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Original Article

Comparison of Enamel Discoloration using Flash-Free and Conventional Adhesive Brackets with Different Finishing Protocols

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Main Points

- Tooth color alterations occurred following fixed orthodontic treatment.
- Flash-free brackets caused significantly less color change than conventional brackets.
- The lowest change in color was achieved in Flash-Free brackets using a tungsten carbide burr plus a Sof-Lex disk.

ABSTRACT

Objective: The aim of this study was to compare the effects of flash-free and conventional adhesive brackets and different finishing techniques on enamel discoloration.

Methods: Forty human premolar teeth were utilized and randomly divided into four groups based on the type of brackets and finishing technique: (1) Gemini® brackets were used for orthodontic bonding. After debanding, adhesive remnants were cleaned using a 12-blade tungsten carbide bur. (2) Gemini® suspenders were used for orthodontic bonding. After debanding the brackets, adhesive remnants were cleaned using12-blade APC™ Flash-Free brackets were used for orthodontic bonding. After debanding, adhesive remnants were cleaned a 12-blade tungsten carbide bur and polished with Sof-Lex disks. (4) APC™ Flash-Free brackets were used for orthodontic bonding. After debanding, the adhesive remnants were cleaned using a 12-blade tungsten carbide bur. A Vita Easyshade spectrophotometer was used to measure the color change values of the 40 teeth.

Results: The color change of the enamel surface in the Flash Free bracket group was significantly less than that in the conventional groups ($p=0.003$ $p<0.05$). The mean ΔE values obtained from the Sof-Lex groups were lower than those obtained from the groups without Sof-Lex, but these results were not statistically significant ($p=0.280$ $p>0.05$).

Conclusion: It is recommended to use Flash-Free brackets and polish with Sof-Lex disk following the clean-up procedures to minimize the possibility of discoloration of the teeth during orthodontic treatment.

Keywords: Teeth discoloration, adhesive precoated brackets, spectrophotometer

INTRODUCTION

One of the most frequent complications occurring during orthodontic treatment is the emergence of tooth color alteration, which remains a major complication that concerns orthodontists. Furthermore, the occurrence of enamel coloration would produce an unexpected financial burden on the patient.[1] Thus, it is a primary goal for a clinician to prevent color changes after orthodontic treatment by protecting the enamel surface.

In orthodontic treatment with fixed appliances, bonding agents can lead to tooth coloration because of the irreversible penetration of resin tags into the enamel structure.[2] Similarly, temporary or permanent damage may

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occur in enamel during the removal of brackets and residual adhesive materials after completing treatment, potentially leading to tooth coloration.[3] The finishing procedures employed and tools (such as tungsten carbide burrs, diamond burrs, abrasive disks and polishing disks) used to remove residual adhesives from the tooth surface may also affect tooth color differently.[3,4]

Adhesive Precoated (APC™) brackets, commonly used today, have an equal and sufficient amount of adhesive at the base. These brackets offer the advantages of no overflow and no need for adhesive clearance during bonding.[5] In *in vitro* studies, it was suggested that the APC™ bracket system provides adequate bonding strength and decreases micro-leakage compared with conventional bonding systems.[5-7] At this point, the choice of bonding and finishing procedures may be essential in aesthetically critical areas during orthodontic treatment. Therefore, the comparison of different brackets and finishing procedures will provide practical and useful information about tooth discoloration for clinicians.

Conflicting findings concerning enamel color changes caused by bonding and debanding processes have prompted us to investigate two different brackets and cleanup protocols.

The hypothesis tested in this study is that different finishing techniques and brackets will be effective in reducing color changes on enamel.

METHODS

The study received approval from the Hatay Mustafa Kemal University Tayfur Ata Sökmen Faculty of Medicine, Clinic Research Ethics Committee (approval no: 08, date 19.04.2018). The sample size was estimated using G Power (3.1.9.7) software with a confidence level of 80%, based on previous research.[8] Forty upper and lower premolars extracted for orthodontic reasons were collected from patients aged 12-30 years. Teeth with caries, cracks, white spot lesions, demineralization areas, or abrasions, those who previously underwent restorative treatment, and those exposed to trauma during extraction were excluded.

