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Evaluation of water atomized solid-state laser apparatus as a method for debonding ceramic orthodontic brackets (An In vitro study)

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Abstract

Background and objectives: The contemporary demand for esthetic less visible ceramic bracket is associated with the disadvantage of complicated and difficult debonding procedure at the end of the treatment. The aim of this study was to evaluate the water atomized laser system for debonding ceramic brackets.

Method: Eighty maxillary premolars were divided into two main groups. In group-1, poly crystalline ceramic brackets (Reflections, Ortho technology, USA) were bonded to buccal enamel surface. In group-2, mono crystalline ceramic brackets (PURE, Ortho Technology USA). Were bonded to buccal enamel surface. For all teeth, the same bracket bonding system was used. Following debonding with both water atomized laser device and manual debonding instrument, teeth and brackets were examined under 10X magnification for assessment of bracket failure (fracture) and of residual adhesive on the enamel surface using a modified adhesive remnant index (ARI). Enamel surfaces were visualized with trans-illumination prior to bonding and after removal of the residual adhesive, so the effect of the debonding forces could be determined. The numbers of the fractured brackets were counted.

Results: Statistical analysis showed a significant difference in the ARI between debonding with water atomized laser and utility-debonding pliers in such away more adhesive remnant was revealed on teeth with laser debonding. Also less enamel damage recorder with laser group debonding compared with conventional debonding procedure, which was statistically significant, additionally more bracket fractures encountered with conventional debonding than debonding with laser apparatus, which was highly significant statistically.

Conclusions: Debonding of ceramic orthodontic brackets could be done with water atomized laser apparatus with minimal enamel surface cracks and lesser chance of bracket fractures.

Key words: water atomized, laser, ceramic brackets, debonding.

Introduction

Ceramic brackets are made mainly of polycrystalline and single-crystal alumina, or zirconia.[1] The extreme hardness of these materials lead a major clinical concern when debonding ceramic brackets which is the risk of enamel fracture,[2] since most ceramic brackets exhibit a high bonding strength[2,3] and don't deform easily because of their mechanical properties

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which are highly brittle, poorly ductile and high value of elastic modulus compared with metal brackets.[1] To overcome the problem of enamel damage, various debonding procedures have been tested, like ultrasonic debonding machines, electro-thermal debonding apparatus, and introduction of specially designed debonding gadgets.[4,5] In addition, lasers have been used experimentally to debond ceramic brackets. The energy of laser beam can disintegrate the orthodontic bonding resin as by the effects of thermal melting, thermal ablation, and photo-ablation.[6] The temperature rise may transmitted to the tooth structure cause pulp enjury.[2] Although any heat generation in the pulpal tissue more than of 5.5uC can cause pulpal tissue necrosis,[7] it has been proven that appropriate laser irradiation led to the ceramic bracket debonding without any harmful effects of temperature rise in the pulpal tissue.[2,8] The introduction of water laser techniques has dramatically reduced the problem of heat generation in pulpal tissue accompanying the laser irradiation procedures.

Although some studies have reported no enamel damage when ceramic brackets are debonded with the appropriate pliers,[9,10] other studies have reported an increase in enamel cracks or crack length following debonding.[11–14] Studies by Liu et al,[12] Mundstock et al,[13] and Artun[14] have reported enamel damage of up to 20% of teeth after debonding of ceramic brackets with pliers. Such damage was related to the bracket type, the bracket base design, and the adhesive system used.[12–14] Bishara et al[15] reported that 18% of teeth exhibited an increase in the number or severity of enamel cracks following debonding.

In an effort to reduce the forces placed on enamel during debonding ceramic brackets by conventional methods, and decrease the likelihood of pulpal damage the purposes of this study were to evaluate water atomized laser apparatus for debonding of different types of ceramic brackets and its effect on enamel surface cracks by the use of stereomicroscope.

Method

The sample

Eighty intact newly extracted human upper premolars for orthodontic reasons were collected and stored in a 0.2% of thymol solution. Teeth with buccal surface defects or caries were excluded, and only selected if thy not subjected to bleaching or pretreatment with phosphoric acid for bonding brackets. The teeth were mounted in stone in custom made metal molds for the study, then after setting of the stone, the teeth were cleaned and polished with pumice powder and rubber polishing cups for 20 seconds to be ready for bonding procedure.

