Original Article

Tooth color change due to different etching and debonding procedures

Hande Gorucu–Coskuner[a]; Ezgi Atik[a]; Tulin Taner[b]

ABSTRACT

Objectives: To compare the effects of different etching techniques, 12–, 24–bladed tungsten carbide burs, and polishing discs on tooth color changes during orthodontic treatment.

Materials and Methods: 59 individuals (mean age: 15.20 ± 1.59 years) were divided into four groups: 37% phosphoric acid and adhesive primer was used in Groups I and II whereas self–etch primer was used in Groups III and IV for enamel preparation. After orthodontic treatment, residual adhesives were cleaned with 12–bladed tungsten carbide burs in Groups I and III, while 24–bladed tungsten carbide burs were used in Groups II and IV. All teeth were polished with medium and fine Sof–Lex XT discs (3M ESPE, St Paul, Minnesota). Color measurements were taken from upper incisors and canines at pretreatment (T0), after cleaning with tungsten carbide burs (T1) and polishing with discs (T2). Wilcoxon test was used for evaluation of L*, a*, b* changes and Kruskal–Wallis for intergroup comparison of color changes.

Results: L*, a*, b* values, except a* at Groups I, II, IV, and b* at Group III, changed significantly ($P < .05$). Groups III and IV showed significantly different color alterations from T0 to T1 ($P < .05$). After polishing, tooth color alterations were not significantly different among the groups.

Conclusions: In self–etch bonding groups, a 12–bladed tungsten carbide bur caused less color change than the 24–bladed tungsten carbide bur. Orthodontic treatment resulted with visible and clinically unacceptable tooth color alterations regardless of the enamel preparation and clean–up techniques. Polishing reduced the effect of tungsten carbide burs, but did not affect the total influence of orthodontic treatment on the tooth color. (*Angle Orthod.* 2018;88:779–784.)

KEY WORDS: Bracket bonding; Adhesive removal; Tooth color; Orthodontic treatment

INTRODUCTION

Recent research has shown that the strongest association with orthodontic treatment is improved esthetics of teeth followed by improvement in overall esthetics.[1] As one of the main points of orthodontic treatment is perfection of esthetics, the effects of orthodontic etching and debonding techniques on tooth structure and appearance should be understood clearly. An adverse effect on tooth structure such as demineralization,[2] enamel tear–outs,[3] micro–cracks,[4] or a clinically detectable color change[5] would lead to esthetically unpleasing results.

Aside from the formation of white spot lesions due to decalcification,[6] tooth discoloration could occur under orthodontic attachments because of the irreversible penetration of resin tags into the enamel structure.[7] It was reported that this resin impregnation into the enamel structure could not be reversed by debonding and cleaning procedures.[8] The length and amount of the resin tags differed between enamel treated with phosphoric acid then bonding (conventional etching) and self–etching primer. Although the resin tags were between 10 to 20 μm after conventional etching, fewer and shorter tags of 5 to 10 μm occurred after treating with self–etching primer.[9] As resin tags are thought to be responsible for tooth color change, all other factors being equal, self–etching systems may produce less iatrogenic color change in enamel following orthodontic treatment.[10] In addition to the effects of etching, it was pointed out that the roughness of the bonding area might be affected by grinding the enamel during adhesive removal and this could lead to color changes at the bonding site.[7,11] Consequently, various burs used

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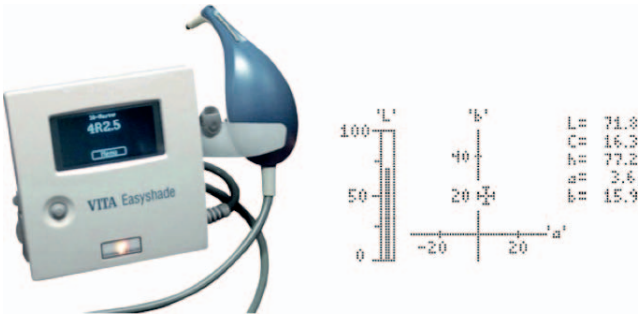

Figure 1. Vita Easyshade device used for color assessment.

for adhesive removal after orthodontic treatment might affect the tooth color differently too.

