Original Article

Influence of four systems for dental bleaching on the bond strength of orthodontic brackets

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ABSTRACT

Objective: To compare the influence of four systems for dental bleaching on the shear bond strength (SBS) of orthodontic brackets.

Materials and Methods: One-hundred and fifty freshly extracted bovine teeth were randomly divided into five groups. In group I the teeth were untreated (control). In the remaining groups the teeth were bleached, as follows: group II: 38% hydrogen peroxide; group III: 10% carbamide peroxide; group IV: resin-based coating material (RBCM), Beauty Coat; and group V: RBCM, White Coat. In all groups the enamel was conditioned with a self-etching primer and brackets were bonded with composite resin. Samples were stored (37°C, 24 hours), tested, and statistically analyzed, with significance predetermined at $P \leq .05$. The adhesive remnant index (ARI) was also evaluated and analyzed.

Results: The SBS of group V (22.49 ± 5.34 MPa) was significantly higher than that of all other groups (I: 17.1 ± 5.11 MPa; II: 14.72 ± 5.42 MPa; III: 12.04 ± 5.29 MPa; and IV: 18.23 ± 5.58 MPa). In contrast, the SBS of group III was significantly lower than that of all groups (except group II). Significant differences in the ARI scores were present between groups.

Conclusions: The use of RBCM for dental bleaching before bonding orthodontic brackets did not reduce the SBS. In contrast, hydrogen and carbamide peroxides negatively affected the SBS. The SBS yielded after bleaching with carbamide peroxide was significantly lower. (*Angle Orthod.* 2011;81:700–706.)

KEY WORDS: Bleaching; Resin-based coating material for bleaching; Bond strength; SEP

INTRODUCTION

The bonding of orthodontic brackets to the tooth surface is necessary to accomplish contemporary clinical treatment. In this context, bond strength has been evaluated and new biomaterials have been introduced to the market.[1–4] Conservative materials, such as self-etching primers (SEPs), have been also recommended to preserve dental structure and maintain satisfactory shear bond strengths (SBS). Recently, different kinds of SEP have shown suitable SBS,[3–7] in addition to healthier enamel surface conditions after debonding.[7–8]

Although the evolution of bonding procedures in orthodontics during the past years has been significant, bonding failures still remain an important side effect, especially after procedures such as dental bleaching. The desire of the patients for dental whitening as well as the advances in cosmetic dentistry have allowed for the development of a safe and popular procedure with regard to this type of dental treatment.[8]

Typically, chemical agents for bleaching are prescribed to obtain acceptable results; however, the application of peroxides can be painful for some patients. In addition, the chemical components of the bleaching agents also affect the SBS of orthodontic

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brackets to the enamel surface[9]; therefore, clinical complications sometimes develop.

On the other hand, new resin-based coating materials (RBCMs) have been developed as an alternative to conventional dental bleaching. The painless application of these flowable polymers is relatively easier, and the results are immediately obtained. The treatment is temporary and could be an important prescription before bonding orthodontic brackets. Nevertheless, to our knowledge, the effects of the RBCM for dental bleaching on the SBS have not yet been evaluated, nor has RBCM been compared with conventional bleaching agents. Thus, this study was conducted to compare the effects of four systems for dental bleaching on the SBS of orthodontic brackets bonded with the same adhesive system. Moreover, the adhesive remnant index (ARI) score was recorded, and the enamel surfaces bleached were observed with a scanning electron microscope (SEM).

MATERIALS AND METHODS

Teeth

A total of 160 freshly extracted bovine teeth were collected and stored in a solution of 0.2% (wt/vol) thymol. One-hundred and fifty teeth were used to evaluate the SBS, whereas 10 teeth were used to prepare the SEM specimens. The criteria for tooth selection included intact enamel surface without any fracture produced during the extraction procedure. The teeth were pumiced with fluoride-free paste (Pressage, Shofu Inc, Kyoto, Japan) and rubber prophylactic cups, washed with water, and air-dried.

Brackets

A total of 150 stainless-steel upper incisors brackets (0.018-inch, Std. Edgw. Tomy Int, Tokyo, Japan) were used. The average surface area of the bracket base was determined to be 13.58 mm^2. This value was obtained by randomly measuring 10 bases of the brackets.

