Evaluation of Microleakage under Sapphire Brackets Bonded with Three Different Orthodontic Adhesives after Thermocycling and Water Storage (An in Vitro Study)

Omaima Lateef Salman[1], Reem Atta Rafeeq Al-Ani[2]

[1]Post Graduate, [2]Assistant Professor, Department of Orthodontics, College of Dentistry, University of Baghdad, Baghdad, Iraq

Abstract

Objectives: To evaluate and compare the microleakage between enamel-adhesive, bracket-adhesive interfaces at occlusal and gingival sides of sapphire brackets bonded with three different light-cure adhesive systems after thermocycling and 2 months water storage.

Materials and Methods: Sapphire brackets bonded to forty eight intact extracted upper premolar randomly assigned according to orthodontic adhesive systems used into three equal groups (n=16) with different color coding: Conventional Transbond XT; Transbond XT plus self-etching primer; Resin-modified glass ionomer cement (RMGIC) GC Fugi Ortho LC. After bonding and thermocycling, half of samples (8 teeth) in each group, tested immediately after thermocycling and 24 hours of water storage and the remaining 8 teeth were incubated in distilled water to be tested after 2 months of water storage. After each storage interval, samples were subjected to a dye penetration test and examined under a stereomicroscope with image analyzer software to assess the degree of microleakage in mm. Data was analyzed using the non-parametric tests.

Results: After both storage time intervals, RMGIC group displayed higher microleakage than other groups with high significant differences with Transbond XT group and more microleakage seen at gingival margin than occlusal margin in all groups. The microleakage values increased after 2 months storage, but without significant differences.

Conclusion: The type of adhesive systems could effect the amount of microleakage and higher value under brackets bonded with RMGIC with more microleakage gingivally than occlusally. The microleakage increased after thermocycling with 2 months water storage.

Keywords: *Microleakage; Dye penetration; Sapphire; Adhesive.*

Introduction

Despite continual effort to improve the qualities of materials and techniques of bonding procedure; including several new bracket materials, faster curing methods, and the introduction of light cure resin-modified glass ionomers and self-etch primer systems[1], the micro-leakage and enamel demineralization are still the major challenges in dental practice. Micro-leakage prompts the formation of 'white spot lesion on the tooth surface around and beneath the orthodontic brackets[2] and reduces the bond strength[3]. Polymerization shrinkage is the main drawback of light-cured adhesives and it is considered the major factor attributed to microleakage, generating additional strain, marginal gaps, and subsequently marginal leakage at the tooth-adhesive or adhesive-bracket interfaces[4],[5].

James et al.[6] were the first demonstrated the increase in likelihood of demineralization caused by microleakage around orthodontic brackets. Arikan et al.[2] and Arhun et al.[4] stated that the area under the brackets is as critical as the area around the brackets and must be considered as such.

Furthermore, microleakage can possibly result from the intraoral temperature variation from hot or cold food consumption that causes repeated expansion and contraction, adding additional stress at the bonding interfaces[7]. Several studies have shown that thermocycling test, a routinely applied aging process to simulate the oral thermal cycles in vitro studies, significantly decreases bond strength and increases microleakage at interfaces[8].

Water storage for specific period varies from months to few years is another artificial aging process[9]. Exposure to oral fluids impairs the bond integrity by causing elastic deformation, biodegradation, and physical alteration of both tooth substance and the adhesive, resulting in micro-leakage and weakening in bond strength over time[10]. Furthermore, increasing the aesthetic demands of adult orthodontic patients motivated the manufacturers to design several types of esthetic brackets, including sapphire brackets. Thus, this study was conducted to assess and compare the microleakage generated between adhesives interfaces at the occlusal and the gingival side of sapphire brackets bonded with three different orthodontic adhesives and estimate the effect of different aging conditions on microleakage values.

