

Assessment of enamel damage after removal of ceramic brackets

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Introduction: Since the introduction of ceramic brackets, research has been performed to evaluate enamel damage caused during their removal. One problem in comparing treated and control groups is the absence of assurance that the surfaces were undamaged before the brackets were bonded and debonded, or that superficial treatment applied to the enamel could hinder damage detection. The aim of this in-vitro study was to evaluate enamel injuries during debonding of 3 types of ceramic brackets. **Methods:** Forty-five premolars, extracted for orthodontic purposes, were divided into 3 groups of 15. The enamel surfaces were photographed with a magnifying loupe (60 times) in an optical stereomicroscope (Stemi 2000-C, Zeiss, Oberkochen, Germany) with a digital camera. A different type of bracket was bonded and debonded in each group: mechanical retention, mechanical retention with a polymer base, and chemical retention. After debonding, the surfaces were again photographed. The photographs were evaluated for quality of enamel surface according to a predetermined scale. The results were tested by method error and the chi-square test. **Results:** The damage evaluation comparing the same surface before bonding and after debonding showed no significant statistical difference between the mechanical retention group and the polymer base retention group. There was a significant statistical difference ($P < 0.05$) for the chemical retention ceramic bracket group. **Conclusions:** The difference between the enamel surfaces before bonding and after debonding brackets with chemical retention was statistically significant; bonding and debonding these brackets resulted in enamel damage. (Am J Orthod Dentofacial Orthop 2008;134:548-55)

Ceramic brackets entered the market in the mid-1980s because of patient demands for more esthetic braces. Since then, much research has been conducted to evaluate their clinical characteristics and properties.

Some studies notably assessed the bond strength between bracket and enamel as well as damage caused to the enamel during the removal of the brackets. Such damage might be evident as cracks or tear-outs, compromising tooth health and integrity. Concerning damage caused to tooth enamel during the removal of ceramic brackets, it is still unclear whether there are differences among chemical retention, mechanical retention, and polymer base retention, or even in comparison with metal brackets.

Research is usually conducted with a control group without intervention, and those tooth surfaces are then

compared with other surfaces that had bracket bonding and debonding. Since the comparison is made between different surfaces, one cannot be certain that lesions detected after bracket debonding were caused by the removal procedure or whether those lesions were present before bracket bonding. Another factor that could alter the results of these studies is the method used to observe the enamel surface, normally a scanning electron microscope (SEM), which requires a special gold treatment to the surface under analysis before observation; this process can make the detection of certain lesions more difficult.

The most commonly used ceramic brackets are composed of aluminum oxide,¹ and, because it is inert, it is not possible to promote chemical retention between the ceramic base and the resin. Therefore, the first ceramic brackets used silane as a chemical mediator to help bond the bracket base to the resin.^{2,3} However, this chemical retention yields a high bond strength that might damage the enamel on bracket removal.^{3,4}

An alternative bonding method was then suggested: mechanical retention, by creating indentations and crevices on the bracket base. These indentations allow mechanical interlocking with the adhesive.⁴ An additional retention alternative is the application of a fine layer of polymers to the bracket base. Bonding occurs between the enamel and the polymer instead of between

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the enamel and the ceramic material, thus reducing the likelihood of enamel damage.⁵ Ceramic brackets hold promise as an esthetic alternative to metal brackets, although their natural brittleness causes many fractures during removal.⁶

Bond failures of ceramic brackets occur predominantly at the enamel-adhesive interface, unlike metal brackets where failures are more common at the bracket-adhesive interface, because the bond strength between ceramic brackets and the adhesive is greater than that between the adhesive and the enamel.⁷ Chemical adhesion involves a remarkable bond strength, and the debonding stress can migrate from the bracket-adhesive interface to the adhesive-enamel interface and consequently damage the enamel.^{1,6}

When Bishara et al⁸ evaluated the debonding of ceramic brackets with mechanical retention and mechanical retention with an epoxy base, they noticed much adhesive on the enamel. This kind of debonding has the advantage of protecting the enamel surface but requires abrasive materials to remove the adhesive residue.

By comparing, with a Stemi 2000-C stereomicroscope (Zeiss, Oberkochen, Germany), digital photographs of the enamel surfaces submitted to bonding and debonding procedures of 3 types of ceramic brackets (mechanical retention, polymer base, and chemical retention), we sought to evaluate (1) the removal techniques recommended by the manufacturers of those bracket types, (2) the adhesive remnant index (ARI) scores after bracket removal, and (3) the damage caused to the enamel by comparing the same surfaces before bracket bonding and after debonding.

