Iran J Orthod. 2024 June; 19(1):e1140. doi:10.32592/ijorth.19.1.1140.
Published online 2024 June 1
Original Article **Open Access**

Evaluation of Enamel Staining Susceptibility after Using Three Kinds of Orthodontic Adhesives and Four Different Clean-Up Techniques

Farzin Razavi [1], Behnam Khosravanifard [2], Sheida Kamrooz [3], Shahla Kamrouz [1*]

[1] Department of Orthodontics, Dentistry Faculty, Azad University, Tehran, Iran
[2] Department of Orthodontics, Dental Branch, Azad University, Tehran, Iran
[3] Department of Biostatistics, Faculty of Basic Sciences, Zanjan University, Zanjan, Iran

*** Corresponding Author:** Shahla Kamrouz
Address: Department of Orthodontics, Dental Branch, Azad University, Pasdaran Street, Tehran, Iran.
Email: shahkamrouz11@yahoo.com

Received: 2023 November 24; **Revised:** 2023 December 19; **Accepted:** 2024 March 12

Abstract

Background: The present study tried to find the proper bonding and debonding technique to preserve the natural enamel surface and avoid discoloration.
Methods: Sixty newly extracted human premolars were randomly divided into three groups, and three orthodontic adhesives were applied to bond the brackets: chemically cured System 1 Plus adhesive (Ormco, USA) (CC), light-cured resin (Transbond XT, 3Munitek, USA) (LC), and resin-modified glass ionomer cement (Fuji Japan) (GI). The specimens were immersed in black tea for one week and debonded. Four prophylactic methods were applied to remove residual resin: 1) tungsten carbide bur (TC), 2) tungsten carbide bur + Sof-Lex polisher (TC + SL), 3) tungsten carbide bur + One Gloss Polisher (TC + OG), and 4) tungsten carbide bur + PoGo polisher (TC + PG). The enamel color was measured according to the CIE standard system (Commission International de l'Eclairage) by Konica Minolta CS Spectroradiometer equipment twice: 1) natural enamel color before bonding and 2) after bonding, staining, debonding, and polishing. The ΔE value is the tooth discoloration, which is measured from the mean Δa*, Δb*, and ΔL* values using the following formula ΔE = [(ΔL*)2 + (Δa*)2 + (Δb*)2]1/2 for each group. Then, it was statistically analyzed using a t-test.
Results and Conclusions: Regarding adhesive materials, CC adhesive showed higher discoloration than LC in all the polishing methods. The lowest discoloration was observed in GI. The highest ΔE* values were obtained using TC only, which was deemed insufficient to remove the residual adhesives. Applying TC + Sof-Lex and TC + PoGo equally enhanced the results; therefore, they were the best polishing methods.

Keywords: Orthodontic adhesive, PoGo, Prophylactic method, Sof-Lex.

Background

A pleasing smile is important in creating ideal facial aesthetics; therefore, it is highly desirable for most orthodontic patients. Changes in the enamel color after orthodontic treatment are a considerable concern as they nullify the main aesthetic objective. Hence, a study to investigate the clinical performance of bracket bonding and debonding procedures and material use is necessary.

Discoloration of restorative composite resins and adhesive resin materials currently used for fixed orthodontic appliances under the effect of variable drinks and foods over time is inevitable. The technique used to polymerize composite resins causes enamel discoloration. A high level of discoloration was seen in adhesive resins with dual-

polymerizing systems (1). Many studies have reported that enamel discoloration may arise from the irreversible resin tag penetration into the enamel structure, which has not been removed by prophylactic procedures after debonding the brackets or from white spots after decalcification (2). According to Zaher et al., the length of the penetration of resin tags into the enamel prisms may determine the level of dental discoloration. This means that the self-etch primers that produce shorter resin penetration cause less color change in the enamel (3). Red wine causes the most severe color changes in the enamel, and black tea ranks second (1). In addition, the formation of white spot lesions due to decalcification has been reported even five years after orthodontic therapy (4). Based on Al Maaitah et al.'s study, the self-etching and conventional acid etching primers had a similar impact on the enamel color, with more color changes in men's and adolescents' teeth compared to girls' and adults' (5). Buonocore (6) introduced an acid etching technique and ushered in a significant era in dentistry in 1955. Newman (7) was the first to introduce the bracket bonding technique in comprehensive orthodontic treatment in 1965. He suggested enamel etching before applying composite resins for bonding brackets to increase their mechanical retention. This method offered considerable advantages, such as a simple and effective bonding method and less chair time.

