

Access this article online
Quick Response Code:

Website: www.jorthodsci.org
DOI: 10.4103/jos.jos_192_21

Optical coherence tomography assessment of the enamel surface after debonding the ceramic brackets using three different techniques

Maimoona Abdul Khader, Soorya Dileep¹, Abdul Gafoor A.², Jijin MJ³, Manisha Sunil, and Parthiban Krishnaraj

Department of Orthodontics and Dentofacial Orthopaedics, Educare Institute of Dental Sciences, Chattiparambu, Malappuram, Kerala, ¹Department of Orthodontics and Dentofacial Orthopaedics, Rajas Dental College and Hospital, Tirunelveli, Tamil Nadu, ²Department of Orthopaedics, Manjeri Medical College, Manjeri, ³Department of Oral Medicine and Radiology, Malabar Dental College and Research Centre, Edappal, Kerala, India

Address for correspondence:

Dr. Soorya Dileep, Assistant Professor, Department of Orthodontics and Dentofacial Orthopaedics, Rajas Dental College and Hospital, Tirunelveli - 627 105, Tamil Nadu, India.
E-mail: soorya.dileep@gmail.com

Submitted: 27-Nov-2021
Revised: 02-Jan-2022
Accepted: 12-Jan-2022
Published: 04-May-2022

Abstract

OBJECTIVE: To assess the enamel surface damage and residual adhesive remnant [adhesive remnant index (ARI)] on extracted premolars after debonding the ceramic brackets using three different debonding techniques, with optical coherence tomography (OCT).

METHODS: Ninety extracted premolars were bonded with ceramic brackets and divided into three groups of 30 teeth each based on debonding techniques used. Twenty-four hours later, they were debonded using three different debonding techniques: debonding pliers, ultrasonic scalers, and Er-YAG laser. A baseline scan was obtained prior to bonding using OCT. The teeth were evaluated for the adhesive remnant on the tooth surface using ARI score, and the amount of enamel surface damage was evaluated using OCT.

RESULTS: We observed that the use of ultrasonic scalers as a debonding technique led to greater incidence of enamel surface damage as measured in OCT. The ARI scores with debonding pliers and laser were significantly greater than that of scaler debonding.

CONCLUSIONS: Results of this *in vitro* study confirmed that use of ultrasonic scalers as a debonding technique led to significantly greater incidence of enamel surface damage when compared to the other two debonding techniques. The ARI scores on the tooth surface using debonding pliers and laser were significantly greater than that of the scaler debonding technique.

Keywords:

ARI, ceramic brackets, debonding, optical coherence tomography (OCT)

Introduction

Ceramic brackets were introduced to orthodontic speciality in the mid-1980s and now are an integral part of the orthodontist's armamentarium.^[1] There are two types of ceramic brackets: polycrystalline and monocrystalline. Both the types are composed of 99.9% aluminium oxide. Polycrystalline and single-crystal brackets are different in their optical clarity. Single-crystal brackets are noticeably clearer and more translucent than polycrystalline

brackets.^[2] Monocrystalline ceramic brackets show more enamel damage than polycrystalline brackets. The bonding mechanism in monocrystalline brackets is only by chemical adhesion, whereas in polycrystalline brackets, it is by both micromechanical and chemical adhesion.^[3,4]

Ceramic brackets have become an important, although sometimes troublesome, part of today's orthodontic practice because of problems such as enamel tearouts, bracket failures, and pain at removal because of their low fracture resistance and high

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Khader MA, Dileep S, Gafoor AA, Jijin MJ, Sunil M, Krishnaraj P. Optical coherence tomography assessment of the enamel surface after debonding the ceramic brackets using three different techniques. *J Orthodont Sci* 2022;11:16.

bond strengths.^[5,6] Enamel surfaces after debonding are mostly examined by optical and scanning electronic tomography.^[7-9] Scanning, tunnelling, and atomic force microscopy techniques have also been explored for dental surface analyses. However, these analyze only the surface. Optical coherence tomography (OCT) is high-resolution, non-invasive, and ultra-fast imaging of tissue microstructures.^[10,11] It can be seen as a technique analogous to ultrasound techniques, and the analyzed reflected wave from the tissue carries the structural information of the biologic sample. Different from ultrasound equipment, OCT uses light instead of sound waves. With the use of broadband sources, such as those generated by ultra-short laser pulses, OCT images of biologic tissues can achieve a spatial axial resolution of a few micrometres.