Materials and Methods

A sample of 48 human upper first premolars previously extracted for orthodontic purpose meeting the criteria of having an intact buccal surface, free from decays, cracks, or restorations, and had not subjected to chemical pretreatment[11], were selected and stored in a solution of 0.1% of thymol (V/W) with distilled water that changed periodically to avoid microbial growth[2],[12].

The standard edgewise Sapphire orthodontic brackets (Pure®/ OrthoTechnology, U.S.A) for maxillary first premolar with slot size of 0.022 inch were used in this study.

The sample was divided according to the orthodontic adhesive systems into 3 equal groups of 16 randomly selected teeth. To differentiate between groups, the teeth were mounted in different color-coded acrylic blocks of dimensions (20 mm x15mm x15mm). Then the samples were stored in distilled water to avoid dehydration until bonding[13].

After cleaning teeth with non-fluoridated pumice for 10 sec.[7] the teeth received the following treatments (according to manufacturer's recommendations);

Group T; Transbond XT: etching the enemal with 37% phosphoric acid gel for 30 sec,and rinsed for 15sec, then Transbond XT primer (3M, unitek) was applied and brackets were bonded with a light-cured, highly filled Transbond XT Adhesive (3M Unitek, Monrovia, California, USA).

Group S; Transbond XT plus: A self-etching primer (Transbond Plus, 3M, unitek, Monrovia, USA) was applied on buccal surface for a minimum 3-5 sec. Then Transbond XT adhesive (3M Unitek) used to bond brackets

Group G; GC Fugi Ortho LC: 20% Polyacrlic acid conditioner (SDI Co., Australia) was applied to the enemal surface for 10-20 sec., then thoroughly washed. GC Fuji Ortho LC was mixed in ratio 3.0g/1.0g of powder to liquid of RMGIC, to bond the brackets.

The adhesives were cured using the LED curing unit (Radii-cal LED, Wood pecker, China) for 10 seconds for each proximal side with light intensity `1200 mW/cm^2, measured before every curing by a radiometer[14].

After those bonding procedures, the samples were kept in distilled water at 37ºC for 24 hours. Next, the teeth subjected to thermocycling following the ISO 11405 recommendations consisting of 500 cycles between 5 °C and 55 °C distilled water baths with immersion time in each being 30 sec. and the transferring time between baths was 10 sec.[15]. Eight teeth were tested immediately following to the thermocycling and after 24hr. storage, and the remaining 8 teeth were tested after thermocycling and after 2 months storage time intervals.

To evaluate the microleakage**,** two subsequent layers of red nail varnish were applied to the entire surface of the teeth except area up to 1 mm around the brackets margins. Once the varnish was dried, the sample blocks were submerged in distilled water to minimize dehydration and then immersed for 24 hours in 2% methylene blue dye[14]. After 24 hours, the samples were cleaned to remove superficial dye and the nail varnish. Each tooth crown was further blocked with clear acrylic resin, then four parallel longitudinal sections for each acrylic blocks were done in a buccolingual direction[2] by using a microtome (MT-4 Diamond cut-off saw, USA) with abundant water coolant. The microleakage of each section examined under a stereomicroscope (Halmilton, Italy) at 40X magnification in a blinded fashion. A digital image was taken by a camera connected to the microscope, then analyzed using ImageJ® software version (Image JV. 1.46r, U.S National Institutes of Health, Bethesda, U.S.A)[14]. The microleakage was measured in mm. at enamel-adhesive and adhesive-bracket interfaces in occlusal and gingival sides for each section.

Statistical Analysis

The microleakage values of the gingival and occlusal sides were measured from four sections of each sample. Descriptives were displayed in terms of means and standard deviations. Data were analyzed using SPSS (statistical package of social science) software version 20 by Kruskal-Wallis, MannWhitney U-tests and Wilcoxon signed rank tests.

