AJDS ALAZHAR
Al-Azhar Journal of Dental Science
Vol. 26- No. 4- 555:561- October 2023
Print ISSN 1110-6751 | online ISSN 2682 - 3314
https://ajdsm.journals.ekb.eg
Orthodontic & Pediatric Dentistry Issue (Orthodontics and Pediatric Dentistry)

EVALUATION OF THERMOCYCLING EFFECT ON SHEAR BOND STERNGTH OF ORTHODONTIC MOLAR TUBE BONDED WITH TWO DIFFERENT ADHESIVE SYSTEMS (ELECTRON MICROSCOPIC STUDY)

Shereen El Mahlawy [1*], Ghada Al karanfilly [2], Mona Dahab [3]

ABSTRACT

Objectives: This study aimed to evaluate the effect of thermocycling on shear bond strength of two different adhesive systems used for bonding orthodontic molar tube. **Materials and Methods:** The study was performed on 60 extracted human molar teeth, randomly divided into two equal groups. In Group I, the conventional light cure adhesive system was used for bonding molar tube. While, Group II was bonded with the single component adhesive system. All teeth were stored for 24 hours in water at 37^{o}C, then 15 specimens of each group were thermocycled between 5 and 55^{o}C for 1000 cycles. The teeth in all groups were deboned using a universal testing machine. Student's t- test was used to compare the shear bond strength between the groups. Scanning electron microscope was used to evaluate the depth of resin tag penetration. **Results:** The mean shear bond strength of group I was (15.9 +/- 3.4 MPa) and that for group II was (13.1 +/- 3.9 MPa).There was a statistically significant difference between the two groups (p= 0.04).The result of student's t- test comparisons of shear bond strength of group I and II following thermocycling indicated that there was a statistically significant difference where (p= 0.02), (p= 0.01) respectively. The comparison of resin tag penetration showed that there was a statistically significant difference between the two groups (p= 0.0003). **Conclusion:** Conventional adhesive group had a significantly higher mean shear bond strength than single component adhesive group. The mean shear bond strength value was significantly decreased following thermocycling at both adhesives. The depth of resin tag penetration at conventional adhesive group was higher than the single component adhesive group.

KEYWORDS: Thermocycling, Shear bond strength, Molar tube, Adhesive system

INTRODUCTION

Bonding in clinical orthodontics has been an important issue, Newman[(1)] was first developed direct bonding of orthodontic brackets in the early 1965s. Ever since, numerous advanced bonding agents have been introduced with their advantages and disadvantages. Bonded molar tubes are routinely used by orthodontists on the account of their proper cost[(2)] , with the improvement of adhesive systems, design of molar tube and the possibility for accurate positioning of the tube as well as saving time may have motivated orthodontists for fitting of less bands[(3)]. However, molar tubes bond failure with either a light cured or chemically cured adhesive is higher than that of cemented molar bands[(4)].

Orthodontic accessories are subjected to high masticatory forces in the molar region which being up to 53kg[(5)]. The bonding resistance of orthodontic tubes depend on multiple factors, such as, type of manufacturing material[(6)], the design[(7)], method of

1. Lecturer of Orthodontics, Faculty of Oral Dental Medicine, Fayoum University
2. Lecturer of Biomaterial, Faculty of Oral Dental Medicine, Fayoum University
3. Lecturer of Oral Biology, Faculty of Oral Dental Medicine, Fayoum University

• ***Corresponding author***: sam25@fayoum.edu.eg

DOI: *10.21608/AJDSM.2023.200939.1428*

polymerization of the adhesive[8] , applied adhesive system[9] and contamination of saliva or blood during the process of bonding[10]. Although the acid etching composite technique has been frequently used in orthodontics, it still has a number of drawbacks such as enamel loss after acid etching[11], possible fractures of enamel during the debonding process and enamel damage after debonding due to cleanup procedures[12]. The surface of enamel is demineralized by acid etching. It approximately removes 10μm from the enamel surface and a porous layer morphology of 5 to 50 μm depth is created[11]. The tags of resin are created into the conditioned enamel microporosities and provide long lasting resistant bond after polymerization through micromechanical interlocking[13]. The bonding issue has been widely studied to achieve a high bond strength. The change in temperature at oral cavity as well as difference in humidity, stresses and composition and amount of plaque create a complicated environment that cannot be imitated in laboratory studies [14].