There are not many studies on the use of OCT for the characterization of the enamel structure after debonding ceramic brackets using different techniques. Therefore, a comparative study was undertaken to evaluate the enamel surface damage on the extracted premolar surface after three different debonding techniques using OCT and to evaluate the residual adhesive remnant using adhesive remnant index (ARI).

Materials and Methods

An *in vitro* study was carried out using 90 premolars extracted for orthodontic purposes. The exclusion criteria are the following conditions: enamel hypoplasia, turbidity or discoloration, cervical abrasion, caries, or fillings. The teeth were rinsed in water and stored in 10% formalin acetate until use; polishing of the bonding (labial) surface was done with non-fluoridated pumice and a polishing brush for 15 sec. It was then rinsed and dried with compressed air. A baseline scan of all teeth was obtained, and it showed no measurable enamel loss on OCT [Zeiss Cirrus™ HD OCT (Carl Zeiss Meditech, Germany)]. The area to be bonded is etched for 30 seconds with 37% phosphoric acid gel, washed, and dried. A primer (Transbond XT, 3M Unitek, USA) was used at the enamel surface; a light cure adhesive resin (Transbond XT, 3M Unitek, USA) was used at the polycrystalline ceramic bracket (UNITEK Gemini, 3M) base and placed on the labial surface of extracted premolars. A dynamometer pressure of 400 gms was exerted on the bracket before curing the adhesive to standardize the thickness of the adhesive layer under the bracket. The adhesive was light-cured for 20 seconds on the mesial and distal sides as recommended by the manufacturer, with a light cure unit (Unicorn Denmart, New Delhi). Teeth were stored in distilled water at room temperature for 24 hours. Institutional Ethics committee of Kannur Dental college has approved the study on 06-01-2014 with reference number –KMC/Eth/11/14.

Teeth were divided into three groups (30 each in a group) based on three different debonding techniques used as follows:

1. Debonding plier (Jaypee; India)
2. Ultrasonic method (piezo-electric scaler, straight chisel, Gulinwood Pecker Medical Instrument Co., Limited, China)
3. Er-YAG laser (DoctorSmile, Pulser; Lamda Spa, Italy).

Debonding pliers applied a squeezing force at the bracket base in a mesio-distal direction for debonding. In the ultrasonic method, a piezo-electric ultrasonic scaler tip started at the incisal margin of the bracket with the bevel of the chisel directed toward the bracket, rather than the enamel surface.^[12] Er-YAG laser debonding (DoctorSmile, Pulser; Lamda Spa, Italy) was done at a power of 4.2 W with a wavelength of 2490 nm by scanning thoroughly the surface of brackets with horizontal movements parallel to the bracket slot, starting from the distal wing of the bracket to the mesial wing, for 9 seconds. The laser application tip was positioned perpendicularly 2 mm away from the brackets;^[13] it softened the adhesive, and the bracket popped out on its own. There was no necessity for the use of debracketing pliers.

A post-debond scan was obtained using OCT for all teeth. Enamel loss (mean depth) was assessed using the measuring tool in OCT [Figures 1-3]. The residual adhesive on the tooth was scored on the basis of naked eye examination using ARI by Artun and Bergland^[14] as follows:

- Score 0 - Indicated that no adhesive was left on the tooth in the bonding area.
- Score 1 - Less than half of the adhesive was left on the tooth in the bonding area.