Therefore, the null hypotheses of this study were (1) two different etching techniques for bonding orthodontic brackets: conventional or self etch does not produce any significant difference in tooth color alterations, (2) at the end of the orthodontic treatment, adhesive remnant removal by 12– and 24–bladed tungsten carbide burs do not have a significant effect on tooth color alterations, (3) polishing with Sof–Lex XT discs (3M ESPE, St Paul, Minnesota) do not have a significant effect on tooth color changes, and (4) orthodontic treatment does not cause visible and clinically unacceptable tooth color changes.

MATERIALS AND METHODS

Ethical approval for this prospective clinical trial was granted from Hacettepe University Interventional Clinical Research Ethics Committee (2016/05–23(KA–16024)).

The study was carried out at Hacettepe University, Faculty of Dentistry, Department of Orthodontics. The sample consisted of 59 patients (43 female, 16 male) with the following inclusion criteria: (1) all permanent teeth erupted except third molars, (2) minimal or moderate crowding (<5 mm) in both dental arches, (3) good oral hygiene, (4) no esthetic restorations or decalcifications in the upper incisors and canines, (5) age range between 14 and 24 years, and (6) no smoking habit. All patients and their parents were informed, and consent was obtained before recruitment into the study.

Color Assessment

Before color assessment, all teeth were polished with non–fluoridated pumice, rinsed and dried. Vita Easyshade (VITA Zahnfabrik GmbH, Bad Säckingen, Germany) (Figure 1) was used to assess color alterations of natural teeth that occurred after bonding and adhesive clean–up procedures. The upper anterior teeth (from canine to canine) were isolated and the color measurements were taken from the middle third of the teeth. All color measurements were done by one author (H.G.C.) three times to minimize the error. The average of the three measurements was calculated at pretreatment (T0), after resin removal with high–speed tungsten carbide burs (T1), and after polishing with Sof–Lex XT discs (3M ESPE, St Paul, Minnesota) (T2). When the total color difference between any two measurements exceeded the threshold of one unit, a fourth measurement was performed, and the closest three measurements were used to calculate the average. Color evaluation was done in accordance with the CIE (Commission Internationale de l'Eclairage) L*a*b* color system (1931) that uses three parameters to define color: L* coordinate corresponds to a degree of lightness and darkness and ranges from 0 (black) to 100 (white), a* and b* coordinates correspond to the Chroma and represent positions on the red (+) / green (–) and yellow (+) / blue (–) axes, respectively. The difference between two colors was calculated with the following formula: $\Delta E = [(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2]^{1/2}$

The following ΔE values were calculated according to the formula:

ΔE1: The color alteration that occurred between pretreatment and adhesive remnant removal with tungsten carbide burs.
ΔE2: The color alteration that occurred between adhesive remnant removal with tungsten carbide burs and polishing with Sof–Lex XT discs (3M ESPE, St Paul, Minnesota).
ΔE3: The color alteration that occurred between pretreatment and polishing with Sof–Lex XT discs (3M ESPE, St Paul, Minnesota).

Bracket Bonding and Adhesive Removal Procedures

Fifty–nine patients (43 female, 16 male) with a mean age of 15.20 ± 1.59 years were included in the study. The patients were consecutively assigned to the study groups. Orthodontic treatment stages of the patients were carried out by two authors (H.G.C, E.A) from the same clinic. The upper incisors and canines of the patients (n = 354) comprised the study sample. The mean treatment duration was 1.1 ± 0.2 years. During treatment, the patients were instructed to brush their teeth regularly, and their oral hygiene was controlled regularly. Before bracket bonding, all teeth were polished with non–fluoridated pumice, rinsed, and dried. The sample was divided into four groups according to bonding and adhesive removal techniques:

