



Research Article

## Comparative Assessment of Enamel Micro-Scratches and Surface Roughness Following Debonding: Clear Aligners vs. Metal Braces in Young Adult Orthodontic Patients.

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**Abstract:** **Background:** Debonding orthodontic attachments can lead to enamel alterations including microscopic scratches and increased surface roughness. Evidence regarding these changes post clear-aligner and metal-brace treatment are limited. **Objective:** The objective of this study was to evaluate enamel micro-scratch and surface roughness changes post-debonding in young adult patients who have undergone orthodontic treatment using clear-aligners or traditional metal braces. **Methods:** This comparative cross-sectional study included 100 young adult patients (18-30 years) who have completed orthodontic treatment using either clear aligners or metal braces. Participants were assigned to one of the two groups based on their type of orthodontic appliances. Following completion of treatment, the metal brackets and clear-aligner attachments were removed. The surfaces of the enamel were assessed for microscopic alterations. Scanning Electron Microscopy (SEM) was performed to assess and describe types of micro-scratch and surface alterations. Surface roughness (Ra) was assessed using a three-dimensional optical profilometer. Comparative images of post-debonding and surface roughness measurements were standardized. Data were analyzed statistically using appropriate tests. **Results:** Following debonding, alterations in enamel surface morphology was evident in both groups. Comparative assessments of micro-scratch and surface roughness changes between the two groups showed differences in the magnitude and characteristics of alterations. **Conclusion:** Alterations in enamel surface morphology including micro-scratch and increased surface roughness was evident following both debonding procedures.

**Keywords:** Enamel Surface Roughness / Enamel Topography, Composite Attachment Removal, Adhesive Remnant Removal, Scanning Electron Microscopy (SEM).

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## INTRODUCTION

The benefits of orthodontic treatment, including improvement in dental and facial aesthetics and function, have resulted in increasing acceptance and demand for orthodontic treatment (1). Although positive outcomes are achieved, the methods of removing orthodontic appliances and remnants of adhesives may have an effect on the quality of enamel surface (1).

There are different methods of removing fixed orthodontic appliances. Most involve removal of the bracket and subsequent elimination of the residual adhesive. During this procedure, many different instruments (abrasives, burs, diamonds, or fluoride) may be used. Microscopic damage to the surface may occur, and the final surface condition depends on the technique and protocol used for polishing (2).

Enamel integrity is essential to retain the surface aesthetics of the teeth. Roughness of the enamel surface can encourage plaque retention, discoloration, and staining (2). It has been shown that, depending on the method and protocol of adhesive removal, different levels of roughness are produced on the enamel surface. These differences can only be assessed using advanced methodology, such as three-dimensional analysis and optical profilometry (3).

Analysis of the changes in the surface topography of enamel, using three-dimensional (3D) surface-measuring techniques, allows objective comparison and evaluation of different methods used for debonding in orthodontics (4). The use of clear aligners has introduced a variation to orthodontic attachment removal. Composite attachments are indirectly bonded to the teeth and must be removed at the end of treatment. Recent 3D studies have demonstrated that the method used to remove attachments may affect enamel topography and roughness (5).

Microscopic analysis can be very effective to identify enamel changes that may be clinically insignificant. Scanning Electron Microscopy and other advanced imaging methods are very effective to analyze surface changes and irregularities on the enamel and other materials caused by orthodontic debonding procedures (6).

Studies focusing on conventional brackets have shown that changes on the enamel surface are caused by the combined effect of removal of the brackets and the residual adhesive. Quantitative evaluation has shown measurable differences in enamel surface roughness due to the method used for the removal of the adhesive and the instrumentation used for that purpose (7).

A recently published systematic review has shown that the method used for removal of orthodontic attachments and finishing of the enamel has a key role for the final state of enamel. The available evidence has focused on the comparison of the instruments or systems used for finishing in fixed orthodontic appliances, rather than comparison of different modalities of orthodontic treatment (8).

Therefore, comparison of enamel surface changes of young adult patients, as a result of debonding of conventional metal brackets and removal of attachments for clear aligners is warranted. In the present study, we aimed to evaluate these changes using SEM, and 3D optical profilometry (5).

## **METHODOLOGY**

### **Study Design and Setting**

This was a comparative cross-sectional clinical study that aimed to evaluate micro-scratch marks and surface roughness on the enamel of young adults following orthodontic debonding with clear aligners or conventional metal brackets. This study was performed in the orthodontic department of a university affiliated dental hospital. A total of 100 participants between the ages of 18 to 30 years were included in the study and equally distributed into two groups based on the type of orthodontic appliance received: Group A included 50 participants who were administered with clear aligners and Group B included 50 participants who were administered with conventional metal braces.

