.3%)	2 (6.7%)	30 (100%)

After debonding the ceramic brackets, the amount of residual adhesive was classified in compliance with a previously defined adhesive remnant index (ARI) that uses a scale of 1 to 4 to assess the amount of resin material adhering to the enamel surface:

1 = 0% on the enamel
2 = <50% on the enamel
3 = >50% on the enamel
4 = 100% on the enamel

This index is important in evaluating the probable risks of enamel damage after debonding. When the debonding site is closer to enamel–adhesive interface, cracking of the enamel becomes more probable.

To categorize the site of debonding, all teeth and brackets were examined with a magnifying loop (×10). The ARI index was also determined using the Photoshop program and magnifying loop (×10) (Fig. 2).

In the Photoshop program, residual adhesives on buccal surfaces of teeth were stained at first. Then, the percentage of ARI on the surfaces was visually estimated. Then, we evaluate the stain surfaces by imaging a computerized grid shield on the photographs in order to determine the exact percentage of ARI.

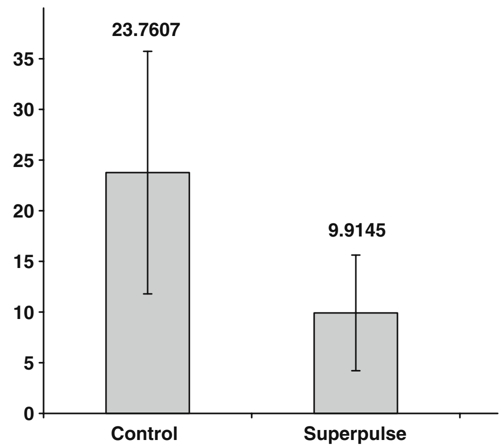


Fig. 3 Means and standard deviations of debonding force in both groups

Results

Means and standard deviations of the shear bond strength in two subgroups are summarized in Fig. 3, which shows that in the control group, teeth have definitely higher values in comparison to the experimental group.

Table 2 ARI index in two groups with the Kruskal–Wallis test

Group	Number	Mean ranks	Chi-square test	p value
Control	15	11.53	23.576	0.0001
Super pulse	15	30.63		

Table 3 ARI index in control and super pulse groups (Mann–Whitney *U* test)

Group	Number	Mean ranks	Sum of means	Mann–Whitney *U* test	Wilcoxon W	Z	*p* value
Control	15	8.93	134.00	14.000	134.000	4.584	0.0001
Super pulse	15	22.07	331.000				

The results of the two groups drew no substantial differences with respect to the surface of debonding, which was mostly within the adhesive (Table 1).

However, observing the results of ARI presented a significant distinction between the control and experimental group. This index denoted that the debonding site in the control group is closer to the enamel–adhesive interface and, consequently, the rate of enamel damage in this group will be greater (Tables 2 and 3).

In clinical use, the bond between the brittle ceramic brackets and adhesive must be strong enough to withstand orthodontic forces and chewing loads, while allowing debonding without enamel damage.

Discussion

Debonding ceramic brackets with a CO_2 laser significantly decreased shear bond strength. Over the last decade there have been efforts to facilitate bracket removal with the aid of a laser. Regarding the major role of adhesive during this process, a CO_2 laser has been the predominant choice due to its higher surface absorption [7–9, 11, 12].

Traditional laser debonding of ceramic brackets has been achieved by the thermal softening of the adhesive resin with heat transmitted through lased brackets. For this reason, a CO_2 laser, where its wavelength is more easily absorbed by the ceramic brackets, is the predominant choice of debonding [6, 7, 9].

In a research done by Obatta and his colleagues, they showed that a Super pulse CO_2 laser is better than a continuous one. This ability is due to more power and less pulse width of the Super pulse laser. The use of a Super pulse CO_2 laser can minimize the risk of tissue damage [13].

Studies showed that whenever the pulse width is longer, the produced heat may be transmitted to the surrounding healthy tissues.

It should be mentioned that although one of the major concerns in debonding of ceramic brackets is the increase of pulp temperature, due to the high surface absorption of CO_2 laser, most of the laser beam is absorbed in the bracket and lower resin layer, so there is less damage to the pulp. In the different studies about laser debonding and pulp temperature that have been reported by many investigators, no pulp damage has been reported [6, 7].

The ARI index evaluates the remnant adhesive on the enamel surface after debonding. It is an important index in evaluating the probable risks of enamel damage after debonding. When the debonding site is closer to the enamel–adhesive interface, cracking of the enamel is more probable [14].

In this study in non-lased teeth, the debonding line transversal distance was closer to the enamel surface than to the bracket side, and in the experimental group, the debonding site was closer to the bracket surface. This result is confirmed by the studies of Stroble, Tocchio, and Azzeh [7, 15, 16].

Conclusions

The present study shows that a CO_2 laser has the potential to replace the conventional method for debonding ceramic brackets due to less debonding force and more adhesive remnant index on the tooth surface.

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