

Effect of Three Light Curing Protocols and Load Cycling on Microleakage of Class V Composite Restorations

*¹Abdolrahim Davari ²Alireza Daneshkazemi ³Tahere Taghizadeh

*¹Associate Professor, Dept. of Operative Dentistry, Social Determinants of Oral Health Research Center, School of Dentistry, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.
E-mail: rdavari2000@yahoo.com

²Associate Professor, Dept. of Operative Dentistry, Social Determinants of Oral Health Research Center, School of Dentistry, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.

³General Practitioner.

Abstract

Objective: Different methods have been suggested to overcome the polymerization shrinkage of composite restorations. Changing the light curing protocol to improve polymerization by using new light curing units is among these methods. The new devices are more efficient, portable and durable and produce less heat. This study aimed to assess the marginal microleakage of class V composite restorations subjected to three different light curing protocols and mechanical cycles.

Methods: This was an in-vitro experimental study. Class V cavities measuring 2x3x1.5 mm were prepared on the buccal and lingual surfaces of 90 extracted human premolar teeth 1.5 mm above and below the cement enamel junction (CEJ). The samples were selected using convenience sampling and divided into 9 experimental groups of 10 each by using the Table of Random Numbers to control for the bias. The cavities were restored with packable composite resin along with Tetric-N-Bond and cured using three light curing protocols of conventional (680 mW/cm² for 30s), soft-start (380 mW/cm² for 10s followed by 680 mW/cm² for 20s) and pulse (680 mW/cm² for 30s, 1s interval and 1s of lighting). The teeth were then subjected to mechanical cycles of 0, 500,000 and 1,000,000 and immersed in 2% Fuchsin for 24h. The teeth were then sectioned in half from the middle of the restoration buccolingually and the degree of microleakage was evaluated under a stereomicroscope (Zeiss, Germany) with 40X magnification. Data were analyzed using the Kruskal Wallis and the Mann-Whitney tests.

Results: Despite the structural differences between the enamel and dentin margins, no significant difference was found in the degree of microleakage between the enamel (occlusal wall, $p>0.05$) and dentin (gingival wall, $p>0.05$) margins among the understudy groups.

Conclusion: The degree of marginal microleakage in soft-start (SS) polymerization was not significantly different from that in conventional and pulse polymerizations of class V composite restorations.

Key words: Conventional, Mechanical cycles, Microleakage, Pulse, Soft-start.

Please cite this article as follows:

Davari AR, Daneshkazemi A, Taghizadeh T. Effect of Three Light Curing Protocols and Load Cycling on Microleakage of Class V Composite Restorations. J Dent Sch 2014; 32(2): 71-79.

Received: 15.04.2013

Final Revision: 08.07.2013

Accepted: 29.10.2013

Introduction:

Use of composite resin restorative material is increasing due to advantages like acceptable esthetics, relatively easy clinical application, preserving the tooth structure, low thermal conductivity and absence of galvanic corrosion. However, composite application is limited in the posterior teeth due to problems such as

polymerization shrinkage. During polymerization, conversion of monomer molecules to a polymer network leads to shrinkage. In general, shrinkage occurs in two phases:

1. Pre-gel: During this phase the composite resin can flow and the stresses are relieved.
2. Post-gel: During this phase, the composite resin cannot flow to relieve the shrinkage

stresses (1, 2).

The remaining stresses can cause fatigue within the restoration or at the restoration-tooth interface leading to bond weakening, gap formation at the tooth-restoration interface and occasionally stress and crack in the restorative material or tooth. Polymerization shrinkage affects the marginal integrity and causes microleakage. Microleakage is defined as the passage of bacteria and their products via the tooth-restoration interface causing pulpal irritation or even necrosis. Several techniques have been suggested to overcome polymerization shrinkage. Changing the light-curing protocol is among the suggested methods. Some studies have demonstrated that in light-cure composites, decreasing the light intensity increases the setting time. Thus, polymerization stresses are decreased as the result of increased flow time of the composite (3).

In SS polymerization technique, primary setting of the material is done with low intensity light in order for the polymerization to start at a slow speed. As the result, stresses are minimized and maximal physical properties are achieved. In fact, this method prolongs the duration of Viscoelastic state of the material and increases its flow (4).