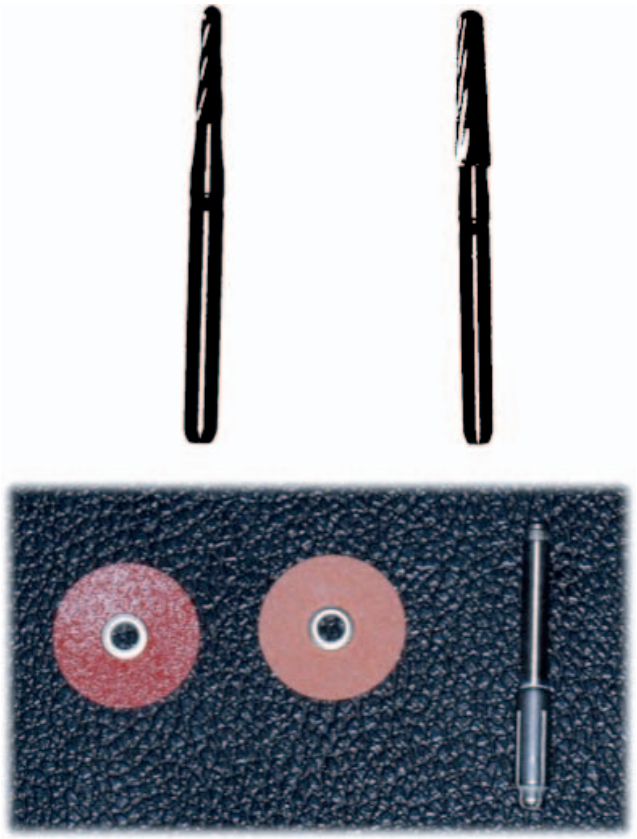

Figure 2. The tungsten carbide burs and polishing discs used for adhesive removal.

Group I (14 patients, 84 teeth): After polishing, the teeth were etched with 37% phosphoric acid for 15 seconds, rinsed, and dried. Transbond XT Adhesive Primer (3M Unitek, Monrovia, Calif) and Transbond XT Adhesive Resin (3M Unitek) were used for bonding metal brackets. After 1.1 ± 0.2 years, at debonding, the residual adhesive was cleaned with 12–bladed tungsten carbide burs (H281K314012, Komet, Germany).

Group II (15 patients, 90 teeth): Bracket bonding was performed as in Group I. After 1.2 ± 0.2 years, following bracket removal, the residual adhesive was cleaned with 24–bladed tungsten carbide burs (H375R314018, Komet, Germany).

Group III (15 patients, 90 teeth): After polishing, the teeth were rubbed with self–etching primer (Transbond Plus, 3M Unitek) for 3–5 seconds per tooth, according to the manufacturer's instructions. The metal brackets were bonded with Transbond XT Adhesive Resin. After 1.0 ± 0.1 years, at debonding, the residual adhesive was cleaned with 12–bladed tungsten carbide burs.

Group IV (15 patients, 90 teeth): Bracket bonding was performed as in Group III. After 1.1 ± 0.2 years, following bracket removal, the residual adhesive was cleaned with 24–bladed tungsten carbide burs.

After cleaning with tungsten carbide burs, color measurements were done. Then all teeth were polished with medium and fine Sof–Lex XT discs (3M ESPE, St Paul, Minnesota). Afterward, the last color measurements were performed. The tungsten carbide burs and polishing discs used in the study are presented in Figure 2.

Statistical Analysis

Descriptive statistics were used for demographic and clinical variables. SPSS Version 21.0 (SPSS Inc., IL, USA) was used for statistical analysis. Wilcoxon test was used for the evaluation of the changes in L*, a*, b* values with bonding and clean–up procedures. As the ΔE1, ΔE2, and ΔE3 values were not normally distributed, Kruskal–Wallis test was used for intergroup comparison of color changes. When a significant difference was observed between the groups, Dunn's test was carried out to determine the group that led to the difference. Pearson's chi square test was carried out to compare the changes in tooth color between the groups after cleaning the adhesive remnants with tungsten carbide burs and polishing discs.