Bleaching Procedure

The teeth were randomly divided into the following five groups:

- Group I (control): the teeth were untreated before bonding the orthodontic brackets. In the remaining groups, the teeth were treated with different systems for dental bleaching.
- Group II: 38% hydrogen peroxide was applied on the enamel for 15 minutes and then it was removed; the surface was then washed rigorously and dried with compressed air free of contaminants. The entire procedure was carried out twice.
- Group III: The enamel was bleached with 10% carbamide peroxide. The teeth were fixed in silicone-based impression material (Speedex; Colténe Whaledent, Altstatten, Switzerland). Reservoir spaces were created directly on the surface using a blocker resin. Soft type tray (0.20-inch) was fabricated, and the bleacher was loaded in the tray and applied for 8 hours; subsequently, the gel was washed rigorously and teeth were brushed with toothpaste. The procedure was repeated every 24 hours for 7 days.
- Group IV: The teeth were conditioned with primers A and B of Beauty Coat (Shofu Inc) for 3 seconds. A thin layer of RBCM for bleaching (Beauty Coat, Shofu Inc) was applied and distributed with a plastic instrument over the entire enamel surface. The RBCM was light-cured for 20 seconds. The samples were stored in distilled water at 37°C for a week. After that, the layer of the RBCM for bleaching was removed with an explorer.
- Group V: The teeth were conditioned with Clearfil Bond (Kuraray Medical, Tokyo, Japan), according to the manufacturer's instructions. The primer of this two-step SEP was applied on the enamel surface and 20 seconds later the surface was dried with mild air flow. The bond was applied, distributed evenly with mild air flow, and light-cured for 10 seconds. A thin layer of RBCM for bleaching (White Coat, Kuraray Medical) was applied and distributed with a plastic instrument over the entire enamel surface. The RBCM was light-cured for 20 seconds. The samples were stored in distilled water at 37°C for a week. After that, the layer of the RBCM for bleaching was removed with an explorer.

Bonding Procedure

In all groups, the bonding procedure was performed immediately after bleaching. The teeth were conditioned with Transbond Plus SEP (3M Unitek, Monrovia, Calif) for 5 seconds and slightly air-dried. The orthodontic brackets were bonded with Transbond Plus CC Adhesive (3M Unitek) and light-cured (Ortholux, 3M Unitek) for 20 seconds.

Storage

A 0.017 × 0.025–inch stainless-steel wire was ligated into each bracket slot to reduce any deformation of the bracket during the debonding process. The teeth were fixed in acrylic resin, and a mounting jig was used to align the facial surface of the tooth so that it was parallel to the force during the SBS test. The teeth were then stored in distilled water at 37°C for 24 hours.[6]

SBS Test

An occluso-gingival load was applied to produce a shear force at the bracket-tooth interface. This was accomplished using the flattened end of a steel rod attached to the crosshead of a universal testing machine (Autograph AGS-X, Shimazdu, Kyoto, Japan). The bond strengths were measured at a crosshead speed of 0.5 mm/min, and the load applied at the time of fracture was recorded in MPa.

Adhesive Remnant Index

Once the brackets were debonded, the enamel surface of each tooth was examined under 10× magnification to determine the amount of residual adhesive remaining on each tooth. The ARI scores were recorded, with the following scale used: 0 = no adhesive left on the tooth; 1 = less than half of the adhesive left on the tooth; 2 = more than half of the adhesive left on the tooth; and 3 = all of the adhesive left on the tooth, with distinct impression of the bracket mesh.[10]

Statistical Analysis

Descriptive statistics, including the mean, maximum and minimum values, and standard deviation, were calculated. Scheffè post-hoc multiple comparisons (one-way analysis of variance), with significance predetermined at $P < .05$, were calculated for the SBS analysis. Similar to the methods describe by Movahhed et al.,[11] the Weibull survival analysis was also carried out to provide additional information on the safety of the bonding system performance.[12] The chi-square test was used to evaluate the ARI.

SEM Observation of the Enamel Surface Morphology

Ten teeth were used for preparing specimens of the enamel surfaces bleached with the different agents evaluated in this study. The teeth were chemically fixed, dehydrated, freeze-dried, and coated with osmium, as described previously.[2] The specimens were then observed under SEM (S-4500, Hitachi, Tokyo, Japan).

