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Original research

Damage on tooth enamel after removal of orthodontic adhesive by Arkansas' stone and tungsten carbide burs

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A R T I C L E I N F O

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A B S T R A C T

Objectives: The main aim of this study was to compare the effectiveness of two different methods to remove orthodontic composite adhesives from enamel concerning the surface damage and remnant composite adhesive on the surfaces.

Methods: Human molars were stored in buffer solution at room temperature before bonding the brackets. Teeth were ultrasonically cleaned in distilled water before bonding procedure. Ninety two brackets were randomly bonded to the buccal surface of twenty three molars using a composite-based adhesive system. After 15 days, the orthodontic composite adhesives were removed by using Arkansas' stone or multi-blade tungsten burs. After debonding process, the remnant composite adhered to the tooth as well as the teeth surfaces were analyzed by photographic images at x40 magnification concerning the (ARI) adhesive remnant or (SRI) surface roughness index. Also, enamel surfaces were inspected by field emission guns scanning electron microscopy (FEGSEM) before bonding and after bracket detachment. The statistical analysis was performed using SPSS® Statistics vs.18.0, considering a significance level of 0.05 to one-way ANOVA. Tukey's test was used for multiple comparisons and Chi-square tests were used to analyze the association between categorical variables.

Results: ARI results revealed no statistically significant differences between the two methods of bracket removal ($p=0.283$). Considering SRI, statistically significant differences were detected between the two procedures ($p<0.001$) considering all worn surfaces revealed lower surface roughness after removal of adhesive by Arkansas stone than that recorded on worn surfaces after removal using tungsten carbide burs.

Conclusion: The removal of orthodontic adhesive promoted less damage on enamel surfaces by using Arkansas stone at low rotation. Nevertheless, finishing procedures can decrease the roughness on enamel without additional damage.

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Lesão do esmalte após remoção de adesivo ortodontico por pedra de Arkansas e pontas laminadas de carbeto de tungsténio

Palavras-chave:
Brackets
Lesão do esmalte
Adesivos ortodonticos

R E S U M O

Objetivos: O objetivo deste estudo foi comparar a eficácia de dois métodos diferentes de remoção do compósito utilizado na adesão de brackets, após a realização do tratamento ortodôntico.
Métodos: Foram utilizados 92 brackets colados em 23 molares previamente selecionados de acordo com os critérios de inclusão/exclusão. Uma vez removidos os *brackets*, foram então utilizados os dois métodos de remoção de compósito: a) pedras de Arkansas; b) brocas multilaminadas de tungsténio, ambas utilizadas em contra-ângulo (baixa rotação). Uma vez removido o compósito, foram analisadas e quantificadas as possíveis lesões advindas do procedimento. A área de compósito remanescente foi calculada em todos os dentes. A análise estatística foi realizada utilizando o SPSS® Statistics vs.18.0, considerando um nível de significância de 0,05 para teste ANOVA. O teste de Tukey foi utilizado para comparações múltiplas e Qui-quadrado para análise entre variáveis categóricas.
Resultados: Após a remoção do compósito com cada um dos métodos verificou-se que, relativamente ao índice adesivo remanescente (IAR), não existiam diferença estatisticamente significativa ($p=0,283$) entre métodos de remoção. Entretanto, diferenças em relação ao índice de rugosidade de superfície (IRS) foram estatisticamente significativas ($p<0,001$) com resultados a favor do método utilizando pedras de Arkansas.
Conclusão: Menor dano ao esmalte foi promovido pela remoção de adesivo ortodóntico com uso da pedra de Arkansas. Entretanto, polimento adicional diminui a rugosidade da superfície sem danos adicionais ao esmalte.

