

Investigation of Changes in Tooth Color During the First Three Months of Fixed Orthodontic Treatment of Individuals Using Toothpaste with Different Content

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Abstract

Background: This research seeks to assess alterations in tooth color throughout fixed orthodontic treatment and make comparisons between individuals using various types of toothpaste.

Materials and Methods: This study involved 24 patients with complete permanent dentition, skeletal and dental Class I malocclusion. The patients were categorized into three groups of 8 individuals, with each group using a distinct type of toothpaste. Records were taken from all patients using an intraoral scanning device (3Shape Trios) before bonding and at the first and third months of treatment. These records were transferred to Adobe Photoshop for further analysis. The CIE (Commission Internationale de l'Eclairage) color system was employed to assess tooth color, and the L, a, and b values were recorded for all teeth, excluding the molars. To ensure standardization during measurements taken from bracketed teeth, samples were collected from three areas of each tooth: mesial, distal, and occlusal. The average of these values was accepted for evaluation. To determine the color differences of measurements taken at different times from the same patient, the ΔE formula was applied to compute the color differences.

Results: In the group using Colgate, statistically significant changes were observed between time points for L and B values in all regions ($p=0.000$), as well as A values in the left mandible ($p=0.004$). In the group using Curaprox, significant changes were found between time points for L and B values in all regions ($p=0.000$). In the group using Rocs, significant changes in L values were observed in all groups ($p=0.000$), in B values in the left maxilla and right mandible ($p=0.000$), in B values in the left mandible ($p=0.005$), and B values in the right maxilla ($p=0.012$). Between-group comparisons revealed a statistically significant difference in $\Delta E1$ values in the right maxilla ($p=0.048$).

Conclusions: All patients undergoing fixed orthodontic treatment had a change in tooth color. When the groups using different toothpaste were compared, a difference in color change was observed in the right maxilla between the first month and baseline measurements. However, there was no difference between the groups in the third month.

Clinical Research (HRU Int J Dent Oral Res 2025; 5(2): 59-65)

Keywords: Intraoral scanning device, toothpaste, tooth color analysis.

Introduction

The objectives of orthodontic treatment for individuals with dental or skeletal malocclusion are to enhance the aesthetics of the orofacial areas, align the teeth for easier oral hygiene, and optimize chewing function. In addition to the benefits of orthodontic treatment, there may be undesirable side effects, including root resorption, pulpal necrosis, temporomandibular disorders, periodontal disease, dental caries, and enamel damage (1). A common unintended side effect of fixed orthodontic treatments is the development of new carious lesions throughout the treatment process. The brackets, bands, ligatures, and

other auxiliary components employed in the treatment can contribute to the formation of white spot lesions around the teeth as time progresses (2). Previous studies have shown that in a patient who does not undergo any orthodontic treatment, the development of new cavities takes at least 6 months. However, in a patient undergoing orthodontic treatment, the challenge of maintaining proper oral hygiene without sufficient care can lead to the development of new cavities in as little as one month. (3). Treatment with removable or fixed orthodontic appliances is an important aspect of modern orthodontics. However,

side effects that can develop during treatment, such as white spot lesions, can negatively impact the aesthetic outcomes provided by the treatment (4). Therefore, methods aimed at preventing demineralization and enhancing remineralization are recommended throughout the orthodontic treatment process. Products containing minerals that aid in remineralization, such as fluoride, calcium, and phosphate, are among the treatment approaches used to prevent the formation of white spot lesions (5, 6). In addition, some proteins, antibodies, and antimicrobial enzymes found in saliva also contribute to the naturally occurring remineralization process (7). An example of such an enzyme with antimicrobial effects is lactoperoxidase (8, 9). However, the observation of discoloration and color changes in the teeth is also considered a side effect of orthodontic treatment (10). In patients treated with metal brackets, the prolonged orthodontic treatment process and long-term low oral pH levels can cause corrosion of these brackets, which may lead to changes in the color of the enamel (11). Acid etching and bonding procedures make the teeth more susceptible to this discoloration (11). Acidic beverages and pigmented foods, such as citrus fruits, can also alter tooth color and should be consumed minimally during orthodontic treatment (12). Another factor that can contribute to color distortion is the irreversible penetration of the adhesive resin into the deeper layers of the tooth enamel. (13). Additionally, in cases where color changes occur on the enamel surface as a result of fixed orthodontic treatment, bonding materials and techniques, debonding procedures, adhesive and resin cleaning methods, composite adhesives, patient diet, and oral hygiene habits are noted to have an impact (14). Especially, in patients who cannot maintain proper oral hygiene, discoloration may occur during the fixed orthodontic treatment process. This study aims to examine the change in tooth color during the first three months of fixed orthodontic treatment and compare individuals using toothpastes with different remineralization mechanisms.

