ORIGINAL RESEARCH

Comparison of Enamel Surface Roughness after Bracket Debonding and Adhesive Resin Removal Using Different Burs with and without the Aid of a Magnifying Loupe

Ahmed A Thawaba[1], Nehal F Albelasy[2], Amira M Elsherbini[3], Ahmad M Hafez[4]

Abstract

Aim: This study aimed to evaluate the impact of using a magnifying dental loupe on enamel surface roughness during adhesive resin removal by different burs.

Materials and methods: Ninety-six extracted premolar teeth were randomly divided according to the bur used with or without the aid of a magnifying loupe into four equal groups ($N = 24$): group I: naked eye tungsten carbide burs (NTC); group II: magnifying loupe tungsten carbide burs (MTC); group III: naked eye white stones (NWS); and group IV: magnifying loupe white stones (MWS). The initial surface roughness (R_a) T0 was evaluated using a profilometer, and the scanning electronic microscopy (SEM) technique. The metal brackets were bonded and debonded after 24 hours with debonding plier. After adhesive removal, R_a was evaluated again (T1) also the time spent on adhesive removal was recorded in seconds. The samples were finally polished by Sof-Lex discs and Sof-Lex spirals, and the third R_a evaluation was performed (T2).

Results: The results of two-way mixed analysis of variance (ANOVA) showed that all burs increased surface roughness at T1 as compared to T0 ($p < 0.001$) with the highest R_a values shown in group III followed by group IV, group I, and group II. After polishing, no significant difference was noted in R_a values in group I and group II at T0 vs T2 ($p = 1.000$), while it was significant in group III and group IV ($p < 0.001$). Regarding the time required for adhesive removal, the shortest time was in group IV followed by groups III, II, and I, respectively.

Conclusion: The use of a magnifying loupe affects the quality of the clean-up procedure by reducing the enamel surface roughness and the time spent on adhesive removal.

Clinical significance: Using a magnifying loupe was helpful during orthodontic debonding and adhesive removal.

Keywords: Magnifying loupe, Profilometer, Scanning electron microscopy, Surface roughness.

The Journal of Contemporary Dental Practice (2022): 10.5005/jp-journals-10024-3432

Introduction

In orthodontics, the primary goal of bracket debonding is to remove attachments and adhesive resin from tooth surfaces without causing iatrogenic damage and restore the enamel surface to the pretreatment condition. The clinician must consider factors such as the possibility of enamel damage and the time required for complete removal. To eliminate the potential risk of plaque retention and to restore the esthetic appearance of the enamel surface, an effective clean-up procedure is required.[1–4]

In the quest for an effective way to remove adhesive remnants after debonding orthodontic brackets, various techniques and instruments have been developed, such as mechanical removal of composite resin, which includes scraping with a scaler or band-removing plier as well as the use of rotary instruments such as tungsten carbide burs, diamond burs, white stones, special composite finishing burs, and Sof-Lex discs mounted on a high- or low-speed handpiece, however. Many studies[2,5,6] reported that they can cause irreversible enamel damage. Oliver and Griffiths[7] reported that the low-speed tungsten carbide bur was the best method for adhesive resin removal after orthodontic debonding. Mohebi et al.[8] revealed that tungsten carbide burs and white stone burs had relatively similar effects on the enamel surface roughness. Many studies have shown that laser energy can be used effectively to remove adhesive remnants and has been found to remove large volumes of a composite at much higher rates than conventional methods.[9–11]

[1,2,4]Department of Orthodontics, Faculty of Dentistry, Mansoura University, Mansoura, Egypt

[3]Department of Oral Biology, Faculty of Dentistry, Mansoura University, Mansoura, Egypt

Corresponding Author: Ahmed A Thawaba, Department of Orthodontics, Faculty of Dentistry, Mansoura University, Mansoura, Egypt, Phone: +0020 1121411384; +0020 1112895996, e-mail: mr.thawaba2021@gmail.com

How to cite this article: Thawaba AA, Albelasy NF, Elsherbini AM, *et al.* Comparison of Enamel Surface Roughness after Bracket Debonding and Adhesive Resin Removal Using Different Burs with and without the Aid of a Magnifying Loupe. J Contemp Dent Pract 2022;23(11):1091–1099.

Source of support: Nil

Conflict of interest: None

The tungsten carbide bur is one of the most commonly used tools for removing resin remnants from the tooth surface.[12] The tungsten carbide burs are preferred for removing ductile materials such as composite resins because the rotation of these burs results in the generation of high shear forces between the blades of the bur and the surface of resin, which results in plastic plowing of the resin. Many types of carbide burs are available in the market and almost all of them have been recommended for adhesive removal.[13]

The white stone burs are made of micro-grained aluminum oxide grits; each stone is perfectly balanced to provide vibration-free performance. In general, they can be used for finishing porcelain, composite restorations, glass ionomer cement, prepared teeth abutment, and enamel surfaces. With improvements in techniques and instruments, many white stone burs have been developed for adhesive resin removal after bracket debonding, and studies conducted to assess their impact on enamel have shown controversial results.[14]

A magnifying loupe is commonly used in dentistry and has been shown to improve ergonomics and precision.[15,16] Although dentistry has been traditionally performed with the naked eye, dentists have used magnification loupes as a visual aid for many decades, with continuous incremental improvements in design and efficacy.[17] Numerous orthodontic procedures, including bracket positioning, debonding, and adhesive resin removal, may benefit from the improved vision provided by magnifying loupes.[18]

A variety of factors, including the type of adhesive resin, debonding method, and the adhesive clean-up procedure can influence the amount of enamel loss. The failure of the micromechanical bond between the composite resin and the acid-etched enamel almost always results in some enamel loss.[19,20] There are many methods for the evaluation of surface roughness and enamel damage, including contact profilometry, noncontact white light 3D profilometry, stereo microscopy, SEM, and atomic force microscopy (AFM).[21]

To date, no universally accepted protocol has been established and many techniques have been utilized to remove adhesive remnants after bracket debonding; however, there is a huge discrepancy in the literature regarding the most effective clean-up procedure for adhesive removal. Therefore, this study aimed to compare the effects of the most commonly used burs for adhesive resin removal, tungsten carbide bur and white stone burs with and without the aid of the magnifying dental loupe on the enamel surface roughness and time spent for adhesive removal. The null hypothesis was that there was no difference between the studied clean-up methods in terms of enamel surface roughness and morphology, as well as time spent on resin removal.