In 2003, Barros, *et al.* evaluated the effect of light curing modes of different intensities on the microleakage of two composite resin restorations. Standard class V cavities were prepared on the buccal enamel surface of 80 recently extracted bovine incisors. The teeth were randomly divided into 8 experimental groups. Two composite resins (Z250 and Charisma) and four different polymerization modes (conventional: 680 mW/cm²/30 seconds; soft start: 380 mW/cm²/10 seconds+ 680 mW/cm²/20 seconds; plasma arc curing: 1480 mW/cm²-3 seconds; combined: 380 mW/cm²-10 seconds + 1480 mW/cm²-3 seconds). The SS and combined modes of polymerization showed more favorable results and were significantly

different from the conventional and plasma arc modes for both resin composites. There were no significant differences between the two composite resins (5).

In a study conducted by Yang, *et al.*, in 2010, the effect of two light curing modes on marginal microleakage of packable resin base restorations was evaluated. In their study, 120 cylindrical specimens were made of EcuSphere-Carat, (Hamburg, Germany), Tetric Ceram HB (3M ESPE, USA) and Filtek P60 (Ivoclar, Lichtenstein, Germany) and cured with SS (600 mW/cm² for 30s and 300mW/cm² for 10s) or the standard (600mW/cm² for 40s) modes with halogen light. Marginal adaptation was checked by measuring the gap width under an electron microscope (6).

Filtek P60 and Tetric Ceram HB in SS mode showed shallower marginal gaps compared to the standard light curing technique ($p < 0.05$, $t = 5.78$ and $p < 0.05$, $t = 5.64$). However, the difference in marginal gap between the two composites and EcuSphere-Carat was not significant ($p > 0.05$ and $t = 1.62$).

There is a possibility that different light curing modes prevent or decrease marginal microleakage. To the best of our knowledge, no previous study has compared the effect of different light curing protocols on the marginal microleakage of class V composite restorations. This study aimed to assess the effect of three light curing modes of Soft-Start (SS), conventional (C) and pulse (P) along with 0, 500,000 and 1,000,000 load cycles on the microleakage of class V composite restorations.

Methods:

In this in-vitro experimental study, samples were selected by convenience sampling and use of Table of Random Numbers. Taking into account similar studies, $\alpha = 0.05$, $\beta = 0.3$ and $d = 8$ and using the related statistical software and formula, sample size was calculated to be 10 in each

group (a total of 90). A total of 90 extracted human premolar teeth were randomly selected. The teeth were intact and free from caries, wear, developmental defects or cracks. The bias was eliminated by the randomization of samples.

Class V cavities measuring 2 (mesio-distal) x 3 (occluso-cervical) x 1.5 mm (cavity depth) were prepared on the buccal and lingual surfaces of teeth 1.5mm above (in the enamel) and below (in the dentin) the CEJ with a high speed hand piece and a fissure bur with 0.8mm diameter (Tizkavan, Tehran, Iran) under water and air spray. The enamel margin received a 45-degree bevel (Figure 1).



Figure 1- Preparation of class V cavity

One fissure bur was used for 5 preparations. A Universal periodontal probe was used to measure the dimensions of the cavities. The teeth were dried with gentle air spray. Enamel was etched for 15s and dentin for 10s simultaneously using 37% phosphoric acid gel (Cond AC 37, FGM-Dental Products Ltd., Joinville, SC, Brazil). The phosphoric acid was washed off by water spray for 15s. Bonding steps were performed according to the manufacturer's instructions (Vivadent) using wet bonding technique. Enamel was completely dried while dentin surface was maintained moist. Tetric-N-Bond (Ivoclar, Vivadent) was applied to the cavity walls by a microbrush; 10s time was allowed for the primer to penetrate into the tooth structure. Air was gently sprayed from 20cm distance on the cavity. By doing so, the solvent was evaporated and a thin uniform layer of bonding agent was obtained. The bonding

agent was light cured for 20s with Wood Pecker LED light curing unit (Zhengzhou, Henan, China) Mainland with an intensity of 400 mW/cm². The cavities were restored with A2 shade of composite resin (Valux resin-based dental restoration material, 3M, ESPE). After 24h of storage in saline solution at room temperature, the composite was polished with a knife-edge composite polishing bur. The teeth were then randomly divided into 3 groups of A, B and C each with 30 specimens. The restoration was covered with a celluloid tape.

Group A: The specimens were light cured using SS mode with an intensity of 380 mW/cm² for 10s followed by 680 mW/cm² for 20s. The tip of the light-curing device had 1-2mm distance from the restoration.

Group B: The specimens were light cured using the conventional mode with an intensity of 680 mW/cm² for 30s. The tip of the light-curing device had 1-2mm distance from the restoration.