Enamel surface checking

Before the step of ceramic brackets bonding, all the buccal surfaces of the extracted teeth were carefully examined with a 10X stereoscope for the presence of any possible enamel damage or crack lines. The enamel surface was also studied under trans-illumination with a fiber optic light head (Kinetic Instruments, Ethel, Conn). The fiber optic light was moved back and forth over each tooth at a distance of 1 cm. Each facial tooth surface was divided into four equal vertical and horizontal zones for detailed mapping of the enamel cracks. Each tooth was evaluated twice.[15]

Ceramic brackets bonding

The teeth were divided into 2 groups of 40 teeth each, one group bonded with poly crystalline ceramic brackets (Reflections, Ortho technology, USA) and the other group bonded with mono crystalline ceramic brackets (PURE, Ortho Technology USA).

All the teeth (Buccal enamel surface) were etched for 45 seconds with 37% phosphoric acid (3M Unitek, USA), then rinsed with water for 30 seconds, and dried with oil free air for 20 seconds.

Ceramic orthodontic brackets (Roth, 0.22) 40 mono-crystalline brackets (PURE, Ortho Technology, USA) for the 1st group and 40 Polycrystalline ceramic brackets (Reflections, Ortho Technology, USA) for the 2nd group were bonded to the buccal surface of all teeth with Transbond XT (3M Unitek, USA) adhesive; applying a constant force with the help of a surveyor as shown in figure (1), excess composite was gently removed before curing and light cured with light unite.

Sample storage

All the teeth with bonded brackets stored in normal saline for 2 weeks in a standard incubator

Brackets debonding

Each of the main groups of the sample is subdivided into two equal groups, (group-a) 20 teeth debonded with water-atomized laser and (group-b) 20 teeth debonded manually with utility pliers. Debonding of the all group-a brackets from both main groups done at the same time using the biolase water laser system (YSGG solid-state laser with water atomization) (I Plus, BIOLASE, USA) by applying the laser head for hard tissue cutting directly to the ceramic bracket which debonded like a popping manner from the tooth as shown in figure (2). Debonding of all group-b brackets from both main groups done at the same time using Utility pliers (Dentaurum, Germany) according to manufactures direction, and then all the teeth were collected for enamel surface evaluation.

Enamel surface and Adhesive Remnant Index

Once the brackets were debonded, the buccal enamel surfaces of all the teeth were examined under 10X stereoscope, so the amount of residual adhesive remaining on each tooth could be determined. Adhesive Remnant Index (ARI) was used to quantify the amount of remaining adhesive according to the following scale:

1= the entire adhesive is on the tooth.
2 = more than 90% of the adhesive is on the tooth.
3 = 10% to 90% of the adhesive is on the tooth.
4 = less than 10% of the adhesive is on the tooth.
5 = no adhesive is on the tooth.

Later on all remaining adhesive was removed from the enamel surface with the use of a high-speed hand-piece and a carbide-finishing bur. The enamel surface was then reevaluated under trans-illumination. The numbers of the brackets fractured or were intact after debonding were counted and recorded and scored as 1 for fracture and 0 for intact.

Statistical analysis

The chi-square test was used to compare the bond failure mode (ARI scores) between the two groups. For the purposes of statistical analysis, the ARI scores 1 and 2, as well as 4 and 5, were combined. Additionally, the chi-square test was used to compare the increase in frequency and severity of enamel cracks before and after debonding. Significance for all statistical tests was predetermined to be $P \leq 0.05$.

Results

The descriptive statistics for each of the four experimental groups are shown in table (1). The lowest ARI scores recorded more with laser debonding groups for both ceramic bracket types and the highest ARI scores recorded with manual debonding groups for both ceramic bracket types.

Chi-square test for comparing between two different ways of debonding (Subgroups a and b) involved significantly different (P=0.045) for mono-crystalline brackets and highly significant (P=0.003) for poly-crystalline, bracket failure modes. For both ceramic bracket types, most of adhesive remained on tooth with laser debonding and most of adhesive remained on the debonded bracket with manual debonding as shown in table (2) and table (3).