Previous reports have shown that improper debonding techniques can lead to significant enamel damage (8). In general, some adverse effects during orthodontic treatment procedures are inevitable (9), and the type of adhesives and resin removal techniques are responsible for these alterations (10).

A proper debonding technique entails carefully removing all attachments and adhesive resins from teeth without causing any damage to the enamel surface and keeping them intact. Paying adequate attention to correct methods and devices and avoiding performing an unskilled procedure are essential to achieving these objectives (11).

The successful use of the bonded appliance includes the safe removal of the brackets and adhesive without damaging the surface of the tooth, which should be performed responsibly and carefully to achieve as little iatrogenic injury as possible (12).

There is controversy over the most appropriate methods for removing adhesive remnants (13-17), and several techniques have been suggested: manual reamer, orthodontic pliers, ultrasonic instruments, surgical scalpel blades, sandblasting, tools using rotary devices, including burs, discs, and rubbers (18-20), and CO2 laser radiation (21).

This study compared enamel color changes after staining with black tea, using three kinds of orthodontic adhesives and four prophylactic methods to remove residual adhesives after debonding.

Methods

This research used a randomized, single-masked experimental design based on cause-and-effect relationship as the most valid approach to solving educational problems, both practical and theoretical. Therefore, a high control was applied to all variables to evaluate enamel color changes after using three kinds of orthodontic adhesives and staining with black tea. The goal of this research was to apply four prophylactic methods.

The sample size was calculated based on a previous study by Al Maaitah et al. (5). Based on the expected ΔE difference of 100 between groups, α=0.05 and β=0.9, the sample size was calculated at 15 for each group and 45 in total. This study was performed on 60 newly extracted human premolars from 12–25-year-old orthodontic patients referred to the Tehran University of Medical Sciences. The tooth samples had intact surfaces free of soft tissues and were stored in thymol.

The color of the natural enamel surface of the mounted teeth was measured before bracket bonding (as baseline color) and after applying these procedures, i.e., bonding, storing in black tea solution for seven days, debonding, and polishing of the teeth, the surface color of the dried teeth was assessed based on the CIE Lab (Commission International de l'Eclairage, L*, a*, b*) system, using a Konica Minolta CS 2000 Spectroradiometer (made in Japan) (Figure 1).

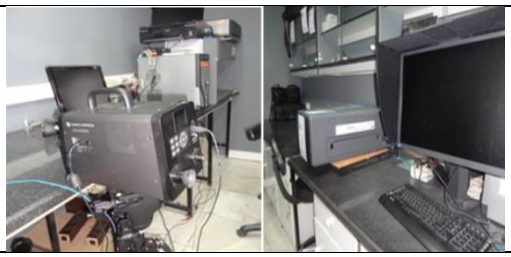

Figure 1. Konica Minolta CS. device.

2.1. Data Collection Instruments

1. Konica Minolta CS 2000 Spectroradiometer (made in Japan)

2. 60 AO (American Orthodontics USA) premolar brackets
3. A low-speed contra-angle handpiece (<20,000 rpm)
4. 6 eight-bladed tungsten carbide finishing burs (1 per 10 teeth)

Three types of orthodontic adhesives:

1. System 1 Plus adhesive (Ormco, USA)
2. Light-cured resin (Transbond XT, 3M Unitek, Monrovia, CA, USA)
3. Resin-modified glass ionomer cement (Fuji Ortho LC, GC Corp., Tokyo, Japan)

Three kinds of polishing materials:

1. Sof-Lex XT aluminum oxide-coated disc (coarse, medium, fine)
2. One Gloss synthetic rubber (polyvinyl siloxane)
3. PoGo (polymerized urethane dimethacrylate resin, fine diamond powder, silicon oxide)

2.2. Data Collection Procedures

I) Tooth specimen preparation: Sixty newly extracted teeth with thoroughly intact buccal surfaces and without any dental caries, cracks, decalcification, discoloration, or restorations were collected, and debris was removed with water and a rubber cup using a low-speed handpiece for 5 seconds; then, the teeth were rinsed and dried for 10 seconds. The premolar teeth were mounted in stone cast to ensure proper control during procedures. Then, the teeth were randomly assigned to three groups and numbered for applying three orthodontic adhesives. The specimens' color measurements were made before bonding the brackets.