Immediately after extraction, teeth were cleansed from blood and tissue residues under streaming water and stored in distilled water at room temperature and in dark medium. Molds in the form of rectangular prisms sized 40 x 20 x 20 mm were prepared, and the teeth were placed in these molds using autopolymerizing acrylic. During this process, the acrylic did not touch the crowns of the teeth. The teeth were then randomly divided into two subgroups (n=20) and bonded with two types of brackets: adhesive precoated brackets (APC™ Flash-Free bracket; 3M Unitek) and conventional stainless steel brackets (Gemini; 3M Unitek). For the reliability and accuracy of the results, the teeth were allocated to the groups using a fixed-probability randomization method.

Before color testing, the teeth were randomly assigned to four groups of 10 specimens each and classified based on the type of brackets and finishing technique.

Specimen Preparation

A fluoride-free prophylaxis paste was utilized to polish the buccal surfaces of the teeth using low-speed soft-bristle brushes. Then, the teeth were rinsed with water and air-dried for 20 seconds. Each tooth underwent etcing with 37% orthophosphoric acid for 30-seconds, followed by a 15-second rinse, and then air-dried for 10 seconds. Afterward, the teeth were primed with a light cure adhesive primer (Transbond XT Primer, 3M Unitek). The Valo (Ultradent, South Jordan, Utah) light-curing device was used to cure the adhesives in Xtra power mode (3200 mW/cm^2) for 3 s in all groups.

Group 1: The orthodontic adhesive Transbond XT (3M Unitek, USA) was placed onto the conventional Gemini 3M ® brackets (3M Unitek, USA) base, and they were positioned on the buccal enamel surface. Finishing technique: The brackets were deboned and adhesive remnants were cleaned using a 12-blade tungsten carbide bur.

Group 2: Gemini 3M® brackets (3M Unitek, USA) were bonded with Transbond XT (3M Unitek, USA). Finishing technique: The brackets were debonded, and adhesive remnants were cleaned using a 12-blade tungsten carbide bur and polished with Sof-Lex discs.

Group 3: A preheated bracket system, APC Flash-Free (3M Unitek), was used. Since the adhesive resin was already in the bracket base, brackets were placed immediately after primer application. Finishing technique: The brackets were debonded, and adhesive remnants were cleaned using a 12-blade tungsten carbide bur and polished with Sof-Lex disks.

Group 4: APC Flash-Free Adhesive-Coated Brackets (3M Unitek) were placed immediately after primer application. Finishing technique: The brackets were deboned and adhesive remnants were cleaned using a 12-blade tungsten carbide bur.

All procedures were performed by the same operator (AK).

After bonding, the teeth in the four groups were placed into the thermal cycle device. In the device, 10,000 cycles were performed to simulate a 1 year oral cavity. Cycles were conducted by maintaining water bath temperatures between 5 °C and 55 °C. After thermal cycling, residual adhesive on the enamel after bracket debonding was removed.

The color determination procedure was conducted by the same operator (AK) before bracket bonding and after rthe emoval of adhesive residues from bracket debonding. Color determination was performed using a Vita Easyshade spectrophotometer (Vita Zahnfabrik, H. Rauter GmbH & Co, Germany). All teeth were measured from the same point, which is the middle third of the teeth. To standardize repeated measurements, calibration was performed before each measurement according to the manufacturer's instructions. To achieve standardization in color measurement, all teeth were measured by a single operator on the same day and in the same room under identical conditions. All measurements were performed three times, and the mean value was recorded. Color measurements were performed in a custom color special shade determination box with an inner surface covered with a neutral gray background. The box was illuminated using 6,500 Kelvin Philips daylight LED bulb, which mimics natural daylight, and the teeth were positioned at a 45° angle to the light source.