Materials and Methods

This *in vitro* study was approved by the Research Ethics Committee of the Faculty of Dentistry, Mansoura University under code No. (A13071221). The sample size underwent calculation using G*power version 3.0.10 based on effect size = 0.40, two-tailed test, α value of 0.05, and a power of 90.0% and was found to be 24 samples in each group according to the study by Mohebi et al.[8]

Sample Preparation, Bonding, and Debonding

Ninety-six extracted premolars were used in this study and collected from the outpatient clinics. Inclusion criteria included intact buccal surfaces with no caries or cracks, white spots, dental restoration, or hypoplasia, and no history of exposure to chemicals such as bleaching materials or previous bracketing. Following extraction, the teeth were cleaned of any debris and embedded in acrylic blocks to facilitate handling and then stored in distilled water at 37°C to avoid dehydration.[12,22] At the start of the experiment, the teeth were pumiced and rinsed with water.

Study Group Design

The total sample (n = 96) was randomly divided into the following four equal groups according to the bur used for adhesive resin removal with or without the aid of a magnifying loupe:

- Group I: (n = 24) NTC
- Group II: (n = 24) MTC
- Group III: (n = 24) NWS
- Group IV: (n = 24) MWS

The initial R_a was primarily measured. Thirteen samples from each group were examined using a profilometer (Mitutoyo 178-560-01D Surftest SJ-21, Sakado, Japan) to determine the mean R_a values at baseline T0, and three samples from each group were randomly selected for the SEM examination. All teeth were then bonded according to the manufacturers' instructions: the buccal surface of teeth was etched with 32% phosphoric acid gel (3M, Scotchbond, Universal Etchant, USA) for 15 seconds, rinsed with water spray for 10 seconds, and air-dried. Then, the etched enamel was sealed with the adhesive primer (Transbond XT; 3M-Unitek, Monrovia, USA), and the metal brackets (Roth 22 Max, Morelli, Sorocaba, SP, Brazil) were bonded to the teeth surfaces using adhesive composite (Transbond XT, Adhesive Paste, 3M-Unitek, Monrovia, USA). The gentle pressure was applied, and the excess material was removed by the tip of an explorer. Each sample was light-cured for 40 seconds (10 seconds/side) using an light-emitting diode (LED)-based light curing unit with a light intensity of 400 mW/cm.[23] Specimens were immersed in distilled water for 24 hours at 37°C.[24,25] Next, the brackets were debonded by gently squeezing the mesial and distal wings with debonding pliers.

After bracket debonding, the adhesive remnant index (ARI) was determined visually by three blinded observers and scored according to the index used by Bishara et al.[26] This index comprises five scores ranging from 5 to 1: Score 5 indicates no composite is left on the enamel. Score 4: <10% composite left on the tooth surface. Score 3: >10% but <90% composite remaining on the tooth. Score 2: Over 90% of the composite remains on the tooth. Score 1: 100% of composite left on the tooth, along with the impression of the bracket base.

Adhesive Resin Removal and Polishing

The adhesive remnants were removed by different burs according to the manufacturer's instructions. In group I (NTC), low-speed 12-fluted tungsten carbide burs (Hager & Meisinger GmbH, Neuss, Germany) were used under naked eye vision with a maximum speed of 160,000 rpm. In group II (MTC), low-speed 12-fluted tungsten carbide burs were used with the aid of an X5 magnifying loupe (Ergovision, China). In group III (NWS), high-speed white stones (Frank Dental, Gmund, Germany) were used with a maximum speed of 120.000 rpm under naked eye vision, and in group IV (MWS), high-speed white stones were used with the aid of an X5 magnifying loupe. All burs were applied using light pressure and continuous motion and the samples were cooled with the air–water syringe. A new bur was used for every two samples to ensure cutting efficiency during adhesive removal and standardization of the procedure. The second surface roughness evaluation was performed after adhesive removal by burs and the time required for complete resin removal was registered in seconds.

The polishing was performed using a medium, fine, and super-fine Sof-Lex discs (3M™ ESPE, Minnesota, USA) in descending order and then followed by Sof-Lex spiral wheels, pink type (3M™ ESPE, Minnesota, USA). They were applied using a light-to-moderate pressure for 15–20 seconds with a constant, continuous, and one-directional motion to avoid enamel damage. According to the manufacturer's recommendations, Sof-Lex discs were used with different speeds: 10,000 rpm for medium-grit discs and 30,000 rpm for fine and superfine grit discs, and speeds between 15,000 and 20,000 rpm for Sof-Lex spirals. After polishing the third surface roughness evaluation was made. All the procedures, bracket bonding, debonding, resin removal, and polishing, were performed by the same operator (AT).

Measurement of Surface Roughness

Thirteen samples from each group were evaluated with a profilometer (Mitutoyo 178-560-01D Surftest SJ-21, Sakado, Japan) to determine the average surface roughness (R_a) at baseline (T0), after adhesive resin removal (T1), and after polishing (T2). Before measurement, the profilometer was calibrated against a reference block. Each specimen was positioned in the same orientation on the profilometer, and a diamond stylus (tip radius: 5 μm) was placed on the tested area and moved across the tooth surface with a static load of 0.4 g, speed of 0.25 mm/s for a 0.5 mm distance. For each sample, three tracings were recorded at three different locations, and the mean R_a values (expressed in μm) were recorded and statistically analyzed.