II) Bonding and debonding: Before bracket bonding, the upper right corner of the premolar teeth was marked with a point precisely at the same distance from the center of their buccal surface. The distance was localized by an Ormco bon gauge as a reference point for two times of color measurement. A 37% phosphoric acid gel was applied for etching the enamel surface (15 seconds for the Transbond XT group and 20 seconds for the light-cured resin-modified glass ionomer cement in the Fuji Ortho LC group). Then the teeth were rinsed and dried for 10 seconds, and a thin layer of primer was applied with an applicator (Ortho SOLO Universal bond enhancer, Ormco, for System 1 Plus Ormco adhesive and Transbond XT Light-cured adhesive for Transbond XT adhesive). Air was gently blown perpendicularly on each tooth for 2-5 seconds, and the adhesive was applied to the bracket's base. Then, the premolar brackets (twin stainless steel AO 0.018-inch, American Orthodontics, USA) were placed and adjusted to the final position with the aid of a bracket placement instrument based on the manufacturer's protocols and attached by applying a constant pressure of 3 kg to place the brackets firmly (22). The excess adhesive was removed, and light-curing on the specimens was performed for 20 seconds on the mesial and distal edges of the bracket. The numbered teeth were placed in three distinct receptacles containing a tea solution. The bonded teeth were immersed in the black tea for one week (23), and during this time, the tea solution was changed every 24 hours. Then, the samples were retrieved and washed for 30 seconds. All the brackets were debonded by gently squeezing with bracket debonding pliers (3M Unitek) and placed in deionized water before color assessment.

III) Prophylactic methods: Five teeth from each type of adhesive group were randomly selected for treatment with one of the four prophylactic methods. At first, the residual adhesives of all teeth were cleaned by eight-bladed tungsten carbide burs. One bur was used for every 10 teeth (24), with a contra-angle low-speed handpiece (<20,000 rpm). Five teeth in each adhesive group only underwent the procedure above; for the remaining teeth, one more stage of the clean-up method was implemented (using a Sof-Lex polisher, One Gloss polisher, or PoGo polisher assigned to each group). Then, remnant adhesives were removed completely, and the surface of the enamel was smoothened so that the adhesive resins were not visible under the operatory lamp light by the naked eye. The researcher performed all the stages of bonding, debonding, and prophylactic procedures. The specimens were sent for further colorimetric assessments.

IV) Color measurement: The enamel color was measured twice for each stage and mean values were obtained. These stages were: 1) the natural color of samples before bonding, 2) the color after bracket bonding, immersion in black tea for one week, debonding, and polishing. The color of teeth was measured according to Commission International de l'Eclairage, L*, a*, b*, the CIE Lab system by Konica Minolta CS 2000 device, at the Science and Technology Ministry of Iran. There are three coordinates to assess the chroma and the value of the enamel surface that is derived from the L*a*b* values:

L*: The color lightness that is assessed from white (L*=100) to black (L*=0)

a*: Dimension of the color in the green (a*<0) and red spectrum (a*>0)

b*: Color dimension in the blue (b*<0) and yellow spectrum (b*>0).

These values represent the effects of the colors absorbed on the middle third of the tooth enamel surface after using three different adhesives. Due to the translucency of the samples, a piece of Leneta paper was placed behind each sample. Two light sources were emitted at 45º perpendicular to the samples' surface. The spectroradiometer was fixed at precisely 0º perpendicular to the samples' surface. The spectroradiometer's aperture was fixed at 0.2º. The distance from the radiometer lens to the sample was nearly 70 cm. These settings would lead to an approximately 2.4-mm-diameter circular viewing area of the middle third of the samples. The baseline L*a*b* values were measured for the three types of composite resin. The mean values of a*, b*, and L* were used for the final analysis. Measurements were made at the laboratory at 25ºC and 21% humidity.