Materials and Methods

Before the study, approval was obtained from the Erciyes University Non-Invasive Clinical Research Ethics Committee (Date: 03.04.2024, Decision No: 2024/253), and all procedures were conducted according to the ethical rules and principles of the Helsinki Declaration. Informed voluntary consent forms were obtained from all patients and their guardians. This study involved 24 patients who sought treatment at the Department of Orthodontics, Faculty of Dentistry, Erciyes University. These patients had no systemic diseases, maintained adequate oral

hygiene, had completed permanent dentition, had skeletal and dental class I malocclusion, and exhibited crowding ranging from three to four millimeters. The patients were categorized into three groups, with each group made up of individuals using different types of toothpaste. According to the data obtained from the study by Tunca and Kaya (15) and the power analysis conducted using the G*Power program, it was determined that there should be at least 35 teeth in each group based on the criteria of $d = -0.583$, $\alpha = 0.05$, and $1 - \beta = 0.95$ (power). For this study, 5 teeth were evaluated in each quadrant of the individual's jaw, and it was determined that there should be at least 7 individuals in each group. To account for potential data loss during the study, 8 individuals were included in each group. They were planned for orthodontic treatment without extractions, and their enamel surfaces showed no defects. For the orthodontic treatment, 0.018" slot Roth (MiniMaster®, American Orthodontics, Armonk, USA) brackets were used, and the bonding procedures were performed by the same dentist (BKB). The three different kinds of toothpaste used by the participants in the study were as follows: Colgate Total toothpaste contains 1450 ppm sodium fluoride. Curaprox Enzycal (Curaden International, Switzerland) toothpaste contains 1450 ppm sodium fluoride as well as a trio of enzymes: lactoperoxidase, amyloglucosidase, and glucose oxidase. Rocs Pro Ortho (R.O.C.S., Moscow, Russia) toothpaste does not contain fluoride but includes magnesium chloride and calcium glycerophosphate. Additionally, all three toothpastes contain silica as an abrasive agent. Before bonding, oral scans were taken from all patients at three time points: before bonding, at the first month, and at the third month of the treatment process. These scans were recorded using the intraoral scanning device 3Shape Trios (3Shape Trios 3 Plus, Copenhagen, Denmark). The patients were given appointments at similar times of the day for intraoral scanning, and the scans were taken in the same unit chair under natural light. To provide numerical data for the color analysis performed, the recordings were transferred to the Adobe Photoshop program (Adobe Inc., San Jose, California, USA), as described in the study by Yoon and colleagues (16). The CIE (Commission Internationale de l'Eclairage) color system was preferred for determining tooth color, and the L, a, and b values were measured on all teeth except for the molars. This technique is the most commonly employed color measurement system, as it provides digital data that closely matches the actual visual response. (17). In this system, the 'L' value indicates the lightness of the tooth color ($L^* = 0$ represents black, and $L^* = 100$ represents white), the 'a' value represents the proximity to red/green tones ($+a^*$ represents red, and $-a^*$ represents green), and the 'b' value represents

the proximity to yellow/blue tones (+b* represents yellow, and -b* represents blue)(18). During the measurements, since brackets were present on the teeth as shown in Figure 1, samples were taken from three standardized regions of each tooth: mesial, distal, and either occlusal or incisal areas. Color differences between measurements taken at different times from the same patient was determined using the ΔE formula (17, 18). This approach aimed to compare the color changes between different time points across the groups.