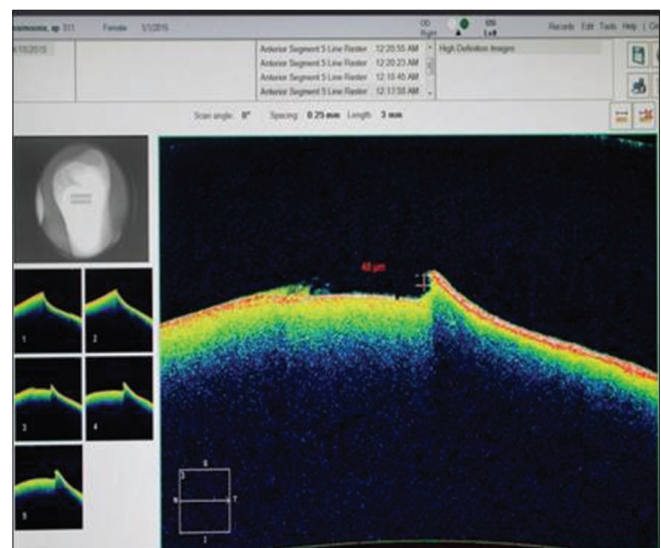


Figure 1: OCT image of a tooth debonded with ultrasonic scalers measuring an enamel loss of 48 µm

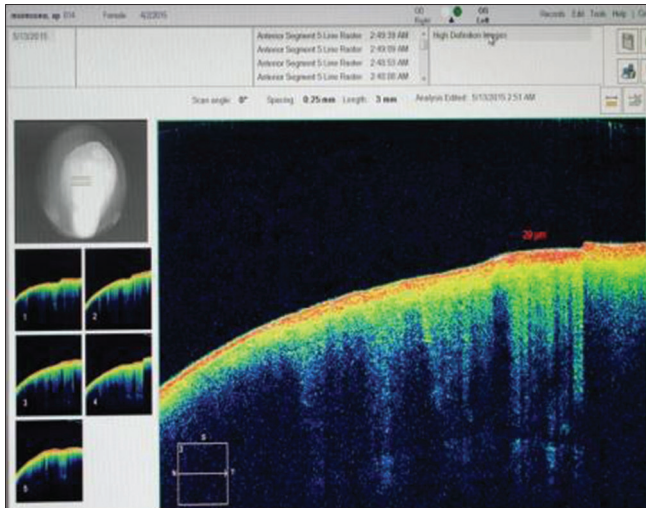


Figure 2: OCT image of a tooth debonded with pliers measuring an enamel loss of 29 μm

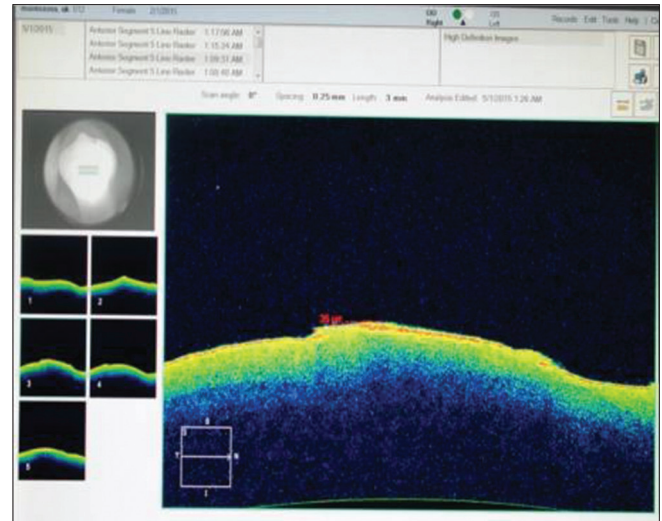


Figure 3: OCT image of a tooth debonded with laser measuring an enamel loss of 35 μm

- Score 2 - More than half of the adhesive was left on the tooth in the bonding area.
- Score 3 - The entire adhesive was still on the tooth with distinct impression of the bracket mesh on the remaining adhesive surface.

