Original Article

Efficacy of auxiliary devices for removal of fluorescent residue after bracket debonding

Rafael Santos Rocha[a]; Fabio Martins Salomão[b]; Lucas Silveira Machado[c]; Renato Herman Sundfeld[d]; Ticiane Cestari Fagundes[e]

ABSTRACT

Objective: To evaluate four protocols for removal of fluorescent materials after bracket debonding.
Materials and Methods: Resin removal from 40 bovine enamel surfaces was performed according to groups (n = 10): conventional (C), white LED (W), LED that evidenced fluorescence (F), and fluorescent lens (FL). The following analyses were performed: sample thickness, superficial area of resin residue, and areas of resin residue or worn enamel in depth. ANOVA and Tukey tests were used to analyze sample thickness ($P \leq .05$). Area measurements were analyzed by Kruskal-Wallis and Dunn's tests ($P \leq .05$).
Results: The FL group showed the highest reduction in enamel thickness. F group final thickness was similar to that of other groups. The largest superficial areas of resin residue were found for the C and W groups, while the FL group had the greatest removal of resin residue. The C group exhibited the largest area in depth of resin residue. The FL and F groups exhibited the most loss of enamel with the least amount of resin residue; in contrast, the C and W groups presented the fewest areas of worn enamel and the most areas of resin residue.
Conclusion: Auxiliary devices were useful for removal of fluorescent residue after bracket debonding. (*Angle Orthod.* 2017;87:440–447)

KEY WORDS: Fluorescence; Dental debonding; Dental enamel

INTRODUCTION

During bracket removal, there may be enamel damage from rotary instruments.[1–3] Also, inadequate removal of residue often leaves areas of resin, which may cause morphological changes on the buccal surface,[1] affecting the patient's esthetics and oral health,[4] especially considering plaque accumulation.[4]

Despite the publication of several studies on protocols for removing resin residue, no consensus has been reached about the ideal protocol.[4] In summary, most studies have analyzed the surface roughness of enamel after removal of the remaining resin.[1,5,6] A systematic review failed to reveal either an effective method of measuring the enamel surface wear or of analyzing the remaining resin bonded to enamel after debonding.[4] The authors concluded that new techniques are necessary to allow complete removal of resin, minimize enamel wear, and optimize the achievement of smooth surfaces after fixed orthodontic treatment.[4]

Within this context, resin removal is challenging to the dental professional, considering the difficulty of differentiating tooth structure from adhesive residue because of esthetic advances in restorative materials of past decades.[2] Aiming to reduce the difficulty of this differentiation, investigators have suggested two innovations: devices with fluorescent light and resins with fluorescent content.[7] Recently, an innovative lighting

[a] Masters Student, Department of Restorative Dentistry, São Paulo State University (Unesp), Institute of Science and Technology, São José dos Campos, SP, Brazil
[b] PhD Student, Department of Restorative Dentistry, São Paulo State University (Unesp), School of Dentistry, Araçatuba, SP, Brazil
[c] Assistant Professor, Department of Conservative Dentistry, Federal University of Rio Grande do Sul (UFRGS), College of Dentistry, Porto Alegre, RS, Brazil.
[d] Professor, Department of Restorative Dentistry, São Paulo State University (Unesp), School of Dentistry, Araçatuba, SP, Brazil.
[e] Assistant Professor, Department of Restorative Dentistry, São Paulo State University (Unesp), School of Dentistry, Araçatuba, SP, Brazil
Corresponding author: Professor Ticiane Cestari Fagundes, Faculdade de Odontologia de Araçatuba, UNESP, Departamento de Odontologia Restauradora, José Bonifácio, 1193, Araatuba, SP, CEP—16015-050, Brasil
(e-mail: ticiane@foa.unesp.br)

Accepted: October 2016. Submitted: August 2016.
Published Online: December 30, 2016