Group C: The specimens were light cured using the pulse mode with an intensity of 680 mW/cm² for one second. The tip of the light-curing device had 1-2mm distance from the restoration surface covered by a celluloid tape. The teeth in each group were then randomly divided into 3 subgroups (a total of 9).

The specimens requiring mechanical loading were mounted in the mold of Load Cycling Device (Vafaye Co, Iran) using autopolymerizing acrylic resin (Acropars 2000, Iran) in such way that the tooth crown was out of the acrylic resin. The specimens underwent load cycling and were then stored in distilled water at room temperature. The entire surfaces of the specimens were covered with 2 coats of nail varnish except for one millimeter around the restoration margins and samples were immersed in 2% methylene blue (neutralized) in 9 different bottles for 24h at room temperature. The specimens were then rinsed under running water to remove excess dye. All teeth were then sectioned by 0.8 bur (Tizkavan, Tehran, Iran)

and high speed hand piece buccolingually along the long axis of the tooth from the middle of the restoration. The penetration depth of methylene blue was evaluated using a stereomicroscope (Zeiss, Germany) at 40X magnification.

The criteria used for classification of microleakage was as follows:

Score 0: No dye penetration

Score 1: Dye penetration into the enamel

Score 2: Dye penetration into the enamel and dentin

Score 3: Dye penetration into the enamel, dentin and axial wall

For each tooth, the section with the greatest degree of microleakage was evaluated for dye penetration assessment. Two examiners independently graded the restorations in terms of microleakage. Controversial cases were re-evaluated until an agreement was reached between the two examiners.

Enamel and dentin margins were separately graded (Figures 2-5).



Figure 2- Score 0 of dye penetration (dentin margin)



Figure 3- Score 1 of dye penetration (enamel margin)

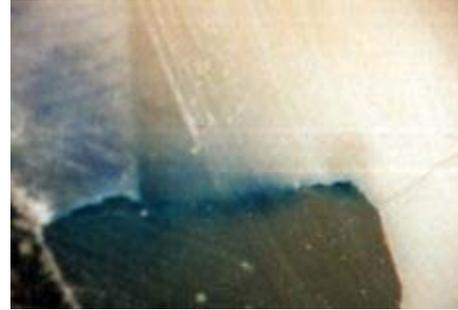


Figure 4- Score 2 of dye penetration (enamel margin)

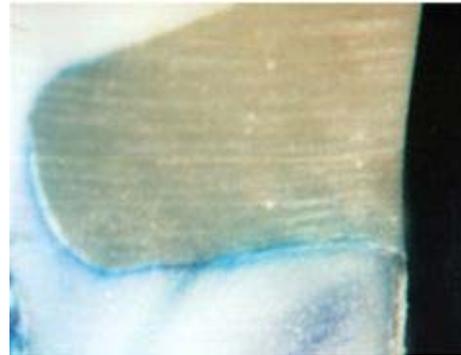


Figure 5- Score 3 of dye penetration (dentin margin)

Data were analyzed using the Kruskal Wallis and the Mann Whitney U tests. The Mann Whitney U test was applied for pair wise comparison of microleakage while the Kruskal Wallis test was used for multiple comparisons.

Results:

Microleakage was microscopically evaluated at the enamel and dentin margins in each group using the Kruskal Wallis and the Mann Whitney tests. No statistically significant differences were found among groups in dentin margin ($p_{ss}=0.337$, $p_p=0.300$, $p_c=0.241$) or enamel margin ($p_{ss}=0.467$, $p_c=0.824$, $p_p=0.291$) microleakage (Tables 1 and 2).

The mean degree of microleakage at the enamel margin of all groups was not significantly different and was 1.73 for SS, 1.6 for C and 1.76 for P groups. The mean microleakage at the dentin margin in group 3 (pulse, 2.6) was higher than that in group 1 (SS, 2.1). The lowest dentin

margin microleakage was seen in group 2 (C, 1.96). However, overall, no significant difference was found. The mean microleakage at both margins was 1.92 in group 1 (SS), 1.78 in group 2 (C) and 1.92 in group 3 (P); which was not significantly different among groups ($p=0.397$, Tables 2-4).

In our study, the highest degree of microleakage in the occlusal margin was score 2 (dye penetration into enamel and dentin) with 64.4% prevalence, followed by score 1 (penetration into enamel) with 31.1% prevalence. The highest

degree of microleakage in the gingival margin was score 2 (dye penetration into enamel and dentin) with 73.3% prevalence followed by score 3 (penetration into enamel, dentin and axial wall) with 15.6% prevalence. No specimen had score 0 (no dye penetration) microleakage at the gingival margin (Table 5).