Quantitative data obtained from OCT images and ARI scores of samples from three different groups were tabulated and were analyzed using one-way analysis of variance (ANOVA) and Chi-square test, respectively, and followed by the post hoc test of Bonferroni to determine whether inter-group variations of data show statistically significant results or not.

Results

Enamel surface damage

Quantitative data obtained from OCT images of samples from three different groups were tabulated and were analyzed using one-way ANOVA, and it revealed that the use of ultrasonic scalers as a debonding technique led to significantly greater incidence of enamel surface damage (maximum depth of enamel loss – 84 μm and a minimum of 42 μm). The mean ± SD value for the 30 brackets debonded by the ultrasonic method is 55.7 ± 10 μm [Table 1]. Evaluation with the post hoc test of Bonferroni shows that there is statistically significant enamel loss on debonding with pliers and scalers, with scaler and laser debonding (p value < 0.001). Moreover, there was no significant difference in enamel surface damage by the use of debonding pliers and laser debonding (p value - 0.477) with a mean difference of 2.56 μm and a standard error of 3.58 [Table 2].

Adhesive remnant index

ARI scores were assessed visually to rate the various debonding techniques with respect to the amount of

Table 1: One-way ANOVA test result for enamel surface damage from three groups

Post-debond enamel loss measured on OCT in μm	plier	Ultrasonic scaler	Laser
N	10	23	12
Mean	31.1	55.7	33.7
SD	6.3	10.0	6.0
Minimum	22.0	42.0	24.0
Maximum	42.0	84.0	42.0
First quartile	25.5	48.0	28.5
Median	31.0	54.0	33.0
Third quartile	36.5	58.0	39.5

F=43.523 P<0.001

Table 2: Multiple comparison-post hoc analysis for enamel surface damage from three groups

Multiple comparison category	Mean difference	Std. error	P
Ultrasonic scaler	24.59	3.1672	<0.001
Laser	2.56	3.5802	0.477
Ultrasonic scaler and laser	22.02	2.9776	<0.001

residual adhesive on each tooth. The overall percentage distribution of ARI scores shows that in group A and group C, none of the samples were free of resin on the surface (score 0); most of the samples were in score 3 and score 2. In group B, 6.7% were free of adhesive. The majority were in score 2 and score 1. The Chi-square test result of 25.877 (P value < 0.001) denotes that there is a significant association between the scores and the groups [Table 3]. Mean ARI scores in different groups show that minimal scores were observed in group B, followed by groups A and C. More specifically, group B showed a minimal value of mean ± SD, (1.6 ± 0.67), and groups A and C showed mean ± SD of (2.433 ± 0.67) and (2.46 ± 0.62), respectively [Table 4]. Evaluation with the post hoc test of Bonferroni shows that the difference in

ARI scores is found to be statistically significant between debonding with pliers and scalers and between scalers and laser (P value < 0.001). There was no statistically significant difference observed between debonding with pliers and laser (P value 0.846) [Table 5].

Discussion

Ceramic brackets were introduced to orthodontics to meet the increased demand for a more aesthetic appliance.^[7] However, the brittle nature of ceramic brackets has resulted in a higher incidence of breakage of the brackets during debonding.^[15] As a result, many clinicians refrain from using ceramic brackets because of the potential problems as well as the difficulty encountered during their removal. Enamel surface damage caused during the removal of ceramic brackets has been the subject of concern to many researchers and has prompted a number of studies.

In this study, the following factors were evaluated:

- 1) The enamel surface damage during debonding ceramic brackets using three different debonding techniques with OCT.
- 2) The residual adhesive remaining using ARI.

Usually, enamel loss from debonding orthodontic brackets is assessed only after cleanup. However, the

debonding procedure consists of two steps: bracket removal and resin cleanup. Each of these steps, mainly the bracket removal technique, can affect the final enamel loss outcome.^[16] Therefore, in this study, enamel losses on various debonding techniques are compared.