MATERIAL AND METHODS

We used 45 labial surfaces of dental enamel obtained from 45 premolars extracted for orthodontic reasons from the tooth bank of the Dental School of Fluminense Federal University in Brazil. All applicable bioethical standards were observed during the procedures.

The teeth were cleaned and dipped in 1% thymol and stored at 5°C. All teeth had intact labial surfaces with no carious lesions. The roots were cut, and the crowns molded with self-curing resin with polyvinyl chloride cylinders three quarters of an inch in diameter and 4 cm in height (Rio Claro, São Paulo State, Brazil), to enhance the control and manipulation of the specimens.

The labial surface of each tooth was placed in the central part of the mold, 1 mm above the polyvinyl chloride cylinder edge. All specimens were rinsed in running water and stored in a medium containing

distilled water at 37°C for 24 hours before bracket bonding.

The 45 enamel surfaces were randomly divided into 3 groups with color codes (G, green; R, red; Y, yellow) to prevent any associations between the group and the commercial type or brand of the brackets. The groups are described as follows.

Group G included 15 premolar enamel surfaces on which were bonded ceramic brackets with mechanical retention (Clarity, 3M Unitek, Monrovia, Calif), and the specimens were numbered from 1 to 15.

Group R contained 15 premolar enamel surfaces on which were bonded ceramic brackets with epoxy-base mechanical retention (InVu, TP Orthodontics, LaPorte, Ind), and the specimens were numbered from 1 to 15.

Group Y comprised 15 premolar enamel surfaces on which were bonded ceramic brackets with chemical retention (Fascination 2, Dentaaurum, Ispringen, Germany), and the specimens were numbered from 1 to 15.

Prophylaxis was done with water and pumice without fluoride with a rubber cup for 5 seconds under low rotation; each rubber cup was replaced after 5 prophylactic procedures. The surfaces were then rinsed for 15 seconds and dried with an oil-free air compressor.

Each specimen from the 3 groups was analyzed under 60 times magnification and photographed with the stereomicroscope twice: T1, when the dental enamel on the labial surfaces of the 45 premolars had undergone prophylaxis; and T2, after the same 45 surfaces of dental enamel had been bonded with brackets and debonded according to the manufacturers' directions, the remaining adhesive material had been removed, and the surfaces were polished.

The enamel on the labial surfaces of the teeth was etched with 37% orthophosphoric acid (3M Unitek) for 30 seconds, rinsed for 30 seconds, and dried with an oil-free air compressor. The commercial adhesive resin Concise (3M Unitek) was used. Each bracket was pressed firmly against the center of the crown with a bracket positioning instrument, and the excess resin was removed.

The brackets were removed 7 days later; during that time, the specimens were kept in a medium containing distilled water at 37°C.

All brackets were removed according to the manufacturers' instructions. Group G (mechanical retention) was removed with a Howes pliers.⁹ Group R (polymer base) was removed by squeezing at the adhesive-bracket base interface with the blades of an orthodontic wire cutter.¹⁰ Group Y (chemical retention) was removed with a Weingart pliers.¹¹

The study method consisted of comparing the dental enamel surfaces before and after bracket bonding

and debonding, and after the removal of excess adhesive.

Before removing excess adhesive and polishing the enamel surfaces, each specimen was assessed with the adhesive remnant index (ARI) under 10 times magnification, with the following classifications: 0, no adhesive on the tooth surface; 1, less than half of the adhesive on the tooth surface; 2, more than half of the adhesive on the tooth surface; and 3, all adhesive remaining on the tooth surface and the resin imprint visible on the bracket base.

The resin was removed from the enamel surfaces by means of latch-type 12-blade tungsten burs (Intensive SA, Grancia, Switzerland); 1 bur was used for each group, and the specimens were cleaned with pumice and water by using rubber cups.

The images captured by the optical stereomicroscope were transferred to a computer with the Image J¹² software program. The images were burned to a CD (Sony, Tokyo, Japan) and developed in a specialized shop and printed on Kodak paper (Eastman Kodak, Rochester, NY). All photographs were analyzed by the same evaluator, who was not aware of when they were taken (T1 or T2) or to which group they belonged (double blind).