These variations affect orthodontic adhesives and it is important for us to determine whether bond strength is influenced by these changes or not, therefore Bishara et al [15] advocated 500 times thermocycling between 5 degree c and 55 degree C for examining new adhesives. Various types of adhesives have been applied in orthodontics for bonding purposes, but the most popular ones for majority of orthodontists are light cured adhesives [16]. The different adhesive systems performance is usually compared by using the bond strength, Reynolds [17] supported values of 5.9 to 7.8 MPa (60-80 kg/cm2) to be a minimum bond strength adequate for orthodontic brackets. Low bond strength materials have tendency to debond at enamel /adhesive interface. However, high bond strength materials displayed cohesive failure, bracket / adhesive deboning [18]. Three step adhesive system requires acid etching of enamel, then use of priming agent before application of adhesive.

Once the tissues are demineralized, primers transform the dental surface from hydrophilic into hydrophobic where complete tissue infiltration can be achieved by the adhesive [19]. The ability to achieve the accurate bond strength for enamel is the great advantage of the three-step system, the value of these adhesives bond strength have approximately reached 31 MPa. Multiple clinical steps makes the technique very sensitive [20]. While, in the two step adhesive system, the priming step does not occur separately[21]. Thus, the clinical technique at this system is simple, procedures are described into two steps so reduced the cost and working time needed for bonding. The primer and adhesive combined together in one package and comes separately [22]. An electron beam with low intensity is radiated to the material and scans the surface of the sample in a scanning electron microscope which is one of the common ways for examining the ultrastructure and morphology of hard tissues like tooth enamel. As the beam enters the enamel, several interactions take place that cause photons and electrons to emit from the sample surface or in close proximity to it[23].

The present study was proposed to evaluate the effect of thermocycling on shear bond strength (SBS) of conventional and single component adhesive systems by using bond strength test.

MATERIALS AND METHODS

This in vitro study was performed on sixty molar teeth, which were extracted for various reasons. Any molars with caries or macroscopic cracks at the buccal surface were excluded. Sample size calculation based on data from a previous study [24] which had a statistical power of 80% with 95% confidence level and significance level of 5%. They were collected from outpatient clinic of faculty of Oral and Dental Medicine, Fayoum University and the study was ethically approved by the ethical committee of the university. Teeth were stored in saline solution at room temperature until the study begins. The teeth were randomly divided into two equal groups.

Each tooth was mounted perpendicular in the middle of the mold at the level of 1mm below the cementoenamel junction in a self-cure acrylic resin block to facilitate positioning of the molar tube. Teeth were polished by brush with pumice for 15 seconds, then rinsed and dried. The buccal surfaces of all teeth were etched with 37% phosphoric acid gel for 30 seconds, then rinsed for 15 seconds and dried with air till the enamel became shaky white. Stainless steel molar buccal tubes (MBT 0.002" ORTHOMETRIC, Brazil) with average surface area of the base (18 mm^2) were bonded to the acid-etched enamel.

Group I was bonded using conventional light cure adhesive "three step system" (MASTER-DENT, USA), the bond was applied by a brush on the etched buccal surface and air was gently flowed to obtain a thin layer, after that curing light was applied for 20 seconds. After applying the composite on the molar tube base it was directly placed on the primed enamel surface and ideally positioned mesiodistally and occlusogingivally. Then it was pressed with steady force to obtain a thin layer and any excess around the tube was removed with a probe.

Group II was bonded using single component adhesive "two step system" (BIOFIX, Brazil). A thin layer of Biofix was applied on the tube base, immediately the tube was correctly positioned on the etched tooth surface and slightly pressed. Light curing was done for total time 20 seconds from both aspects mesially and distally for 10 seconds each at a distance 3mm with a light intensity of (1000 mW/cm2).The bonded samples were stored in water for 24 hours at 37^{o}C, then 15 specimens of each group were thermocycled (SD MECHATRONIC THERMOCYCLER, GERMANY) for 1000 complete cycles. Where, cold water bath immersion for 30 seconds at 5°C and hot water bath immersion for 30 seconds at 55°C and the dwell time was 10 seconds. The thermocycling was done following the recommendation of the International Organization for Standardization. FIG (1) The test was done for both groups by using the universal testing machine (Instron model 3345), where the force applied on the mounted specimens was directed occlusogingivally and parallel to the buccal tooth surface. The blade was oriented perpendicularly on the tube base and the force was applied at speed 1mm/min until failure of the tube. For each specimen the force required for achieving bond failure was assessed in Newtons (1N=100g) and SBS was measured by division of the debonding force values by the area of molar tube base and the final score was recorded in megapascales (MPa). Data were collected and calculated using computer software (Blue universal Instron, England). Fig (2).