Figure 1. The points represent the areas where color analysis was performed in the intraoral scan image taken with the 3Shape Trios device.

Statistical Analysis

When the measurements the lower and upper teeth were separated into four quadrants: right maxilla, right mandible, left maxilla and left mandible. Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS, Version 24.0, IBM Inc., USA), the normality of the data was evaluated using the Shapiro-Wilk test. Data between time points were evaluated using the Friedman test and repeated measures ANOVA. Pairwise comparisons between measurements were made using the Bonferroni test. The comparisons between groups were conducted using One-Way ANOVA and the Kruskal-Wallis test. For data that were homogeneous, the Tukey test was applied, while the Tamhane test was used for heterogeneous data. The significance threshold was set at $p < 0.05$.

Results

This study was conducted with 24 patients aged 14 to 18, who exhibited Class I malocclusion and practiced proper oral hygiene. Color analysis was performed on the scanning records obtained from the patients, which

provided numerical data to examine changes in tooth color tones. Subsequently, the outcomes of the statistical analysis were examined. According to Table 1, which compares the L value across time points, a statistically meaningful reduction in the L value was noted in all areas throughout the treatment period in all three toothpaste groups ($p < 0.05$). Based on the data presented in Table 2, which illustrates the change in the A value during treatment, a statistically meaningful reduction was noted in the left mandible for the Colgate group ($p = 0.004$) and Curaprox ($p = 0.009$) toothpaste groups, while in the right mandible, the group using Rocs toothpaste showed a meaningful decrease ($p = 0.029$). When examining Table 3, the evaluation of the B value between time points shows a statistically meaningful decrease throughout the treatment in all toothpaste groups and all regions ($p < 0.05$).

The $\Delta E1$ value in Table 4 represents the color deviation between the first month and the baseline records, while $\Delta E2$ represents the color deviation between the third month and the baseline records. The color variations of all evaluated teeth in the first month ($\Delta E1$) and third month ($\Delta E2$) exhibited notable changes in color, ranging from 6.85 to 11.10 ΔE units. The clinical significance of these color changes was evaluated by comparing the color variation values with the established threshold for clinical detection, which is 3.7 ΔE units (19). Thus, in our study, color differences that were clinically noticeable were identified in all teeth throughout the orthodontic treatment. A statistically meaningful difference between groups was found only in the $\Delta E1$ value in the right maxilla ($p = 0.048$). No meaningful difference was observed in the $\Delta E2$ values between groups.

Discussion

This study evaluated the color changes that can occur in the teeth during fixed orthodontic treatment and the differences in these color changes between groups using kinds of toothpaste with different remineralization activities. Potential color changes in teeth following orthodontic treatment are highly significant for both clinicians and patients(20). There are studies in the literature that suggest orthodontic procedures can affect the color of the enamel (11, 17, 21) However, there are no studies examining the effect of using toothpastes with different remineralization mechanisms on tooth color during fixed orthodontic treatment. Additionally, in existing studies, it has been observed that color analysis was conducted without brackets on the teeth. White spot lesions that may develop during orthodontic treatment, with their milk-like color, can disrupt the aesthetic appearance and, thus, reduce patient satisfaction with the outcome of the orthodontic treatment (21).

Table 1. The change in the L value over time is shown.