The CIE L*a*b* system was used to define color, which used three coordinates to represent color.[9] In the CIE (L* a * b *) color system, the L * axis represents the lightness (value) in black and white coordinates. A value of "0" corresponds to black, and a value of "100" corresponds to white (excellent reflector). The b* axis represents blue for negative values and yellow for positive values, while the a * axis indicates red (+ a *) and green (- a *), and the b * axis yellow (+ b *) -blue (-b *) value; they together express the saturation of the hue. The a* and b* coordinates are 0 in neutral colors and increase in more dense and saturated colors. The major advantage of the CIE L*a*b* system is that color difference can be expressed numerically. ΔE values mathematically express the color difference within the samples or between samples over time on L*a*b*. A single number from the formula defines the total difference rather than the nature and direction of color difference.[10] In the human eye, there is limited ability to perceive color differences, and it cannot perceive ΔE<1. The ΔE value of 2-3.7 represents the range that can be recognized clinically.[11,12] In this study, the ΔE threshold was set as 3.7 in agreement with literature.[13,14]

In the current study, discoloration was calculated using the following formula:

$\Delta E= [(\Delta L)^2+ (\Delta a^*)+ (\Delta b)^2]^{1/2} =(\Delta b)^2]^{1/2}= [(L_s-L_ö)^2 + (a_s-a_ö)^2 + (b_s-b_ö)^2]^{1/2}$.

Clinical Color Match for Color Difference (ΔE)

0: Excellent

0.5-1: excellent

1-2: Good

2-3.5: Clinically acceptable

>3.5: Mismatch

Teeth were rated according to the above-mentioned values.

Statistical Analysis

Data were analyzed using SPSS (IBM Corp., Armonk, NY, USA) version 20.0. The normal data distribution was assessed using the Kolmogorov-Smirnov test, whereas data homogeneity was assessed using Levene's test. The ΔE differences was assessed using Tukey's multiple comparison test among groups. A p value<0.05 was considered statistically significant.

RESULTS

Table 1 presents the color change in the groups according to bracket type and finishing technique. Based on statistical analyses, both bracket types had significant effects on color change after bonding and finishing procedures independent of the finishing protocols used (p=0.003 and p<0.05). The finishing procedure had no significant effect on color change (p>0.05). In addition, there was no significant interaction between bracket type and finishing technique (Table 1).

Table 2 presents the mean color change in the groups and intergroup comparisons. When ΔE values were assessed: the ΔE value was >3.7 in all groups, indicating intense color change. The mean ΔE was found to be 11.22 in group 1 and 9.00 in group 2, indicating no significant difference between groups 1 and 2. Mean ΔE was found to be 5.83 in group 3. A significant difference was found in ΔE between group 1 and 3 (p<0.05). No significant difference was found in the remaining binary comparisons between groups (G1-G4, G2-G3, G2-G4, G3-G4) (p>0.05).

In the study, the highest ΔE value was observed in group 1 (ΔE=11.22) while the lowest ΔE value in group 3 (ΔE=5.83). For mean values, 95% confidence interval was calculated as 8.1406-14.3042 in group 1 and 3.7287-7.9236 in group 3 (Table 2).

When color change (ΔE) was assessed between groups, it was observed that the extent of color change was lower in group 3 where Flash-Free brackets were used than in group 1 where Gemini brackets were used, and that the mean value was lower in groups where Sof-Lex was used (Group 2 and Group 3) than in those where Sof-Lex were not used (Group 1 and Group 4). In conclusion, it was found that ΔE values in all groups were above the clinically acceptable level (ΔE: 3.7).