### **Participants and Eligibility**

Young adults between the ages of 18 to 30 years who were completed with comprehensive orthodontic treatment and were scheduled for removal of their orthodontic appliance/clear aligner attachments were included in this study. Participants were required to have a permanent dentition and clinically healthy labial enamel on the teeth that was assessed. Developmental enamel defects, extensive restorations or veneers on assessed surfaces, active caries, enamel fractures, severe fluorosis, previous orthodontic treatment, history of trauma affecting the assessed teeth were some of the reasons for excluding the participants. Patients who had undergone professional enamel abrasion or teeth bleaching immediately before the assessment were also excluded.

### **Sampling and Grouping**

Using a consecutive sampling strategy, eligible patients were recruited until 100 were attained. Clear-aligner therapy was completed by 50 consecutive patients, who comprised the clear-aligner group. Likewise, 50 consecutive patients who completed treatment with conventional metal brackets comprised the metal-brace group. The two groups were evaluated under similar clinical conditions to permit comparison of enamel micro-scratches and roughness.

### **Clinical Debonding and Enamel Surface Preparation**

Following the completion of clear-aligner therapy, the bonded attachments were removed using the clinic's standardized protocol for the removal of attachments. The composite was removed and the surface was polished. For patients in the metal-brace group, orthodontic debonding pliers were used to remove the brackets, and the adhesive was removed following the clinic's standardized procedure. The enamel surface was then polished. The same protocol and sequence was followed as much as was clinically permissible to reduce procedural variation. The teeth chosen for evaluation were isolated, cleansed with water and non-abrasive prophylaxis, and rinsed and gently air-dried prior to assessment.

### **Data Collection Tools and Measurement**

Data were collected using a structured clinical data collection form, scanning electron microscopy (SEM), and a three-dimensional optical profilometer. The clinical data collection form captured patient age, sex, type of dental appliance, and treatment characteristics. SEM was used to evaluate the enamel surface, to view post-debonding irregularities, scratches and grooves. For this study, scratches on the enamel surface were semi-quantitatively evaluated, and classified as: none/minimal, mild, moderate and severe. The three-dimensional optical profilometer was used for quantitative evaluation of surface features. The average roughness of the surface (Ra) and the maximum height of surface irregularities (Rz) were recorded. The mean scratch length and scratch density were evaluated from standardized, high-power, images of the enamel surface.

### Surface Roughness Assessment

The surface roughness measurements were performed on standardized areas of the labial enamel surface. The profilometer was calibrated, according to the manufactures instructions, before data collection. For each surface to be assessed, measurements were repeatedly taken in standardized locations, and the mean of valid readings was taken for analysis. Ra was defined as the average of absolute vertical deviations of the measured surface profile from the mean line; and Rz was defined as the average maximum vertical deviations within the defined measurement segments. The same measurement orientation and acquisition settings were used for participants of both the control and test groups.

### SEM Evaluation

Representative enamel surfaces were analyzed with scanning electron microscopy (SEM) after debonding and polishing. Standardized conditions for imaging were applied to all the samples. SEM images were assessed for the presence and severity of linear scratches, grooves, surface depressions and irregular enamel morphology. For each image, the number of micro-scratches was counted in a given field and the length of representative scratches was measured using an image analysis tool. Assessment was done using coded images to minimize bias.

### Data Management and Statistical Analysis

Data were entered into the Statistical Package for the Social Sciences (SPSS) for statistical analysis. Descriptive statistics were calculated as frequencies and percentages for nominal variables and as means and standard deviation for continuous variables. The normality of continuous variables was assessed.

Independent-samples t-tests were performed to compare the means of surface roughness and other continuous enamel surface measurements between the clear-aligner and metal-brace groups. The chi-square test was performed to compare micro-scratch severity between the two groups. One-way analysis of variance was performed to compare surface roughness among the different groups created by the treatment duration. Pearson correlation analysis was performed to determine the relationships among Ra, micro-scratch, and scratch length. A two-sided p-value of less than 0.05 was considered statistically significant.