FIG (1) Thermocycling

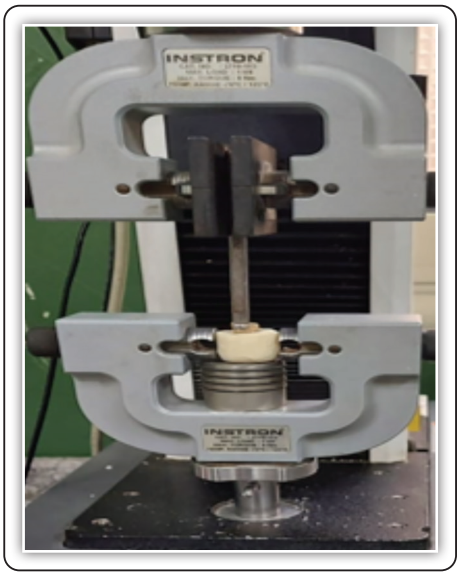

FIG (2) Debonding

In order to evaluate the penetration of resin into enamel surface, specimens from each group were sectioned after debonding. The teeth are sectioned buccolingually along the center of the brackets and parallel to the long axis of crown by using hard tissue microtome (SP 1600; Leica Biosystems, Germany). The microtome was set so that each section was 300-µm thick then sputter coated with gold palladium for investigation under scanning electron microscope (JEOL-JSM- 5200, Japan) operated at 25 kV with magnification of 1500x. The penetration depth of resin tag was assessed by the electron microscope measuring tool and compared between both groups.

RESULTS

The Statistical Package for Social Sciences IBM was used for the statistical analysis of data, student's t-test was used to compare the means between the two groups and values were considered statistically significant where $p \leq 0.05$.

Table (1) shows statistical analysis for SBS mean values in Megapascals (MPa) between the two groups with and without thermocycling. The mean shear bond strength of group I without thermocycling was (15.9 +/- 3.4MPa) and that of group II was (13.1 +/- 3.9 MPa), there was a statistically significant difference between the two groups (p= 0.04). While the mean SBS of group I with thermocycling was (12.6 +/- 4.3 MPa) and that of Group II was (9.7 +/- 3.5Mpa).The student's t-test comparisons of SBS at group I and II following thermocycling showed that the mean difference was statistically significant where (p= 0.02), (p= 0.01) respectively.

Table (2) shows statistical analysis for mean values of resin tag penetration depth into enamel surface between the two groups in microns (*µm*). The mean depth of penetration at group I was (10.4 +/-2.7 *µm)* while that of group II was (6.5 **+/-** 2.5 *µm)*.There was a high statistically significant difference between the two groups (p= 0.0003), where group I shows higher resin tag involved into enamel layer than group II. Almost flat and uniform enamel interface thickness of adhesive resin layer was shown at group I, while more irregular adhesive resin layer was observed at group II. Enamel morphology and crystal orientation were maintained in both groups except for enamel rod subjected to etching show microporosities. Fig (3)

TABLE (1) Comparison of shear bond strength between group I and II:

Group	Shear bond Strength (Mean+/-SD)		Mean difference	P value
	Without thermocycling	With thermocycling		
G I	15.9 +/- 3.4	12.6 +/- 4.3	-3.3	0.02 *
G II	13.1 +/- 3.9	9.7 +/- 3.5	-3.4	0.01*
Mean difference	-2.8			
P value	0.04 *			

GI: Conventional adhesive system GII: Single component adhesive system
*SD: Standard deviation *: $p \leq 0.05$*

TABLE (2) Comparison of resin tag penetration between group I and II:

Variable	G I	G II	Mean difference	P value
Depth of penetration (Mean +/- SD)	10.4 +/-2.7	6.5 +/-2.5	3.9	0.0003***

G I: Conventional adhesive system G II: Single component adhesive system
*SD: Standard deviation ***: $P \leq 0.001$*

