Original Article

Comparison of Enamel Color Alterations Associated with Different Staining Agents around Orthodontic Brackets: An *In vitro* Study

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Abstract

Objective: Color of natural teeth changes after orthodontic treatment. The aim of the study was to evaluate color changes of enamel before and after fixed mechanotherapy and compare the effects of different staining agents on enamel discoloration. **Materials and Methods:** Hundred freshly extracted premolars were divided into four groups of $n = 25$ each. Baseline color measurements were taken before bonding through reflectance spectrophotometer (X-Rite i1Pro). Postbonding samples were suspended in test solutions; Group 1 (control group) samples stored in distilled water and Group 2, 3, and 4 in tea, coffee, and turmeric solutions, respectively for a week. The samples were then debonded and cleaned with eight fluted tungsten carbide bur followed by pumicing. Color evaluations were made in accordance with Commission Internationale de l'Eclairage L* a* b color system. ΔE values were compared for samples before and after debonding. **Results:** Mean ΔE difference value was found maximum for Group 3 (mean 12.4560, standard deviation [SD] 4.7207) and minimum for Group 1 (mean 9.7120 SD 4.2009). One-way ANOVA was used for intergroup comparison with $P < 0.05$. No statistical significance was found in the ΔE difference values in between the groups. **Conclusion:** Orthodontic bonding and debonding procedures have an effect on enamel discoloration clinically, although various stains used in the study had no statistical significant difference among themselves.

Keywords: *Commission Internationale de l'Eclairage Lab system, debonding, enamel discoloration, orthodontic bonding, spectrophotometer*

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Introduction

The adhesion between orthodontic resins and enamel is exceptional in dentistry although it is recommended to be temporary, yet it should be durable enough to withstand orthodontic forces. Following completion of fixed mechanotherapy; the brackets and bonding resins must be removed with minimum trauma to the tooth and ideally, without any residual resin.[1] Bonding, debonding, and clean-up procedures may result in enamel changes such as microcracks and enamel fractures caused by either forcibly removing brackets or scratches and abrasions caused by mechanical removal of the remaining composite materials.[2]

Color alterations in enamel may result from the irreversible penetration of resin tags into the enamel structure at depths reaching up to 50 μm. The resin impregnation into the enamel structure cannot be retrieved by debonding and clean-up procedures; some amount may be left even though a layer of enamel is removed. Further, enamel discoloration may occur by direct absorption of food colorants and products arising from the corrosion of the orthodontic appliance even after orthodontic treatment.[3]

This discoloration after fixed mechanotherapy can cause patient disappointment and its especially challenging when orthodontic adhesives are subjected to prolonged exposure to staining materials during lengthy treatment. In

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addition, postdebonding protocols involving the removal of adhesive residues with various rotary abrasive tools or hand-held instruments may increase the irregularity of the enamel surface, which may lead to color alterations.[4]

Most studies in orthodontic literature have reported color alteration of natural teeth before and after fixed appliance therapy. Results obtained in those studies are however inconclusive regarding the contributory effects of different protocols on the color changes of the enamel during treatment. Taking into consideration the diet of the Indian population, which chiefly includes beverages such as tea and coffee, and spices such as turmeric gives an impetus for the study wherein enamel discoloration will be compared before and after debonding.

Objective of the study

1. To evaluate the color changes of enamel before and after fixed orthodontic therapy
2. To compare the effects of different staining agents on enamel discoloration after the removal of fixed appliance.

Materials and Methods

This was an *in vitro* study; the total sample comprised n = 100 freshly extracted premolars (upper/lower, first/second) which were further divided into four groups:

Group 1 - Control group (CG) comprises n = 25 samples. In this group, the samples were bonded and stored in distilled water at room temperature for 7 days

Group 2 - Experimental group (EG) comprises n = 25 samples. In this group, the samples were dipped in tea at room temperature for 7 days

Group 3 - EG comprises n = 25 samples. In this group, the samples were dipped in coffee at room temperature for 7 days

Group 4 - EG comprises n = 25 samples. In this group, the samples were dipped in turmeric solution at room temperature for 7 days.

The sample selection was based on the following:

Inclusion criteria

1. Teeth free of caries/restorations
2. Teeth which are nonhypoplastic
3. Teeth which are free of dental wears, fractures, and structural abnormalities.