Results

Table 1 revealed highly significant differences among the three groups at different interfaces and after both storage intervals (p=0.000); G group exhibited the highest mean value at both adhesive interfaces followed by that S group then T group. There were high significant pairwise differences between most of the sample groups. Table 2 showed that the gingival side exhibited higher microleakage than the occlussal side, with highest mean value in G group at enemal-adhesive after 2months water storage. Statistically significant differences were found at bracket-adhesive in S group after 24 hours storage, and in T group after 2 months storage; while at enamel-adhesive seen in T group after 2 months, and in S group after both storage intervals, and G group after 2 months storage.

Table (1) Descriptive statistics and effect of different types of adhesives on the microleakage (mm.) among study groups.

Interface	Duration	Adhesives	Microleakage (mm)		KWH test		MWU test		
			Mean	S.D.	X2 test	p-value	Groups	Test statistic	p-value
Bracket adhesive	24 hr	T	0.282	0.213	12.821	0.000 **	T-S	8	0.012*
		S	0.656	0.250			T-G	1	0.001**
		G	0.886	0.256			S-G	14	0.059#
	2 month	T	0.398	0.390	12.186	0.000 **	T-S	6	0.006**
		S	0.932	0.313			T-G	4	0.003**
		G	1.365	0.460			S-G	12	0.036*
Enamel adhesive	24 hr	T	0.437	0.384	13.726	0.000 **	T-S	4	0.003**
		S	1.234	0.410			T-G	5	0.005**
		G	1.233	0.233			S-G	29	0.753#
	2 month	T	0.563	0.316	14.707	0.000 **	T-S	3	0.002**
		S	1.248	0.353			T-G	0	0.001**
		G	1.281	0.208			S-G	27	0.600#

*Significant $p < 0.05$; ** Highly significant $p \leq 0.01$; # Non-significant $p > 0.05$

Table (2) Comparisons of microleakage in gingival and occlusal margins at bracket-adhesive and enamel-adhesive interfaces among study groups

Interface	Adhesives duration	Duration	Micoleakage (mm)				Difference	
			Occlusal		Gingival			
			Mean	S.D.	Mean	S.D.	WSR test	p-value
Bracket adhesive	T	24 hr	0.274	0.255	0.290	0.208	-0.135	0.893#
		2 months	0.275	0.264	0.521	0.580	-1.992	0.046*
	S	24 hr	0.426	0.214	0.886	0.406	-2.240	0.025*
		2 months	0.820	0.566	1.043	0.458	-1.400	0.161#
	G	24 hr	0.868	0.391	0.904	0.267	-0.560	0.575#
		2 months	1.285	0.423	1.444	0.575	-1.120	0.263#
Enamel-adhesive	T	24 hr	0.366	0.250	0.507	0.573	-0.734	0.463#
		2 months	0.395	0.298	0.731	0.414	-1.960	0.049*
	S	24 hr	0.899	0.383	1.568	0.651	-2.240	0.025*
		2 months	1.113	0.402	1.382	0.359	-1.960	0.049*
	G	24 hr	1.160	0.317	1.306	0.196	-1.400	0.161#
		2 months	1.103	0.099	1.458	0.389	-2.100	0.036*

**Significant $p < 0.05$; # Non-significant $p > 0.05$

Dissucusion

The microleakage around and under the orthodontic brackets is a major factor that endangers the longevity of the orthodontic bond and increase a patient's risk of white spot lesions that may develop as early as 1 month of orthodontic treatment[16]. The microleakage in the present study was assessed by the most commonly used method, the dye penetration, as it is simple, rapid, economical and used in most previous studies[2],[14],[17].

The microleakage was measured at enamel-adhesive and adhesive-bracket interfaces similar to studies of Arhun et al.[4] and Vincente et al.[18], as their final clinical outcome is different. Microleakage at enamel-adhesive interface prompt the occurrence of white spot lesions, while the microleakage at adhesive-bracket interface may lead to bracket debonding. However, James et al[6] stated no relation between microleakage and bond strength.

The result of this study showed that all groups displayed microleakage and the highly significant more microleakage under bracket bonded with RMGIC adhesive at both adhesive interfaces as compared to the Transbond XT SEP system and the total-etched Transbond XT adhesive after both storage intervals.