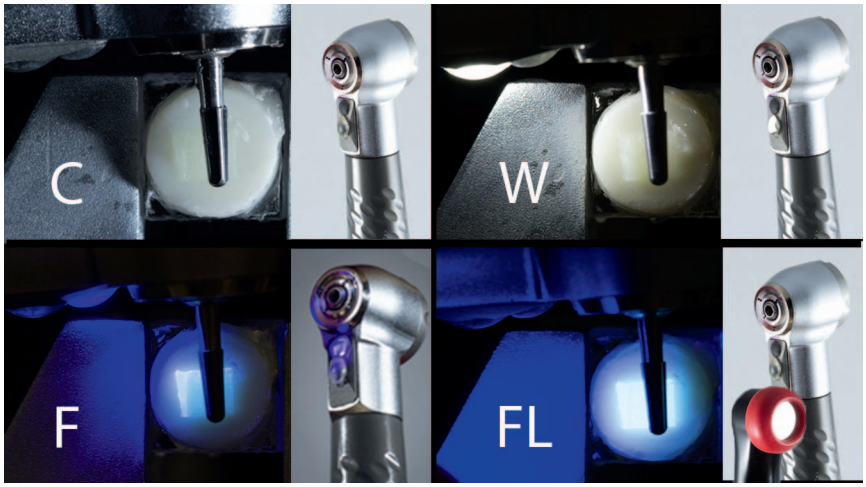

Figure 1. Devices used to perform the different protocols: conventional (C), white LED (W), LED that evidence fluorescence (F), and a curing light with fluorescent lens (FL).

system, having the property of disclosing fluorescent resin, has been connected to a high-speed turbine. Another innovation is fluorescent light emitters, such as light emitting diode (LED) curing units connected to fluorescent lenses. Adhesives and resins with fluorescent content have been developed to facilitate their differentiation from dental enamel when irradiated by a light that evidences fluorescence.[8]

There is a lack of studies quantifying enamel wear or resin residue remaining after various methods of bracket removal. Thus, this study was designed to analyze the effect of different techniques of removing orthodontic brackets from the standpoint of the presence of resin residue and enamel wear. The null hypothesis was that there would be no statistical difference among different techniques for removal of resin residue in terms of total thickness of specimens, measurement of areas of fluorescent residue, or dental enamel wear.

MATERIALS AND METHODS

Preparation of Specimens

Forty bovine teeth were selected on the basis of the following exclusion criteria: stained teeth, morphological changes of the clinical crown, and enamel cracks. After selection, the teeth were cleaned and stored in saline with 0.1% thymol in a refrigerator at 4°C until needed for the study.

The teeth were sectioned to leave only 3 mm of remaining root. Following, 6.5-mm-diameter enamel-and-dentin discs were obtained with a glass-cutting diamond bur (Dinser Ferramentas Diamantadas Ltd, Sacomã, SP, Brazil) connected to a bench drilling machine (FGC-16; Ferrari, São Paulo, SP, Brazil), under constant irrigation.

Then the dentin surfaces were exposed and ground with abrasive discs (grit #320) until the specimens were approximately 2 mm thick. Following that, the enamel was planed and polished with abrasive discs (grits #600, #800, and #1200), mounted in a polishing machine Aropol E (Arotec Indústria e Comércio Ltd, Cotia, São Paulo, SP, Brazil]) at 100 rpm with a load of 475 g under irrigation. Between discing, the specimens were immersed in an ultrasonic device for removal of residue.

Bonding of Brackets and Removal of Resin Residue

One operator performed all procedures for bracket cementation, according to the sequence (1) surface prophylaxis, (2) rinsing and drying of the enamel, (3) delineation of bracket area with adhesive tape, (4) etching with 35% phosphoric acid (UltraEtch; Ultradent Products Inc, South Jordan, Utah) for 30 seconds, (5) rinsing with water for 30 seconds and air drying, (6) application of fluorescent adhesive (Opal Seal, Ultradent), and (7) bracket cementation (Morelli, Sorocaba, SP, Brazil) with fluorescent resin (Opal Bond MV, Ultradent Products, Inc, South Jordan, Utah). A tensiometer was used with a load of 300 g for 10 seconds during cementation.[9] Light curing was performed using a LED unit for 40 seconds at 1000 mW/cm^2 (Valo, Ultradent, in standard mode) After 24 hours of storage at normal relative humidity and 37°C, the brackets were removed with metallic tweezers.