Three representative specimens of each group were examined with an SEM (Joel, JSM-6510 LV, Tokyo, Japan) at T0, T1, and T2 to evaluate the effects of different burs and polishing techniques on the enamel morphology. Before evaluation, the selected samples were dehydrated using a sequence of ascending ethanol concentrations (30%, 50%, 75%, 80%, 90%, 95%, and 100%) and then immersed in hexamethyldisilazane for 10 minutes. Then, each specimen was mounted on an aluminum stub and coated twice (90 seconds per round) with a 15 nm gold metallic sputter-deposited layer using a sputtering machine (SPI-module Sputter Coater Module, Pennsylvania, USA). Then, the samples were observed in SEM at 20–30 kV, at a working distance ranged from 11 to 20 mm, and under a magnification of 1000×.[27]

The obtained images were evaluated by three blinded examiners. The characteristics were then graded by using the enamel damage index enamel damage index (EDI) developed by Schuler and van Waes.[28] This index includes four scores: score 0, a smooth surface without scratches, and perikymata might be visible; score 1, an acceptable surface with fine scattered scratches; score 2, a rough surface with numerous coarse scratches or slight grooves visible; and score 3, a surface with coarse scratches, wide grooves, and enamel damage visible to the naked eye. All study procedures were represented in Flowchart 1.

Statistical Analysis

Data were tabulated and analyzed using IBM-SPSS software (IBM Corp. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp). Quantitative data were initially tested for normality using Shapiro–Wilk's test, which was normally distributed. The mean and standard deviations of R_a values were statistically calculated by two-way mixed ANOVA followed by *posthoc* Tukey's honest significant difference (HSD) for pairwise comparisons. For the analysis of the time consumed for adhesive removal, the mean and standard deviations were calculated using one-way ANOVA followed by *posthoc* Tukey's HSD for pairwise comparisons. Medians of EDI were tested using Kruskal–Wallis's *H* (KW-*H*)-test. The significance level was fixed at 5% and $p \leq 0.05$ was considered statistically significant.

Results

Quantitative Observations

Regarding the initial surface roughness, the analysis of two-way mixed ANOVA revealed no statistically significant difference between all four groups at T0 ($p = 0.926$, Table 1). The ARI comparisons after bracket removal showed no significant difference between all studied groups ($p = 0.908$, Fig. 1).

After adhesive resin removal (T1), the two-way mixed ANOVA showed a statistically significant difference in R_a values between all groups ($p < 0.001$), with the mean R_a values, increased to (0.936 ± 0.045 and 0.830 ± 0.052 μm) in group I (NTC), and group II (MTC) respectively, and to (1.326 ± 0.070 and 1.209 ± 0.077 μm) in group III (NWS), and group IV (MWS), respectively. The pairwise comparisons using *posthoc* Tukey's HSD tests revealed a statistically significant difference between each pair of groups ($p < 0.001$, Table 1).

The R_a values after polishing (T2) with Sof-Lex discs and Sof-Lex spiral wheels showed a statistically significant difference in all tested groups ($p < 0.001$) and the mean R_a values significantly decreased as compared to T1 (0.410 ± 0.046 and 0.422 ± 0.040 μm) in group I (NTC), and group II (MTC) respectively, and (0.644 ± 0.038 and 0.506 ± 0.060 μm) in group III (NWS), and group IV (MWS), respectively. Pairwise comparisons revealed a statistically significant difference between all pairs ($p < 0.001$) except the group I (NTC) vs group II (MTC) was not statically significant ($p = 1.000$, Table 1).

Comparisons of mean R_a values between the three-time intervals (T0, T1, and T2) using a two-way mixed ANOVA test showed statistically significant differences in each group ($p < 0.001$), and the pairwise comparisons revealed a statistically significant difference at T1 vs T0 and T1 vs T2 in all groups ($p < 0.001$), while there was no significance at T0 vs T2 in both group I (NTC) and group II (MTC) ($p = 1.000$), as the enamel restored approximately to its pre-treatment condition. However, in the group III (NWS) and group IV (MWS), the R_a values showed a statistically significant difference between all three time points T0, T1, and T2 ($p < 0.001$), indicating that surface roughness after polishing (T2) was still higher than that at baseline (T0) (Table 1).

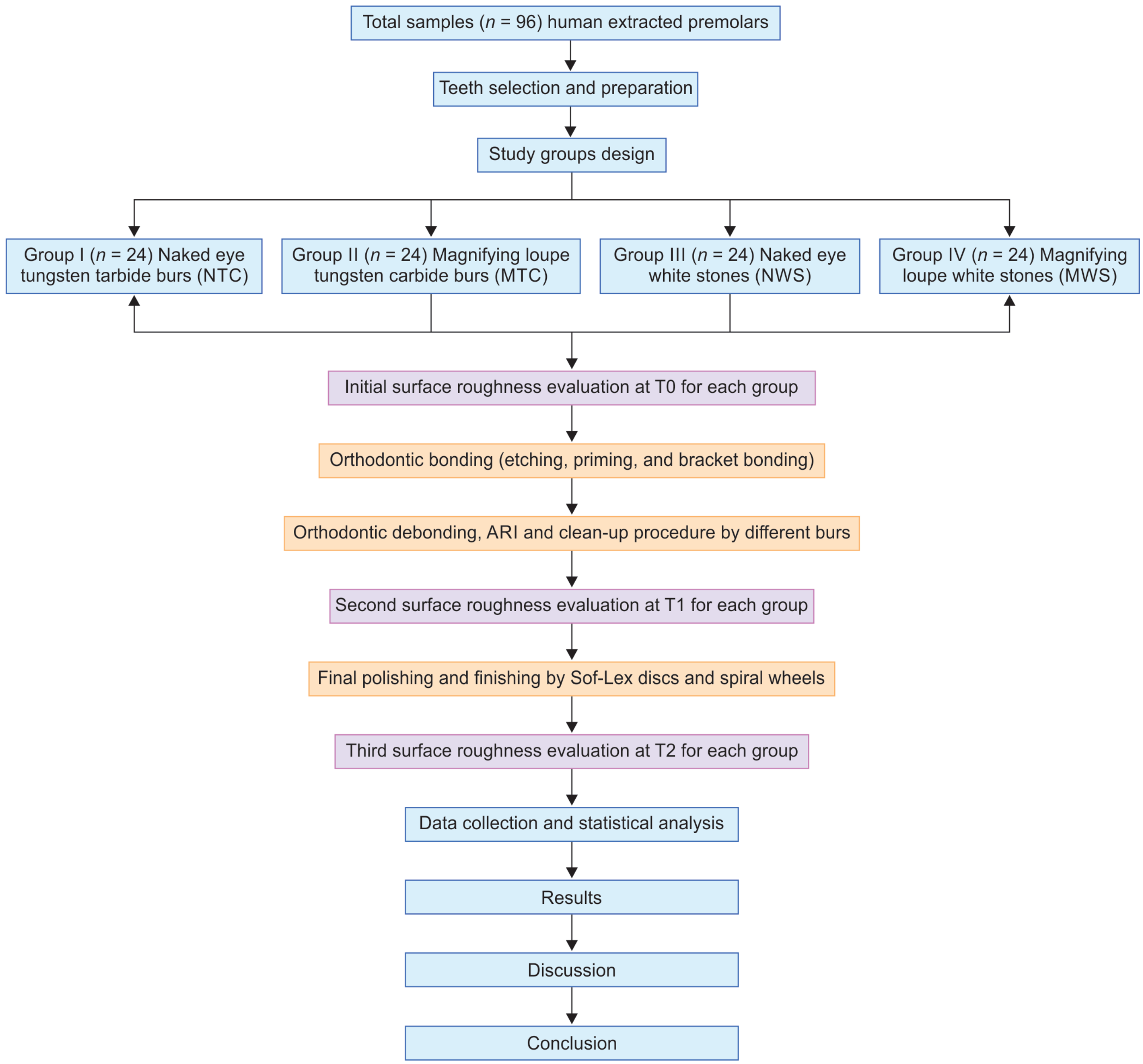
Regarding the mean time required for resin removal by the tested burs, a statistically significant difference was found between the four groups ($p < 0.001$). Group I (NTC) was the most time-consuming method with a mean time of 56.6 ± 4.6 seconds, followed by group II (MTC) with a mean time of 51.8 ± 3.8 seconds, and group III (NWS) with a mean time of 33.0 ± 2.7 seconds. The group IV (MWS) was the fastest method, with a mean time of 29.5 ± 4.1 seconds. Tukey's HSD *posthoc* tests were run for pairwise comparisons, which revealed a statistically significant difference in each pair except group III (NWS) vs group IV (MWS) ($p = 0.114$, Table 2).