### Ethical Considerations

Participants were given the opportunity to understand the purpose and procedures of the study, and signed informed consent was obtained before data collection. Participation was entirely voluntary, and participants were informed that they could withdraw from the study at any time and that this would not affect their orthodontic care in any way. Information about the participants was coded to maintain confidentiality. The researcher ensured that the information was collected and stored in a secure manner and used it only for research purposes.

## RESULTS

**Table 1: Demographic Characteristics of Study Participants (N = 100)**

| Variable                  | Clear Aligners n (%) | Metal Braces n (%) | Total n (%) |
|---------------------------|----------------------|--------------------|-------------|
| <b>Age (years)</b>        |                      |                    |             |
| 18–21                     | 16 (32.0)            | 15 (30.0)          | 31 (31.0)   |
| 22–25                     | 19 (38.0)            | 20 (40.0)          | 39 (39.0)   |
| 26–30                     | 15 (30.0)            | 15 (30.0)          | 30 (30.0)   |
| <b>Gender</b>             |                      |                    |             |
| Male                      | 21 (42.0)            | 23 (46.0)          | 44 (44.0)   |
| Female                    | 29 (58.0)            | 27 (54.0)          | 56 (56.0)   |
| <b>Treatment duration</b> |                      |                    |             |
| <18 months                | 18 (36.0)            | 12 (24.0)          | 30 (30.0)   |
| 18–24 months              | 24 (48.0)            | 25 (50.0)          | 49 (49.0)   |
| >24 months                | 8 (16.0)             | 13 (26.0)          | 21 (21.0)   |

Table 1 provides the demographic data of 100 study participants. Groups A and B each had 50 participants, with a slightly higher number of females than males. The age group 22-25 years had the highest number of participants and the average duration of the orthodontic treatment for the participants was 18-24 months.