Introduction

The process of bonding and detachment of brackets followed by a finishing procedure after orthodontic treatment can cause iatrogenic damage of enamel surfaces. Thus, the damage on the enamel begins at the etching by orthotofosforic acid and then on the application of acidic primer to establish the bonding of the composite adhesive and bracket. After or during the orthodontic treatment, the detachment of the bracket/adhesive assembly results in cracks in the outer enamel surface. Then, the remnant composite adhesive is mechanically removed by using rotatory burs leading to a removal of enamel layers and then increasing the roughness of the enamel.[1-3] That contribute for a opaque feature of the teeth as well as for acumulation of oral biofilm, leading to gingival irritation and an increase of stains on the enamel surface.[4,5] In the case of composite adhesive remain on enamel surface, the tooth surfaces reveal a high tendency to staining and accumulation of oral biofilms.[6]

The bond strength at the bracket-adhesive-tooth interface must withstand forces during oral movements although that strength magnitude should allow the removal of the brackets avoiding fractures in the enamel. The bond strength of the bracket-enamel-tooth interface should not exceed 14 MPa[7] and therefore previous studies report a proper range of bond strength from 6 up to 10 MPa.[8,9]

The seek for an efficient and safe method for the removal of composite adhesive after debonding the brackets resulted in the introduction of a wide variety of instruments and procedures. Several shapes of low or high speed burs such as tungsten carbide, Arkansas' stones, Sof-Lex® discs, and special finishing systems composed of zirconia or pumice slurries are used to remove composite adhesive after bracket detachment.[5,10,11] Technological improvement of burs has been performed, each time less aggressive to the enamel. The use of multi-step procedures involving fine tungsten carbide burs and ultra-fine grinding discs coated with alumina are the first choice to be considered on the removal of composite adhesives. However, the multi-step procedures seem to be more time-consuming and can result in a variation of enamel roughness.[10,12] Polishing systems, including rubber cups embedded with diamond particles and silicon carbide brushes are used to enhance the enamel roughness resulting in a smooth appearance.[13,14] Those procedures involving burs or rubber cups produce different degrees of polishing and can promote abrasion followed by a significant loss of enamel.[8] However, the clinical evaluation of the damage of the enamel is usually performed only by visual inspection or by rubbing hand scalers against the enamel surface where the bracket was bonded. A few studies have been published on other more effective methods of inspection that reveal clinical applicability.[15]

The main aim of this study was to compare the effectiveness of two different methods to remove orthodontic composite adhesives from enamel concerning the surface damage and remnant composite adhesive on the surfaces.

Materials and methods

Ninety two stainless steel brackets (Miniormesh™ Loant, Ormco™, Glendora) were randomly bonded to the buccal and lingual surfaces of twenty three human molars using a composite-based adhesive system, as seen in Figure 1A-D. Previously, human molars were stored in buffer solution at room temperature and then ultrasonically cleaned in distilled water before the bonding of the brackets.

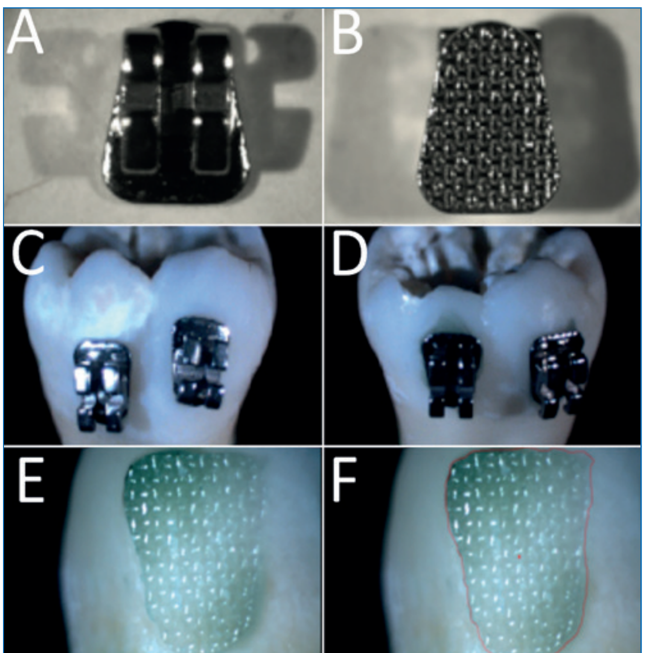

Figure 1. Stainless steel brackets (A,B) before and (C,D) after bonding on enamel surfaces of human molars. (E,F) Composite adhesive remained on enamel surface after bracket detachment.