RESULTS

The amount of changes in L*, a*, b* values that occurred with adhesive removal and polishing are shown in Table 1 for all groups. L* values decreased (shifted to dark) significantly in all groups ($P < .05$) with adhesive removal by tungsten carbide burs. However after polishing with discs, L* values showed statistically significant increases ($P < .001$). From T0 to T2, no significant difference was observed in terms of L* value. The a* value showed a significant change in Group III after cleaning with tungsten carbide burs ($P < .05$). The only significant change of a* value from T1 to T2 was observed in Group I. The changes from T0 to T2 indicated that there was a significant difference in Group I in the a* value ($P < .05$). In Groups I, II, and IV, b* values showed statistically significant changes from T0 to T1 ($P < .05$). In all groups, b* values mostly increased from T1 to T2 ($P < .01$). From T0 to T2, the only significant difference in b* value was observed at Group III ($P < .01$).

The median, minimum, and maximum values and intergroup comparisons of ΔE1, ΔE2, and ΔE3 are shown in Table 2. The only significant intergroup difference was observed in ΔE1, which resulted from Groups III and IV ($P = .011$). After polishing with Sof–Lex XT discs (3M ESPE, St Paul, Minnesota), the tooth color alterations did not show significant differences among the groups. ΔE1 and ΔE3 changes for the groups are presented in Tables 3 and 4. The distribution of tooth color changes as not visible, visible

Table 1. Mean and Standard Deviations of L, a, b Value Changes That Occurred With Treatment

	T1–T0	*P* Value	T2–T1	*P* Value	T2–T0	*P* Value
Group I						
L	–2.21 ± 3.80	<.001***	2.24 ± 3.17	<.001***	.03 ± 4.20	.806
a	.02 ± 1.02	.801	.30 ± .69	<.001***	.32 ± 1.01	.012*
b	–1.70 ± 3.03	<.001***	1.43 ± 1.82	<.001***	–.27 ± 2.60	.336
Group II						
L	–2.99 ± 3.44	<.001***	2.26 ± 3.16	<.001***	–.73 ± 3.95	.032
a	.02 ± .91	.782	–.10 ± 1.17	.910	–.07 ± 1.21	.719
b	–.95 ± 3.27	.017*	.81 ± 2.04	<.001***	–.14 ± 3.36	.872
Group III						
L	–1.35 ± 4.31	.001***	1.34 ± 3.19	<.001***	–.01 ± 3.97	.713
a	.16 ± 1.50	.008**	.02 ± 1.06	.593	.17 ± 1.42	.074
b	.38 ± 2.39	.218	.97 ± 2.19	<.001***	1.35 ± 3.03	<.001***
Group IV						
L	–1.56 ± 5.77	.002**	2.26 ± 3.32	<.001***	.70 ± 6.16	.864
a	–.10 ± 1.45	.550	.27 ± 1.27	.054	.17 ± 1.42	.202
b	–1.54 ± 3.14	<.001***	.92 ± 1.98	<.001***	–.61 ± 3.35	.068

* $P < .05$; ** $P < .01$; *** $P \leq .001$.
T0: Pretreatment.
T1: After resin removal with tungsten carbide burs.
T2: After polishing with Sof–Lex XT discs.

but clinically acceptable, and clinically unacceptable, did not show statistically significant differences among the groups either after treating with tungsten carbide burs or polishing with Sof–Lex XT discs (3M ESPE, St Paul, Minnesota) compared to pretreatment values.

DISCUSSION

Currently, various methods are being used to assess tooth color. These range from visual subjective comparisons using paper, colored porcelain or acrylic resin shade guides, to objective measurements using instruments such as spectrophotometers, colorimeters, and image analysis techniques.[12] As factors such as lighting conditions, surface structure, translucency, and optical properties of the material used greatly affect human visual perception,[13] an intraoral dental spectrophotometer was preferred for color determination in the present study. Tooth colors were identified according to the CIE L*a*b* system and the difference between two colors was indicated as ΔE. ΔE values below 1 were considered as not visible, between 1 and 3.7 were considered as visible but clinically acceptable, and above 3.7 were considered as visible and clinically unacceptable.[14,15]