Sample-size calculation was performed based on the data of a pilot study using G*Power software. Considering the effect size F as 0.6917 (based on pilot mean values) and α at 0.05, the sample size per group of 10 specimens was required for 80% power. Specimens were then randomly divided into the groups

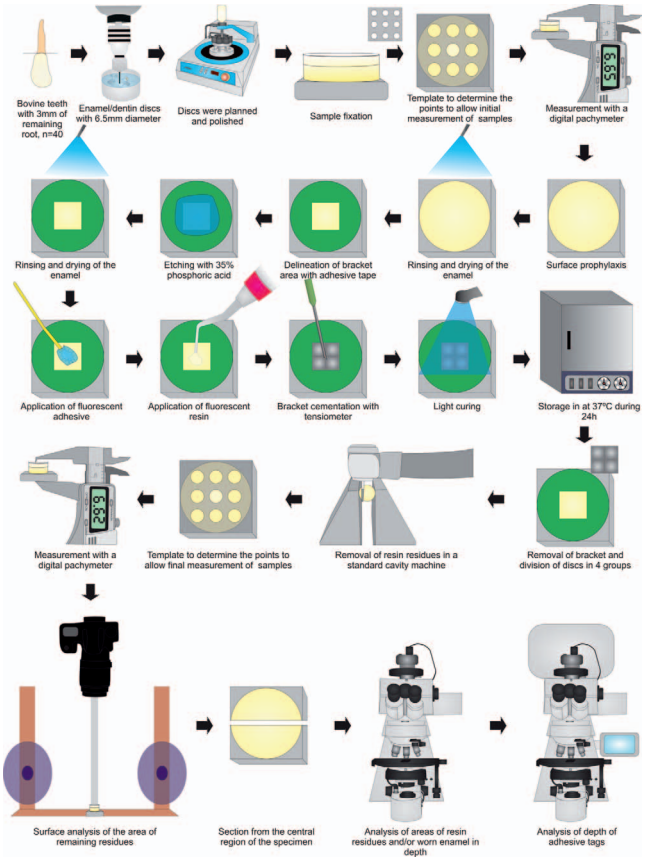

Figure 2. Schematic diagram of methodology.

presented in Table 1 (n = 10). The resin residue was removed by the same operator using a high-speed handpiece mounted on a standard cavity machine with a carbide bur (#H22GK.314.016 Komet , Santo André, SP, Brazil), according to the four preestablished protocols (Table 1 and Figure 1). The complete methodology can be found in Figure 2.

Analysis of Specimen Thickness

Specimen thickness was measured using a digital pachymeter (Absolute Digimatic, Mitutoyo, Tokyo, Japan) at nine sites, using a template to determine the points to allow measurement of the same sites before bracket cementation and after removal of the resin residue (Figure 3).

Surface Analysis of the Area of Remaining Residue

A digital DSLR camera (Canon 60D, Canon, Tokyo, Japan) with macro objective 100 mm f/2.8 was mounted on a pedestal and adjusted with parameters of shutter speed, aperture, and ISO at a focal distance of 30 mm, without flash. A dark chamber with two equal

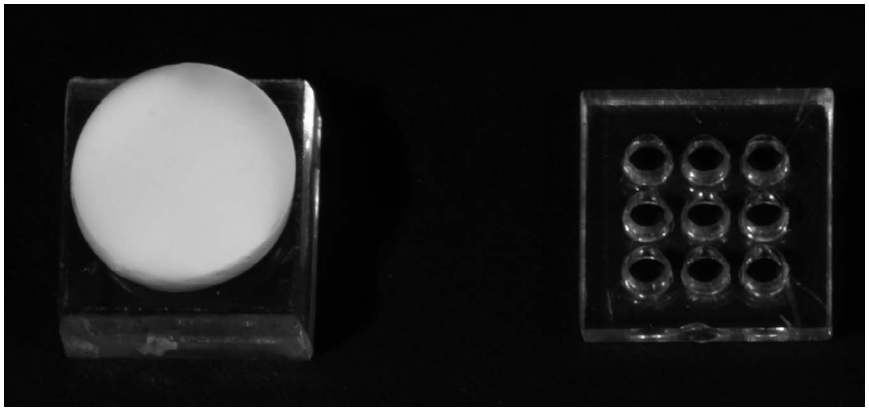

Figure 3. Template for determining points for thickness measurement (right), in which the template presents the same size as the base, both previously having been given a lateral mark, which in combination reproduces the measurement points at the same site.

ultraviolet lamps was the only light source used for achieving images. All specimens were positioned in a standardized manner at the center of the focal point (f/2.8).[10]

The images were numbered, and any existing fluorescent areas were measured on the software Image J (Wayne Rasband National Institutes of Health, Bethesda, Md), using the threshold function to calculate the area of remaining fluorescent residue. When no area corresponding to fluorescence of resin materials was detected, a zero value was assigned to the specimen. When several areas of fluorescent material were detected, their sum was considered the total area value.