Following composite manufacturer's recommendations, enamel surfaces were etched using a 37% phosphoric acid solution for 30 seconds. Surfaces were washed with distilled water for 5 min and then dried with oil-free air at room temperature. After etching procedure, enamel surfaces was conditioned with a primer adhesive (Ortho Solo™, Ormco Corporation) by rubbing with a microbrush for 10 seconds. A composite adhesive system (Gréngloo™, Ormco™, Glendora) was used for the bonding of the brackets onto the conditioned enamel surfaces. Brackets including composite adhesive were positioned on the surfaces. The Gréngloo™ composite adhesive contains a temperature-sensitive dye, which lightens when it reaches the body temperature and returns to a green color (Figures 1E-F) when the temperature is below 37ºC. The green color facilitates the detection of the adhesive, which remains around the bracket during the process of bonding. After removal of the remaining adhesive, bracket-composite adhesive was exposed to light-curing using a Coltolux 75 (Coltène/Whaledent Altstatten, Switzerland) at 1000 mW/cm^2 for 20 s.

After 15 days, the brackets were detached on mesial-distal shear loading by using the universal Weingart orthodontic plier (EQ-Line Dentaurum™, Germany). After detachment of brackets, the adhesive-tooth assemblies were divided into two groups: (A) composite adhesive for removal by (A) Arkansa's stone rotatory tip or (B) multi-blades tungsten carbide burs. Photographs were obtained for the remaining composite adhesive on the enamel surfaces at x40 magnification using magnifying lenses (Leica™ Wild, Leica) coupled to a photographic camera (Leica™ DFC295, Leica) (Figure 1E). The area of remaining composite adhesive was calculated for each surface via Leica Application Suite Software (version 3.5.0) (Figure 1F). Then, the composite adhesive was removed by using Arkansas'stone tip (Edenta™, Switzerland) or multi-blade tungsten burs (Ormodent™, Canada) at low rotatory speed for 45 s. Four rotary Arkansa's stone tips or multi-blade burs were used in order to maintain a standard precision cut performance. After composite adhesive removal, photographs of the enamel surfaces were also obtained at x40 magnification for analyses considering the (ARI) adhesive remnant or (SRI) surface roughness index.[16] The analysis and measurement of the ARI and SRI were performed by a researcher, blinded and well-trained on image analysis, by using Leica Application Suite 3.5.0 Software. ARI and SRI revealed the degree of adhesion considering a classification scale, as seen in Table 1.

Table 1. Classification of the enamel surfaces after bracket detachment considering ARI and SRI analyses (Artun, Bergland, 1984)[16].

Adhesive Remnant Index (ARI)	
1	100% composite adhesive remained on enamel surfaces
2	More than 90% composite adhesive remained on enamel
3	More than 10% composite adhesive remained on enamel
4	Range from 10 to 90% composite adhesive adhered to enamel
5	Composite adhesive was totally removed from enamel
Surface roughness Index (SRI)	
0	Enamel surfaces without any groves, scars or damage
1	Smooth enamel surfaces with a few randomly grooves or scars
2	Enamel revealing narrow and shallow grooves or scars
3	Rough enamel surfaces with deep grooves or scars
4	Extremely rough surfaces with very deep groove or scars

Data were statistically analyzed by one-way ANOVA at a significance level of 5% ($p<0.05$) using SPSS vs. 18.0 software (Chicago, USA). Tukey's test was used for multiple comparisons and therefore Kolmogorov-Smirnov tests were applied when required. Chi-square tests were used to analyze the association between categorical variables.

The remnant composite adhered to the tooth as well as the teeth surfaces were also analyzed by field emission guns electron scanning microscopy (FEGSEM) coupled to energy dispersive spectroscopy (EDS) (FEI Nova 200, USA). FEGSEM images were obtained by (SE) secondary or (BSE) backscattered electrons mode at 10-15 kV. For FEGSEM-EDS analyses, enamel surfaces were previously sputter-coated with Ag-Pd thin films.

Results

The composite adhesive area remained on enamel surfaces, is shown in Table 2 and Figure 1F.

Table 2. Composite adhesive area (µm²) of the test samples submitted to both removal methods.

	Total (n=91)		Removal method				$p^{‡}$
			Arkansas (n=46)		Tungsten (n=45)		
	Mean	(std)	Mean	(std)	Mean	(std)	
Area (µm²)	23.87	(4.664)	24.20	(4.131)	23.52	(5.177)	0.488

std – standard deviation; ‡ – student t-test.