Exclusion criteria

1. Carious teeth and restored teeth
2. Attrited teeth and teeth with intrinsic stains or white spot lesions
3. Fractured teeth and teeth with dental anomaly
4. Iatrogenic damaged teeth during extraction
5. Teeth previously undergone endodontic, orthodontic, or chemical treatment.

Collection of data

The teeth were obtained from patients aged 15 to 30 years (mean 19.86, standard deviation [SD] 2.39) who were undergoing orthodontic extractions. All extracted teeth were cleansed and stored in distilled water at room temperature in dark until the experiment, to eliminate the effects of lighting and temperature.

Specimen preparation

The teeth were mounted in wax molds. To standardize the area of adhesion and subsequent color measurements, a customized template was used. The molds were formed of specific dimensions and were mounted on 1½ inch thick thermocol sheet with the help of wooden toothpicks. Similar dimension imprints were made on the thermocol so that the samples could be mounted in the exact position every time. The teeth were cleaned and pumiced before the bonding procedure [Figure 1].

Bonding procedures

All the samples (n = 100) were etched with etchant 37% phosphoric acid gel (Etching Gel, Prime Dental Product) for 30 s after which they were washed and dried with oil-free compressed air. Then, they were bonded with 3M Unitek Transbond™ XT (Light cure adhesive paste) using 3M Unitek Transbond™ XT (Light Cure Adhesive Primer). LED light curing system (Bluedent LED Smart) was used with curing cycle of 30 s. After this, the samples were divided into the above-mentioned four groups. Color assessments were performed before and after debonding and cleaning procedures for each group.

Color assessment

Color assessments were performed twice in both experimental and CG (after polishing teeth before

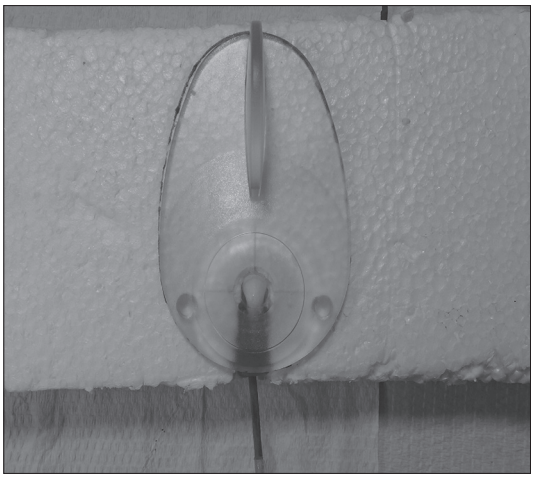

Figure 1: Teeth cleaned and pumiced before bonding procedure and mounted on thermocol sheet

bonding and after suspending in respective solutions after bonding – debonding and finishing procedure). All color recordings were made on dry enamel surface. Measurements were made from the exposed area of the template using hand-held spectrophotometer (X-Rite i1Pro, Measuring tool 5.0.10) while the samples were mounted on the thermocol [Figure 2]. Color evaluations were made in accordance with Commission Internationale de l'Eclairage (CIE) L* a* b color system.

CIE defines a color space,[5] CIE Laboratory, which supports the accepted theory of color perception is based on three separate color receptors (red, green, and blue) in the eye. The L* value is a measure of the lightness of an object, a* value is a measure of redness (positive a*) or greenness (negative a*), and b* value is a measure of yellowness (positive b*) or blueness (negative b*). The advantage of the CIE Laboratory system is that color differences can be expressed in units that can be related to visual perception and clinical significance.

The color changes (ΔE*) were calculated from the L*, a*, and b* values for each specimen according to the following formula, which determines the three-dimensional color space:

Figure 2: Use of X-Rite i1Pro reflectance spectrophotometer for color evaluation

$$\Delta E^* = [(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2]^{1/2}$$

A perceptible color change that is ΔE >1.0 will be referred to as acceptable up to the value ΔE = 3.7 in subjective visual determinations made *in vitro* under optimal lighting conditions.[2]

Debonding and resin removal

After the staining procedure, the brackets were removed with a debonding plier. The adhesive residue was removed using eight fluted tungsten carbide bur from MDT debonding kit (operated at low speed) with adequate water cooling. After this, the teeth were cleaned and pumiced and polished until a normal luster was restored to the enamel surface observed by the naked eye.