Table 1. Results of the 2-way ANOVA for the color parameters with respect to the effects of type of bracket and finishing type (p<0.05)

Source of variation	Sum of squares	DF	Mean square	F	p value
Corrected model	187.868	3	62.623	3.988	0.015
Intercept	2624.802	1	2624.802	167.141	0.001
Bracket type (A)	161.822	1	161.822	10.304	**0.003**
Finishing technique (B)	18.866	1	18.866	1.201	0.280
A X B	7.180	1	7.180	0.457	0.503
Error	565.349	36	15.704		
Total	3378.019	40			

Table 2. Mean color change (ΔE) values in the groups

	N	Mean	Std. deviation	Std. error	95% Confidence interval for mean value		Min.	Max.
					Lower Limit	Upper Limit		
Group 1	10	11.22a	4.31	1.36232	8.1406	14.3042	5.79	19.26
Group 2	10	9.00ab	4.93	1.55911	5.4746	12.5285	3.51	14.94
Group 3	10	5.83b	2.93	0.92719	3.7287	7.9236	0.51	9.77
Group 4	10	6.35b	3.37	1.06548	3.9421	8.7626	1.10	10.42
Total	40	8.1006	4.39469	0.69486	6.6951	9.5061	0.51	19.26

Different letter indicates statistical significance ($p<0.05$)

DISCUSSION

Color differences after orthodontic treatment can lead to dissatisfaction in patients and a reduction in treatment success. Thus, discoloration is an important issue in orthodontics. Although this study has an *in vitro* design, human teeth were used as samples to achieve maximal clinical compatibility. In the literature review, it was observed that human premolar teeth were used in majority of *in vitro* studies.[15,16] In the current study, teeth were cleansed by removing tissue residues and attachments under streaming water and stored in distilled water in a dark indoor area. Distilled water was renewed weekly to prevent bacterial infiltration. In previous studies, several solutions including normal saline, tirol solution, distilled water, alcohol solution at varying concentrations, formalin, and chloramine-T were used to store teeth.[2,17]

Measurement errors can occur because environmental and psychological factors may affect the sensitivity of human eyes during color determination. Thus, it is recommended to use color measurement devices to exclude human factors. The spectrophotometer is the most commonly used device for measuring tooth color, providing objective, consistent, and reproducible results. In addition, spectrophotometers are preferred due to their superiority in establishing color differences where the human eye will have difficulty identifying.[18] In clinical practice, many electronic color measurement devices have been used to measure tooth color. Kim-Pusateri et al.[19] compared four distinct dental color measurement devices (SpectroShade®, ShadeVision®, Vita Easyshade®, and ShadeScan®) regarding accuracy and reliability. The authors reported that ShadeScan® had significantly lower reliability, while there was no significant difference among the remaining three devices. When compared regarding accuracy, there were significant differences among devices, and Vita Easyshade® had the highest accuracy (96.4%. In the current study, Vita Easyshade® was preferred for the determination of changes in tooth color because of its accuracy and ease of use. To rule out intraobserver errors, each measurement was performed by the same operator (AK) in a triplet manner. The test materials were aged by simulating intraoral media in *in vitro* testing for biocompatible materials. This procedure is generally performed using a thermal cycle process. In this study, a thermal cycle process was used to simulate a variable temperature that mimicked intraoral media in the most realistic manner. This process plays an important role in performing an *in vitro* study in the most realistic manner.

In the literature, the intraoral temperature was reported as 36.4 °C during resting.[20] It was reported that intraoral temperature ranged from 0 °C to 70 °C for foods and beverages, whereas the inner surface temperature of restorations ranged from 9 °C to 52 °C. In addition, it has been reported that the intraoral temperature remained at 5-55 °C in most instances. The thermal cycle process is generally performed using cycles between 5 °C and 55 °C. The highest and lowest intraoral temperatures were recorded 20-50 times per day; thus, it was reported that 10,000 cycles corresponded to one year of oral function.[21] In the current study, tooth samples were subjected to 10,000 thermal cycles at 5-55 °C, corresponding to 1 year of intraoral use. In the color measurement phase, L*a*b* values were measured in each tooth in a triplet manner, and the mean value was recorded to minimize errors. In the literature, $\Delta E>3.7$ is accepted as the threshold value for the clinical perception of color change in orthodontics.[13,17] In the present study, the same threshold value was used for color assessment and measurements.