The remnant composite adhesive removed by Arkansas' stone method showed a mean area of 24.20 ± 4.131 µm² while the composite adhesive removed with tungsten carbide burs showed a less mean area at 23.52 ± 5.177 µm². The mean area analyzed on both groups were not a statistically significant different ($p = 0.488$) and therefore that did not effect the ARI or SRI analyses (Table 2).

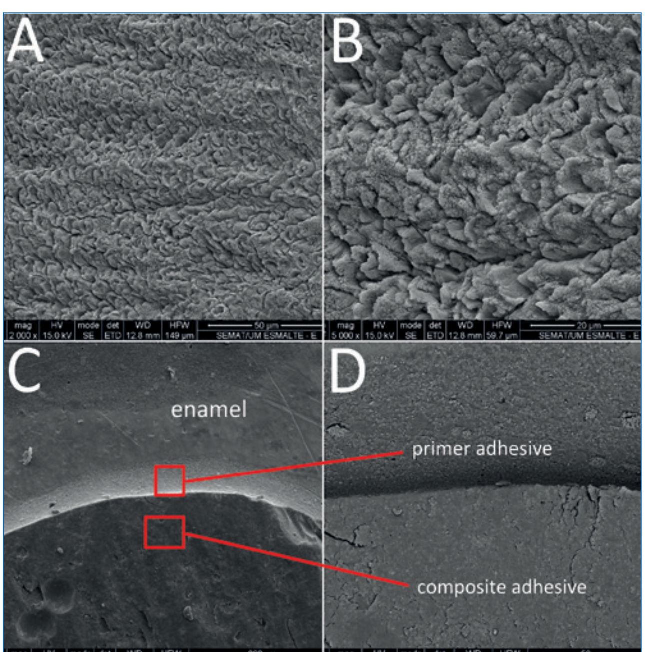

Figure 2. FEGSEM images obtained on enamel (A,B) after etching procedure and (C,D) on adhesive-enamel surfaces after bracket detachment.

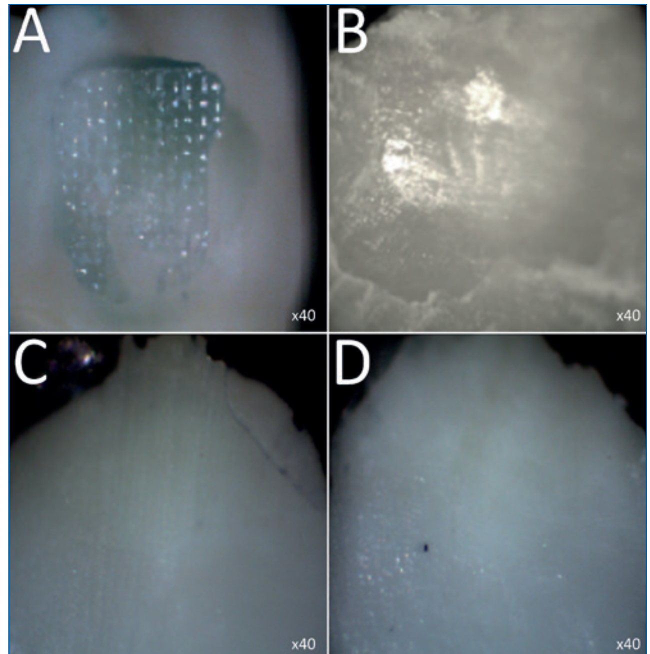

Figure 3. Photographic images obtained on enamel surfaces at x40 magnification after composite adhesive removal. (A) More than 90% composite adhesive remained on enamel; (B) Remaining composite adhesive ranging from 10 to 90% on enamel; (C) Less than 10% composite adhesive remained on enamel; (D) Composite adhesive was totally removed from enamel