Regarding the EDI, a KW-*H*-test showed a statistically significant difference between all groups at T1 and T2 ($p = 0.012$). Pairwise comparisons revealed a statistically significant difference between all pairs at T1 except group I (NTC) vs group II (MTC) and group III (NWS) vs group IV (MWS) ($p = 1.000$). However, after the Bonferroni correction for multiple tests, there was no statistically significant difference for any pair. However, at T2, pairwise comparisons revealed a statistically significant difference between group III (NWS) vs all three other groups ($p = 0.041$) even after the Bonferroni correction for multiple tests (Table 3).

Qualitative Observations

Scanning electronic microscopy observations were not intended for objective comparisons, but rather for a better demonstration of what happened to the enamel surface. At the baseline (T0), SEM images showed that the enamel surface was smooth with no scratches or grooves (Fig. 2A). The images after adhesive resin removal (T1) demonstrated that the group I (NTC) and group II

Flowchart 1: The study procedures



(MTC) showed EDI score 2, which represents a rough enamel surface with numerous coarse scratches and slight grooves (Figs 2B and C) while the group III (NWS) and group IV (MWS) showed score 3, with coarse scratches, wide deep grooves (Figs 2D and E). After polishing (T2), the Sof-Lex discs and spirals produced a smooth and homogeneous enamel surface in group I (NTC) and group II (MTC), while group III (NWS) and group IV (MWS) showed a slightly roughened enamel surface with fewer scratches and shallow grooves even after polishing (Figs 2F to I).

Discussion

Debonding procedures can be harmful to the enamel surfaces and their future health. These undesirable outcomes can occur during bracket removal or adhesive clean-up including the persistence of adhesive remnants and enamel surface damage.[29] Many studies investigated various options for adhesive clean-up techniques from the enamel surface, with the main goal of restoring the tooth surface to its original condition or as close to it as possible.[30–32] So far, there is no ideal protocol for orthodontic debonding and adhesive resin removal without causing iatrogenic side effects on the enamel structure.

Dental loupes are widely used in many dental practices, especially in endodontics and microsurgery interventions. The advantages of using a magnification system include decreased work time, increased work quality, and a better working posture.[33] The magnifying loupe is especially important during orthodontic debonding to save as much enamel tissue as possible during adhesive removal.[34] However, the efficiency of using the magnifying loupe during orthodontic debonding and adhesive removal has

Table 1: Two-way mixed ANOVA and pairwise comparisons of R_a among three groups at different time intervals

	T0	*T1*	*T2*			
Group	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	*F*	*p*	*Partial* η^2
Group I	0.4085 ± 0.038	0.9362 ± 0.045	0.4097 ± 0.046	69.25	<0.001	0.812
Group II	0.4090 ± 0.050	0.8296 ± 0.052	0.4223 ± 0.040			
Group III	0.4082 ± 0.037	1.3263 ± 0.070	0.6440 ± 0.038			
Group IV	0.3995 ± 0.039	1.2092 ± 0.077	0.5058 ± 0.060			
P°	0.926	<0.001	<0.001			
Pairwise comparisons (p-value) of (R_a) mean values at T1 and T2 between each pair of groups						
Group I vs Group II		<0.001	1.000			
Group I vs Group III		<0.001	<0.001			
Group I vs Group IV		<0.001	<0.001			
Group II vs Group III		<0.001	<0.001			
Group II vs Group IV		<0.001	<0.001			
Group III vs Group IV		<0.001	<0.001			
Pairwise comparisons (p-value) of (R_a) mean values within each group over three times						
Group	*T0 vs T1*	*T0 vs T2*	*T1 vs T2*			
Group I	<0.001	1.000	<0.001			
Group II	<0.001	1.000	<0.001			
Group III	<0.001	<0.001	<0.001			
Group IV	<0.001	<0.001	<0.001			

Statistically significant at $p < 0.05$. Partial Eta squared (η^2) is a measure of effect size. *p* = Pairwise comparisons within each group; *P°* = Pairwise comparisons within each time