The evaluator was trained before the analysis and assigned a score to each photo according to the following scale: 0, enamel surface free from cracks or tear-outs (Fig 1, A); 1, enamel surface with cracks (Fig 1, B); 2, enamel surface with tear-outs (Fig 1, C); and 3, enamel surface with cracks and tear-outs (Fig 1, D).

The evaluator repeated this evaluation a week later. To ensure data reproducibility, the kappa index was used. This statistic assesses interrater reliability when observing or coding qualitative categorical variables. Kappa is considered an improvement over percentage agreement to evaluate this type of reliability. Kappa has a range from 0 to 1.00, with greater values indicating better reliability. Generally, a kappa score over .70 is considered satisfactory.

The nonparametric chi-square test was used to check the quality of the surfaces before and after bracket removal, and compare them among the groups. A 5% probability significance level was adopted.

RESULTS

Verification of the reproducibility rate between the 2 evaluations by the same evaluator a week apart yielded a kappa index of 0.85, pointing to excellent concordance.

The results for the ARI are shown in Table I. The evaluations before bracket bonding and debonding for the 3 groups focused on enamel damage. Damage was

assessed after adhesive removal, and the results are given in Table II.

According to the chi-square nonparametric statistical test at a 5% probability level (Table II), no significant differences were found in the evaluation of the enamel surfaces of groups G (mechanical retention) and R (mechanical retention with a polymer base) before bracket bonding and after debonding. In group Y (chemical retention), the differences were statistically significant ($P < 0.05$).

DISCUSSION

Enamel damage caused during the removal of ceramic brackets has been the subject of concern to many researchers and has prompted a number of studies. Some of these evaluated bonding factors, such as the etching time on the enamel surface and the type of adhesive used.^{2,4,7,13-19} Others assessed the different types of bracket base retentions.^{2,4,7,8,16,17,20-28} Because of concern about the removal method, several studies evaluated which would cause less damage to the enamel,^{6,29-34} and some tested the methods of adhesive remnant removal and surface polishing.^{35,36}

Some authors reported that chemical retention brackets do not exhibit greater bond strength compared with both mechanical retention ceramic brackets and metal brackets^{2,18,37}; others asserted that chemical retention brackets produce significantly higher bond strengths than brackets with other types of retention bases.^{4,7,16,20,25,38}

For the removal of group G ceramic brackets (mechanical retention), the tips of the Howes pliers were positioned over the mesiodistal sides of the metal arch wire slot, and a gentle squeeze was applied to induce fracture in the center of the slot. As a result, 1 side came off, and it was necessary to gently rock the bracket toward the side that debonded first to fully debond the bracket. This technique proved simple, quick, and convenient.

Group R ceramic brackets (polymer base) were removed by squeezing the tips of a wire cutting pliers over the adhesive-bracket base interface. Although the procedure did not require a great deal of strength, some fragments popped off during removal, and the bracket base shattered into 3 splinters. Parts of the polymer base remained bonded to the enamel surface and were easily removed with the same bur used to remove resin remnants.

Group Y (chemical retention) ceramic brackets were wrapped in a blue Sep-A-Ring (TP Orthodontics) and debonded by placing the blades of the Weingart pliers over the mesial and distal sides of the bracket base. The bracket manufacturer recommended that the