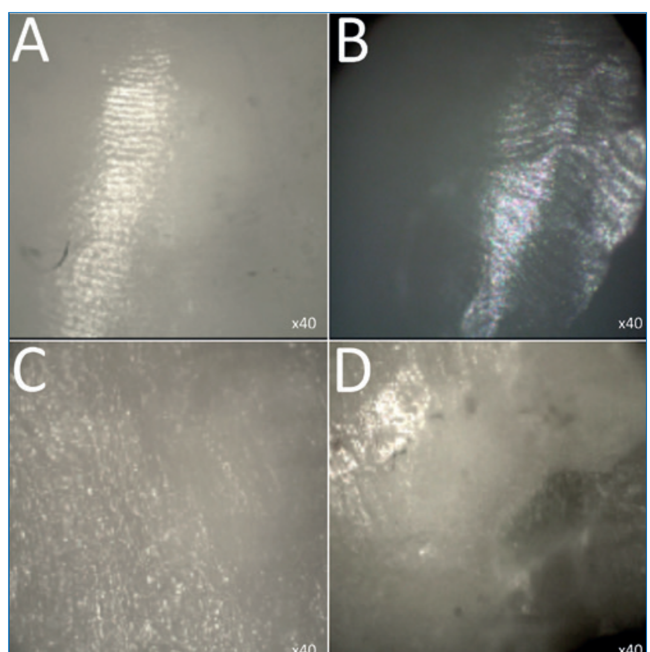

Figure 4. Photographic images obtained on enamel surfaces at x40 magnification after composite adhesive removal. (A) Smooth enamel surfaces with a few randomly grooves or scars; (B) Enamel revealing narrow and shallow grooves or scars; (C) Rough enamel surfaces with deep grooves or scars; (D) Extremely rough surfaces with very deep groove or scars.

FEG-SEM images of the enamel surfaces before bonding and after bracket detachment are shown in Figure 2.

Enamel surfaces after etching procedure revealed a rough feature to increase the mechanical interlocking of the orthodontic composite adhesive system as seen in Figure 2A-B. The standard morphologic aspect of the enamel surface after etching is noticed by FEGSEM. After bracket detachment, a thick composite adhesive layer remained on the enamel surface (Figure 2C-D) that was removed by the finishing technique. FEGSEM obtained by BSE mode showed the fillers in the composite adhesive microstructure. Also, a radial thin layer of primer adhesive was noted around the composite adhesive thick layer (Figure 2D).

Results considering (ARI) adhesive remnant and (SRI) surface roughness index analyses are shown in Table 3. Images of enamel surfaces are shown in Figure 3.

Regarding ARI analysis, one case revealed values between 10 and 90% composite adhesive adhered to enamel after using the removal methods. A percentage less than 10% remaining composite adhered to enamel was found for 73 samples. Enamel surfaces free of composite adhesive were identified on 17 samples (Table 3 and Figure 3D). On Arkansas' method group, less than 10% composite adhesive remained on enamel (Figure 3B) was detected for 35 samples while no composite adhesive was noticed on 11 samples. On tungsten bur method, 90% remaining composite adhesive adhered to enamel was detected for 1 sample (Figure 3A). Composite adhesive adhered to enamel recorded from 10 to 90% (Figure 3C) was noticed for 4 samples while less than 10% composite adhesive remained on enamel was detected for 36 samples (Table 3 and Figure 3C). No composite adhesive was only noticed on 7 samples, as shown in Figure 3D.

Regarding the surface roughness index (SRI), all 46 samples treated by Arkansas' stone tips revealed fine and shallow scars. Forty samples submitted to tungsten carbide bur method revealed rough surfaces with deep grooves (Figure 4C) while 3 samples showed extreme deep grooves (Figure 4D). Only 3 samples treated by tungsten carbide burs revealed fine and shallow grooves ($p < 0.001$) as seen in Figure 4B.

Discussion

In this study, the photographs of orthodontic adhesive remained onto enamel surfaces obtained at x40 magnification were used to examine statistical differences concerning the damage on the enamel surfaces after using two different rotary tips to remove remaining adhesive. The finishing procedure period and the evaluation area were controlled in order to compare the effectiveness of the two methods regarding the removal of remaining composite adhesive avoiding damage on enamel. The enamel surface was also analyzed immediately before bonding and after the bracket detachment to determine that the enamel damage would be caused only by the use of the rotatory finishing tips.

After bracket detachment, only one case of enamel damaged was found in the present study. In literature, a few studies reported the enamel damage after the detachment of brackets. The shear forces induced by the use of orthodontic pliers can result in cracks in the outer enamel layer, which was etched prior to bracket bonding. Cracks can propagate leading to fracture of enamel structure.[17]

Regarding the adhesive remnant index used in this study, we can notice that there were no statistically significant differences between the two methods of composite adhesive removal. However, statistically significant differences were detected between the two methods considering the enamel

Table 3. Results considering ARI and SRI analyses.