2.3. Statistical Analysis of Data

ΔE* value expressed the enamel surface's discoloration and was measured from the mean Δa*, Δb*, and ΔL* values for each sample using the following formula (10):

$$\Delta E_{2-1} = \left[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\right]^{\frac{1}{2}}$$

$$= \left[(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2\right]^{\frac{1}{2}}$$

Shapiro–Wilk test of normality was applied to the results of ΔE values. Since the results were normally distributed, the ΔE values were statistically analyzed with a t-test for the type of adhesive materials and clean-up procedures, indicating two different variables, including the possibility of interactions between the two factors

Results

The premolars were randomly assigned to three groups and coded for applying three orthodontic adhesives and four clean-up methods (Figure 2).

Based on the data, the following findings were noted:

1. Natural enamel color before bonding according to the CIE standard system (Table 1)

The first column presents the baseline L* value that indicates the enamel surface's degree of lightness and darkness. The second column shows the color chroma from red in positive to green in negative values, and the third column shows a* value and yellow to blue chroma from positive to negative values (25). The results of natural enamel color measurement of 60 samples in 12 groups (n=5) according to the CIE (Commission International de l'Eclairage) standard system indicated the ranges of each enamel color value before bracket bonding were as follows: L*=72.47–78.47, a*= 1.55–3.16, and b*=16.15–19.03. There were no significant differences between groups before bonding (Table 1).

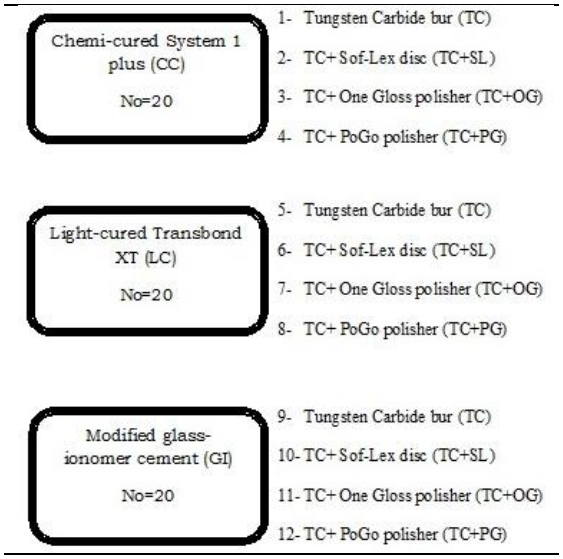

Figure 2. Sixty samples. Each adhesive was applied to 20 premolar teeth, with 5 samples for each prophylactic method.

2. Adhesives' discoloration effect after staining, debonding, and polishing (Table 2)

Chemically cured adhesive (CC): The enamel surface discoloration before and after treatment expressed in DE* unit (Delta E) was high and statistically significant. The mean of L* values decreased. It shifted in the dark direction. The means of a* value that pertains to the chroma increased and became more chromatic, shifting to the red direction. The b* values increased and became more chromatic and shifted to the yellow direction.

Light-cured resin (LC): The color change mean values (DE*) in this group were high and statistically significant. The mean of L* values for all samples decreased. It means they shifted in the dark direction. The mean of a* values increased and shifted to red, and the b* value increased and shifted to yellow.

Glass ionomer cement (GI): In this adhesive group, all the samples showed changes in the value and chroma of the enamel surface. The mean of L* values decreased. It shifted to the dark direction. The mean of the a* value increased and shifted to

the red direction, and the b* value became more yellow.

Table 1. Mean CIE and standard deviation for L*, a* and b* of natural enamel color of each group before bonding (n=60)

	Groups	L* Mean (SD)	a* Mean (SD)	b* Mean (SD)
CC (n=20)	1. (CC+TC)	75.08 (1.43)	3.16 (1.06)	19.03 (2.58)
	2. (CC+TC+SL)	75.70 (3.10)	2.02 (1.77)	16.78 (4.69)
	3. (CC+TC+OG)	74.78 (.96)	2.79 (.71)	18.08 (.98)
	4.(CC+TC+PG)	75.87 (1.82)	2.68 (.91)	16.15 (1.21)
LC (n=20)	5. (CC+TC)	74.94 (2.12)	1.75 (.62)	17.07 (2.55)
	6. (CC+TC+SL)	75.13 (4.95)	2.20 (1.2)	18.03 (4.99)
	7. (CC+TC+OG)	75.85 (2.19)	2.07 (.44)	17.30 (3.59)
	8.(CC+TC+PG)	77.56 (1.94)	1.59 (.77)	17.19 (3.80)
GI (n=20)	9. (CC+TC)	72.47 (1.41)	2.37 (.51)	18.69 (2.30)
	10. (CC+TC+SL)	78.47 (1.78)	1.99 (.45)	16.26 (3.41)
	11. (CC+TC+OG)	77.52 (1.65)	1.89 (.93)	16.59 (2.83)
	12.(CC+TC+PG)	78.41 (1.09)	1.55 (.38)	18.22 (2.77)