Using 3D scans obtained by OCT, it was able to quantify and compare enamel losses between the debonding techniques. An enamel loss of about 20 to 30 µm mean depth may be considered comparable with prophylaxis after dental cleanup.^[16] Because the enamel thickness is in the range of 1500 to 2000 µm, the prophylaxis procedure causes enamel loss in the range of 7–14 µm.^[17] Other studies also reported little to no enamel loss but are usually based on qualitative analysis such as scanning electron microscopy.^[18]

Statistical post hoc and Chi-square tests revealed that the use of ultrasonic scalers led to a greater depth of enamel surface damage with a mean value of 55.7 µm (SD ± 10). This finding is similar to that of the study by Krell *et al.*,^[19] who found that ultrasonic removal caused a greater enamel loss than removal of the bracket with debonding pliers. In contrast to this, findings by Bishara and Trulove^[6,20] found that the enamel damage as a result of adhesive removal was not significantly different among the three debonding techniques (debonding pliers, the ultrasonic method, and the electrothermal method) used. Bond failure with ultrasonic instrumentation occurred at the enamel adhesive interface in the present study, resulting in more adhesive removal along with enamel surface; this could be the reason that ultrasonic instrumentation led to more incidence of enamel surface damage.

In this study, no significant difference in enamel surface damage was found by the use of debonding pliers and laser debonding. The mean values for these two techniques were 31.1 µm with SD ± 6.3 µm for debonding pliers and 33.7 µm with SD ± 6 µm for laser debonding.^[1,2] This finding is similar to that of the study by Oztoprak *et al.*,^[13] in which they have found that the use of Er-YAG laser as a debonding technique increased the ARI score and thus reduced the risk of enamel fracture on debonding. According to Tocchio *et al.*,^[21] the debonding mechanism using laser energy can be explained by thermal softening, thermal ablation, or photoablation. In thermal softening, decomposition of the adhesive resin is by heat transmitted through the bracket. Therefore, in most previous studies, carbon dioxide laser whose wavelength is easily absorbed by ceramic brackets has been preferred for debonding.^[22,23] However, on obtaining sufficient heat, a rise of temperature can increase the pulpal temperature, which may cause damage to the pulp. Because of this problem, Nd-YAG laser that would directly influence

Table 3: Percentage distribution of ARI scores in each group and Chi-square test result

Ari Score	Category						Total	
	Group A (plier)		Group B (Ultrasonic scaler)		Group C (Laser)		N	%
	N	%	N	%	N	%		
Score 0	0	0.0	2	6.7	0	0.0	2	2.2
Score 1	3	10.0	9	30.0	2	6.7	14	15.6
Score 2	11	36.7	18	60.0	12	40.0	41	45.6
Score 3	16	53.3	1	3.3	16	53.3	33	36.7
Total	30	100.0	30	100.0	30	100.0	90	100.0

test $\chi^2=25.877$ $df=6$ $P<0.001$

Table 4: Descriptive statistics of ARI scores in three groups

Category	N	ARI score		
		Mean	SD	Std. error
Group A (Plier)	30	2.433	0.6789	0.1240
Group B (Ultrasonic scaler)	30	1.600	0.6747	0.1232
Group C (Laser)	30	2.467	0.6288	0.1148
Total	90	2.167	0.7680	0.0810

Table 5: Multiple comparison-post hoc analysis to test difference in ARI scores in three groups

Multiple comparison		Mean Difference (I-J)	Std. Error	P
Plier	Ultrasonic scaler	0.83	0.1707	<0.001
Plier	Laser	-0.03	0.1707	0.846
Laser	Plier	-0.83	0.1707	<0.001

the resin by enhancing effects of thermal ablation and photoablation has been used by Hayakawa.^[24] In this study, the Er-YAG laser was selected because even though it has similar effects on the adhesive resin, it appears to have lesser thermal effects than the Nd-YAG laser.^[25] To reduce the heat conduction to the pulp, the effect of the energy was tried to be reduced by scanning through the surface of the bracket rather than applying it on just one point. Meanwhile, time could be provided for the tissues to cool. Infrared lasers such as Er-YAG, Nd-YAG, and carbon dioxide primarily have a thermal effect on water-containing tissues.^[26] The laser light of the Er-YAG laser can be absorbed by the resin that might contain a readily vaporizable constituent, such as water or a residual monomer. Laser energy softened the adhesive and the brackets popped out on their own, so there was no need for the use of debonding pliers in this study.