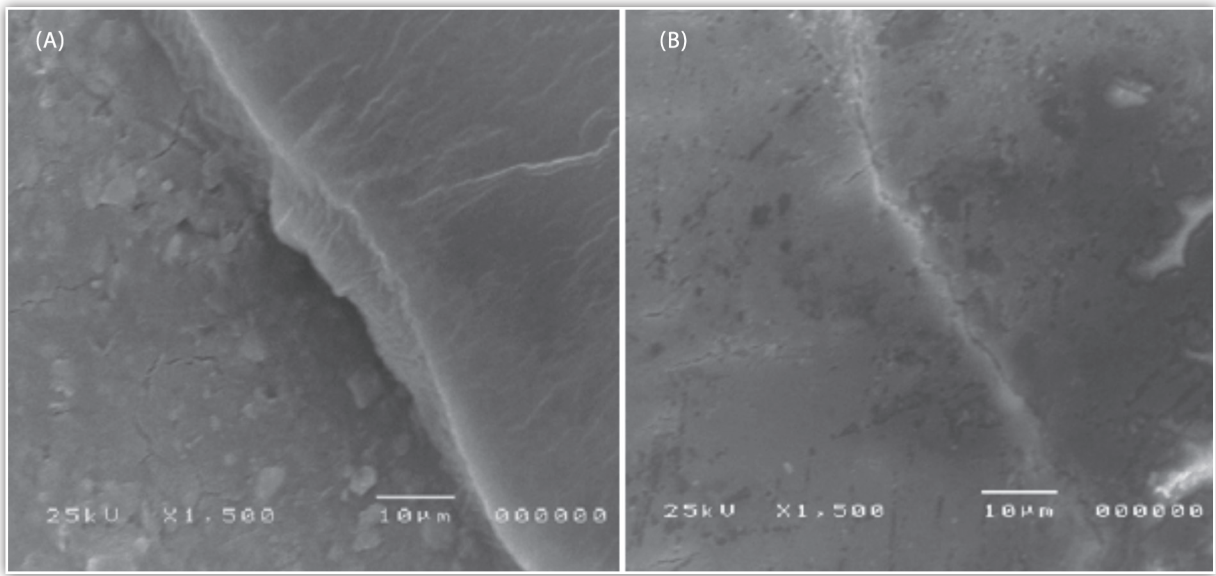

FIG (3) Resin tag penetration under scanning electron microscope. (a) Conventional adhesive system. (b) Single component adhesive system.

DISCUSSION

Achieving effective SBS among adhesives, enamel and orthodontic attachments is important at daily practicing of clinical orthodontics. Conventional bonding system utilizes three various agents (primer, adhesive resin and enamel etchant). The introduction of two step adhesive system reduced bonding steps, decreases the contamination possibility throughout bonding and saves the chair side time of orthodontic treatment. At the present in vitro study, the shear bond strength of three and two steps adhesive systems were tested on account of the shearing nature of masticatory forces.

Comparing the mean SBS between the two groups revealed that conventional light cure adhesive (Master-Dent) which was (15.9+/- 3.4 Mpa) was found to be statistically significantly higher than single component adhesive (Biofix) which was (13.1+/-3.9Mpa). However, SBS of the single component adhesive was clinically acceptable, such that it was reported by Reynolds(17) that the minimum SBS needed to sustain the orthodontic and oral forces was at range (5.9 to 7.8 Mpa).

The findings of the present study were compatible with a previous study (24) which reported that SBS of brackets bonded with (Transbond XT) conventional light cured bonding system is greater than single component bonding system (Biofix).In contrary, another study (25) observed the mean SBS of the brackets bonded with primer incorporated adhesive system (GC Ortho Connect), it was found to be (12.68±6.25 MPa) and this was higher than the conventional bonding system (Enlight LV) group which was (11.60±2.95 MPa).

Composite materials with high bond strength may be undesirable to the enamel substrate, it should permits debonding without damaging the surface of enamel. Enamel fractures were demonstrated on specimens in vitro by Retief (26) even as low as (9.7 Mpa) bond strengths. Since adhesives for orthodontic bonding are usually exposed in oral cavity to thermal changes, it is necessary to investigate whether such variations in temperature initiate stresses at the adhesive that could affect the bond strength (15).