In orthodontics, many techniques have been used to remove residual adhesive from the enamel surface after debonding. It has been reported that cleansing with water-cooling and low-speed tungsten carbide burrs is the method associated with the least harm to enamel.[22] In a study, Eminkahyagil et al.[23] compared the effects of high-speed tungsten carbide burr, low-speed tungsten carbide burr, and Sof-Lex disk on enamel. The authors reported that the most rapid method was cleansing with a high-speed tungsten carbide burrs, but this technique was associated with the greatest harm to enamel. Sof-Lex disks had the longest duration for the cleaning procedure.[23] Although a smooth surface was achieved with Sof-Lex disks, significant residue was left on the enamel surface. Retief and Denys[24] and Zarrinnia et al.[25] recommend using 12-blade tungsten carbide with adequate air cooling at high speed, followed by polishing with ultra-fine grain Sof-Lex disks and smoothening with rubber and paste. In their study, Zachrisson and Arthun[26] evaluated the effects of distinct finishing techniques on enamel surfaces and suggested that the best result was achieved by low-speed tungsten carbide burr and polishing. Similarly, the least color change was achieved by the tungsten carbide burr plus Sof-Lex disks in this study.

It was seen that tungsten carbide burr followed by Sof-Lex disk polishing resulted in the least clinical color change in both brackets. The Sof-Lex disk group showed less color change because Sof-Lex causes less damage to enamel and provides a smoother surface than the tungsten carbide burr. In their study, Zachrisson and Arthun[26] reported that diamond burr use caused more extensive material loss from the enamel surface and greater damage to the enamel than a tungsten carbide burr. In a previous study, it was suggested that tungsten carbide burr, used to minimize damage in the enamel surface, provided a smoother end-face.[25] Some authors reported that there was no correlation between surface roughness and coloration,[27] whereas others reported that light reflection was increased with a reduction in surface roughness, thereby decreasing color changes.[28] In this study, it was observed that Sof-Lex application aiming to decrease surface roughness, led to less color change in both bracket types compared with the remaining groups.

In a study, Trakyali et al.[29] investigated the effects of reinforced composite and tungsten carbide burrs used in finishing and polishing procedures. The authors reported that there was no change in color between the two burr systems, but the reinforced composite burr provided a smoother surface. In a similar study, the effects of reinforced composite and tungsten carbide burrs on color change were investigated in orthodontic treatment. It has been reported that reinforced composite burrs provide a smoother end-face and fewer color change.[30] In contrast, in the current study, there was no significant color change with distinct finishing techniques. In the Flash-Free bracket groups, less color change was observed in both finishing protocols compared with the Gemini bracket group in this study. The self-adhesive in the Flash-Free bracket system ensures less composite overflow around the bracket. This may be the reason for less color change in Flash-Free brackets. Visible and clinically unacceptable tooth color alterations may occur following orthodontic treatment. Esthetic outcomes are as important as functional demands.[31] Orthodontic bonding with Flash-free systems and polishing with Sof-Lex disk following the clean-up procedures may reduce the color change of the enamel.

This study has some limitations due to its *in vitro* design. First, the color measurement process requires great sensitivity because it is affected by many environmental and operator-related factors. Thus, a color measurement box was used to provide artificial daylight to eliminate the adverse effects of ambient light, ensuring standardization. In addition, all baseline and final measurements were performed by a single operator.

CONCLUSION

It was observed that both the brackets and finishing techniques used in this *in vitro* study caused coloration at the tooth surface. There was a greater color change in teeth cleaned from adhesive residues using carbide burr alone compared with those cleaned using tungsten carbide burr plus Sof-Lex removed adhesive residues. The lowest change in color was achieved with the Flash-Free bracket, which underwent finishing procedure with a tungsten carbide burr plus Sof-Lex disk. Based on these results, Flash-free brackets, along with the finishing procedure using a tungsten carbide burr plus Sof-lex disk, which was associated with the least color change, may contribute to treatment success.

Ethics

Ethics Committee Approval: The study was approved by the Hatay Mustafa Kemal University Tayfur Ata Sökmen Faculty of Medicine, Clinic Research Ethics Committee (approval no: 08, date 19.04.2018).

Informed Consent: Not applicable.

Peer-review: Externally peer-reviewed.

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