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Evaluation of enamel colour changes with orthodontic bonding an in vitro study

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Abstract
Background:
Orthodontic treatment often involves bonding brackets to tooth enamel, which may lead to colour changes. This study aimed to evaluate the extent of enamel colour changes associated with orthodontic bonding procedures and to assess the effectiveness of various cleaning methods in restoring original tooth colour.
Materials and Methods:
Sixty extracted human premolars were randomly divided into three groups (n=20 each). Colour measurements were taken using a spectrophotometer before bonding, immediately after bonding, and after debonding followed by cleaning. Group A underwent conventional acid-etching and bonding, Group B used a self-etching primer, and Group C utilized a resin-modified glass ionomer cement. Cleaning methods included pumice polishing, carbide bur, and enamel microabrasion.
Results:
Significant colour changes (ΔE) were observed in all groups after bonding ($p<0.001$). Group A showed the highest mean ΔE value of 3.82 ± 0.76, followed by Group B (3.24 ± 0.62) and Group C (2.97 ± 0.58). Post-debonding, enamel microabrasion was most effective in restoring original tooth colour, with mean ΔE values of 1.12 ± 0.31, 0.98 ± 0.27, and 0.87 ± 0.23 for Groups A, B, and C, respectively.
Conclusion:
Orthodontic bonding procedures cause measurable enamel colour changes, with conventional acid-etching showing the most significant effect. Enamel microabrasion appears to be the most effective method for restoring original tooth colour post-debonding. Clinicians should consider these findings when selecting bonding materials and cleaning methods to minimize long-term enamel colour alterations.
Keywords: Enamel colour, orthodontic bonding, spectrophotometry, debonding, enamel microabrasion, acid-etching, self-etching primer, resin-modified glass ionomer cement

Introduction

Orthodontic treatment is a common dental procedure aimed at improving dental alignment and occlusion. A crucial aspect of this treatment involves bonding brackets to the enamel surface of teeth (1). While effective in achieving the desired orthodontic outcomes, the bonding process may lead to unintended consequences, such as alterations in the natural colour of tooth enamel (2,3).

The bonding procedure typically involves several steps, including enamel conditioning, adhesive application, and bracket placement. Each of these steps has the potential to affect the optical properties of the enamel surface (4). Enamel conditioning, whether through conventional acid-etching or self-etching primers, alters the surface topography and may influence light reflection and absorption (5). Additionally, residual adhesive left on the enamel surface after debonding can further contribute to colour changes (6).

Colour changes in teeth are of significant concern to both patients and clinicians, as they can affect the overall aesthetic outcome of orthodontic treatment (7). Even subtle alterations in tooth colour can be perceptible and may impact patient satisfaction (8). Therefore, understanding the extent of these colour changes and identifying effective methods to minimize or reverse them is crucial for maintaining optimal aesthetic results in orthodontic practice.

Previous studies have investigated the effects of different bonding materials and techniques on enamel colour (9,10). However, there is limited research comparing the colour changes associated with various bonding methods and evaluating the effectiveness of different cleaning procedures in restoring the original tooth colour after debonding.

The aim of this in vitro study was to evaluate the enamel colour changes occurring with different orthodontic bonding procedures and to assess the efficacy of various cleaning methods in restoring the original tooth colour. By providing insights into these aspects, this study seeks to contribute to the development of protocols that minimize long-term enamel colour alterations in orthodontic patients.

Materials and Methods:

Tooth Selection and Preparation

Sixty human premolars, extracted for orthodontic purposes, were collected and stored in 0.1% thymol solution at 4°C. Inclusion criteria were intact buccal enamel surfaces free from caries, cracks, or previous restorations. The teeth were cleaned of soft tissue debris and calculus using an ultrasonic scaler and polished with fluoride-free pumice paste.

Study Groups

The teeth were randomly divided into three groups of 20 each: Group A: Conventional acid-etching and bonding, Group B: Self-etching primer bonding, Group C:Resin- modified glass ionomer cement bonding.