At the current study specimens were thermocycled 1000 times in water between 5°C and 55°C to cover fluctuations of temperature at oral cavity. The mean SBS of conventional adhesive group with thermocycling was (12.6+/-4.3Mpa) and that of single component adhesive group was (9.7+/-3.5Mpa). These findings revealed that the SBS was statistically significantly decreased following thermocycling at both adhesive systems. However, It has been indicated that (6-8Mpa) is an adequate SBS for bonding the orthodontic attachments to teeth[27]. The results of the current study were in accordance with a study[28] which demonstrated that thermal changes significantly decrease the mean SBS of conventional adhesive system (Resilience) and that there is no significant difference in SBS at 300, 500 and 6000 cycles. Another study [29] showed that SBS following thermocycling of brackets that was bonded with (Fuji Ortho LC) was (6.4+/-4.5Mpa) and those bonded with (Transbond plus XT) was (6.1+/3.2Mpa), comparisons between the two groups reported that there was no significant difference.

The observed decline in SBS mean values can be clarified by water exposure and thermal changes of specimens throughout thermocycling. Such that the thermal expansion coefficient for teeth, brackets and adhesives are different, repetitive expansion and contraction generate stresses during thermocycling. By passing time these stresses accumulation decreases the adhesion of bracket and tooth and accordingly gives rise to failure of bond[30]. Different factors could affect the resin tags depth such as acid etching pattern, composite material viscosity, size of particles, etc[31]. At the present study the electron microscopic scanning revealed that the mean value of resin penetration depth into enamel surface at conventional adhesive system group was (10.4 +/-2.7 *µm)* which was found to be statistically significantly higher than single component adhesive system that was (6.5**+/**2.5*µm)*.

This result was in agreement with a study [24] which indicated that the resin tag penetration of the single component adhesive system (Biofix) was (3-9µm) compared to (Transbond XT) the conventional bonding system which was (10-20µm). After debonding, there is a possibility that the tags of resin may remain into enamel surface, about 5 µm are hardly removed with uniform debonding and clean up [32]. Following debonding, the entrapped residual resin with cleaning up may cause drawbacks laterally, such that these tags of resin could discolorate by time, and cause later an aesthetic problems to the patient [33]. Thus adhesive systems of lower resin tag penetration depth and sufficient bond strength are adequate for both the patient and the clinician.

CONCLUSIONS

- Conventional adhesive group had a significantly higher mean SBS than single component adhesive group.
- The mean SBS value was significantly decreased following thermocycling at both groups.
- The depth of resin tag penetration at single component adhesive group was lower than the conventional adhesive group. Thus, after debonding the residual resin will be less on the enamel surface.
- Single component adhesive system has a clinically adequate bond strength, decreases the cost and chairside time by excluding the primer step.

REFERENCES

1. Newman G.V: Epoxy adhesion for orthodontic attachment. Progress report. Am J of Orthod Dentofacial Orthop .1965; 51(12):901-12.
2. Murray PG, Millett DT, Cronin M. Bonded molar tubes: a survey of their use by specialist orthodontists. J Orthod. 2012; 39:129–35.
3. Fleming PS, O'Brien K. Self-ligating brackets do not increase treatment efficiency. Am J Orthod Dentofac Orthop. 2013; 143(1):11-9.
4. Millett DT, Mandall NA, Mattick RC et al. Adhesives for bonded molar tubes during fixed brace treatment. Cochrane Database Syst Rev. 2017; 2: CD008236.