COLGATE	Mean (S.D.)	p*	CURAPROX	Mean (S.D.)	p*	ROCS	Mean (S.D.)	p*
<u>Right Maxilla L</u>			<u>Right Maxilla L</u>			<u>Right Maxilla L</u>		
T0	71,92 (2,13)		T0	72,60 (1,68)		T0	72,85 (1,59)	
T1	67,50 (1,69)	0,000	T1	65,15 (1,38)	0,000	T1	65,32 (1,00)	0,000
T2	64,75 (2,44)		T2	64,70 (2,35)		T2	64,47 (1,58)	
	Mean (S.D.)	p*		Mean (S.D.)	p*		Mean (S.D.)	p*
<u>Left Maxilla L</u>			<u>Left Maxilla L</u>			<u>Left Maxilla L</u>		
T0	71,55 (1,72)		T0	72,35 (1,35)		T0	72,85 (1,47)	
T1	66,95 (1,67)	0,000	T1	65,40 (0,90)	0,000	T1	65,37 (1,13)	0,000
T2	64,72 (1,82)		T2	64,77 (1,56)		T2	64,87 (1,25)	
	Mean (S.D.)	p*		Mean (S.D.)	p*		Mean (S.D.)	p*
<u>Left Mandible L</u>			<u>Left Mandible L</u>			<u>Left Mandible L</u>		
T0	72,50 (2,31)		T0	74,02 (2,01)		T0	73,47 (2,12)	
T1	66,62 (1,18)	0,001	T1	66,02 (2,13)	0,000	T1	64,60 (1,56)	0,000
T2	63,60 (1,91)		T2	64,42 (2,02)		T2	63,47 (1,17)	
	Mean (S.D.)	p*		Mean (S.D.)	p*		Mean (S.D.)	p*
<u>Right Mandible L</u>			<u>Right Mandible L</u>			<u>Right Mandible L</u>		
T0	72,20 (2,71)		T0	72,92 (1,24)		T0	72,50 (2,34)	
T1	66,55 (1,10)	0,000	T1	65,72 (1,90)	0,000	T1	64,72 (1,65)	0,000
T2	63,67 (1,99)		T2	64,15 (1,78)		T2	63,75 (1,25)	

T0: Start of treatment, T1: First month of treatment, T2: Third month of treatment
 S.D.: Standard Deviation

Table 2. The change in the A value over time is shown.

COLGATE	Mean (S.D.)	p*	CURAPROX	Mean (S.D.)	p*	ROCS	Mean (S.D.)	p*
<u>Right Maxilla A</u>			<u>Right Maxilla A</u>			<u>Right Maxilla A</u>		
T0	10,15 (2,38)		T0	8,42 (0,94)		T0	8,87 (1,18)	
T1	8,87 (1,54)	0,260	T1	9,35 (1,25)	0,200	T1	9,77 (1,37)	0,202
T2	9,75 (1,64)		T2	8,95 (1,57)		T2	9,62 (1,07)	
	Mean (S.D.)	p*		Mean (S.D.)	p*		Mean (S.D.)	p*
<u>Left Maxilla A</u>			<u>Left Maxilla A</u>			<u>Left Maxilla A</u>		
T0	9,62 (1,88)		T0	8,27 (1,16)		T0	8,37 (0,94)	
T1	8,35 (1,81)	0,162	T1	8,47 (1,16)	0,508	T1	8,67 (1,04)	0,578
T2	8,75 (1,32)		T2	8,00 (1,54)		T2	8,67 (0,91)	
	Mean (S.D.)	p*		Mean (S.D.)	p*		Mean (S.D.)	p*
<u>Left Mandible A</u>			<u>Left Mandible A</u>			<u>Left Mandible A</u>		
T0	11,35 (1,52)		T0	10,72 (1,04)		T0	11,57 (1,26)	
T1	9,40 (1,35)	0,004	T1	9,42 (0,92)	0,009	T1	10,47 (1,05)	0,105
T2	10,17 (1,31)		T2	9,77 (0,85)		T2	11,05 (0,49)	
	Mean (S.D.)	p*		Mean (S.D.)	p*		Mean (S.D.)	p*
<u>Right Mandible A</u>			<u>Right Mandible A</u>			<u>Right Mandible A</u>		
T0	10,72 (2,02)		T0	9,92 (0,75)		T0	11,62 (1,06)	
T1	9,07 (1,39)	0,064	T1	9,15 (0,93)	0,184	T1	10,52 (1,10)	0,029
T2	10,17 (1,64)		T2	9,85 (0,99)		T2	10,80 (0,95)	

T0: Start of treatment, T1: First month of treatment, T2: Third month of treatment
 S.D.: Standard Deviation

Table 3. The change in the B value over time is shown.