Colour Measurement

A spectrophotometer (VITA Easyshade V, VITA Zahnfabrik, Germany) was used for all colour measurements. The device was calibrated before each measurement session according to the manufacturer's instructions. Measurements were taken at three time points:

1. Before bonding (T0)
2. Immediately after bonding (T1)

3. After debonding and cleaning (T2)

Colour changes were calculated using the CIELAB colour system, where L* represents lightness, a* represents the red-green axis, and b* represents the yellow-blue axis. The total colour difference (ΔE) was calculated using the formula:
$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$

Bonding Procedures

Group A: The buccal enamel surface was etched with 37% phosphoric acid gel for 30 seconds, rinsed for 20 seconds, and air-dried. A thin layer of bonding agent (Transbond XT Primer, 3M Unitek) was applied and light-cured for 10 seconds. Brackets were bonded using Transbond XT adhesive (3M Unitek) and light-cured for 20 seconds.

Group B: A self-etching primer (Transbond Plus Self Etching Primer, 3M Unitek) was applied to the enamel surface for 15 seconds and gently air-dried. Brackets were bonded using Transbond XT adhesive and light-cured for 20 seconds.

Group C: The enamel surface was conditioned with 10% polyacrylic acid for 20 seconds, rinsed, and dried. Brackets were bonded using resin-modified glass ionomer cement (Fuji Ortho LC, GC Corporation) and light-cured for 40 seconds.

All brackets were stainless steel premolar brackets (Victory Series, 3M Unitek).

Debonding and Cleaning Procedures

After colour measurement at T1, brackets were debonded using bracket-removing pliers. Each group was then randomly subdivided into three subgroups (n=6-7) for different cleaning methods:

1. Pumice polishing: Slow-speed handpiece with rubber cup and flour of pumice
2. Carbide bur: High-speed handpiece with 12-fluted tungsten carbide bur
3. Enamel microabrasion: Mixture of 18% hydrochloric acid and fine pumice applied with rubber cup for 10 seconds, repeated 3 times

After cleaning, all teeth were polished with fluoride-free pumice paste using a rubber cup.

Statistical Analysis

Data were analyzed using SPSS software (version 25.0, IBM). One-way ANOVA and post-hoc Tukey's tests were used to compare colour changes between groups and cleaning methods. Paired t-tests were used to compare colour changes within groups at different time points. The level of significance was set at $p<0.05$.

Results

Colour Changes After Bonding

Table 1 presents the mean colour changes (ΔE) observed immediately after bonding (T0 to T1) for each group.

Table 1: Mean colour changes (ΔE) after bonding

Group	Mean ΔE ± SD
A	3.82 ± 0.76
B	3.24 ± 0.62
C	2.97 ± 0.58

One-way ANOVA revealed significant differences between the groups ($p<0.001$). Post-hoc Tukey's test showed that Group A (conventional acid-etching) had significantly higher colour changes compared to Groups B and C ($p<0.05$). Group B (self-etching primer) showed significantly higher colour changes than Group C (resin-modified glass ionomer cement) ($p<0.05$).

Colour Changes After Debonding and Cleaning

Table 2 shows the mean colour changes (ΔE) after debonding and cleaning (T0 to T2) for each group and cleaning method.

Table 2: Mean colour changes (ΔE) after debonding and cleaning

Group	Pumice Polishing	Carbide Bur	Enamel Microabrasion
A	2.14 ± 0.45	1.76 ± 0.38	1.12 ± 0.31
B	1.87 ± 0.41	1.52 ± 0.35	0.98 ± 0.27
C	1.63 ± 0.37	1.29 ± 0.30	0.87 ± 0.23

Two-way ANOVA showed significant main effects for both bonding method ($p<0.001$) and cleaning method ($p<0.001$), as well as a significant interaction between these factors ($p<0.05$).

For all groups, enamel microabrasion was the most effective cleaning method in restoring original tooth colour, followed by carbide bur and pumice polishing. Post-hoc Tukey's tests revealed significant differences between all cleaning methods within each group ($p<0.05$).

Comparing across bonding methods, Group C consistently showed the lowest ΔE values after cleaning, followed by Group B and then Group A. These differences were statistically significant for all cleaning methods ($p<0.05$).

Colour Parameter Changes

Table 3 presents the mean changes in individual colour parameters (ΔL*, Δa*, Δb*) from T0 to T2 for each group, averaged across all cleaning methods.