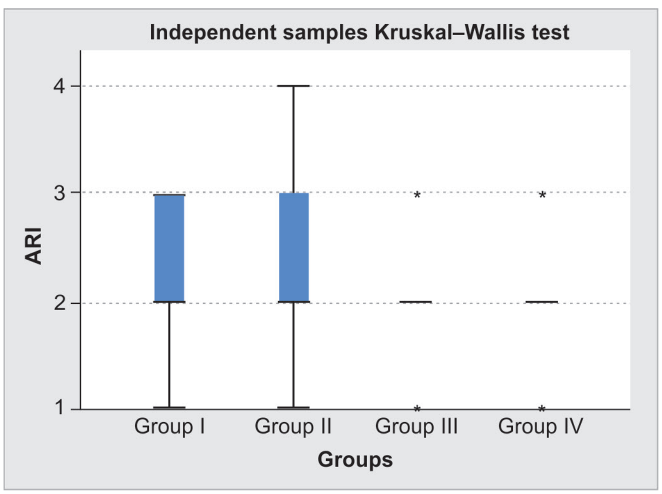


Fig. 1: The ARI in the four groups

not been widely reported in the literature. Therefore, the current study aimed to evaluate the impact of using the magnifying loupe X5 on enamel surface roughness during the clean-up procedure using different burs.

Today, using the Sof-Lex discs is one of the most commonly used techniques for composite and enamel finishing. However, using the Sof-Lex discs alone for adhesive removal and enamel polishing is a more time-consuming procedure and must be used in conjunction with other methods of adhesive removal.[35] In this study, the Sof-Lex discs were used for enamel polishing after the adhesive remnants were removed by different burs followed by Sof-Lex spirals, which have a flexible nature, and abrasive particles are embedded throughout the spiral to provide a paste-like gloss appearance.

The SEM affords a subjective inspection that can be used as supportive evidence for quantitative measurements.[9] The AFM and a profilometer can be used when multiple mechanical scans are needed for analyzing average surface roughness.[32] The profilometer was preferred in our study due to its low cost and accessibility.

In the current study, no significant differences were found in average R_a values at baseline (T0) among the tested groups, with a *p*-value = 0.971. After the bracket debonding, the amount of adhesive remnants were evaluated depending on the ARI used by Bishara et al.[26] The results of this study revealed that there were no statistically significant differences in the ARI between all groups with a *p*-value = 0.975, and score 2 was predominant, indicating that the samples were eligible to compared for surface roughness and consumed time. These results agreed with the study conducted by Vidor et al.[35]

The results of this study demonstrated that R_a values were significantly increased as compared to the baseline (T0) in group I (NTC) and group II (MTC) with a *p*-value < 0.001. However, the R_a values were significantly higher in group III (NWS) and group IV (MWS). This result was supported by SEM analysis that showed an EDI score of 2 for group I (NTC) and group II (MTC) and a score of 3 for group III (NWS) and group IV (MWS).

Schiefelbein and Rowland[36] obtained similar results and concluded that the white stones caused more severe enamel damage than the tungsten carbide bur. Also, a systematic review conducted by Olszowska et al.[31] stated that the use of tungsten carbide burs for adhesive removal was more effective than white stones, and the white stones should not be used as they caused severe enamel damage. Moreover, Albuquerque et al.[25] concluded that the tungsten carbide bur presented the best results while the white stones presented the worst results. On contrary, Shafiee et al.[24] found that the tungsten carbide burs produced surface roughness similar to that created by the white stone burs. Also, Mohebi et al.[8] stated that the effects of the tungsten carbide and white stone burs on the enamel surface roughness were comparable.

After polishing, the Sof-Lex discs and Sof-Lex spirals significantly decreased the R_a values as compared to T1 in all studied groups. However, the pairwise comparisons of R_a after polishing (T2) vs the baseline (T0) showed nonstatistically significant differences in the tungsten carbide bur groups, where the enamel surface was restored approximately to its pretreatment condition, while in the white stone groups, the surface roughness massively decreased but still higher than that at baseline. The SEM images demonstrated that the enamel still had irreversible fewer scratches and shallow grooves in the white stone groups even after polishing.

Table 2: One-way ANOVA and *post hoc* Tukey's HSD of time consumed for adhesive removal (seconds) in the four groups

Group	*Mean*	*SD*	*F*	*p-value*	*Partial η²*
Group I	56.6	4.6	158.997	<0.001	0.909
Group II	51.8	3.8			
Group III	33	2.7			
Group IV	29.5	4.1			
Tukey posthoc tests	*Mean difference*		*p-value*		
Group I vs Group II	4.846		0.012		
Group I vs Group III	23.615		<0.001		
Group I vs Group IV	27.077		<0.001		
Group II vs Group III	18.769		<0.001		
Group II vs Group IV	22.231		<0.001		
Group III vs Group IV	3.462		0.114		

Statistically significant at $p < 0.05$. Partial Eta squared (η^2) is a measure of effect size.

These results were consistent with Faria-Júnior et al.[37] who found that the Sof-Lex discs created the smoothest enamel surface and the lowest R_a values compared to sound enamel. Additionally, the findings obtained by Özer et al.[32] and Pinzan-Vercelino et al.[38] stated that the Sof-Lex discs and Sof-Lex spiral wheels resulted in lower R_a values and restored the enamel surface closer to its pretreatment status without enamel damage. As opposed to our results, Shah et al.[39] observed that the greatest enamel roughness was produced when the Sof-Lex discs and Sof-Lex spiral wheels were used. This disagreement is due to the fact that they used the coarse Sof-Lex disc (blue series), which was different from the discs used in our study (brown, orange, and yellow series). Also, Eliades et al.[40] found that the polishing using the Sof-Lex discs didn't reduce the enamel roughness.