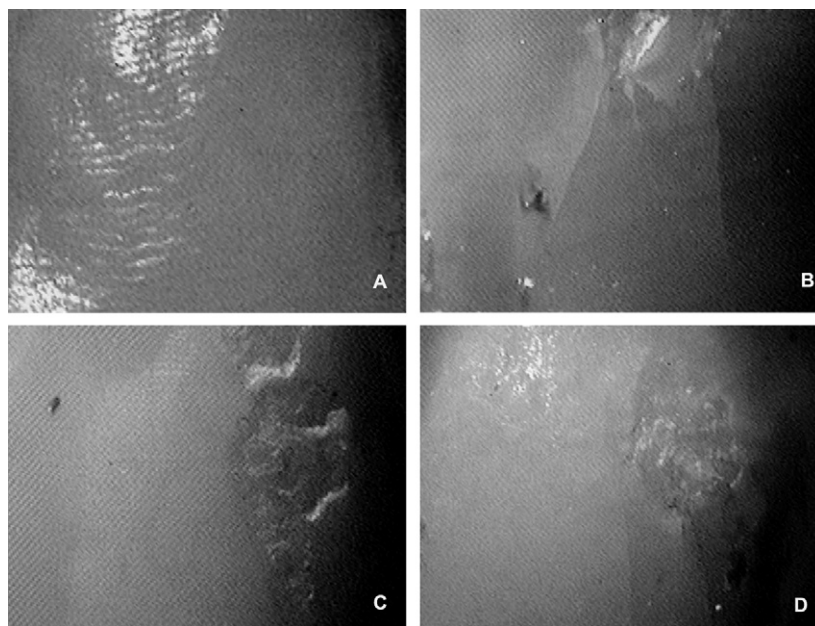


Fig 1. Photomicrographs of surface enamel: **A**, no damage; **B**, damage in the form of a crack; **C**, damage in the form of tear-outs; **D**, damage in the form of tear-outs and cracks.

Table I. Quantities and values attributed to each group according to the ARI

Group	ARI score			
	0	1	2	3
G, mechanical retention	0	1	5	9
R, polymer base	4	3	2	6
Y, chemical retention	11	1	1	2

0, No adhesive on tooth surface; 1, less than half of the adhesive on tooth surface; 2, more than half of the adhesive on tooth surface; 3, all adhesive remaining on tooth surface and resin imprint visible on the bracket base.

instrument not be used to pull the bracket off the surface enamel but, rather, to apply a torsional rotation from right to left. This technique apparently required greater strength than was needed for the removal of the other brackets in this study. Clinically, this characteristic might prove less comfortable for the patient.

After bracket removal, the specimens were evaluated with the ARI⁸ and a 10 times magnifying glass. The scores are shown in Table I.

If no adhesive remained on the enamel surface after bracket removal—and a score of 0 was assigned—bond failure occurred at the adhesive-enamel interface, entailing greater damage risks for the tooth enamel.^{1,6} In this study, the chemical retention group scored 0 on 11 specimens, notably above the number of 0 scores of the other 2 groups.

Table II. Score totals for surface evaluation before bonding (T1) and after debonding (T2) of brackets

Score	Group G, mechanical retention		Group R, polymer base		Group Y, chemical retention	
	T1	T2	T1	T2	T1	T2
0	8	6	12	11	13	8
1	5	7	2	2	1	7
2	1	1	0	1	1	0
3	1	1	1	1	0	0
Chi-square	0.62		2.24		6.69	
P	0.892 [†]		0.523 [†]		0.035*	

0, No cracks or tear-outs (Fig 1, A); 1, enamel surface with cracks (Fig 1, B); 2, enamel surface with tear-outs (Fig 1, C); 3, enamel surface with cracks and tear-outs (Fig 1, D).

*Significant at $P < 0.05$; [†]not significant.

With an ARI score of 1 (less than half of the adhesive on the enamel surface), there were 1 specimen from the mechanical retention group, 3 from the polymer base group, and 1 from the chemical retention group.

For an ARI score of 2 (more than half of the adhesive on the enamel surface), the following results were found: 5 in the mechanical retention group, 2 in the polymer base group, and 1 in the chemical retention group.

An ARI score of 3 (all adhesive on the enamel surface with an imprint of the bracket base) was

assigned to 9 of the mechanical retention group, 6 of the polymer base group, and 2 specimens of the chemical retention group. The more adhesive remaining on the enamel surface after bracket removal, the lower the likelihood of damage to the enamel, but this adhesive necessitates removal with latch-type burs.³⁹

In this study, more than half the of mechanical retention bracket specimens had bond failure at the bracket-adhesive interface. The bond failure sites of the polymer base ceramic brackets were uneven. On the other hand, the most common site for the bond failure of the chemical retention ceramic brackets was at the adhesive-enamel interface, thus entailing damage risks for the enamel surface.^{1,6}

The pattern of bond failure interface observed after removal of chemical retention ceramic brackets in this study supports the findings of previous studies.^{22, 25,40}

In our study, the ARI scores were used to confirm the results of comparing the before and after debonding photos from the optical stereomicroscope. With today's technology of digital capture and electronic surface integration, the crude scale of the ARI seems outdated. It can be considered a limitation of this study; otherwise, the main purpose was to evaluate before and after photos from the same surface, and it is suggested in future studies that the researchers might use software that calculates percentages to a tenth of a percent for differences in surface characteristics. This would allow probability calculations of a continuous rather than a discrete variable. Atomic force microscopy and its accompanying software also allow for detailed descriptions of adhesive remnants and could be used in future studies.