37% phosphoric acid has been used as an enamel conditioner in our study because it is the most commonly used etchant in clinical practice. In our study, 022 slot polycrystalline Siamese twin ceramic brackets (UNITEK Gemini Clear Ceramic Brackets, 3M) were used. They have a mechanical retentive base with grooves that provide a mechanical interlock to the adhesive. It has been claimed that chemical retention provided higher bond strength when compared with mechanical retention.^[3] Studies have shown that ceramic brackets with a mechanical retentive base have the least chance of enamel surface damage during debonding due to separation at the bracket adhesive interface rather than enamel adhesive interface as seen in chemical retention bases. Eliades *et al.*^[3] in their study reported that the combination of the ceramic base with both mechanical and chemical retention led to greater incidence of bracket fracture, compared to mechanically and chemically retentive bases.

Statistical evaluation revealed that the ARI values for the ultrasonic scaler method were less than those of the other two techniques with a mean value of 1.6 (SD \pm 0.6747). This may be because of the fact that bond failure with the ultrasonic scaler occurred at the enamel adhesive interface and more adhesive was removed along with the brackets, resulting in minimal adhesive remaining on the enamel surface, whereas in the other two techniques, sites of bond failure were at the bracket-adhesive interface. The results were similar to that of the study conducted by Bishara and Trulove,^[6,20] who had evaluated the ARI using the index proposed by Oliver R.G.^[27] and found that the ARI scores were greater when ceramic brackets were debonded using debonding pliers.

The limitations of our study are that being an *in vitro* study, the results may differ from *in vivo* conditions,

in which there may be a difference in debonding force, temperature, moisture, and other oral conditions, which may reduce the bond strength and alter the amount of enamel loss on debonding. We recommend further *in vivo* studies to be undertaken with intra-oral scanners, which may provide a complete picture to the tooth surface following orthodontic bracket debonding.

Conclusion

The results of this *in vitro* study confirmed that use of ultrasonic scalers as a debonding technique led to significantly greater incidence of enamel surface damage when compared to the other two debonding techniques. The ARI scores on the tooth surface using debonding pliers and laser were significantly greater than that of the scaler debonding technique. The findings of our study suggest that in debonding ceramic brackets, pliers or laser is comparatively better than ultrasonic scalers because they show minimal enamel damage.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Jena AK, Duggal R, Mehrotra AK. Physical properties and clinical characteristics of ceramic brackets: A comprehensive review. *Trends Biomater Artif Organs* 2007;20:101-5.
2. Karamouzos A, Athanasiou AE, Papadopoulos MA. Clinical characteristics and properties of ceramic brackets: A comprehensive review. *Am J Orthod Dentofacial Orthop* 1997;112:34-40.
3. Eliades T, Viazis AD, Lekka M. Failure mode analysis of ceramic brackets bonded to enamel. *Am J Orthod Dentofacial Orthop* 1993;104:21-6.
4. Eliades T, Lekka M, Eliades G, Brantley W. Surface characterization of ceramic brackets: A multitechnique approach. *Am J Orthod Dentofacial Orthop* 1994;105:10-8.
5. Swartz ML. Ceramic brackets. *J Clin Orthodontics* 1988;22:82-8.
6. Bishara SE, Trollove TS. Comparisons of different debonding techniques for ceramic brackets: An in-vitro study. Part 1. Background and methods. *Am J Orthod Dentofacial Orthop* 1990;98:145-53.
7. Campbell PM. Enamel surfaces after orthodontic bracket bonding. *Angle Orthod* 1995;2:103-10.
8. Zarrinnia K, Eid NM, Kehoe MJ. The effect of different debonding techniques on the enamel surface: An *in vitro* qualitative study. *Am J Orthod Dentofacial Orthop* 1995;108:284-93.
9. Knosel M, Mattysek S, Jung K, Sadat-Khonsari R, Kubein-Meesenburg D, Bauss O, *et al.* Impulse debracketing compared to conventional debonding. *Angle Orthod* 2010;80:1036-44.
10. Fujimoto JG. Optical coherence tomography for ultrahigh resolution *in vivo* imaging. *Nat Biotechnol* 2003;21:1361-7.
11. Bouma BE, Tearney GJ, editors. *Handbook of Optical Coherence Tomography*. New York: Marcel Dekker; 2002.