Increasing the loading cycles and the three polymerization techniques did not significantly increase microleakage at the enamel and dentin margins (Tables 6, 7).

Table 1- Comparison of mean microleakage in enamel margin of different groups subjected to load cycling

Load cycling	Zero			500000			1000			p-value
	Median	mean	SD	Median	mean	SD	Median	mean	SD	
Light curing technique										
Soft start	2	1.60	0.52	2	1.70	0.48	2	1.90	0.57	0.467
Conventional	2	1.5	0.71	2	1.60	0.52	2	1.70	0.48	0.824
Pulse	2	1.60	0.52	2	1.7	0.48	2	2	0.67	0.319
P-value		0.979			0.865			0.522		
Kruskal-wallis test						$p>0.05$				

Table 2-Comparison of the mean microleakage at the dentin margin of different groups subjected to load cycling

Load cycling	Zero			500000			1000			p-value
	Median	mean	SD	Median	mean	SD	Median	mean	SD	
Light curing technique										
Soft start	2	2	0.47	2	2	0.47	2	2.3	0.67	0.337
Conventional	2	1.8	0.63	2	1.90	0.57	2	2.2	0.42	0.241
Pulse	2	1.9	0.32	2	2.1	0.32	2	2.2	0.63	0.300
P-value		0.628			0.617			0.857		
Kruskal-wallis test						$p>0.05$				

Table 3- Comparison of the mean microleakage at both enamel and dentin margins of different groups subjected to load cycling

Load cycling	Zero			500000			1000			p-value
	Median	mean	SD	Median	mean	SD	Median	mean	SD	
Light curing technique										
Soft start	2	1.8	0.52	2	1.85	0.49	2	2.1	0.64	0.214
Conventional	2	1.65	0.67	2	1.75	0.55	2	1.95	0.51	0.283
Pulse	2	1.75	0.44	2	1.9	0.45	2	2.1	0.64	0.129
P-value		0.759			0.593			0.639		
Kruskal-wallis test						$p>0.05$				

Table 4- Comparison of the mean microleakage at dentin and enamel margins among the study groups

Margin score	Number	Median	mean	SD	p-value
Enamel	90	2	1.7	0.55	
Dentin	90	2	2.04	0.52	<0.001

Mann-Whitney test

Table 5- Comparison of the mean microleakage at dentin and enamel margins among the study groups

Margin score	0	1	2	3	Total
Enamel	1 (1.1%)	28(31.1%)	58(64.4%)	3(3.3%)	90(100%)
Dentin	0(0%)	10(11.1%)	66(73.3%)	14(15.6%)	90(100%)

Mann-Whitney test

Table 6- Comparison of the mean microleakage based on the light curing protocol

Light curing porotocol	Median	mean	SD	p-value
Soft start	2	1.92	0.56	
Conventional	2	1.78	0.58	0.379
Pulse	2	1.92	0.53	

Kruskal-wallis test

Table 7- Comparison of the mean microleakage based on the load cycling

Load cycling	Median	mean	SD	p-value
Zero	2	1.73	0.55	
500000	2	1.83	0.49	0.01
1000000	2	2.05	0.59	

Discussion

Polymerization shrinkage is a complex phenomenon depending on several factors. Volumetric shrinkage causes debonding stresses at the tooth-restoration interface.

Parts of these stresses are compensated by the flow of the material during the first phase of viscous polymerization before the material reaches the gelation phase. Time to reach gelation depends on the speed of reaction; which per se is influenced by the intensity of the light curing unit and the concentration of the initiator molecules (7). Soft-start polymerization aims to prolong the reaction time before reaching the gelation point. In this technique, by decreasing the intensity of primary lighting, the flow capacity of composite increases. After that, high intensity light is used to achieve complete polymerization and ideal mechanical properties (8).

In our study, a light curing unit (Wood Pecker LED, Zhengzhou, Henan, China (Mainland)] with three different lighting protocols of soft-start (with primary intensity of 380 mW/cm² for 10s followed by an intensity of 680 mW/cm² for 20s), conventional (with an intensity of 680 mW/cm² for 30s) and pulse (with an intensity of 680 mW/cm² for 30s+ 1 s of lighting+ 1s interval) were used and the effect of these three polymerization techniques on the microleakage of class V composite restorations was evaluated. Packable composite resin (ESPE, Valux) along with N-Bond (Tetric, Vivadent) was used. The preparation design of the cavities simulated the clinical setting. The bond strength of the currently used bonding systems is high enough to resist polymerization shrinkage stresses at the initial phases of curing; but after the application of functional loads or thermal stresses, bond failure may occur. Thus, the restored teeth in our study were divided into 3 groups and subjected

to 500,000 and 1,000,000 thermal cycles.