Many authors have asserted that the removal of chemical retention brackets can result in enamel damage and that the extent of this damage largely depends on the bracket material and the debonding technique.^{31,34,35,37,41} Some researches reported gaping enamel fractures during ceramic bracket removal.^{14,41}

According to our results, the best performing groups—those exhibiting the least damage on the enamel surface—were the mechanical retention and polymer base ceramic brackets (Table II). Previous research showed similar results for these bracket types.^{8,27}

The observation method used to compare the before and after photos involved an optical stereomicroscope with an attached digital camera, which allowed us to store several images of the same dental surface at different stages of the research. Therefore, the initial image of the specimen before the bonding procedure could be used as the control and later compared with the same surface after bracket debonding, without the need for any special treatment.

As can be seen in Table II, although specimen distribution was random, the chemical retention group had the most surfaces with a score of 0 at phase T1: 13 specimens, equivalent to an enamel surface free from cracks or tear-outs. At T1, the mechanical retention group had the most specimens (5) with scores of 1 (cracks on the enamel surface). Studies that use SEM do not permit such accurate prebonding considerations such as those in this study.

The data in Table II suggest a mistake in group Y from T1 to T2; the tear-outs in a sample at T1 had disappeared by T2. This can be attributed to the technique or the evaluator's mistake. The evaluator repeated this evaluation 1 week later, and the kappa index was 0.85, indicating excellent concordance. Even so, this could be attributed to the evaluator's mistake; thus, it suggests that studies with several evaluators will allow analyzing agreement between appraisers, thus reducing mistakes. This would have strengthened our conclusions.

Figure 2 shows the enamel surface of a specimen from group G (mechanical retention). Figure 2, A, is the photomicrography of the enamel surface before bracket bonding, showing visible damage in the form of a crack. Figure 2, B, is the photomicrography of the same enamel surface after bracket bonding and debonding; the only visible damage is the crack. There is sufficient ground to conclude, therefore, that the procedures of bonding and debonding the mechanical retention ceramic bracket did not cause alterations on this enamel surface. If this analysis were conducted with SEM, only 1 of the phases would be observed, and once detected, the surface damage would be attributed to bracket bonding and debonding.

Figure 3 shows the photomicrography of a specimen from group R (polymer base). Figure 3, A, shows no damage to the enamel, but Figure 3, B, taken after the bracket had been bonded and debonded, shows a crack.

Figure 4 shows the photomicrography of the enamel surface of a specimen from group Y (chemical retention). Figure 4, A, shows no damage to the enamel surface before bracket bonding. After debonding, however, some cracks can be seen on the enamel surface (Fig 4, B).

The groups with the most significant alterations on the enamel surface before bonding and after debonding were the chemical retention ceramic brackets. Eliades et al²² and Merrill et al³⁷ evaluated the bonding of ceramic brackets and also observed more damage associated with the removal of chemical retention brackets. The T1 and T2 scores for the chemical retention brackets are compared in Table II. The alter-

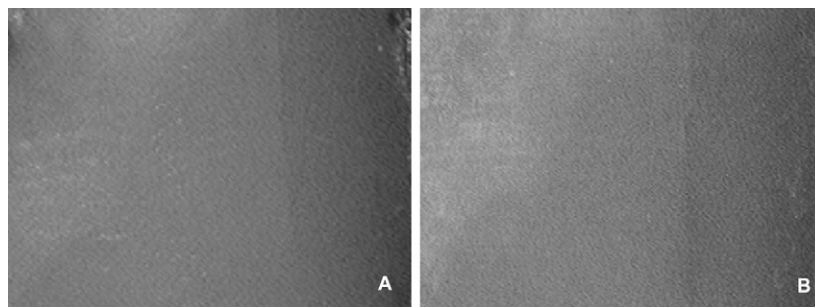


Fig 2. Photomicrography of a specimen from the mechanical retention group: **A**, before bonding; **B**, after debonding.