Analysis of Areas of Resin Residue and Worn Enamel in Depth

An 0.8-mm-thick section was obtained from the central region of the specimen using a diamond disc (Buehler Diamond Wafering Blade, Buehler Ltd, Lake Bluff, Ill), under constant irrigation, using a metallographic cutter (Isomet 2000, Buehler). Analyzing and measuring fluorescence of this portion was achieved by fluorescent light microscopy (Leica Microsystems, Wetzlar, Germany; ultraviolet 368 nm oxytetracycline). The intensity of fluorescence according to the area of remaining material was determined by the software LAS v4.1 (Leica Applications Suite, version 4.1; Leica), a methodology adapted from Dayem.[11] To verify the wear of enamel and that of the remaining resin residue, a horizontal line was traced, based on adjacent untreated enamel areas that were not worked on, and this line was used as a guide to determine negative (worn enamel) or positive (resin residue) areas.

Analysis of Depth of Adhesive Tags

Among the sections analyzed by fluorescence microscopy, two of each group that presented areas of remaining resin residue were analyzed by confocal microscopy (Leica TCS SP2, Leica, Mannheim, Germany). A mixed gas laser was used as the light source, which was excited at a maximum wavelength of 543 nm. An oil immersion objective (100×, aperture 1.25) was used for image recording in fluorescent mode, and a representative area of each section was scanned in 2-μm sections. The image to be analyzed was obtained from the mean of sections. Three tag lengths were measured on each section. Means were calculated for each specimen, and means and standard deviations were calculated for all specimens to obtain a median value for tag length.

Statistical Analysis

Values of specimen thickness were evaluated by one-way ANOVA and Tukey test (α at 0.05). Results from other analyses did not pass the Shapiro-Wilk normality test; therefore, Kruskal-Wallis and Dunn's tests were used (α at 0.05).

Table 1. Study Groups and Devices Used in Each Group

Group	Method of Removal	Device	Manufacturer
C	High-speed handpiece	Cobra LED Ultra Vision	Gnatus, Ribeirão Preto, SP, Brazil
W	High-speed handpiece with white LED	Valo	Ultradent Products, Inc, South Jordan, Utah
F	High-speed handpiece with LED that evidences fluorescence	Black Light Lens	
FL	High-speed handpiece and a curing light with fluorescent lens		

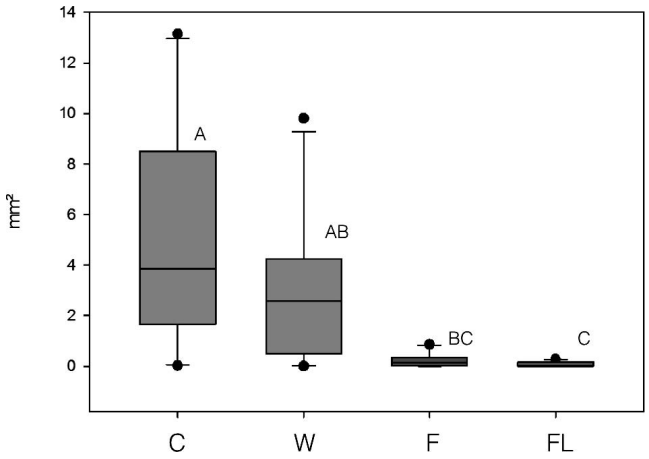

Figure 4. Box plot showing areas (mm²) of fluorescent resin residue on the surface. Different letters indicate statistical differences between groups; $P \leq .05$.

RESULTS

All groups presented statistically similar initial thicknesses (Table 2). After residue removal, group FL exhibited the greatest thickness reduction, being significantly different from groups C and W (Table 2). Group F presented values similar to those of the other groups (Table 2).

Greater superficial areas of remaining resin were observed for groups C and W (Figure 2). However, group W was statistically similar to group F, and group FL exhibited the smallest superficial area of residue (Figure 4). Examples representating images of each group are presented in Figure 5.

Concerning the measurement of areas in depth, group C presented the greatest area of resin residue, being comparable only with group W (Figure 6). Groups W, F, and FL exhibited statistically similar values (Figure 6). However, analysis of worn enamel revealed that groups F and FL presented more negative areas, representing loss of enamel structure (Figure 6). Groups C and W presented the greatest preservation of enamel surface (Figure 6). Representative images of each group can be observed in Figures 7 and 8.