	Total (N=92)		Removal method: Arkansas (n=46)		Removal method: Tungsten bur (n=46)		*p*
	n	(%)	n	(%)	n	(%)	
Remnant adhesive index							0.386*
ARI =100%	10	(11)	3	(7)	7	(16)	
ARI> 90%	53	(58)	28	(61)	25	(56)	
10%≤ARI ≤90%	28	(31)	15	(33)	13	(29)	
ARI <10%	0	(0)	0	(0)	0	(0)	
ARI =0%	0	(0)	0	(0)	0	(0)	
Remnant adhesive index after removal method							0.283***
ARI =100%	0	(0)	0	(0)	0	(0)	
ARI > 90%	0	(0)	0	(0)	0	(0)	
10%≤ ARI ≤ 90%	1	(1)	0	(0)	1	(2)	
ARI <10%	73	(80)	35	(76)	38	(84)	
ARI =0%	17	(19)	11	(24)	6	(13)	
Surface roughness index							<0.001***
undamaged surface	0	(0)	0	(0)	0	(0)	
smooth surface	0	(0)	0	(0)	0	(0)	
fine and shallow scars	48	(53)	46	(100)	2	(4)	
rough surface with deep grooves	40	(44)	0	(0)	40	(89)	
Extremely damaged surface revealing very deep grooves	3	(3)	0	(0)	3	(7)	

* Independent Cui-square test; ***Fitting chi-square

surfaces were smoother possessing fine and shallow scars after the removal procedure using Arkansas' stone tips when compared to that after the use of tungsten carbide burs. The tungsten carbide multi-blade bur method induced a heterogeneous morphologic aspect of the enamel surfaces showing rougher surfaces with deeper scars. During removal of the composite adhesive by using both methods in this study, the excessive loss of enamel was prevented considering a removal period of 45 s. However, photographs obtained on enamel surfaces after adhesive removal revealed unavoidable abrasion scars due to the use of the abrasive rotatory tips or burs. The tungsten carbide burs are available in several sizes, shapes, and different particle sizes. Tungsten carbide rotatory burs having 12 and 30 blades are the most commonly used to remove composite adhesive from enamel.[5] The multi-blade tungsten carbide rotatory bur can rapidly remove remaining composite adhesive adhered to enamel although that can destroy the outer enamel layer and increase the roughness.[4,5,18] The hardness, shape and speed of the rotatory blades of the tungsten carbide burs play a significant role on the damage of the enamel surfaces.[17] Tungsten carbide rotatory burs, at low speed, can result in a pattern of finer scars followed by less loosening of enamel, when compared to carbide drills tungsten at high speed.[19,20] The difference in cutting effectiveness of rotary abrasive tips can be determined by various parameters, such as: tool rotation speed, pressure on the handheld device during removal of the composite, the type and shape of the instrument and the flow rate through the tip to the cutting adhesive-tooth interface.[3] Those factors were controlled in this study since removal was performed by a well-trained and blinded operator on the equipment and method of analysis.

The development of new methods and tools resulted in the technologic improvement of the abrasive rotatory tips, discs and burs. For instance, there are tips composed of stainless steel or silicon coated or else embedded with diamond particles at different size and shapes.[11] Also, physic methods involving ultrasonic vibration or carbon dioxide and Nd:YAG laser have been used to avoid damage of the enamel.[5,21]

Conclusions

Within limitations of an *in vitro* study on the effectiveness of remaining composite adhesive removal using two different methods after bracket detachment, the main outcome on the present work can be drawn:

- comparing the effectiveness of the two methods, there were no statistically significant differences on the adhesive remnant index after the removal of composite adhesive adhered to enamel. However, statistically significant differences were detected between the both methods considering the roughness index and degree of loosening of enamel;
- Arkansas' rotatory stone tip method at low speed was effective to remove the composite adhesive avoiding a high destruction of the outer enamel layer. Enamel surfaces revealed a homogeneous morphological aspect possessing finer scars and lower roughness after removal of composite adhesive by Arkansa's when compared with the tungsten multi-blade carbide rotatory burs.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Conflicts of interest

The authors have no conflicts of interest to declare.

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