After adhesive removal with tungsten carbide burs, L* values decreased (shifted to the black direction) in all groups. This finding was in agreement with Karamouzos et al.[5] and Al Maaitah et al.[16] who used tungsten carbide burs for removing adhesives. Eliades et al.[7] found no difference between etching–mediated and no etching–mediated bonding and attributed this to surface roughness induced by invasive adhesive grinding. In the present study, after polishing with discs, a final color measurement was performed. The results showed that after polishing, L* values increased significantly and that there was no significant difference found between T0 and T2 values. Corekci et al.[17] also performed tooth color measurement after polishing and did not find significant differences between pretreatment and post–treatment L*, a*, and b* values. Cleaning with tungsten carbide burs led to surface irregularities and scratches on the enamel; using a Sof–Lex disc (3M ESPE, St Paul, Minnesota) decreased the surface irregularities.[18] Thus, a flat, smooth tooth surface allowed more specular reflection and more precise color measurement and improved light reflection.[17,19] Although most variables returned to almost initial values after polishing, the a* value in

Table 2. Median, Minimum, Maximum Values, and Intergroup Comparisons of ΔE1, ΔE2, and ΔE3*

	Group I (min–max)	Group II (min–max)	Group III (min–max)	Group IV (min–max)	*P* Value
ΔE1 (T1–T0)	4.60 (.70–11.40)	4.50 (.30–11.90)	4.00 (.40–16.80)	5.60 (.80–16.40)	.021 (3–4, $P = .011$*)
ΔE2 (T2–T1)	2.6 (.2–16.4)	3.3 (.50–11.20)	3.20 (.40–10.20)	4.00 (.50–11.00)	.227
ΔE3 (T2–T0)	4.30 (.90–15.90)	4.20 (.60–11.40)	4.7 (.60–13.00)	4.8 (.7–19.2)	.097

*$P < .05$.
T0: pretreatment.
T1: after cleaning with tungsten carbide burs.
T2: after polishing with Sof–Lex XT discs.

Table 3. Tooth Color Alterations That Occurred After Adhesive Remnant Removal With Tungsten Carbide Burs (ΔE1)

	Not Visible	Visible, but Clinically Acceptable	Visible and Clinically Unacceptable	
	$\Delta E < 1$	$1 \leq \Delta E < 3.7$	$\Delta E \geq 3.7$	Total
Group I	1 (1.2%)	27 (32.1%)	56 (66.7%)	84 (100%)
Group II	2 (2.2%)	29 (32.2%)	59 (65.6%)	90 (100%)
Group III	2 (2.2%)	39 (43.3%)	49 (54.4%)	90 (100%)
Group IV	2 (2.2%)	27 (30%)	61 (67.8%)	90 (100%)
Total	7 (2%)	122 (34.5%)	225 (63.6%)	354 (100%)

Table 4. Tooth Color Alterations That Occurred Between Pretreatment and Polishing With Sof–Lex Disks (ΔE3)

	Not Visible	Visible, but Clinically Acceptable	Visible and Clinically Unacceptable	
	$\Delta E < 1$	$1 \leq \Delta E < 3.7$	$\Delta E \geq 3.7$	Total
Group I	1 (1.2%)	33 (39.3 %)	50 (59.5 %)	84 (100%)
Group II	2 (2.2%)	35 (38.9 %)	53 (58.9 %)	90 (100%)
Group III	2 (2.2%)	37 (41.1%)	51 (56.7%)	90 (100%)
Group IV	2 (2.2%)	28 (31.1%)	60 (66.7%)	90 (100%)
Total	7 (2%)	133 (37.6%)	214 (60.5%)	354 (100%)

Group I and b* value in Group III were significantly different from the pretreatment values after polishing.

The first null hypothesis was not rejected: When etching patterns were compared, no significant difference was observed between the conventional and self–etching groups. In the literature, there were conflicting results regarding the effects of different etching procedures on tooth color. Zaher et al.[10] found that self–etching created less resin penetration and stated that these systems may produce less iatrogenic color change in enamel following orthodontic treatment. Boncuk et al.[20] found increased color change in the conventional group when compared to the self–etch group. In the current study, no difference was observed between self–etching and conventional etching groups. Also Al Maaitah et al.[16] and Joo et al.[21] did not find significant differences between teeth treated with conventional etching or self–etching after polishing with regard to color alteration. In those two studies,[16,21] long–term discoloration was not evaluated. As the depth of the resin tags did not influence short–term superficial discoloration, use of self–etching or conventional etching might not lead to a significant difference in the short term.