Table 2. Means and Standard Deviations in Thickness (mm) of Specimens Before and After Removal of Residue

Group	Initial	Final	Difference
C	6.68 ± 0.07 A	6.67 ± 0.06 A	−0.01 ± 0.03 A
W	6.64 ± 0.04 A	6.63 ± 0.04 AB	−0.02 ± 0.04 A
F	6.66 ± 0.04 A	6.63 ± 0.04 AB	−0.03 ± 0.03 AB
FL	6.66 ± 0.05 A	6.59 ± 0.07 B	−0.06 ± 0.04 B

* Different letters indicate statistical differences between groups; $P \leq .05$.

Concerning the depth of tags, a total mean depth of 8.7 μm (±2.8 μm) was obtained. Figure 9 represents the measurements performed to achieve the mean length of tags.

DISCUSSION

The innovative methodology employed in this study enabled us to quantify the changes occurring on the enamel surface after bracket debonding. The hypothesis of no difference among the four techniques for removal of resin residue was not accepted, since the use of fluorescent light was more effective when the aim was to quantify removal of residue.

Analysis of specimen thickness revealed no statistical difference between groups on the initial measurement, evidencing the standardization of specimens' preparation. The groups that were not subjected to fluorescent lighting required more frequent maintenance of enamel thickness; however, the results demonstrated that a greater quantity of residue was present in these groups. This greater quantity of residue indicated that the operator had difficulty in visualizing the resin—an extremely common clinical situation—especially in differentiating between composite resin and dental enamel.[12]

Group C presented the greatest values of areas with remaining residue (Figures 5 and 7). It has been shown that incomplete removal of residue may cause accumulation of dental plaque,[4] which may give rise to white

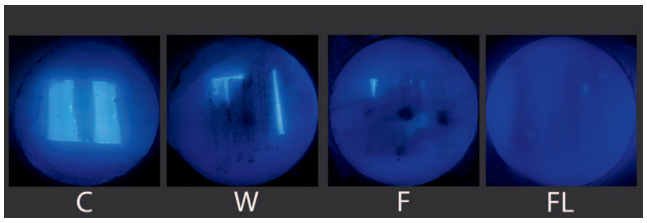

Figure 5. Images per group indicating surface analysis of fluorescence of residue: conventional (C), white LED (W), LED that evidence fluorescence (F), and a curing light with fluorescent lens (FL).

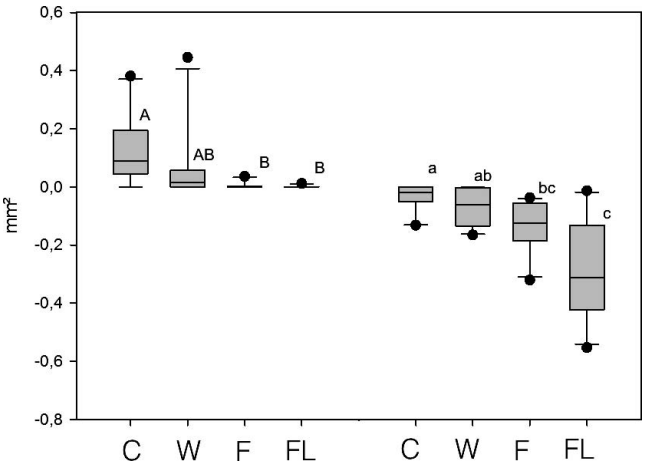

Figure 6. Box plot showing areas (mm^2) of resin residue and worn enamel in depth. Different uppercase letters indicate statistical differences between groups having resin residue; $P \leq .05$. Different lower case letters indicate statistical differences between groups having worn enamel; $P \leq .05$.

spot lesions[13] as well as undergo shade alterations over time.[14]

Conversely, group FL presented the smallest area of residue (Figures 5 and 8) and the greatest enamel wear (Figure 6). According to Koprowski et al.,[3] enamel thickness may exceed 1.4 mm; thus, the wear of 0.06 mm observed for group FL—the greatest mean wear—would represent a structure loss of only 4.6% of the total enamel. Sundfeld et al.[15] presented clinical cases of enamel microabrasion with long follow-up periods that revealed microreduction of up to 0.08 mm in thickness. There was no harm to the enamel structure, so the authors considered the observed wear to be clinically acceptable.