Each subgroup included five specimens.

Table 2. Effect of Three Adhesive Resins on the Enamel Color after Bonding, Staining, Debonding, and Polishing

	Before		After		Difference Before and After		DE	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CC N=20								
L*	75.34	1.88	58.50	5.36	-16.84	5.86		
a*	2.67	1.17	8.25	2.31	5.59	1.92	357.45	1.97
b*	17.51	2.81	24.15	3.57	6.64	3.57		
LC N=20								
L*	75.87	3.01	61.65	6.97	-14.22	5.18		
a*	1.91	0.73	6.39	2.49	4.48	2.27	259.85	1.45
b*	17.40	3.54	24.50	3.56	7.10	3.55		
GI N=20								
L*	76.72	2.90	66.87	6.53	-9.85	4.10		
a*	1.95	0.63	4.45	2.11	2.49	1.76	125.90	1.03
b*	17.44	2.83	21.19	3.13	3.75	3.08		

3. The effects of the three orthodontic adhesives (CC, LC, and GI) on the staining susceptibility of the enamel color before treatment and after bonding, staining, debonding, and polishing are presented in Table 2. According to this table, differences in the enamel color of all specimens were significant. ($P<0.01$).

4. The effect of using prophylactic methods on the enamel color after applying three adhesives was as follows:

In the evaluation of tungsten carbide bur (TC), tungsten carbide bur + Sof-Lex polisher (TC + SL), tungsten carbide bur + One Gloss polisher (TC + OG), and tungsten carbide bur + PoGo Polisher (TC + PG), the results, detailed in Table 3, showed significant lightness (L*) decrease across most methods except for tungsten carbide alone, with significantly different results for methods combining tungsten carbide with other polishers. Red/green value (a*) changes were generally more significant across all the methods, with increased redness after treatment. In contrast, changes in the yellow/blue value (b*) showed less consistent results, with some methods showing non-significant changes.

The different protocols for removing residual adhesive significantly affected enamel discoloration, evidenced by shifts in color spectrum values after application. For instance, the combination of tungsten carbide bur and PoGo polisher showed significant decreases in L* values and increases in a* values, indicating a darker and redder enamel color after treatment.

Finally, based on the results of two-way ANOVA, the combined effects of both adhesive and prophylactic methods were also statistically significant.

Discussion

Bracket bonding has revolutionized orthodontic treatment and has played an important role in fixed mechanotherapy. Despite having great advantages, it may result in changes in the enamel surface's color with enamel loss and irreversible damage due to improper techniques or using low-quality materials.

According to overall results, chemically cured System 1 Plus adhesive showed higher discoloration than light-cured adhesive (Transbond XT) in all polishing methods, especially in changing the means of L* and a* values. According to the results, the translucency of the teeth was shifted to the dark, and the color lightness decreased in all specimens. The* values increased, becoming more reddish. Increased mean b* values showed the samples had become more chromatic after staining and more yellowish under the effect of black tea. The lowest discoloration was observed with resin-modified glass ionomer cement, which was compatible with the findings of a study by Ye et al. (23). They showed that chemically cured adhesives had the most staining susceptibility and resin-modified glass ionomer cement showed the least. Differences in the chemical structure of resin components in chemically cured adhesives, such as monomers, and polymeric structures, and the concentration of amines and diketones may affect staining susceptibility. In addition, composition and filler content have some differences. Chemically cured adhesives might cause discoloration since they contain high amounts of inorganic fillers (26). The low pH in the glass ionomer cement group explains the modality of bonding in this adhesive. The mechanism of molecular bond between the calcium of enamel and carboxyl groups facilitates mechanical retention because of adequate wetting of enamel that produces a reversible hydrolytic bond (2). The color change mean values (ΔE*) of samples treated with chemically cured System 1 Plus adhesive showed the highest range of color change among all the adhesive resins. The mean value of the color change (ΔE*) for resin-modified glass ionomer cement was the least, and light-cured adhesive (Transbond XT) resulted in moderate color change.