COLGATE	Mean (S.D.)	p*	CURAPROX	Mean (S.D.)	p*	ROCS	Mean (S.D.)	p*
Right Maxilla B			Right Maxilla B			Right Maxilla B		
T0	16,22 (2,04)		T0	14,35 (1,67)		T0	15,40 (0,95)	
T1	11,60 (1,69)	0,000	T1	10,32 (1,76)	0,000	T1	13,30 (2,54)	0,012
T2	12,15 (1,60)		T2	10,35 (1,95)		T2	11,95 (1,08)	
	Mean (S.D.)	p*		Mean (S.D.)	p*		Mean (S.D.)	p*
Left Maxilla B			Left Maxilla B			Left Maxilla B		
T0	16,45 (1,51)		T0	14,20 (1,27)		T0	15,80 (1,22)	
T1	11,85 (1,01)	0,000	T1	10,55 (1,57)	0,000	T1	12,87 (2,29)	0,000
T2	12,25 (1,75)		T2	10,57 (2,04)		T2	12,17 (1,49)	
	Mean (S.D.)	p*		Mean (S.D.)	p*		Mean (S.D.)	p*
Left Mandible B			Left Mandible B			Left Mandible B		
T0	16,70 (1,59)		T0	15,47 (1,30)		T0	17,17 (2,02)	
T1	10,75 (2,13)	0,000	T1	9,97 (1,88)	0,000	T1	13,57 (2,09)	0,005
T2	11,57 (1,45)		T2	10,55 (1,54)		T2	13,22 (1,51)	
	Mean (S.D.)	p*		Mean (S.D.)	p*		Mean (S.D.)	p*
Right Mandible B			Right Mandible B			Right Mandible B		
T0	16,82 (1,62)		T0	15,37 (1,87)		T0	17,62 (0,81)	
T1	10,65 (1,49)	0,000	T1	9,82 (1,30)	0,000	T1	13,55 (2,04)	0,000
T2	11,80 (1,19)		T2	10,45 (1,10)		T2	13,87 (1,56)	

T0: Start of treatment, T1: First month of treatment, T2: Third month of treatment

S.D.: Standard Deviation

Table 4. The table shows the comparison data of the differences in color changes over time between the groups using toothpaste.

RIGHT MAXILLA		Mean (S.D.)	p*	RIGHT MAXILLA		Mean (S.D.)	p*
	COLGATE	7,00 (1,54)			COLGATE	8,64 (1,23)	
ΔE1	CURAPROX	8,84 (1,70)	0,048	ΔE2	CURAPROX	9,01 (2,86)	0,846
	ROCS	8,25 (1,75)			ROCS	9,21 (1,46)	
LEFT MAXILLA		Mean (S.D.)	p*	LEFT MAXILLA		Mean (S.D.)	p*
	COLGATE	6,85 (1,48)			COLGATE	8,34 (1,10)	
ΔE1	CURAPROX	7,93 (1,43)	0,260	ΔE2	CURAPROX	8,61 (2,00)	0,749
	ROCS	8,28 (2,23)			ROCS	8,97 (1,70)	
LEFT MANDIBLE		Mean (S.D.)	p*	LEFT MANDIBLE		Mean (S.D.)	p*
	COLGATE	9,01 (2,18)			COLGATE	10,49 (1,73)	
ΔE1	CURAPROX	10,04 (1,50)	0,580	ΔE2	CURAPROX	11,10 (2,75)	0,846
	ROCS	10,12 (2,48)			ROCS	11,03 (2,26)	
RIGHT MANDIBLE		Mean (S.D.)	p*	RIGHT MANDIBLE		Mean (S.D.)	p*
	COLGATE	8,96 (2,48)			COLGATE	10,16 (1,53)	
ΔE1	CURAPROX	9,47 (2,13)	0,890	ΔE2	CURAPROX	10,22 (2,44)	0,833
	ROCS	9,02 (2,25)			ROCS	9,60 (2,46)	

ΔE1: The color change between the first month of treatment and the start of treatment

ΔE2: The color change between the third month of treatment and the start of treatment

Therefore, this study investigated whether there would be a difference when toothpastes with different remineralization mechanisms were used. In a comprehensive orthodontic treatment plan, the color and appearance of the teeth should also be considered(21).