There is no available removal technique that does not cause some wear of tooth structure, since acid etching creates micromechanical retention between enamel and adhesive,[16] as observed in Figure 9 by confocal microscopy analysis. This wear may be explained by the fact that the device was used in association with fluorescent adhesive, allowing removal of all etched and infiltrated enamel. The operator might have been influenced by the fluorescent disclosure, thus providing greater wear values.[11,17] In human teeth, acid etching can produce porosities 5 to 50 μm deep.[18] This porosity may reach 53 μm, as revealed in the study of Kumar et al.,[19] in which the authors employed confocal microscopy to measure the depth of tags after etching with 37% phosphoric acid for 30 seconds and applying an adhesive system. In this study, the mean value of tags observed by confocal microscopy was 8.7 μm, which may be explained by the high viscosity of the adhesive employed. According to the manufacturer, Opal Seal adhesive consists of 38% glass ionomer fillers besides nanoparticles. It is known that the greater the concentration of fillers, the greater is the material viscosity, which prejudices its wettability, impairing the adhesive penetration in the tag.[20] Zaher et al.[21] concluded that the greater the tag length, the greater is the enamel shade alteration after removal of orthodontic brackets, which justifies the tag's complete removal.

Considering the aforementioned benefits of complete adhesive removal, it should be emphasized that the accessory lens emits light in a broader area with higher intensity compared with the LED lighting system coupled to the head of the high-speed handpiece. This accessory lens filters the light from higher wavelength LEDs (two 465nm and one 445nm), decreasing their intensity to 405nm. This low wavelength LED is responsible to detect fluorescence, since it is stimulat-

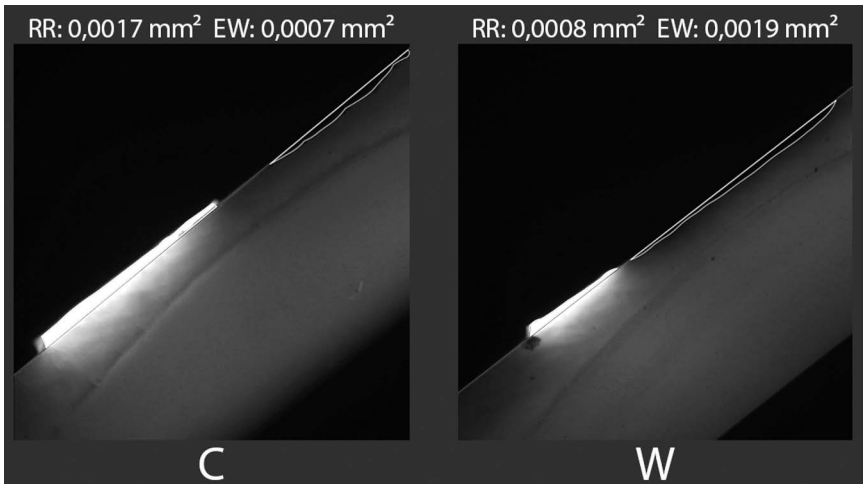

Figure 7. Images made by fluorescence microscopy used to analyze areas of resin residue (RR) and worn enamel (EW) in depth: conventional (C) and white LED (W).

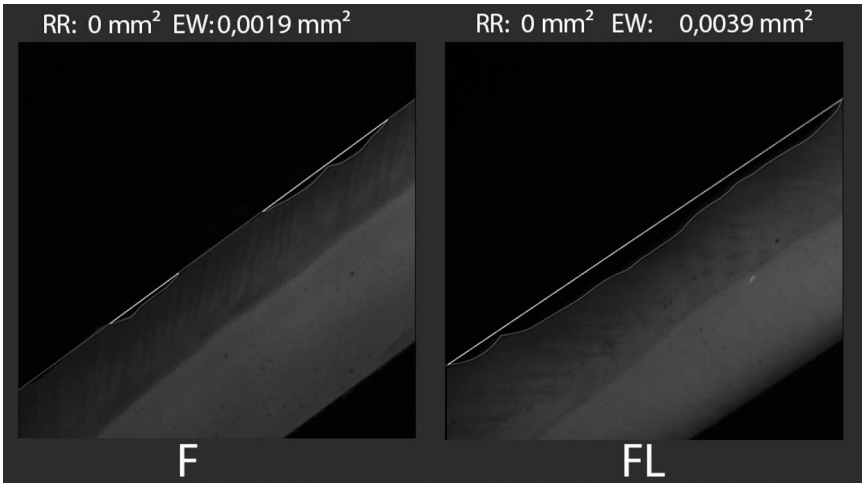

Figure 8. Images made by fluorescence microscopy used to analyze areas of resin residue (RR) and worn enamel (EW) in depth: LED that evidences fluorescence (F) and a curing light with fluorescent lens (FL).