RESULTS

Sheer Bond Strength

The SBS mean values (expressed in MPa) and descriptive statistics are shown in Table 1. The SBS of group V (22.49 ± 5.34 MPa) was significantly higher than that of all other groups (group I: 17.1 ± 5.11 MPa, $P = .0047$; group II: 14.72 ± 5.42 MPa, $P = .0001$; group III: 12.04 ± 5.29 MPa, $P = .0001$; group IV: 18.23 ± 5.58 MPa, $P = .0489$). In contrast, the SBS of group III was significantly lower than that of all other groups, except group II (group I: $P = .0298$; group IV: $P = .0025$; group V: $P = .0001$). The SBS value of group IV was comparable to that of the control group.

Table 1. Mean Bond Strength Values (MPa) and Descriptive Statistics

Group	n	Mean	SD[a]	Range	Sheffé[b]	m[c]	S_0 (MPa)[c]	P_{f10} (MPa)[c]
I	30	17.1	5.1	10.1–36.1	A	3.4	19	9.9
II	30	14.7	5.4	5.1–30.2	A, B	2.4	16.8	6.7
III	30	12.0	5.2	0.4–27.9	B	2.4	14.3	5.7
IV	30	18.2	5.5	6.2–32.3	A	2.9	20.6	9.6
V	30	22.4	5.3	15.3–38.4	C	4.5	24.6	14.9

[a] SD, standard deviation.

[b] Scheffè post-hoc multiple comparisons (1-way ANOVA); $p < 0.05$. Groups with different letters are significantly different from each other.

[c] Weibull parameters m and S_0 were obtained from cumulative failure probabilities by unweighted least-squares fitting to the data shown in Fig. 1. The loads for 10% probability of failure were also calculated P_{f10}.

On the other hand, the loads for 10% probability of failure (P_{f10}) of the Weibull analysis corroborated that the SBS values in groups III and II were lower than those of the other groups (5.7 and 6.7 P_{f10} MPa, respectively). In both cases, the values were lower than the average suggested to be necessary for orthodontic treatment and tooth movement. The graphic of the cumulative failure probabilities vs shear load is shown in Figure 1.

Adhesive Remnant Index

The scores indicating the amount of adhesive remaining after debonding are shown in Table 2. The chi-square comparisons of the ARI scores among all of the groups ($\chi^2 = 48.418$) indicated that the groups were significantly different ($P = .001$). Although the frequencies of the scores 1 and 2 were common in some groups, the greatest amount of adhesive remnant was found in the control group, followed by groups IV and V. On the other hand, a lower quantity of residual adhesive was observed in groups III and II; however, the lowest ARI scores were found in group III.

SEM Observation of Enamel Surface Morphology

Figure 2 shows the human enamel surfaces observed under SEM after bleaching with the different agents evaluated in this study (an untreated surface served as control). The micrographs illustrated that all experimental surfaces were different from that of the untreated specimen. The SEM images of the surfaces bleached with hydrogen and carbamide peroxides (Figure 2B,C) show the effects produced on the enamel by the chemicals. In contrast, the SEM images of the enamel treated with RBCM for bleaching