Statistical analysis

The results were analyzed statistically using paired *t*-test and ANOVA. The significance value is established at $P < 0.05$. SPSS software (version 20.0; IBM SPSS Statistics, Dharwad, Karnataka, India) was used for the statistical analysis.

Results

Ranges of mean of each color coordinate of enamel surface before bonding for all the groups [Table 1] was: CIE L* −76.9640–79.212; CIE a* −0.900–−1.568; CIE b* −1.168–3.380.

The L* value decreases for all the groups (control and experiment) before and after experiment. The a* value become more negative for all the four groups. The b* values for Groups 1, 2, and 3 became less positive while for Group 4 the b* value became more positive.

The mean values of ΔE difference for each group before and after staining procedure are shown in Table 2. All values for ΔE are >3.7 for each group including control and EG. The greatest color change was noted for Group 3 i.e., for the samples dipped in coffee mean was 12.4560 and SD 4.7207. The least change was noted for Group 1, i.e., for samples dipped in water mean was 9.7120 and SD 4.2009. Group 2 and Group 4 had values of mean

Table 1: The mean and standard deviation of Commission Internationale de l'Eclairage L*, a*, b* for individual groups before and after staining

Groups	*n*		Before L*	After L*	Before a*	After a*	Before b*	After b*
Group 1	25	Mean	78.996	66.120	−1.568	−1.772	1.168	0.7560
		SD	6.09046	4.58094	0.36937	1.17456	1.55502	4.30804
Group 2	25	Mean	76.9640	61.8920	−1.3240	−1.5880	2.6480	0.8720
		SD	2.69535	3.62444	0.89874	0.62738	2.34203	2.25010
Group 3	25	Mean	79.2120	62.4480	−0.9000	−1.2840	3.3800	3.2560
		SD	5.56756	3.94230	0.81701	0.87449	3.13116	3.24334
Group 4	25	Mean	78.2760	63.4720	−1.1760	−1.4520	1.8600	4.9400
		SD	4.46666	5.20124	0.82476	1.33576	1.80416	4.47930

SD: Standard deviation

11.4960 (SD 3.1503) and mean 11.3400 (SD 4.8448), respectively for color change which were all statistically insignificant when compared intergroup.

Although pairwise comparisons showed a significant color change after debonding and finishing among the four groups; however, the color change was not statistically significant between the EG and the CG. This can be seen in Table 3 where *P* value within the groups is 0.159 which is >0.05, thus insignificant.

Discussion

The sensitivity of the human eye in detecting small color differences is limited, and interpretation of visual color comparisons is subjective, depending on investigators personal opinion, thus the reproducibility of these investigations is low.[6] Spectrophotometers measure the reflectance of light within the entire visible spectrum, whereas colorimeters evaluate the reflected light only through three wavelengths namely red, green, and blue. In the present study, color measurement was performed according to the CIE Laboratory color scale on a reflection spectrophotometer.

The L* value is a measure of the lightness of an object and is quantified on a scale such that a perfect black has an L* value of zero and a perfect reflecting diffuser an L* value of 100. In the present study, the L* value decreases for all the groups (control and experiment) before and after the experiment which means that the effect of water and stains both contribute in decreasing the whiteness of the teeth [Table 1].

The a* value is a measure of redness (positive a*) or greenness (negative a*). In the present study, the a* values become more negative before and after the experiment for all the four groups. This denotes that water and the stains used in this experiment made the tooth color change more toward green before and after the experiment.

The b* value is a measure of yellowness (positive b*) or blueness (negative b*). For the present study, the b* values for Groups 1, 2, and 3 became less positive, which means the colour alteration before and after experiment for the above groups was toward pale yellow while for Group 4 (turmeric) the b* value became more positive which signifies that it stains the teeth more yellow than the other stains used in the experiment.

The results of the investigation show that all values for ΔE are >3.7 for each group including control and EG. This shows that there was a clinically significant color change after debonding and finishing among all the groups.

For pairwise comparisons as seen in Table 3, *P* value within the groups is 0.159 which is >0.05, hence nonsignificant. Thus, the effect of stains used in this study, in altering the color of the enamel clinically was almost similar to one another for the given test period.