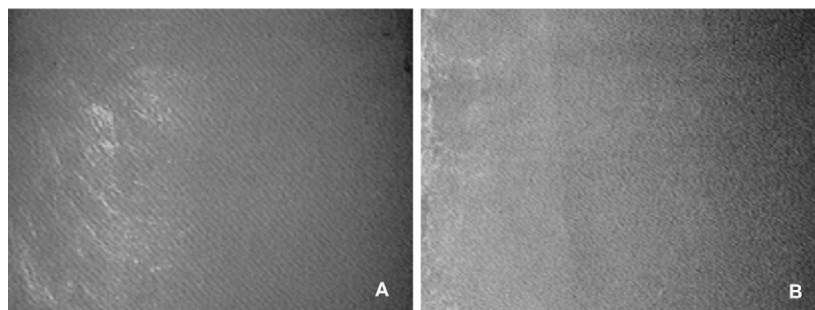


Fig 3. Photomicrography of a specimen from the polymer base group: **A**, before bonding; **B**, after debonding.

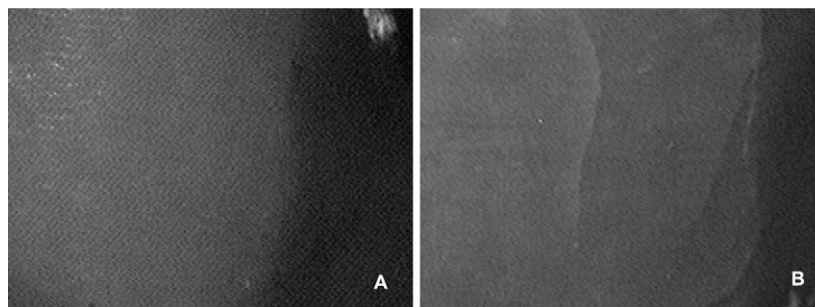


Fig 4. Photomicrography of a specimen from the chemical retention group: **A**, before bonding; **B**, after debonding.

ations are only cracks. Before the bonding-debonding procedures, there was 1 damaged specimen with a crack, and, after that, there were 7 damaged specimens with cracks. According to this study and the bracket manufacturer's recommended procedures, the enamel surface was not severely damaged, except for a few cracks.

In light of the chi-square nonparametric statistical test at a 5% probability level, the only significant statistical difference between the T1 and T2 phases was in the chemical retention group.

The optical stereomicroscope proved a practical, user-friendly, and overall satisfactory device for analyzing the enamel surfaces of the specimens in this study. However, further studies are needed to evaluate this observation method of dental enamel surfaces and to compare this device with SEM.

The orthodontist's major concern should always be the integrity of the enamel surface. Accordingly, all procedures involved in bracket bonding and debonding should be performed with extreme care: eg, prophylaxis of the enamel surface, optimal etching time, appliances

that promote adequate bond strength, and a reliable debonding technique.

In view of the above and according to other researchers, mechanical retention and polymer base ceramic brackets are the most suitable brackets for preservation of the original enamel surface. Although these brackets also caused some enamel alterations after bonding and debonding, these were the least severe of all groups.

Therefore, patients should be taught to take proper care of their appliances to prevent damage or untimely replacement as well as to minimize the likelihood of damage to the enamel surface.

The enamel damage was observed from brackets of different manufacturers, different types of retention, and different methods of removal, following the recommendation of each manufacturer. It could be confusing and unclear to define which variable affects the enamel damage after removal of a ceramic bracket. But the results were consistent, even in ARI scores and comparisons among groups, that the chemical retention brackets cause more damage to the enamel in debonding. However, any of these variables could be standardized so that the results could only explain the difference of 3 brackets when the manufacturer's directions for removal were used. We recommend that future researchers should narrow the scope of the study.

CONCLUSIONS

In line with the methodology adopted and the results from this study, the following conclusions can be drawn.

1. Removal of mechanical retention brackets according to the manufacturer's instructions is easy, quick, and safe.
2. Most polymer base ceramic brackets popped off during removal with an orthodontic wire cutter. Orthodontists should therefore debond this type of bracket with the archwires secured in the bracket slots.
3. Compared with the other groups, the removal of chemical retention brackets required additional force application.
4. The mechanical retention brackets left the most adhesive on the enamel surface after debonding. The chemical retention brackets yielded the least favorable results: more than half of their specimens fractured at the enamel-adhesive interface.
5. No statistically significant differences in enamel damage were observed in the groups of mechanical retention and polymer base brackets by comparing

the same surface before bonding and after debonding.

6. For the chemical retention brackets, the difference between the enamel surfaces before bonding and after debonding was statistically significant at a 5% probability level, indicating that the procedures of bonding and debonding resulted in enamel damage.

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