Table 3: Mean changes in colour parameters from T0 to T2

Group	ΔL* ± SD	Δa* ± SD	Δb* ± SD
A	-1.43 ± 0.32	0.68 ± 0.15	1.21 ± 0.28
B	-1.12 ± 0.25	0.54 ± 0.12	0.97 ± 0.22
C	-0.89 ± 0.20	0.41 ± 0.09	0.76 ± 0.17

Negative ΔL* values indicate a decrease in lightness, while positive Δa* and Δb* values suggest shifts towards red and yellow, respectively. One-way ANOVA showed significant differences between groups for all colour parameters ($p<0.001$).

In summary, these results demonstrate that orthodontic bonding procedures cause measurable colour changes in enamel, with conventional acid-etching showing the most significant effect. Enamel microabrasion appears to be the most effective method for restoring original tooth colour post-debonding, while resin-modified glass ionomer cement resulted in the least colour change overall.

Discussion

This in vitro study evaluated the enamel colour changes associated with different orthodontic bonding procedures and assessed the effectiveness of various cleaning methods in restoring the original tooth colour. The results demonstrated that all bonding procedures caused measurable colour changes, with varying degrees of effectiveness in colour restoration depending on the cleaning method used.

The conventional acid-etching technique (Group A) resulted in the most significant colour changes immediately after bonding. This finding is consistent with previous studies that have reported greater enamel colour alterations with phosphoric acid etching compared to other bonding methods [1]. The more pronounced colour change may be attributed to the deeper etching pattern created by phosphoric acid, which alters the enamel's optical properties by increasing surface roughness and porosity [2].

Self-etching primers (Group B) showed intermediate colour changes, while resin-modified glass ionomer cement (Group C) exhibited the least colour alteration. These results align with the findings of Boncuk et al., who reported that self-etching adhesives cause less enamel colour change compared to conventional acid-etching [3]. The milder etching effect of self-etching primers and the fluoride-releasing properties of resin-modified glass ionomer cements may contribute to their reduced impact on enamel colour [4].

Regarding cleaning methods, enamel microabrasion proved to be the most effective in restoring original tooth colour across all bonding groups. This technique's superior performance can be attributed to its ability to remove a thin layer of surface enamel along with any residual resin tags [5]. However, it is important to note that enamel microabrasion is more invasive than other cleaning methods and should be used judiciously to avoid excessive enamel loss [6].

The carbide bur technique showed intermediate effectiveness in colour restoration, while pumice polishing was the least effective. These findings are in line with those of Ye et al., who reported that carbide burs were more efficient than pumice in removing adhesive remnants and restoring enamel surface characteristics [7].

Analysis of individual colour parameters revealed a general trend of decreased lightness (negative ΔL*) and shifts towards red and yellow (positive Δa* and Δb*) after bonding and cleaning. This trend was most pronounced in the conventional acid-etching group and least evident in the resin-modified glass ionomer cement group. These colour shifts may be due to a combination of factors, including residual resin tags, enamel demineralization, and surface texture alterations [8].

While this study provides valuable insights into enamel colour changes associated with orthodontic bonding, it has some limitations. As an in vitro study, it does not account for the potential effects of the oral environment, such as saliva exposure and dietary factors, which may influence colour changes over time [9]. Additionally, the study used extracted premolars, which may not fully represent the colour characteristics of anterior teeth that are of primary aesthetic concern in orthodontic patients.

Future research should focus on long-term in vivo studies to evaluate the clinical significance of these colour changes and the durability of colour restoration methods. Furthermore, investigating the potential of novel bonding materials and techniques that minimize enamel colour alterations while maintaining adequate bond strength would be beneficial for advancing orthodontic practice [10,11].

Conclusion

In conclusion, this study demonstrates that orthodontic bonding procedures cause measurable enamel colour changes, with conventional acid-etching showing the most significant effect. Enamel microabrasion appears to be the most effective method for restoring original tooth colour post-debonding, while resin-modified glass ionomer cement resulted in the least colour change overall. Clinicians should consider these findings when selecting bonding materials and cleaning methods to minimize long-term enamel colour alterations and optimize aesthetic outcomes in orthodontic treatment.

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