Seghi *et al*. in their study have suggested that generally ΔE values <1 unit are considered as color match, as they cannot be identified by the observers clinically.[7] Investigations done by Wozniak proposed that differences exceeding 2 units may indicate color change.[8] However, most studies have represented that ΔE values <3.7 units show acceptable matching and are not clinically visible whereas beyond this value, the differences are clinically visible.[2,3,6,9] In the present study, the color difference threshold was set at 3.7 units; all the differences noted were found to exceed the threshold value for clinical detection implicating the clinical significance of the effects induced. This can be explained as-postdebonding and adhesive cleaning enamel surface mainly composed of cut enamel infiltrated by resin tags, occupying the sites of enamel rods dissolved from acid etching.

Silverstone *et al*. in his study suggested that resin impregnation in enamel usually reaches upto 30–50 μm, which may alter the refractive index of the region by modifying the diffusely reflected light component, thus influencing the color parameters.[10] In addition, reflected light component and surface roughness-dependent

Table 2: The mean and standard deviations of ΔE for individual groups

Groups		*n*	Mean	SD
Group 1	Before ΔE	25	11.2080	4.02916
	After ΔE	25	20.9200	3.24114
	ΔE_B-ΔE_A	25	9.7120	4.20092
Group 2	Before ΔE	25	12.4440	1.88792
	After ΔE	25	23.9400	2.90560
	ΔE_B-ΔE_A	25	11.4960	3.15033
Group 3	Before ΔE	25	11.0440	3.97870
	After ΔE	25	23.5000	3.22813
	ΔE_B-ΔE_A	25	12.4560	4.72071
Group 4	Before ΔE	25	11.5600	2.91947
	After ΔE	25	22.9000	4.43208
	ΔE_B-ΔE_A	25	11.3400	4.84484

SD: Standard deviation

Table 3: The values for one-way ANOVA difference

	Sum of squares	df	Mean square	*F*	Significant
Between groups	97.212	3	32.404	1.768	0.159
Within groups	1759.918	96	18.332		
Total	1857.130	99			

P=0.159, *P*>0.05. No significant difference between the groups

parameter are highly sensitive to cleaning and polishing procedures influencing the L* values of the substrate as stated by Chung.[11] The lack of statistically significant differences with respect to ΔE difference values between the groups implies that the effect of surface roughness induced by cleaning and polishing procedures might outweighed the differences in the composition of enamel surfaces subjected to debonding. This observation is however important to the orthodontist who may adversely affect the enamel surface by grinding the enamel during adhesive removal.

Study done by Hosein *et al*. has shown that least enamel loss was after the use of tungsten carbide bur in slow speed handpiece.[12] In addition, polishing the enamel surface with pumice and rubber cup removed 10.7 μm of enamel surface as was determined by Obrien *et al*. (1988). In the present study, 8 fluted tungsten carbide bur (MDT debonding kit) was used at slow speed for adhesive removal from the tooth surface. After this, the tooth surface was polished with pumice and rubber cup, to ensure minimum enamel damage.

The lack of significance within the ΔE difference values within the groups can also be explained on the basis of time factor taken into consideration for the test period. Studies have shown that the quality of polymerization type, light activation conditions, curing time, filler particles of the matrix of adhesive resins, type of staining agent, and immersion procedures also affect and modify the optical properties.[13] Jahanbin *et al*. concluded that most of the color changes were attributed to the uptake of stains by the components of the enamel and not the resin tags.[9] This is in accordance with our study where there was no significant difference in between the groups after the polishing procedure.

In addition, the interpretation of the L* a* and b* values as obtained in the study and their change before and after the experiment depicts that the teeth become less whiter and pale yellow color due to the effect of these stains (i.e., water, tea and coffee) except for turmeric which makes the teeth look more yellow than the others. Previously done studies have discussed about the ΔE values before and after debonding and their clinical significance but none have interpreted the actual effect of stains on tooth color and the type of alteration caused due to them on account of the changing L* a* and b* values.

Conclusion

Despite potential methodological limitations, based on the study results, the following conclusions can be drawn:

1. Orthodontic bonding and debonding procedures do have an effect on enamel discoloration
2. The effect of various stains used in the study, namely water, tea, coffee, and turmeric had similar effects on enamel color alteration and did not vary significantly
3. In general, the tooth color changed in all the four groups, they became less white and pale yellow except for those dipped in turmeric which were more yellow than the rest
4. Color stability of orthodontic materials such as transparent brackets, elastomeric threads, modules and chains are more susceptible to change with colored beverages than the tooth color itself.

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Conflicts of interest

There are no conflicts of interest.

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