5. Roldán SI, Restrepo LG, Isaza JF et al. Are maximum bite forces of subjects 7 to 17 years of age related to malocclusion? Angle Orthod. 2016:86:456-61.
6. Mirzakouchaki B, Shirazi S, Sharghi R et al. Shear bond strength and debonding characteristics of metal and ceramic brackets bonded with conventional acid-etch and self-etch primer systems: an in-vivo study. J Clin Exp Dent .2016; 8:38–43.
7. Shyagali TR, Bhayya DP, Urs CB et al. Finite element study on modification of bracket base and its effects on bond strength. Dental Press J Orthod.2015; 20:76–82.
8. Li M-Z,Wang J-R, Liu H et al. Effects of light curing modes and ethanol-wet bonding on dentin bonding properties. J Zhejiang Univ Sci B.2016; 17:703–711.
9. Juriši´c S, Juriši´c G, Juri´c H. Influence of adhesives and methods of enamel pretreatment on the strenght of orthodontic brackets. Acta Stomatol Croat. 2015; 49:269-74.
10. Toodehzaeim MH, Rezaie N 2015. Effect of saliva contamination on microleakage beneath bonded brackets: a comparison between two moisture-tolerant bonding systems. J Dent. 2015; 12:747-55.
11. Pus MD, Way DC. Enamel loss due to orthodontic bonding with filled and unfilled resins using various clean-up techniques. Am J Orthod. 1980; 77:269-83.
12. Zachrisson BU, Artun J. Enamel surface appearance after various debonding techniques. Am J Orthod. 1979; 75:121-37.
13. Diedrich P. Enamel alterations from bracket bonding and debonding: a study with the scanning electron microscope. Am J Orthod 1981; 79(5):500-22
14. Graber LW, Robert L, Vanarsdall RL, Vig WL. Bonding in orthodontics. In: Orthodontics, current principles and techniques. 5th ed. Elsevier Mosby.727-784.
15. Bishara SE, Ajlouni R, Laffoon JF. Effect of thermocycling on the shear bond strength of a Cyanoacrylate orthodontic adhesive. Am J Orthod Dentofacial Orthop. 2003; 123:21-24.
16. Keim RG, Golieb EL, Nelson AH, Vogels DS.Study of orthodontic diagnosis and treatment procedures. Part 1. Results and trends. J Clin Orthod. 2008; 42:625-40.
17. Reynolds IR. A Review of Direct Orthodontic Bonding. Br J Orthod .1975; 2(3):171-8.
18. Reda J, Kristina K, Dalia S. Bracket bond failures: incidence and association with different risk factors, a retrospective study. Int J Environ Res public Health .2023;20 (5):4452
19. Alex G. Is total-etch dead? Evidence suggests otherwise. Compend Contin Educ Dent.2012; 33(1):12-4, 6-22, 4-5.
20. Tsujimoto A, Iwasa M, Shimamura Y, et al. Enamel bonding of single-step self-etch adhesives: influence of surface energy characteristics. J Dent. 2010; 38(2):123-30.
21. Ozer F, Blatz MB. Self-etch and etch-and-rinse adhesive systems in clinical dentistry. Compend Contin Educ Dent. 2013; 34(1):12-4, 6, 8.
22. Ansari ZJ, Sadr A, Moezizadeh M, et al. Effects of one year storage in water on bond strength of self-etching adhesives to enamel and dentin. Dent Mater J. 2008; 27(2):266-72.
23. Kumar SS, Rubio EJ, Noor-A-Alam M et al. Structure, Morphology, and Optical Properties of Amorphous and Nanocrystalline Gallium Oxide Thin Films. J Phys Chem C.2013; 117(8): 4194-200.
24. A R Pillai, A Gangadharan, S Kumar, J Gangadharan. Comparison in Shear Bond Strength of Orthodontic Brackets between Biofix and Conventional Bonding Systems: An in vitro Study. J Ind Orthod Soc. 2014; 48(4):461-5.
25. Joseph R, Ahmed N, Younus A A, et al. Evaluation of Shear Bond Strength of a Primer Incorporated Orthodontic Composite Resin: An In-Vitro Study. Cureus 2022; 14(4): e24088.
26. Retief DH. Failure at the dental adhesive etched enamel interface. J Oral Rehab. 1974; 1:265-84.
27. Powers JM, Messersmith ML. Enamel etching and bond strength. In: Brantley WA, Eliades T, eds. Orthodontic Materials: Scientific and Clinical Aspects. Stuttgart, Germany: Thieme; 2001:105–122.
28. AR Davari, S Yassaei, M. Goldani, et al .Effect of thermocycling on shear bond strength of a conventional etch and rinse adhesive system IJO. 2011; (6): 18-22.
29. Bishara S, Ostby A, Laffoon J,et al.Shear Bond Strength Comparison of Two Adhesive Systems Following Thermocycling. Angle Orthod. 2007; 77(2):337-41.
30. Helvatjoglu-Antoniades M, Koliniotou-Kubia E, Dionyssopoulos P. The effect of thermal cycling on the bovine dentine shear bond strength of current adhesive systems. J Oral Rehabil. 2004; 31:911-7.
31. Fjeld M, Øgaard B. Scanning electron microscopic evaluation of enamel surfaces exposed to three orthodontic bonding systems. Am J Orthod Dentofac Orthop 2006; 130(5):575-81.
32. Fitzpatrick DA, Way DC. The effects of wear, acid etching, and bond removal on human enamel. Am J Orthod 1977; 72(6): 671-81.
33. Ogaard B. Prevalence of white spot lesions in 19-year-old: a study on untreated and orthodontically treated persons 5 years after treatment. Am J Orthod Dentofac Orthop 1989; 96(5): 423-27.