However, the remineralizing of demineralized enamel by RMGIC might counteract the risk of enamel demineralization caused by microleakage between adhesive-enamel interface[19]. The most important factor related to microleakage under orthodontic brackets is the polymerization shrinkage[2] which varies by the adhesive composition which includes the filler content, diluent percentage, the degree of conversion of the monomer, and the curing technique[20]. Bracket bonded in group S showed highly significant more microleakage than the group T, similar to study of Uysal et al[3]. Enamel etching with phosphoric acid results in lower microleakage due to the improvement in resin tag formation, and deeper etching pattern compared with that of self-etching primer that is not deep enough to ensures better resin penetration which is a curical factor in the fight against microleakage. Nevertheless, a deeper etching pattern does not guarantee a sealant–enamel interface that is free of microleakage[21]. This is supported by an in vivo study[22], which found that after 24 months there is no difference between sealants applied over phosphoric acid-etched teeth, and self-etching adhesives.

The gingival sides in this study showed a relatively greater microleakage than the occlusal sides at both storage intervals, which was significant in most adhesive interface of groups. This is consistent with Arhun et al.[4] and Ramoglu et al.[19] studies, which related this variation to the relative surface curvature, which may lead to thicker adhesive at the gingival side.

Percolation might cause microleakage and occurs due to mismatch in the coefficients of thermal expansion of brackets, enamel and adhesive[7]. In this study, thermaocycling test was used to simulate percolation, similar to Ulker et al. study[23]. Another variable influences the microleakage is the adhesive degradation as a result of immersion in water or exposure to oral fluids[24]. The result of this study revealed an increasing in microleakage in samples tested after 2 months water storage for all adhesive types, this may attributed to water diffusion into the bonding interface causing hydrolytic degradation of the interface components[24]. The hot water from the thermocycling test, might speed up the hydrolysis of the resin and extract the under polymerized resin[25]. But, this increasing is not-statistically significant might be due to insufficient time required for the degradation to take place.

Conclusion

The type of adhesive systems significantly effected the amount of microleakage and higher value under brackets bonded with RMGIC with more microleakage gingivally than occlusally. The microleakage increased after thermocycling with 2 months water storage.

Acknowledgement: We would like to thank Dr. Zuhair Al-Johar for his assistance in final drafting of the article.

Ethical Clearance: The Research Ethical Committee at scientific research by ethical approval of both MOH and MOHSER in Iraq

Conflict of Interest: None

Funding: Self-funding

References

[1] Gange P, The evolution of bonding in orthodontics. Am J Orthod Dentofacial Orthop; 2015 147: 56-63.

[2] Arıkan S, Arhun N, Arman A, Cehreli SB. Microleakage beneath ceramic and metal brackets photopolymerized with LED or conventional light curing units. Angle Orthod. 2006; 76:1035–1040.

[3] Uysal T, Ulker M, Ramoglu SI, Ertas H. Microleakage under metallic and ceramic brackets bonded with orthodontic self-etching primer systems. Angle orthod.2008; 186:1089-94.

[4] Arhun N, Arman A, Cehreli SB, Arikan S, Karabulut E, Gulsahi K. Microleakage beneath ceramic and metal brackets bonded with a conventional and an antibacterial adhesive system. Angle Orthod. 2006;76:1028–1034.

[5] Buyuk SK, Cantekin K, Demirbuga S, Ozturk MA. Are the low-shrinking composites suitable for orthodontic bracket bonding? Eur J Dent 2013;7:284-8..

[6] James JW, Miller BH, English JD, Tadlock LP, Buschang PH. Effects of high speed curing devices on shear bond strength and microleakage of orthodontic brackets. Am J Orthod Dentofacial Orthop. 2003;123:555–561

[7] Sabzevari B, Ramazanzadeh BA, Moazzami SM, et al. Microleakage under Orthodontic Metal Brackets Bonded with Three Different Bonding Techniques

with/without Thermocycling. J Dent Mater Tech. 2013;2:21-28.