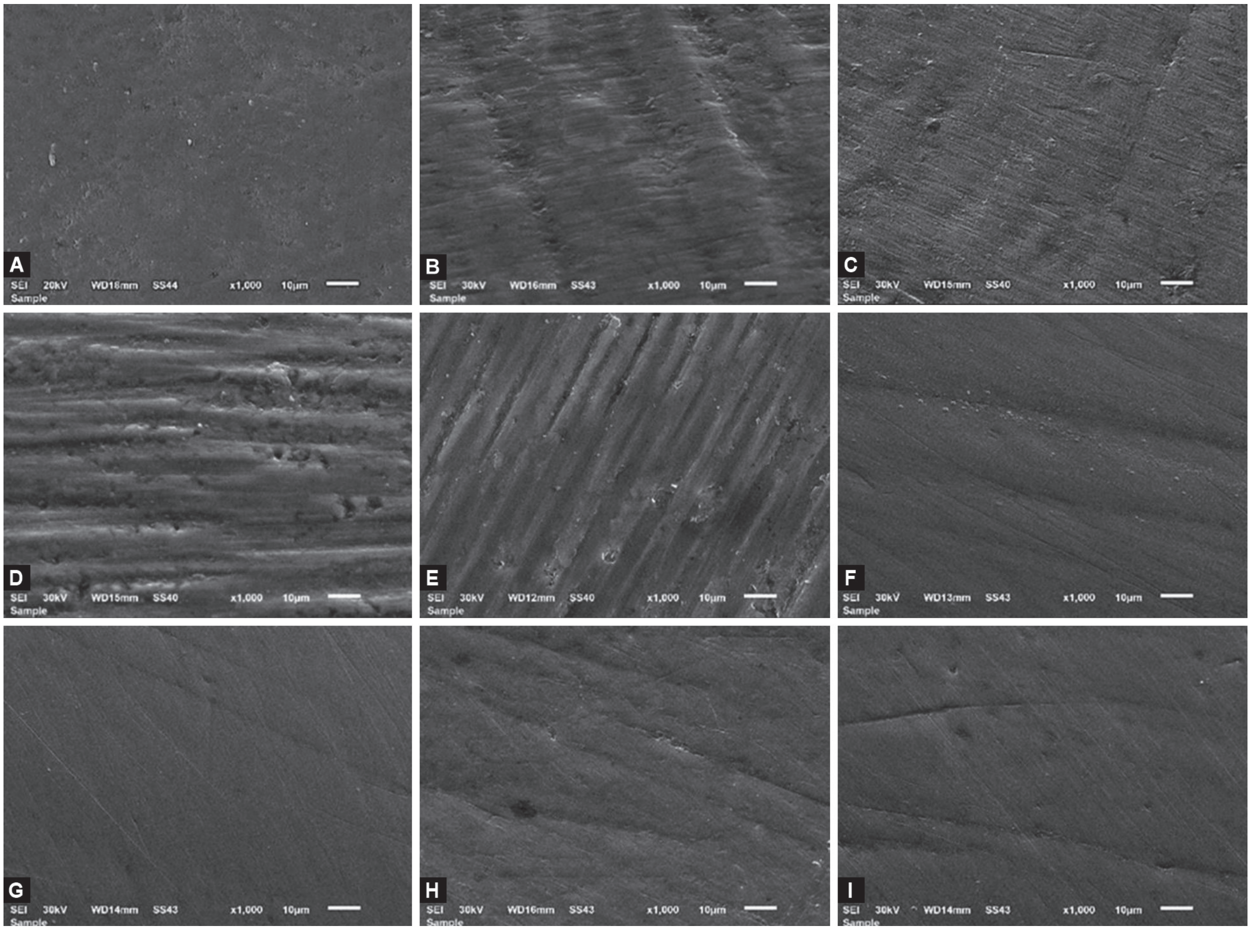
The present study has shown a statistically significant difference in the time required for resin removal among all groups. The tungsten carbide burs consumed a longer time (56.6 ± 4.6 and 51.8 ± 3.8 seconds in group I [NTC] and group II [MTC], respectively), while the white stones were the fastest method with a mean time of 33.0 ± 2.7 and 29.5 ± 4.1 seconds in group III (NWS) and group IV (MWS), respectively. This is consistent with the results of Tenório et al.[41] which have shown that the mean time spent for resin remnants removal by the tungsten carbide bur was 56 ± 5.2 seconds and not consistent with Vidor et al.[35] results, which concluded that the tungsten carbide bur was the less time-consuming method. This disagreement might be because they use high-speed tungsten carbide burs. Also, Mohebi et al.[8] revealed that the white stone spent a longer time for resin removal as compared to the tungsten carbide bur, and these might be due to that they used white stones on a low-speed handpiece.

In this study, the effectiveness of using the magnifying loupe during the clean-up procedure was assessed qualitatively and quantitatively as compared to the naked eye vision. The results showed that a magnifying loupe improves the quality of debonding and clean-up procedures by reducing surface roughness and enamel damage. Also, the required time for adhesive removal and polishing was reduced. These results agreed with the results of Baumann et al.[18] and Bernardi et al.[42] who stated that the wearing of a magnifying loupe during orthodontic debonding significantly reduced the risk of potential enamel damage and the amount of resin remnants left on the teeth surfaces as compared to the naked eye vision and disagreed with Mohebi et al.[8] results, who concluded that there were no significant differences in the surface roughness and the time required for resin removal between the naked eye vision and magnifying loupe groups.

Table 3: The median and *p* value of KW-*H*-test of EDI in four groups at T1 and T2

Time	*Group I*	*Group II*	*Group III*	*Group IV*	*KW-H H [2]*	*p-value*
T1	2 (2–2)	2 (2–2)	3 (3–3)	3 (3–3)	11	0.012
T2	1 (1–1)	1 (1–1)	2 (2–2)	1 (1–1)	11	0.012
Pairwise comparisons		*At T1*			*At T2*	
Group I vs Group II		1.000			1.000	
Group I vs Group III		0.114			0.041	
Group I vs Group IV		0.114			1.000	
Group II vs Group III		0.114			0.041	
Group II vs Group IV		0.114			1.000	
Group III vs Group IV		1.000			0.041	

Statistically significant at $p < 0.05$.



Figs 2A to I: SEM photomicrographs of enamel surface at 1000× magnification. (A) Enamel surface at T0; (B) Enamel surface at T1 in group I; (C) Enamel surface at T1 in group II; (D) Enamel surface at T1 in group III; (E) Enamel surface at T1 in group IV; (F) Enamel surface at T2 in group I; (G) Enamel surface at T2 in group II; (H) Enamel surface at T2 in group III; and (I) Enamel surface at T2 in group IV

Careful adhesive removal and efficient methods of restoring the enamel surface as much as possible to its pretreatment state are essential. Our results demonstrated that working with magnifying loupe during the adhesive resin removal produced the best results with reduced surface roughness and less risk of enamel damage and also, the time spent on clean-up procedures was decreased. The high-speed white stone burs should not be used as they caused greater enamel surface damage. The polishing of the tooth surface is recommended after adhesive removal by any method.