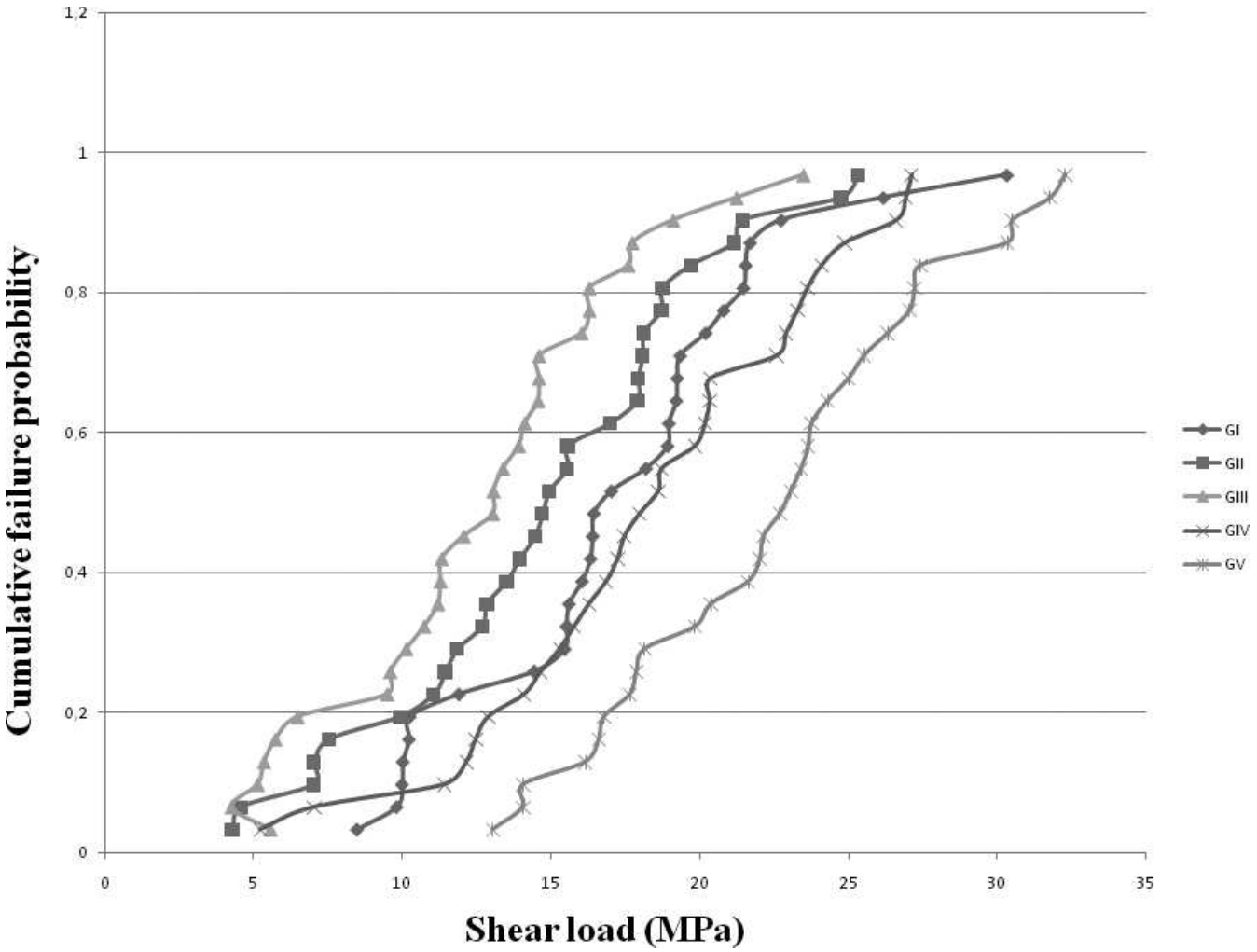

Figure 1. Cumulative failure probabilities vs shear load. Group I: untreated; group II: hydrogen peroxide; group III: carbamide peroxide; group IV: resin-based coating material (RBCM), Beauty Coat; group V: RBCM, White Coat.

show some remaining particles on the surface (Figure 2D,E).

DISCUSSION

Sheer Bond Strength

The use of bovine enamel to evaluate bond strength has been questioned; however, it has been demonstrated that bovine enamel can be successfully used to study enamel bond strength,[13] and there is no correlation between bovine enamel roughness and bond strength.[14] In this context, diverse studies have been carried out with bovine teeth, and there are numerous original articles published in the literature.[15–18] Furthermore, bovine teeth have been effectively used to evaluate the bond strength of orthodontic brackets after dental bleaching.[19,20] In studies of SBS, the sample size is an additional important factor, and it was suggested that at least 20, and preferably 30, specimens should be tested if valid conclusions are to be drawn from in vitro bond strength studies.[21] Hence, in this study bovine teeth were selected, and we collected 30 samples for each group.