ed by a lightning source between 395 to 405 nm.[20] However, this accessory lens requires that either the operator use both hands or a second operator be brought in to handle the device and activate it every 20 seconds during the procedure. The new high-speed handpiece has a command that allows choosing between white LED, fluorescent light (390–410 nm), or no light. The advantage is that the second operator is eliminated, since light is emitted from the head of the handpiece.

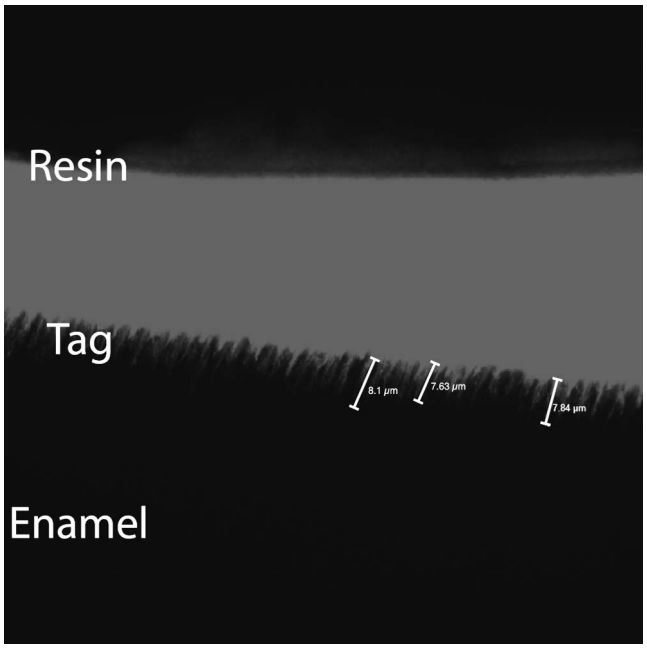

Figure 9. Confocal microscopy analysis, at 100× magnification. Resin: remaining resin. Tag: tags in enamel. Enamel: dental enamel, presented as a darkened area resulting from an absence of fluorescence.

Fluorescence tends to be an excellent option to aid in removing resin residue, having great prospects for other purposes, such as an auxiliary tool for caries diagnosis[22] during cavity preparation.

Other techniques are available for analysis of areas such as microtomography, yet this technique is limited by the difficulty of reconstructing the software when materials with low filler content are used, such as dental adhesives,[23] which is a fundamental aspect of this study. Considering the limitations of laboratory studies, further investigation should be conducted to complement the present findings.

CONCLUSIONS

- The largest areas of remaining residue were left after using only the conventional technique with a high-speed handpiece.
- Auxiliary devices, which identify fluorescent materials, were useful for removing fluorescent residue after bracket debonding, causing minimum damage to the dental enamel.

ACKNOWLEDGMENT

This work was supported by the São Paulo Research Foundation (FAPESP; grant 2014/23681-6).

REFERENCES

1. Ahrari F, Akbari M, Akbari J, Dabiri G. Enamel surface roughness after debonding of orthodontic brackets and various clean-up techniques. *J Dent (Tehran)*. 2013;10:82–93.
2. Janiszewska-Olszowska J, Tandecka K, Szatkiewicz T, Sporniak-Tutak K, Grocholewicz K. Three-dimensional quantitative analysis of adhesive remnants and enamel loss resulting from debonding orthodontic molar tubes. *Head Face Med*. 2014;10:37.