12. Boyer D, Engelhardt G, Samir E. Bishara. Debonding orthodontic ceramic brackets by ultrasonic instrumentation. *Am J Orthod Dentofacial Orthop* 1995;108:262-6.
13. Oztoprak MO, Nalbantgil D, Erdem AS, Tozlu M, Arun T. Debonding of ceramic brackets by a new scanning laser method. *Am J Orthod Dentofacial Orthop* 2010;138:195-200.
14. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid etch enamel pre-treatment. *Am J Orthod* 1984;85:333-40.
15. Sinha PK, Nanda RS. The effect of different bonding and debonding techniques on debonding ceramic orthodontic brackets. *Am J Orthod Dentofacial Orthop* 1997;112:132-7.
16. Bishara SE, Fehr DE. Ceramic brackets: Something old, something new, a review. *Semin Orthod* 1997;3:178-88.
17. Thompson RE, Way DC. Enamel loss due to prophylaxis and multiple bonding/debonding of orthodontic attachments. *Am J Orthod* 1981;79:282-95.
18. Bishara SE, Ostby AW, Laffoon J, Warren JJ. Enamel cracks and ceramic bracket failure during debonding in vitro. *Angle Orthod* 2008;78:1078-83.
19. Krell KV, Courey JM, Bishara SE. Orthodontic bracket removal using conventional and ultrasonic debonding techniques, enamel loss, and time requirements. *Am J Orthod Dentofacial Orthop* 1993;103:258-66.
20. Bishara SE, Trulove TS. Comparisons of different techniques for ceramic brackets: An *in vitro* study. Part II. Background and methods. *Am J Orthod Dentofacial Orthop* 1990;98:263-73.
21. Tocchio RM, Williams PT, Mayer FS, Standing KG. Laser debonding of ceramic orthodontic brackets. *Am J Orthod Dentofacial Orthop* 1993;103:155-62.
22. Strobl K, Bahns TL, Willham L, Bishara SE, Stwalley WC. Laser aided debonding of orthodontic ceramic brackets. *Am J Orthod Dent Orthop* 1992;101:152-8.
23. Ma T, Marangoni RD, Flint W. *In vitro* comparison of debonding force and intrapulpal temperature changes during ceramic orthodontic bracket removal using a carbon dioxide laser. *Am J Orthod Dentofacial Orthop* 1997;111:203-10.
24. Hayakawa K, Nd : YAG Laser for debonding ceramic orthodontic brackets. *Am J Orthod Dent Orthop* 2005;128:638-47.
25. Wigdor H, Abt E, Ashrafi S, Walsh JT Jr. The effect of lasers on dental hard tissues. *J Am Dent Assoc* 1993;124:65-70.
26. Keller U. Laser in dentistry, future trends in biomedical applications of lasers. *SPIE* 1991;1525:282-8.
27. Oliver RG. The effect of different methods of bracket removal on the amount of residual adhesive. *Am J Orthod Dent Orthop* 1988;93:196-200.