Limitations of This Study

This study was conducted in the laboratory, where it is impossible to mimic the intra-oral conditions.[39] Intraoral factors such as saliva, oral hygiene, temperature, and pH can all have an impact on the results.[43] In addition, the biological effects of the tested methods on the pulp and the dentine were not assessed. The AFM and confocal laser microscopy, are being used for 3D surface analysis of enamel surfaces, which helps in obtaining more reliable information about surface roughness and the amount of enamel loss caused by different clean-up methods, and such methods are planned for future *in vitro* studies. The metal brackets were used in this study however, the other types of brackets such as ceramic brackets may have a different impact on the results which should be assessed in future studies.

Conclusion

The null hypothesis was rejected, the use of a magnifying loupe affects the quality of the clean-up procedure, by reducing the enamel surface roughness and the time spent on adhesive removal. The enamel surface was restored closer to its pretreatment condition after adhesive resin removal by low-speed tungsten carbide burs and polishing by the Sof-Lex discs and spirals, while the high-speed white stones resulted in greater surface roughness and irreversible enamel damage even after polishing.

References

1. Zachrisson BU, Årthun J. Enamel surface appearance after various debonding techniques. Am J Orthod Dentofacial Orthop 1979;75(2):121–137. DOI:10.1016/0002-9416(79)90181-7.
2. Campbell PM. Enamel surfaces after orthodontic bracket debonding. Angle Orthod 1995;65(2):103–110. DOI:10.1043/0003-3219(1995)065<0103:ESAOBD>2.0.CO;2.
3. Ryf S, Flury S, Palaniappan S, et al. Enamel loss and adhesive remnants following bracket removal and various clean-up procedures in vitro. Eur J Orthod 2012;34(1):25–32. DOI:10.1093/EJO/CJQ128.
4. Ireland AJ, Hosein I, Sherriff M. Enamel loss at bond-up, debond and clean-up following the use of a conventional light-cured composite and a resin-modified glass polyalkenoate cement. Eur J Orthod 2005;27(4):413–419. DOI:10.1093/EJO/CJI031.