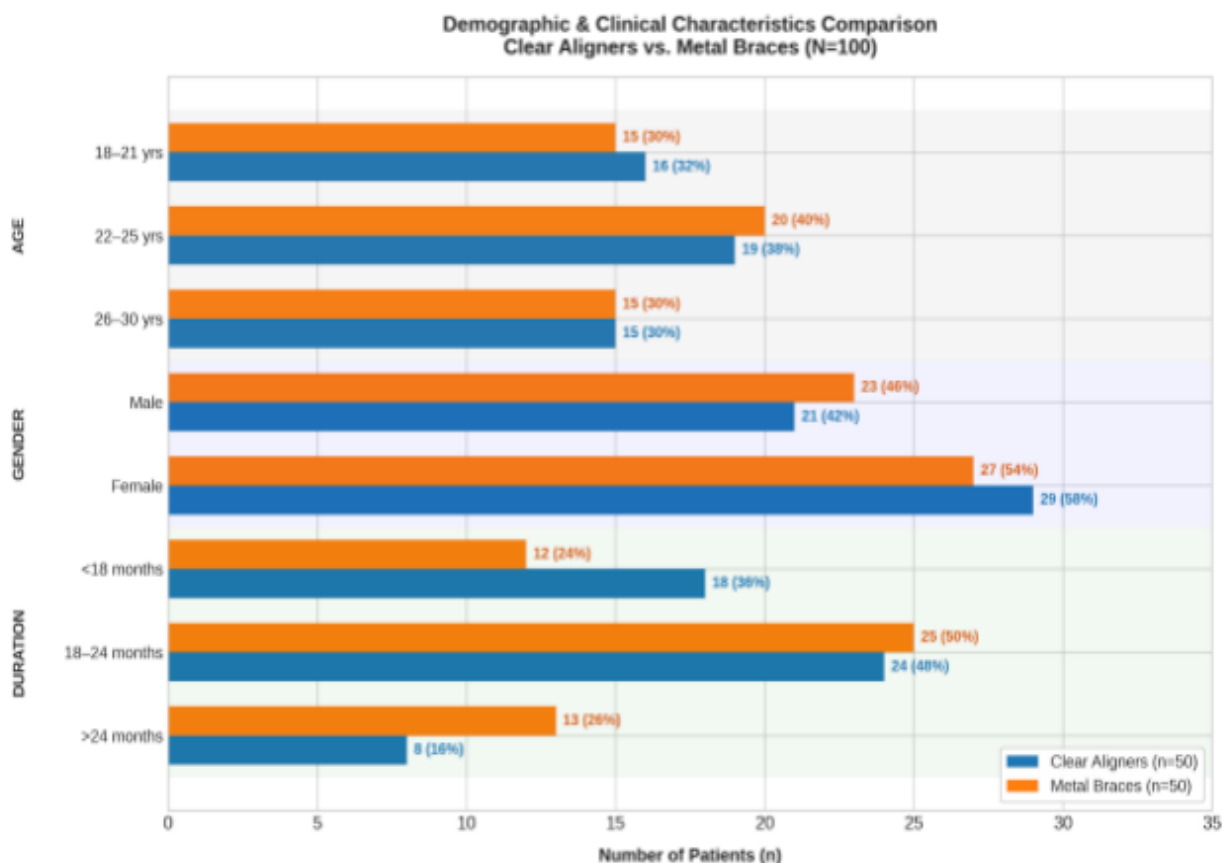


**Table 2: Distribution of Enamel Micro-Scratch Severity Assessed by Scanning Electron Microscopy (SEM)**

| Micro-scratch severity | Clear Aligners n (%) | Metal Braces n (%) | Total n (%) |
|------------------------|----------------------|--------------------|-------------|
| None/minimal           | 21 (42.0)            | 9 (18.0)           | 30 (30.0)   |
| Mild                   | 20 (40.0)            | 18 (36.0)          | 38 (38.0)   |
| Moderate               | 8 (16.0)             | 18 (36.0)          | 26 (26.0)   |
| Severe                 | 1 (2.0)              | 5 (10.0)           | 6 (6.0)     |
| Total                  | 50 (100.0)           | 50 (100.0)         | 100 (100.0) |

Chi-square test:  $\chi^2 = 11.42$ ,  $p = 0.010$

Table 2 shows differences in the presence of micro-scratches between the two treatment groups. A higher number of patients in the clear-aligner treatment group showed either no/minimal micro-scratches while patients in the metal-brace group had predominantly moderate to severe micro-scratches. The difference between the two groups was statistically significant ( $\chi^2 = 11.42$ ,  $p = 0.010$ ).

**Table 3: Comparison of Enamel Surface Roughness (Ra) Between Clear-Aligner and Metal-Brace Groups**

| Group          | n   | Mean Ra (μm) | SD   | SE    |
|----------------|-----|--------------|------|-------|
| Clear Aligners | 50  | 0.38         | 0.11 | 0.016 |
| Metal Braces   | 50  | 0.57         | 0.15 | 0.021 |
| Total          | 100 | 0.48         | 0.16 | 0.016 |

Independent-samples t-test:  $t = -7.10$ ,  $p < 0.001$

Table 3 indicates that mean surface roughness of enamel was  $0.38 \pm 0.11 \mu\text{m}$  for the clear-aligner group and  $0.57 \pm 0.15 \mu\text{m}$  for the metal-brace group. The difference was statistically significant ( $t = -7.10$ ,  $p < 0.001$ ).