Regarding prophylactic methods, the highest tooth color change (ΔE*) was observed in the group using Tungsten carbide bur only, which proved an insufficient method to remove the residual adhesives. Applying the final polishing stage after finishing by TC enhanced the outcomes. TC + Sof-Lex and TC + PoGo were not significantly different; therefore, they were the best polishing methods. The ΔE* value with TC + One Gloss was only lower than the TC group. The results of this study may help orthodontists by offering an ideal attitude in the field of aesthetics, leading to the satisfaction of their patients at the end of the orthodontic procedure, which is the main aim of this kind of treatment.

Table 3. Comparison of four prophylactic methods on the enamel color before and after bonding, staining, and debonding

Prophylactic Method	ΔL* (Mean)	Δa* (Mean)	Δb* (Mean)	P-value (L*)	P-value (a*)	P-value (b*)	Significance (L*, a*, b*)
TC	-8.74	2.00	3.15	<0.05	<0.05	>0.05	S, S, NS
TC+SL	-7.69	1.37	3.61	<0.01	<0.01	>0.05	VS, VS, NS
TC+OG	-17.56	6.18	8.09	<0.01	<0.01	<0.01	VS, VS, VS
TC+PG	-15.50	4.61	3.50	<0.01	<0.01	<0.01	VS, VS, VS

Conclusions

The present study showed that despite bracket bonding advances in orthodontic treatments, it risks enamel discoloration, particularly when using chemically cured System 1 Plus adhesive, which showed significantly higher discoloration compared to the light-cured Transbond XT adhesive. This discoloration was notably inclined toward darker and redder hues across all the polishing methods tested. Resin-modified glass ionomer cement exhibited the least discoloration.

Enhanced prophylactic methods significantly mitigate enamel discoloration risks. Specifically, a combination of tungsten carbide bur with Sof-Lex and PoGo polishers was most effective in preserving enamel aesthetics and efficiently minimizing color changes.

References

1. Falkensammer F, Arnetzl GV, Wildburger A, Freudenthaler J. Color stability of different composite resin materials. The Journal of prosthetic dentistry. 2013;109(6):378-83. doi: 10.1016/S0022-3913(13)60323-6
2. Eliades T, Kakaboura A, Eliades G, Bradley TG. Comparison of enamel colour changes associated with orthodontic bonding using two different adhesives. Eur J Orthod. 2001;23(1):85-90. PMID: 11296513 doi: 10.1093/ejo/23.1.85
3. Zaher AR, Abdalla EM, Abdel Motie MA, Rehman NA, Kassem H, Athanasiou AE. Enamel colour changes after debonding using various bonding systems. J Orthod. 2012;39(2):82-8. PMID: 22773670 doi: 10.1179/1465312512Z.0000000009
4. Ogaard B. Prevalence of white spot lesions in 19-near-olds: A study on untreated and orthodontically treated persons 5 years after treatment. Am J of Orthod and Dentofacial Orthop. 1989;96(5):423-7. doi: 10.1016/0889-5406(89)90327-2
5. Al Maaitah EF, Omar AA, Al-Khateeb SN. Effect of fixed orthodontic appliances bonded with different etching techniques on tooth color: a prospective clinical study. Am J of Orthod and Dentofacial Orthop. 2013;144(1):43-9. doi: 10.1016/j.ajodo.2013.02.020
6. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res. 1955;34(6):849-853. doi:10.1177/00220345550340060801
7. Newman GV. Epoxy adhesives for orthodontic attachments: progress report. Am J Orthod. 1965;51(12):901-912. doi:10.1016/0002-9416(65)90203-4
8. Howell S, Weekes WT. An electron microscopic evaluation of the enamel surface subsequent to various debonding procedures. Aust Dent J. 1990;35(3):245-52. PMID: 2203330 doi: 10.1111/j.1834-7819. 1990.tb05402.x
9. Graber TM, Eliades T, Athanasiou AE. Risk management in orthodontics: experts' guide to malpractice. Australian Orthod J.2004;1.
10. Boncuk Y, Çehreli ZC, Polat-Özsoy Ö. Effects of different orthodontic adhesives and resin removal techniques on enamel color alteration. Angle Orthod. 2014;84(4):634-41. doi: 10.2319/060613-433.1
11. Graber LW, Vanarsdall RL, Vig KWL, Huang GJ. Orthodontics: Current Principles and Techniques. 6th ed. Philadelphia: Elsevier Inc; 2017
12. Bishara SE. Textbook of orthodontics.By W.B. Saunders Company Philadelphia. Pennsylvania. 2001:198.
13. Campbell PM. Enamel surfaces after orthodontic bracket debonding. Angle Orthod. 1995;65(2):103-10. PMID: 7785800 doi: 10.1043/0003-3219(1995)065<0103:ESAOBD>2.0.CO;2
14. Dragiff DA. A new debonding procedure. J of Clin Ortho. 1979;13(2):107-11.
15. Habibi M, Nik TH, Hooshmand T. Comparison of debonding characteristics of metal and ceramic orthodontic brackets to enamel: an in-vitro study. Am J Orthod Dentofacial Orthop. 2007;132(5):675-9. PMID: 18005843 doi: 10.1016/j.ajodo.2005.11.040
16. Rouleau BD Jr, Marshall GW Jr, Cooley RO. Enamel surface evaluations after clinical treatment and removal of orthodontic brackets. Am J Orthod. 1982;81(5):423-6. PMID: 6758600 doi: 10.1016/0002-9416(82)90081-1
17. Zarrinnia K, Eid NM, Kehoe MJ. The effect of different debonding techniques on the enamel