[8] Helvatjoglu-Antoniades M, Kalinderis K, Pedulu L, Papadogiannis Y. The effect of pulse activation on microleakage of a 'packable' composite resin and two 'Ormocers'. J Oral Rehabil 2004; 31: 1068-74.

[9] De Munck J., Van Landuyt K., Coutinho E., et al. Micro-tensile bond strength of adhesives bonded to class-I cavity-bottom dentin after thermo-cycling. Dent Mater. 2005; 21: 999–1007.

[10] Arnold RW, Combe EC, Warford JH Jr. Bonding of stainless steel brackets to enamel with a new self-etching primer. Am J Orthod Dentofacial Orthop. 2002;122:274-276.

[11] Bishara SE, Ostby AW, Laffoon JF, Warren J. Shear bond strength comparison of two adhesive systems following thermocycling: a new self-etch primer and a resin-modified glass ionomer. Angle Orthod.2007; 77: 337-41.

[12] Baygin O, Korkmaz F, Tüzüner T, Tanriver M. The effect of different enamel surface treatments on the microleakage of fissure sealants. Lasr med sci. 2012;27:153-160.

[13] Montasser M, Drummond J, Roth J R, Al-Turki L, Evans CA. Rebonding of orthodontic brackets. Part II, an XPS and SEM study. Angle Orthod. 2008; 78: 537-44.

[14] Atash R, Fneiche A, Cetik S, Bahrami B, Balon-Perin A, Orellana M, & Glineur R. In vitro evaluation of microleakage under orthodontic brackets bonded with different adhesive systems. Eur J Dent. 2017; 11: 180

[15] Sokucu, Oral, et al. "Shear bond strength of orthodontic brackets cured with different light sources under thermocycling." Eur J Dent. 2010; 3: 257.

[16] O'Reilly MM, Featherstone JD. Demineralization and remineralization around orthodontic appliances: an in vivo study. Am J Orthod Dentofacial Orthop. 1987;92:33–40.

[17] Davari A, Yassaei S, Karandish M, et al. In vitro evaluation of microleakage under ceramic and metal brackets bonded with LED and plasma arc curing. J Contemp Dent Pract. 2012;13:644-649.

[18] Vicente A, Ortiz AJ, Bravo LA. Microleakage beneath brackets bonded with flowable materials: effect of thermocycling. Eur J Orthod. 2009; 31: 390-6.

[19] Ramoglu SI, Uysal T, Ulker M, et al. Microleakage under ceramic and metallic brackets bonded with resin-modified glass ionomer. Angle Orthod. 2009;79:183-143.

[20] Sener Y, Uysal T, Basciftci FA, Demir A, Botsali MS. Conventional and high-intensity halogen light effects on polymerization shrinkage of orthodontic adhesives. Angle Orthod. 2006;76:677–681.

[21] Celiberti P, Lussi A. Use of a self-etching adhesive on previously etched intact enamel and its effect on sealant microleakage and tag formation. J Dent. 2005;33:163–171.

[22] Feigal RJ, Quelhas I. Clinical trial of a self-etching adhesive for sealant application: success at 24 months with Prompt L-Pop. Am J Dent. 2003;16:249–251.

[23] Ulker M, Uysal T, Ramoglu SI, Ertas H. Microleakage under orthodontic brackets using high-intensity curing lights. Angle Orthod 2009; 79: 144-9.

[24] De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, et al.. A critical review of the durability of adhesion of tooth tissue: methods and results. J Dent Res. 2005;84:118-132.

[25] Hashimoto M, Ohno H, Sano H, Tay FR, Kaga M, Kudou Y, Oguchi H, Araki Y, Kubota M. Micromorphological changes in resin–dentin bonds after 1 year of water storage. J Biomed Mater Res. 2002; 63: 306–311.