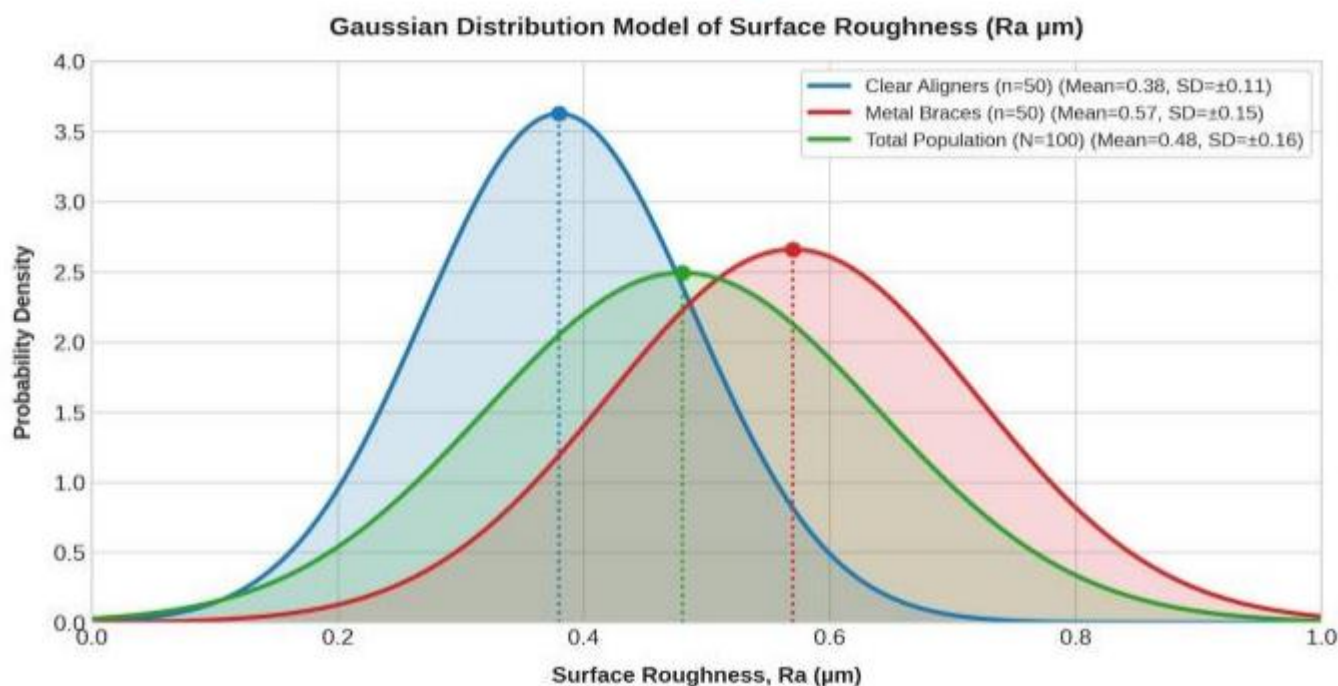


**Table 4: Comparison of Individual Enamel Surface Characteristics Between Treatment Groups**

| Surface characteristic                        | Clear Aligners Mean $\pm$ SD | Metal Braces Mean $\pm$ SD | t-value | p-value |
|-----------------------------------------------|------------------------------|----------------------------|---------|---------|
| Surface roughness, Ra ( $\mu\text{m}$ )       | 0.38 $\pm$ 0.11              | 0.57 $\pm$ 0.15            | -7.10   | <0.001  |
| Maximum roughness depth, Rz ( $\mu\text{m}$ ) | 2.41 $\pm$ 0.63              | 3.36 $\pm$ 0.82            | -6.46   | <0.001  |
| Micro-scratch count                           | 4.18 $\pm$ 2.07              | 7.26 $\pm$ 2.84            | -6.28   | <0.001  |
| Mean scratch length ( $\mu\text{m}$ )         | 31.46 $\pm$ 9.18             | 44.72 $\pm$ 12.35          | -6.05   | <0.001  |

Table 4 shows that in all assessed parameters, the metal-brace group showed greater surface alterations on enamel than the clear-aligner group. Mean Ra and Rz, micro-scratches, as well as mean scratch length, were higher in the metal-brace group and differences were statistically significant ( $p < 0.001$ ).

**Table 5: Association of Treatment Characteristics With Enamel Surface Roughness**

| Variable                        | Clear Aligners Mean Ra $\pm$ SD | Metal Braces Mean Ra $\pm$ SD | p-value |
|---------------------------------|---------------------------------|-------------------------------|---------|
| Treatment duration <18 months   | 0.34 $\pm$ 0.09                 | 0.51 $\pm$ 0.13               | <0.001  |
| Treatment duration 18–24 months | 0.37 $\pm$ 0.10                 | 0.55 $\pm$ 0.14               | <0.001  |
| Treatment duration >24 months   | 0.46 $\pm$ 0.12                 | 0.68 $\pm$ 0.16               | <0.001  |
| Overall                         | 0.38 $\pm$ 0.11                 | 0.57 $\pm$ 0.15               | <0.001  |

One-way ANOVA within treatment-duration categories: significant trend observed,  $p < 0.001$ .

Treatment duration had a significant effect on the roughness of the enamel surface, as illustrated in Table 5. The longer the treatment period, the higher the roughness of the enamel surface in both treatment groups. Mean Ra values of the metal-bracket group were always higher than the clear aligner group. The difference was highly significant,  $p < 0.001$ .

**Table 6: Correlation Between Micro-Scratch Characteristics and Enamel Surface Roughness**

| Variable             | Ra ( $\mu\text{m}$ ) | Micro-scratch count | Scratch length |
|----------------------|----------------------|---------------------|----------------|
| Ra ( $\mu\text{m}$ ) | 1.000                | 0.68**              | 0.61**         |
| Micro-scratch count  | 0.68**               | 1.000               | 0.73**         |
| Scratch length       | 0.61**               | 0.73**              | 1.000          |

Note: \*\* $p < 0.001$  for all reported correlations.