surface: an in vitro qualitative study.Am J Orthod Dentofacial Orthop.995;108(3):284-93. doi:10.1016/S0889-5406(95)70023-4
18. Coley-Smith A, Rock WP. Distortion of metallic orthodontic brackets after clinical use and debond by two methods. Br J Orthod. 1999;26(2):135-9. PMID: 10420248 doi: 10.1093/ortho/26.2.135
19. Hosein I, Sherriff M, Ireland AJ. Enamel loss during bonding, debonding, and cleanup with use of a self-etching primer. Am J Orthod Dentofacial Orthop. 2004;126(6):717-24. PMID: 15592221 doi: 10.1016/j.ajodo.2003.10.032
20. Zachrisson BU, Skogan Ö, Höymyhr S. Enamel cracks in debonded, debanded, and orthodontically untreated teeth. Am J Orthod.1980;77(3):307-19.
21. Smith SC, Walsh L. Removal of orthodontic bonding resin residues by CO2 laser radiation: Surface effects. J Clin Laser Medic Surg.1999. 17(1):13-8
22. Bishara SE, Olsen ME, VonWald L, Jakobsen JR. Comparison of the debonding characteristics of two innovative ceramic bracket designs. American journal of orthodontics and dentofacial orthopedics. 1999;116(1):86-92. doi:10.1016/S0889-5406(99)70307-0
23. Ye C, Zhao Z, Zhao Q, Du X, Ye J, Wei X. Comparison of enamel discoloration associated with bonding with three different orthodontic adhesives and cleaning-up with four different procedures. Journal of dentistry. 2013;41:e35-40. doi:10.1016/j.jdent.2013.07.012
24. Berger SB, Palialol AR, Cavalli V, Giannini M. Surface roughness and staining susceptibility of composite resins after finishing and polishing. J Esthet Restor Dent. 2011;23(1):34-43. PMID: 21323837 doi: 10.1111/j.1708-8240.2010.00376.x
25. Mane SP, Gulve ND, Patani SN. Effectiveness of Clean-up Procedures on Stain Susceptibility of Different Orthodontic Adhesives. Journal of Indian Orthodontic Society. 2014;48(4):251-5. doi: 10.5005/jp-journals-10021-1254
26. Eldiwany M, Friedl KH, Powers JM. Color stability of light-cured and post-cured composites. Am J Dent. 1995;8(4):179-81. PMID: 7576383