Dental bleaching is a common and safe procedure used in contemporary clinical practice. Typically, the materials used for dental bleaching are peroxides, but in some cases the application of these chemicals can be painful. The effects of peroxides on the SBS of orthodontic brackets have been widely evaluat-

Table 2. Distribution Frequency and Percentages of the Adhesive Remnant Index (ARI)[a]

	ARI Scores (%)				
Group	0	1	2	3	n
I	0 (0)	5 (16.6)	17 (56.6)	8 (26.6)	30
II	7 (23.3)	14 (46.6)	7 (23.3)	2 (6.6)	30
III	9 (30)	16 (53.3)	3 (10)	2 (6.6)	30
IV	0 (0)	9 (30)	16 (53.3)	5 (16.6)	30
V	3 (10)	9 (30)	17 (56.6)	1 (3.3)	30

[a] $\chi^2 = 48.418$; df = 12; $P = .001$.

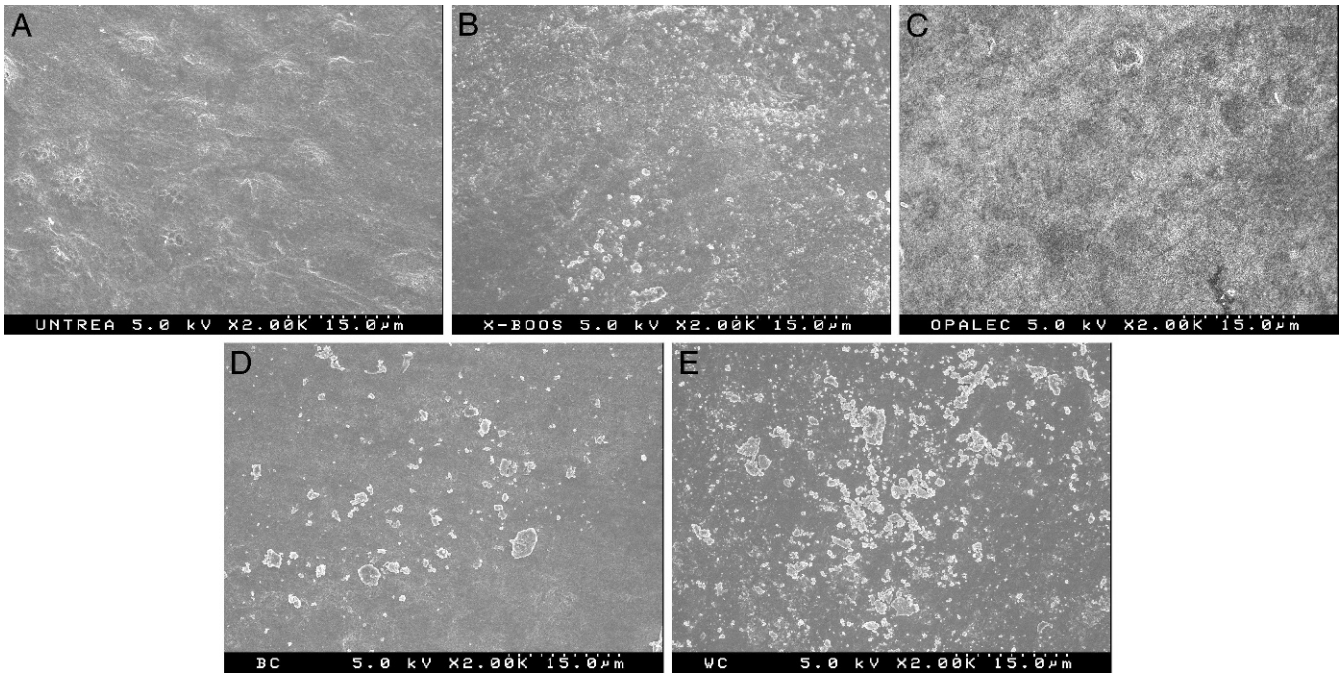

Figure 2. Representative scanning electron microscope (SEM) images of human enamel surfaces. (A) Untreated; (B) hydrogen peroxide; (C) carbamide peroxide; (D) resin-based coating material (RBCM), Beauty Coat; (E) RBCM, White Coat. Original magnification 2000× and 5.0 kV.

ed.[19,20,22–30] However, to our knowledge, the effects of RBCM for dental bleaching have not been previously evaluated.