3. Koprowski R, Machoy M, Woźniak K, Wróbel Z. Automatic method of analysis of OCT images in the assessment of the tooth enamel surface after orthodontic treatment with fixed braces. *Biomed Eng Online*. 2014;13:48.
4. Janiszewska-Olszowska J, Szatkiewicz T, Tomkowski R, Tandecka K, Grocholewicz K. 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.
5. Dumbryte I, Jonavicius T, Linkeviciene L, Linkevicius T, Peciuliene V, Malinauskas M. The prognostic value of visually assessing enamel microcracks: do debonding and adhesive removal contribute to their increase? *Angle Orthod*. 2015;86(3):437–447.
6. Vidor MM, Felix RP, Marchioro EM, Hahn L. Enamel surface evaluation after bracket debonding and different resin removal methods. *Dent Press J Orthod*. 2015;20:61–67.
7. Bush MA, Hermanson AS, Yetto RJ, Wieczkowski G. The use of ultraviolet LED illumination for composite resin removal: an in vitro study. *Gen Dent*. 2010;58:e214–e218.
8. Tüfekçi E, Pennella DR, Mitchell JC, Best AM, Lindauer SJ. Efficacy of a fluoride-releasing orthodontic primer in reducing demineralization around brackets: an in-vivo study. *Am J Orthod Dentofacial Orthop*. 2014;146:207–214.
9. Frota PHDB, Tanaka A, Loguercio AD, Lima DM, Carvalho CN, Bauer J. Effect of different times of solvent evaporation and pH in two self-etching adhesive systems on the shear bond strength of metallic orthodontic brackets. *Int J Adhesion and Adhesives*. 2014.
10. da Silva RD, da Silva MA, de Oliveira OB, Melo AC, de Oliveira RN. Dental fluorescence: potential forensic use. *Forensic Sci Int*. 2013;231:167–171.
11. Dayem RN. Assessment of the penetration depth of dental adhesives through deproteinized acid-etched dentin using neodymium:yttrium-aluminum-garnet laser and sodium hypochlorite. *Lasers Med Sci*. 2010;25:17–24.
12. Ferracane JL. Resin composite—state of the art. *Dent Mater*. 2011;27:29–38.
13. Pretty IA, Ekstrand KR. Detection and monitoring of early caries lesions: a review. *Eur Arch Paediatr Dent*. 2016;17:13–25.
14. Tekçe N, Tuncer S, Demirci M, Serim ME, Baydemir C. The effect of different drinks on the color stability of different restorative materials after one month. *Restor Dent Endod*. 2015;40:255–261.
15. Sundfeld RH, Sundfeld-Neto D, Machado LS, Franco LM, Fagundes TC, Briso AL. Microabrasion in tooth enamel discoloration defects: three cases with long-term follow-ups. *J Appl Oral Sci*. 2014;22:347–354.
16. Fjeld M, Øgaard B. Scanning electron microscopic evaluation of enamel surfaces exposed to 3 orthodontic bonding systems. *Am J Orthod Dentofacial Orthop*. 2006;130:575–581.
17. Habibi M, Nik TH, Hooshmand T. Comparison of debonding characteristics of metal and ceramic orthodontic brackets to enamel: an in-vitro study. *Am J Orthod Dentofacial Orthop*. 2007;132:675–679.
18. Gwinnett AJ. Histologic changes in human enamel following treatment with acidic adhesive conditioning agents. *Arch Oral Biol*. 1971;16:731–738.
19. Ramesh Kumar KR, Shanta Sundari KK, Venkatesan A, Chandrasekar S. Depth of resin penetration into enamel with 3 types of enamel conditioning methods: a confocal microscopic study. *Am J Orthod Dentofacial Orthop*. 2011;140:479–485.
20. Prabhakar AR, Murthy SA, Sugandhan S. Comparative evaluation of the length of resin tags, viscosity and microleakage of pit and fissure sealants—an in vitro scanning electron microscope study. *Contemp Clin Dent*. 2011;2:324–330.
21. Zaher AR, Abdalla EM, Abdel Motie MA, Rehman NA, Kassem H, Athanasiou AE. Enamel colour changes after debonding using various bonding systems. *J Orthod*. 2012;39:82–88.
22. Theocharopoulou A, Lagerweij MD, van Strijp AJ. Use of the ICDAS system and two fluorescence-based intraoral devices for examination of occlusal surfaces. *Eur J Paediatr Dent*. 2015;16:51–55.
23. Hirata R, Clozza E, Giannini M, Farrokhmanesh E, Janal M, Tovar N, et al. Shrinkage assessment of low shrinkage composites using micro-computed tomography. *J Biomed Mater Res B Appl Biomater*. 2015;103:798–806.