The teeth were reevaluated via the transillumination technique described earlier. Enamel cracks lines following debonding were compared with the cracks that were apparent before bonding, and increases in number or severity were noted. The changes observed are presented in Table (4), and results indicate that most of the teeth that debonded with laser revealed no change in crack frequency and severity (80% for mono-crystalline brackets and 75% for poly-crystalline brackets) while most of the teeth that debonded manually revealed increase in crack frequency and severity (55% for both types of ceramic brackets).

Results from the statistical analysis of Chi-square () also indicate that changes in enamel cracks resulting from use of the two different types of debonding were significantly different as shown in table (5).

The number of bracket pieces fractured during debonding was counted, to help investigators determine the severity of bracket failure as shown in table (6).

Chi-square test revealed statistically a highly significant differences (P = 0.000)) in bracket failure rates when the two types of debonding techniques were compared. It was obvious that for most of the brackets that were fractured into pieces, debonding had been done with the Utility pliers

Discussion

The effects of the laser-aided debonding of ceramic brackets were investigated with the use of both the CO_2 and the YAG lasers. The CO2 laser debonding was investigated more extensively, whereas for the Nd:YAG laser only a proof of principle was tested. This is because both lasers cause essentially the same physical effects, namely, softening of the composite with heat generated by the laser beam[16], a problem, which could be solved by the water-cooling that, is present already for atomization.

In this in vitro study, we evaluated the efficiency and the safety of water atomized solid-state YSGG laser for debonding esthetic ceramic brackets, which represent a problem due to the associated enamel surface cracks and fracture at debonding time.

The result of the present study revealed that debonding of ceramic brackets of both the mono- and pol-crystalline types with water atomized lasers increase the chance of adhesive failure between the bracket base and bonding material as shown by modified ARI, which lead to the conclusion of less mechanical effect on enamel surface during debonding as happens with conventional debonding procedures which usually associated with more cohesive failure of both the bonding material and the bracket structure itself. This is agree with Suliman et al 2014 who conducted a quantitative analysis about enamel loss after ceramic bracket debonding and revealed many types of ceramic cohesive failures with debonding[17]. While the result of this study disagree with Chen et al 2007 who concluded that most adhesive fractures occurred at the ceramic-resin interface which reduces the risk of enamel fracture; however, more time is required to remove the remaining resin on the enamel surface[18].

Enamel surface cracks was significantly lower with laser debonding as a result of less mechanical force applied to the enamel surface during the debonding procedure which is certainly more during manual debonding with utility pliers as it is the mechanism by which debonding happens by these instruments by applying heavy force to produce both adhesive and cohesive failures, which is also agreed with the results of a study done by Lijima et al 2010 on the effect of CO_2 laser debonding on enamel surface who concluded that, the hardness and elastic modulus of enamel are not affected by CO_2 laser irradiation.

And CO_2 laser debonding may not cause iatrogenic damage to enamel.[19] Also agree with Azzeh and Feldon who conducted a comprehensive review on the laser debonding of ceramic brackets.[20] While disagree with Feldon et al 2010 who proposed the absence of any relation between laser debonding and the reduction of enamel surfaces damage after debonding of ceramic brackets in a study about Diode laser debonding of ceramic brackets.[21]

Reducing enamel damage during debonding of ceramic brackets and removing of adhesive remnant is desirable,[22] hence removing the brackets intact as one piece is an important requirement for enamel surface preservation, since the mechanical effort required to remove the fractured bracket will damage the enamel surface integrity.[23] This study revealed that the use of water atomized solid state laser apparatus is very efficient for debonding esthetic ceramic brackets of both mono-crystalline and poly-crystalline type with minimal enamel surface damage and bracket fracture compared with conventional utility debonding pliers.

Conclusion

Debonding of ceramic orthodontic brackets could be done with water atomized laser apparatus with minimal enamel surface cracks and lesser chance of bracket fracturs.