In this study, intraoral scanning records were taken from the patients during the first and third months of the treatment process, and the color analysis of the teeth was conducted. The reason for taking the records within one month was that white spot lesions could develop in as short as a month during orthodontic treatment, and the development of these lesions can also affect tooth color (3). In literature studies on tooth color analysis, spectrophotometers are commonly used(17, 22). However, in our study, due to the presence of brackets, the use of a spectrophotometer was not feasible. Thus, in this study, color analysis was conducted based on the methodology of Yoon and colleagues(16), and the scanning records obtained with the 3Shape Trios intraoral scanning device were transferred to Adobe Photoshop for measurements. A study comparing the Trios3 scanning device with a spectrophotometer(23), indicated that additional precautions should be taken when records are obtained with the Trios3, but both devices were found to have very high repeatability (over 87%). In our study, all orthodontic treatment procedures were performed by a single clinician. Additionally, it was believed that comparing the obtained records within themselves would lead to consistent results. Due to the presence of brackets on the teeth during treatment, to ensure standardization, samples were taken from the mesial, distal, and occlusal or incisal areas of the teeth, and the mean value of the three regions was considered as the value for each tooth. When comparing the color parameters before and after treatment, statistically significant changes were observed following orthodontic treatment. Upon reviewing the data, significant color changes were observed in all teeth examined after fixed orthodontic treatment. The study's results revealed a significant reduction in the L value, which represents lightness. These findings indicate that, in clinically noticeable color changes, the teeth generally darken. This data aligns with previous research (24-27). According to Paul et al., a difference of less than 2.0 units in the L* value is considered noticeable and is considered a clinically acceptable color change(28). However, in our study subjects, the change in the L* value exceeds this threshold limit due to darkening of the tooth color, and the clinical significance of the color change can be supported by this literature information. When comparing between groups, a difference was observed in only one quadrant in the first month ($p=0,048$). By the end of the third month, no statistically meaningful variation was observed

between the patients using different toothpastes. The short follow-up period in this study, the fact that the records were taken at relatively close time points, and that the patients involved in the study were individuals who maintained adequate oral hygiene, are believed to be the reasons why no meaningful difference was found between the groups. In addition, the fact that the diet of individuals cannot be controlled and that some foods they may consume in their diet (e.g. coffee, tea, tomato paste) may cause this coloration can be seen as a limitation of this study. However, considering the lack of clinical studies on the methods and products used, this study can be considered as an example for future research.

Conclusion

Statistically significant changes in tooth color were observed in all patients during the first and third months of fixed orthodontic treatment. It was observed that the teeth darkened during orthodontic treatment, and this darkening was visibly apparent. When comparing the groups using kinds of toothpaste with different remineralization mechanisms, a difference in color change was observed only in the right maxilla region at the end of the first month. However, by the conclusion of the third month, no notable difference was observed. Additionally, using toothpaste with different remineralization activities during orthodontic treatment did not affect tooth discoloration at the first or third month of treatment.

Funding No funding resource is associated with this study.

Conflict of Interest declare that they have no conflict of interest.

Ethical Approval Ethical approval was obtained from the Erciyes University Non-Invasive Clinical Research Ethics Committee (Date: 03.04.2024, Decision No: 2024/253).

Author Contributions

Protocol/project development: BKB, TÖ.
 Data collection and management: BKB, TÖ.
 Data analysis: BKB, TÖ.
 Manuscript writing/editing: BKB, TÖ

Acknowledgement Spelling and grammar corrections were made using artificial intelligence (ChatGPT).

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