5. Karan S, Kircelli BH, Tasdelen B. Enamel surface roughness after debonding : Comparison of two different burs. Angle Orthod 2010;80(6):1081–1088. DOI:10.2319/012610-55.1.
6. Pont HB, Özcan M, Bagis B, et al. Loss of surface enamel after bracket debonding: an in-vivo and ex-vivo evaluation. Am J Orthod Dentofacial Orthop 2010;138(4):1–9. DOI:10.1016/J.AJODO.2010.01.028.
7. Oliver RG, Griffiths J. Different techniques of residual composite removal following debonding—time taken and surface enamel appearance. Br J Orthod 1992;19(2):131–137. DOI:10.1179/BJO.19.2.131.
8. Mohebi S, Shafiee HA, Ameli N. Evaluation of enamel surface roughness after orthodontic bracket debonding with atomic force microscopy. Am J Orthod Dentofacial Orthop 2017;151(3):521–527. DOI:10.1016/J.AJODO.2016.08.025.
9. Stein S, Kleye A, Schauseil M, et al. 445-nm diode laser-assisted debonding of self-ligating ceramic brackets. Biomed Tech (Berl) 2017;62(5):513–520. DOI:10.1515/BMT-2016-0027.
10. Mundethu AR, Gutknecht N, Franzen R. Rapid debonding of polycrystalline ceramic orthodontic brackets with an Er:YAG laser: An in vitro study. Lasers Med Sci 2014;29(5):1551–1556. DOI:10.1007/S10103-013-1274-9.
11. 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(2):203–210. DOI:10.1016/S0889-5406(97)70217-8.
12. Hong YH, Lew KKK. Quantitative and qualitative assessment of enamel surface following five composite removal methods after bracket debonding. Eur J Orthod 1995;17(2):121–128. DOI:10.1093/EJO/17.2.121.
13. Kim SS, Park WK, Son WS, et al. Enamel surface evaluation after removal of orthodontic composite remnants by intraoral sandblasting: A 3-dimensional surface profilometry study. Am J Orthod Dentofacial Orthop 2007;132(1):71–76. DOI:10.1016/J.AJODO.2005.07.027.
14. Bandıca M, Tonetto M, Frizzera F, et al. Methods for removal of resin remaining after debonding of orthodontic brackets: A literature review. J Dent Res Rev 2014;1(2):105–107. DOI:10.4103/2348-2915.133960.
15. Wajngarten D, Botta AC, Garcia PPNS. Magnification loupes in dentistry: A qualitative study of dental students' perspectives. Eur J Dent Educ 2021;25(2):305–309. DOI:10.1111/EJE.12605.
16. Braga T, Robb N, Love RM, et al. The impact of the use of magnifying dental loupes on the performance of undergraduate dental students undertaking simulated dental procedures. J Dent Educ 2021;85(3):418–426. DOI:10.1002/JDD.12437.
17. Shanelec DA. Optical principles of loupes. J Calif Dent Assoc 1992;20(11):25–32. PMID:1284393.
18. Baumann DF, Brauchli L, van Waes H. The influence of dental loupes on the quality of adhesive removal in orthodontic debonding. J Orofac Orthop/Fortschritte Der Kieferorthopädie 2011;72(2):125–132. DOI:10.1007/s00056-011-0010-y.
19. Gwinnett AJ, Gorelick L. Microscopic evaluation of enamel after debonding: clinical application. Am J Orthod Dentofacial Orthop 1977;71(6):651–665. DOI:10.1016/0002-9416(77)90281-0.
20. Bishara SE, Trulove TS. Comparisons of different debonding techniques for ceramic brackets: An in vitro study. Part II. Findings and clinical implications. Am J Orthod Dentofacial Orthop 1990;98(3):263–273. DOI:10.1016/S0889-5406(05)81604-X.
21. Janiszewska-Olszowska J, Tandecka K, Szatkiewicz T, et al. Three-dimensional analysis of enamel surface alteration resulting from orthodontic clean-up-comparison of three different tools. BMC Oral Health 2015;15(1):131–136. DOI:10.1186/S12903-015-0131-6.
22. Erdur EA, Akin M, Cime L, et al. Evaluation of enamel surface roughness after various finishing techniques for debonding of orthodontic brackets. Turkish J Orthod 2016;29(1):1–5. DOI:10.5152/turkjorthod.2016.15-00016r1.
23. Swanson T, Dunn WJ, Childers DE, et al. Shear bond strength of orthodontic brackets bonded with light-emitting diode curing units at various polymerization times. Am J Orthod Dentofacial Orthop 2004;125(3):337–341. DOI:10.1016/J.AJODO.2003.04.011.
24. Shafiee H-A, Mohebi S, Ameli N, et al. Enamel surface roughness after orthodontic bracket debonding and composite resin removal by two types of burs. J Dent Sch Shahid Beheshti Univ Med Sci 2015;33(3):210–219. DOI:10.22037/jds.v33i3.24711.
25. Albuquerque G de S, Filho MV, Lucato AS, et al. Evaluation of enamel roughness after ceramic bracket debonding and clean-up with different methods. Brazilian J Oral Sci 2010;9(2):81–84. DOI:10.20396/bjos.v9i2.8641848.
26. Bishara SE, Ortho D, Truiove TS. Comparisons of different debonding techniques for ceramic brackets: An in vitro study. Part I. Background and methods. Am J Orthod Dentofacial Orthop 1990;98(2):145–153. DOI:10.1016/0889-5406(90)70008-Z.
27. Saghiri MA, Asgar K, Lotfi M, et al. Back-scattered and secondary electron images of scanning electron microscopy in dentistry: a new method for surface analysis. Acta Odontol Scand 2012;70(6):603–609. DOI:10.3109/00016357.2011.645057.
28. Schuler FS, van Waes H. SEM-evaluation of enamel surfaces after removal of fixed orthodontic appliances. Am J Dent 2003;16(6):390–394. PMID: 15002953.
29. Palmer JA, Mang T, Tabbaa S, et al. Analysis of enamel surface roughness after different adhesive removal techniques for orthodontic bracket debonding. Lasers Dent Sci 2018;2(2):95–101. DOI:10.1007/s41547-018-0024-5.
30. Alessandri Bonetti G, Zanarini M, Incerti Parenti S, et al. Evaluation of enamel surfaces after bracket debonding: An in-vivo study with scanning electron microscopy. Am J Orthod Dentofacial Orthop 2011;140(5):696–702. DOI:10.1016/J.AJODO.2011.02.027.
31. Janiszewska-Olszowska J, Szatkiewicz T, Tomkowski R, et al. Effect of orthodontic debonding and adhesive removal on the enamel – Current knowledge and future perspectives – A systematic review. Med Sci Monit 2014;20:1991–2001. DOI:10.12659/MSM.890912.
32. Özer T, Başaran G, Kama JD. Surface roughness of the restored enamel after orthodontic treatment. Am J Orthod Dentofacial Orthop 2010;137(3):368–374. DOI:10.1016/J.AJODO.2008.02.025.
33. Aboalshamat K, Daoud O, Mahmoud LA, et al. Practices and attitudes of dental loupes and their relationship to musculoskeletal disorders among dental practitioners. Int J Dent 2020;11(3):1–7. DOI:10.1155/2020/8828709.
34. Cochrane NJ, Lo TWG, Adams GG, et al. Quantitative analysis of enamel on debonded orthodontic brackets. Am J Orthod Dentofacial Orthop 2017;152(3):312–319. DOI:10.1016/J.AJODO.2017.01.020.
35. Vidor MM, Felix RP, Marchioro EM, et al. Enamel surface evaluation after bracket debonding and different resin removal methods. Dental Press J Orthod 2015;20(2):61–67. DOI:10.1590/2176-9451.20.2.061-067.oar.
36. Schiefelbein C, Rowland K. A comparative analysis of adhesive resin removal methods. Int J Orthod Milwaukee 2011;22(2):17–22. PMID:21827051.
37. Faria-Júnior ÉM, Guiraldo RD, Berger SB, et al. In-vivo evaluation of the surface roughness and morphology of enamel after bracket removal and polishing by different techniques. Am J Orthod Dentofacial Orthop 2015;147(3):324–329. DOI:10.1016/j.ajodo.2014.10.033.
38. Pinzan-Vercelino CRM, Souza Costa AC, Gurgel JA, et al. Comparison of enamel surface roughness and color alteration after bracket debonding and polishing with 2 systems: A split-mouth clinical trial. Am J Orthod Dentofacial Orthop 2021;160(5):686–694. DOI:10.1016/J.AJODO.2020.06.039.
39. Shah P, Sharma P, Goje SK, et al. Comparative evaluation of enamel surface roughness after debonding using four finishing and polishing systems for residual resin removal—an in vitro study. Prog Orthod 2019;20(1):18–28. DOI:10.1186/s40510-019-0269-x.

40. Eliades T, Gioka C, Eliades G, et al. Enamel surface roughness following debonding using two resin grinding methods. Eur J Orthod 2004;26(3):333–338. DOI:10.1093/EJO/26.3.333.
41. Soares Tenório KC, Neupmann Feres MF, Tanaka CJ, et al. In vitro evaluation of enamel surface roughness and morphology after orthodontic debonding: Traditional cleanup systems versus polymer bur. Int Orthod 2020;18(3):546–554. DOI:10.1016/j.ortho.2020.04.006.
42. Bernardi S, Continenza MA, Macchiarelli G. Microscopic evaluation of the enamel surface after debonding procedures: An ex vivo study using scanning electron microscopy. Microscopie 2018;85(3):418–426. DOI:10.4081/microscopie.2018.7190.
43. Ulusoy Ç. Comparison of finishing and polishing systems for residual resin removal after debonding. J Appl Oral Sci 2009;17(3):209–215. DOI:10.1590/s1678-77572009000300015.