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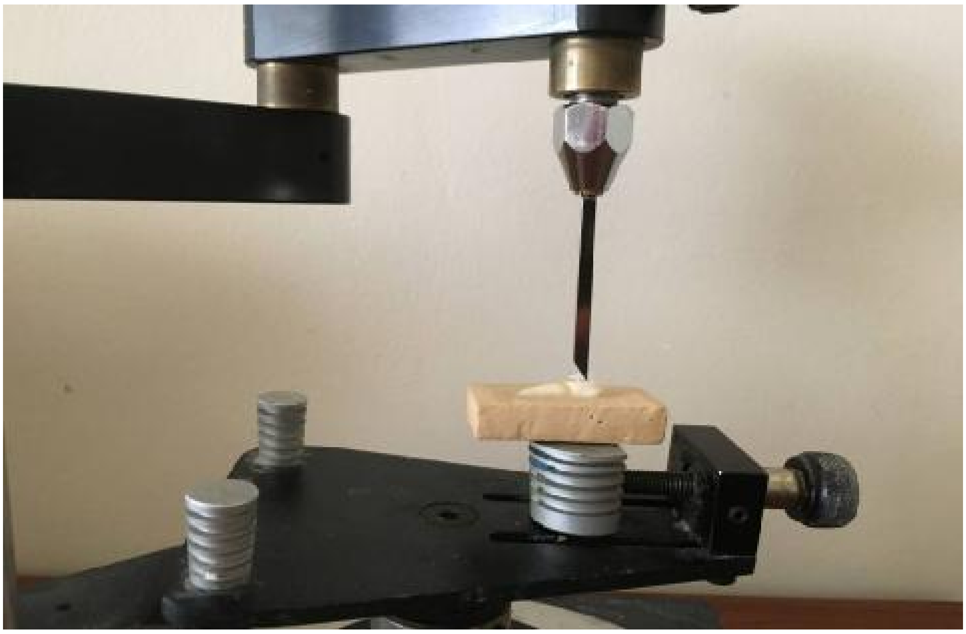

Figure (1) Bracket bonding procedure with the help of a surveyor for applying a constant force

Figure (2) bracket debonding using water atomized laser

Table (1) Frequency distribution of Modified ARI

Groups	n	Modified ARI				
		1	2	3	4	5
Mono-crystalline Laser Debonding	20	15	4	1	-	-
Poly-crystalline Laser Debonding	20	12	6	1	1	-
Mono-crystalline Manual Debonding	20	2	2	5	7	4
Poly-crystalline manual Debonding	20	1	2	6	9	2

Table (2) Chi-square test for ARI for mono-crystalline brackets

	Value	df	Significance
Pearson Chi-Square	15.821[a]	8	0.045
Likelihood Ratio	17.257	8	0.028
Linear-by-Linear Association	7.292	1	0.007
N of Valid Cases	20		

$P \leq 0.05$

Table (3) Chi-square test for ARI for ploy-crystalline brackets

	Value	df	Significance
Pearson Chi-Square	30.000[b]	12	0.003
Likelihood Ratio	24.461	12	0.018
Linear-by-Linear Association	9.454	1	0.002
N of Valid Cases	20		

$P \leq 0.05$

Table (4) Changes in the frequency and severity of cracks before and after debonding of ceramic brackets with two different types of debonding technique.

Groups	n	Increased	No change
Mono-crystalline Laser Debonding	20	4 (20%)	16 (80%)
Poly-crystalline Laser Debonding	20	5 (25%)	15 (75%)
Mono-crystalline Manual Debonding	20	11 (55%)	9 (45%)
Poly-crystalline manual Debonding	20	11 (55%)	9 (45%)

Table (5) Chi-square test for changes in the frequency and severity of cracks before and after debonding of ceramic brackets

	Value	df	Significance
Pearson Chi-Square	9.006[a]	3	0.029
Likelihood Ratio	9.258	3	0.026
Linear-by-Linear Association	2.340	1	0.126
N of Valid Cases	80		

$P \leq 0.05$

Table (6) Comparison of changes in severity of bracket fracture with two different types of debonding technique

Groups	n	Intact	FRUCTURED
Mono-crystalline Laser Debonding	20	18 (90%)	2 (10%)
Poly-crystalline Laser Debonding	20	18 (90%)	2 (10%)
Mono-crystalline Manual Debonding	20	5 (25%)	15 (75%)
Poly-crystalline manual Debonding	20	8 (40%)	12 (60%)

Table (7) Chi-square test for Comparison of changes in severity of bracket fracture with two different types of debonding technique

	Value	df	Significance
Pearson Chi-Square	28.808[a]	3	0.000
Likelihood Ratio	31.398	3	0.000
Linear-by-Linear Association	3.006	1	0.083
N of Valid Cases	80		

$P \leq 0.05$