Table 6 illustrated positive correlations between enamel surface roughness and micro-scratch characteristics. Ra exhibited a positive and strong correlation with the number of micro-scratch ( $r = 0.68$ ) and positive and moderate to strong correlation with scratch length ( $r = 0.61$ ). The number of micro-scratch was also positively and strongly correlated with scratch length ( $r = 0.73$ ). All the reported correlations were found to be statistically significant at  $p < 0.001$ .

## DISCUSSION

This study evaluated the type of enamel surface changes that occur during debonding in clear aligner and metal brace groups. Enamel surface changes were observed in both groups. However, the metal braces group showed greater micro-scratch severity and roughness, and deeper and longer micro-scratches. The present study showed that the debonding of metal brackets from teeth results in alteration of the enamel surface, and the nature of the debonding process is likely the predominant factor for the type and degree of enamel surface alterations that occur.

Evidence shows that bracket removal can damage the enamel surface. The force required for bracket removal, as well as the adhesive removal procedure, can potentially cause scratching and surface irregularities. Evidence shows that the technique utilized to remove the bracket from the enamel is critical to reducing damage to enamel (9).

Higher mean Ra values were reported in the metal-brace group in the current study, which supports the notion that roughness of enamel is affected by the clinical sequence that occurs after the removal of the fixed orthodontic appliances. Results of other studies have shown that roughness of enamel following the removal of orthodontic brackets varies depending on the adhesive resin and the technique employed for the removal of the residual adhesive. Standardization of removal procedures is essential (10).

The higher Rz values in the metal-brace group, in addition to higher mean Ra values, indicate more pronounced surface irregularities in that group. Concerns for damage to the enamel surface in previous studies comparing different bracket-removal techniques have also been related to scratching and changes in the surface morphology of the enamel (11).

When comparing the clear-aligner attachment removal group and the metal-brace group in the current study, clear-aligner attachment removal produced a lower total micro-scratch count and lower mean scratch lengths. This indicates that, compared with metal-bracket removal, clear-aligner attachment removal causes less damage to the enamel surface. Recent three-dimensional research has shown that the method chosen to remove clear-aligners can alter enamel topography and roughness parameters, indicating that the removal method itself is an important factor in enamel preservation (5).

In the current study, higher values of Ra were found on teeth with a higher number of micro-scratches and longer micro-scratch length. These results indicate that a greater quantity of microscopic surface damage was related to greater surface roughness. The results of a recently published systematic review suggest that when various mechanical instruments and finishing procedures used to remove the orthodontic adhesive are compared, considerable variation in the final condition of the enamel surface exists, and some methods and procedures result in considerably rougher surfaces than others (12).

The association between longer treatment duration and increased Ra values in both groups should be interpreted with caution. The length of treatment may be associated with a number of other clinical factors. The findings, however, illustrate that there is value in evaluating a range of treatment-related factors when assessing post-orthodontic enamel (13).

The results of the current study suggest that objective surface analysis methods should be used to assess enamel preservation. In the current study, SEM and three-dimensional profilometry were used. SEM allowed for close up photographs of micro-scratch surface defects, and three-dimensional profilometry, allowed for the measurement of surface defects. Using the two methods together showed the microscopic and the numerical differences between clear aligners and metal braces. More controlled clinical studies with defined procedures for debonding and polishing would show what contributes most to preservation of enamel surfaces.

## CONCLUSION

This study reported alterations to enamel surfaces following both clear-aligner and metal-brace debonding in young adult patients. The metal-brace group exhibited more severe micro-scratching, increased surface roughness and deeper micro-scratching, longer micro-scratching, and greater micro-scratching counts, compared to the clear-aligner group. SEM combined with three-dimensional optical profilometry offered a range of morphological and numerical assessments to evaluate post-debonding changes to enamel surfaces. It was postulated that the preservation of the integrity of the enamel surface may be influenced by the type of orthodontic appliance as well as the method of debonding.

### Limitations of Study

The sample size of this study was relatively small at 100 participants, and enamel was assessed only immediately following debonding. Different durations of treatment, the type of adhesives used, and differences in the clinical procedures of debonding may have resulted in alterations to the enamel surface. Finally, this study did not assess the long-term consequences of the microscopic changes to enamel.

## Future Suggestions

Larger samples should be studied using longtve, prospective methods to access the stability of alterations to enamel following debonding. Further standardization of adhesive systems, debonding instrumentation, and polishing procedures is warranted. Further research using three-dimensional imaging and other methods to assess surfaces may help establish the most effective, least harmful debonding techniques for clinical orthodontics.

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