The use of 30%,[20] 35%,[19,24,30] and 38%[29] hydrogen peroxide bleaching systems 24 hours before bonding significantly reduced the SBS orthodontic brackets; nevertheless, if the procedure is performed 7 days before bonding, it does not significantly reduce the force required to debond the brackets.[28] Under the conditions of the present study, the use of 38% hydrogen peroxide did not significantly affect the SBS; however, the mean value of that group was 2.4 MPa lower than that of the control group.

In contrast, the use of 10%[23,27] and 16%[26] carbamide peroxide 24 hours before bonding significantly reduced the SBS of orthodontic brackets. In view of the fact that the group treated with 10% carbamide peroxide presented the lowest SBS, the findings of this study are comparable to those of previous reports.[23,26,27] Another important observation was that the teeth treated with 10% carbamide peroxide achieved more effective whitening than did those treated with 38% hydrogen peroxide.

The quick and simplified technique of SEP for enamel conditioning has become popular in orthodontics.[6,22] The effects of 16% carbamide peroxide applied immediately before bonding have included significantly lower SBS of teeth bonded with SEP.[26] In this study, the use of 10% carbamide peroxide for dental bleaching yielded significantly lower SBS than for all of the groups (except group II) tested in this study.

Although external bleaching with hydrogen and carbamide peroxides has been shown to satisfactorily camouflage the white spot lesions,[25] both chemicals negatively affect the SBS. The use of peroxides immediately before the placement of orthodontic brackets should be contraindicated; otherwise, the bonding procedure must be delayed by at least 7,[23,28] and preferably 30, days.[26]

As an alternative, the use of RBCM for dental bleaching is strongly recommended if orthodontic brackets will be bonded immediately; these new materials are painless and their application and results are known to be quicker than those of conventional bleaching systems. RBCM are also easy to handle and economical, when prescribed for temporary bleaching, and their use prior to orthodontic treatment might be advantageous.

The use of RBCM for dental bleaching did not reduce the SBS. These findings are particularly important to satisfying patients' esthetics requirements prior to orthodontic treatment without compromising bond strength. If these types of material are not available, a flowable composite resin can be used to obtain similar results; however, further studies should be carried out to corroborate the existence of suitable SBS.

Adhesive Remnant Index

Greater consideration has been given to the debonding techniques and the amount of adhesive remnant,[6] in addition to the effect that these proce-

dures have on the enamel surface. Damage to the enamel can be attributed to not only the conditioning procedure but also to the processes of bracket removal and post-debonding tooth cleaning.[31]

It has been demonstrated that the amount of adhesive remaining tends to be larger when a high SBS is obtained.[6,18] In this regard, the control group and group V showed higher SBS; the amount of residual adhesive was also larger than in the other groups. In agreement with the findings of a previous study,[30] less residual adhesive has been found after dental bleaching with peroxides. This may be explained by the idea that the effects of the chemical agents cause a bond failure on the enamel bonding interface.

SEM Observation of Enamel Surface Morphology

The appearance of the untreated enamel surface was different than that of the four treated surfaces (Figure 2). The effect of the carbamide peroxide seemed to be greater, and the micrograph can be associated with the lowest values of SBS and ARI. Although the specimens were carefully cleaned and chemically prepared,[2] the micrographs illustrated that the enamel treated with RBCM for bleaching presented some particles on the surface. A possible explanation could be that the resin-based materials are filled with particles; therefore, the amount of residual adhesive was higher in groups IV and V.

CONCLUSIONS

- The application of RBCM for dental bleaching did not reduce the SBS, and, therefore, it can be used immediately before bonding of orthodontic brackets.
- The RBCM for dental bleaching used in group III did not affect the SBS. However, the SBS value was significantly increased when the teeth were treated with the RBCM tested in group IV.
- Thirty-eight percent hydrogen and 10% carbamide peroxides negatively affect the SBS. However, the carbamide peroxide significantly decreased the SBS and should be contraindicated before the bonding of orthodontic brackets.
- Although the control group showed the highest ARI scores, the amount of adhesive remnant was higher in the groups treated with RBCM than in those treated with peroxides.
- SEM micrographs illustrated greater damage on the enamel surface when the teeth were treated with peroxides.

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