The second null hypothesis was rejected: when ΔE1 values were compared, a significant difference was observed between the two self–etching groups. Although using 12–bladed tungsten carbide burs caused less color alteration, 24–bladed carbide burs led to greater color alteration in the self–etching groups. The reason for greater color change might be inadequate adhesive removal with the 24–bladed tungsten carbide bur. Joo et al.[21] reported that a greater amount of thin residual adhesive resin layers undetectable by the naked eye remained after finishing in teeth treated with self–etching primers. As the 24–bladed tungsten carbide bur results in less adhesive removal when compared to the 12–bladed bur, the reason for greater color change might be an undetectable adhesive layer left in Group IV.

The third null hypothesis was rejected: although significant differences were observed in ΔE values within the self–etching groups before polishing, the difference became statistically not significant after polishing. Besides, all L*, a*, b* values that changed significantly after treating with tungsten carbide burs, tended to return to pretreatment values except a* in Group I and b* in Group III after polishing with discs. From the clinical perspective, polishing with Sof–Lex XT discs (3M ESPE, St Paul, Minnesota) might reduce the negative effect of tungsten carbide burs, but could not totally negate the influence of orthodontic treatment on changes in tooth color. Polishing of the enamel surface after removal of residual adhesive resins is also recommended to eliminate enamel surface roughness.[19] Although the intergroup differences became insignificant, and the values that establish the tooth color became approximate to initial levels after polishing, color alterations (ΔE3) were still considered clinically unacceptable in all groups.

The last null hypothesis was rejected: orthodontic treatment resulted in visible and clinically unacceptable tooth color alterations, whether conventional or self–etching was used, whether 12– or 24–bladed tungsten carbide burs were used, or whether polishing was done or not. After polishing, even though the percentage of teeth without visible color alteration did not change, the percentage with visible and clinically unacceptable color alteration decreased from 63.6% to 60.5%. The threshold for clinically unacceptable color change was set as $\Delta E = 3.7$. After polishing, the range of mean ΔE3 values was between 4.2 and 4.8. Although those values seem to be clinically unacceptable, only a very small percent of patients complain of tooth color alterations after orthodontic treatment. This may be due to the long duration of treatment, forgetting pretreatment color of the teeth, or the improvement in the alignment of teeth making the patients so pleased that they cannot detect the difference in the color.

There are only three previous in vivo studies[5,16,17] that evaluated the effects of orthodontic treatment on tooth color. In vitro tests may not accurately reflect the clinical situation because of the lack of saliva, food staining, and the inability to simulate the mechanical abrasion caused by brushing.[11] This was the first in vivo study that evaluated both the effects of etching

pattern and adhesive removal technique on tooth color alterations. Fifty–nine patients and 354 teeth with comparable age, crowding, and treatment durations were included in this prospective study. One of the limitations of this study was that no template was used for color assessment and the color determination was done at the middle third of the teeth. As it was a clinical study and the patients' tooth alignment changed during treatment, it was not feasible to produce a template for the area of color assessment for every tooth. Instead, color measurement was performed at the middle third of all teeth and the brackets were bonded on that area. As this was an in vivo study, the adhesive remnants, resin tags, or surface roughness could not be evaluated and associated with tooth color differences. Further in vivo studies should be performed to better understand the reasons for tooth color alterations with orthodontic treatment and to compare the results.

CONCLUSIONS

- During orthodontic treatment, neither conventional nor self–etching caused statistically different tooth color alterations.
- Adhesive remnant removal with 12–bladed tungsten carbide burs led to less color alteration than 24–bladed tungsten carbide burs between the self–etch groups.
- After polishing with Sof–Lex XT discs (3M ESPE, St Paul, Minnesota), the effect of tungsten carbide burs on tooth color became insignificant.
- Visible and clinically unacceptable tooth color alterations were observed after orthodontic treatment, regardless of the etching and adhesive removal techniques.

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