The thickness of the restorative material, size and percentage of filler particles and the distance from the tip of the light-curing unit to the restoration surface affect the passage of light (9). Thus, all these factors were standardized in our study so that any reduction in polymerization shrinkage can be attributed to the lighting protocol. Our study results showed that soft-start, conventional and pulse light curing protocols along with different mechanical cycles were not significantly different in terms of microleakage in the enamel and dentin margins ($p_p=0.129$, $p_c=0.283$ and $p_{ss}=0.214$).

This finding is not in accord with the results of Ratih, *et al.* in 2006 (10). They found that soft-start polymerization depended on the primary lighting intensity and the correlation between the primary and final lighting intensities. If the primary light curing intensity is 180 mW/cm² and 166 mW/cm² and the final light curing intensity is 600 mW/cm² and 450 mW/cm², marginal fit decreases compared to the conventional method (with an intensity of 450 mW/cm² or 600 mW/cm²). However, if the primary light intensity is higher (360mW/cm² and 315 mW/cm²), the marginal fit in the soft-start technique would be better than that in the conventional method. The reason is that the primary light curing with low intensity plays no role in the composite resin setting and polymerization only occurs by high intensity lighting. Thus, marginal fit or microleakage will not be different in the three methods if the intensity of the primary lighting is not sufficient. This justification is in accord with the findings of Friedl, *et al.* in 2000 (8).

Also, high intensity of primary light curing does not allow adequate flow to decrease the stresses in the composite resin. On the other hand, if the light intensity is not adequately high, it cannot activate adequate number of initiator molecules to initiate the reaction. Thus, final curing of the polymerized composite requires high intensity

lighting. Therefore, in our study, minimum intensity (380 mW/cm²) was used in the SS technique. In another study by Yap, *et al.* in 2001, SS method was not effective to decrease polymerization shrinkage compared to the conventional method (11). They stated that such lack of difference may be due to the different concentrations of photo initiators in different types of composites (12).

This issue may explain the difference between our study results and those reporting that soft-start method decreases microleakage or improves marginal fit. In our study, microleakage in the enamel and dentin margins was not significantly different among the pulse, soft-start and conventional polymerization techniques. This finding indicates that adhesive systems (new generation) are resistant to composite-enamel and composite-dentin bond failures. Increasing the load cycles could not significantly increase the marginal microleakage in the enamel or dentin margins of class V composite restorations. This finding is in agreement with the results of Hakimeh, *et al.* (2000), Bedran-de-Castro, *et al.* (2004), Mitsui, *et al.* (2003) and Campos, *et al.* (2008) (13-16) but in contrast to those of Jang, *et al.* (2001)(17). This difference may be due to the type of composite resin used. Moreover, Jang, *et al.* (2001) thermocycled specimens for 500 cycles before subjecting them to mechanical cycles. They concluded that mechanical loading increases the microleakage (17). Our results were in contrast to those of Sarr, *et al.* (2010) (18). They stated that load cycling increased the microleakage in all specimens. This difference may be attributed to the fact that in their study, specimens were placed in dye during and after loading while in our study specimens were placed in dye after mechanical loading. Moreover, in the current study, 60N load was applied which was lower than the load exerted during mechanical loading on teeth in the study by Sarr, *et al.* (125N) (18).

In addition to the discussed subjects regarding the load, number of cycles, placement in dye and association with thermocycling, such conflicting results may be due to the type of extracted teeth, using disinfecting agents before the experiment, size of prepared cavities, number of mechanical cycles, the load applied and type of dye as well. Also, the bond strength of bonding agents is high enough to resist mechanical loads immediately after bonding and during the clinical service and does not compromise the integrity of the tooth-restoration interface.

Conclusion:

The degree of marginal microleakage in soft-start polymerization was not significantly different from that in conventional and pulse polymerizations of class V composite restorations. Within the limitations of this study,

we concluded that soft-start polymerization was not effective for decreasing the microleakage in medium-size class V composite restorations. Clinical studies are required to assess extensive restorations polymerized by the mentioned three techniques. In this study, increasing the mechanical loads did not affect the microleakage of class V cavities. Conduction of similar studies on larger sample sizes may yield significant results.

Acknowledgment

This study was part of a doctorate thesis approved by Shahid Sadoughi University in Yazd (#1441). The authors would like to thank all those cooperated in the conduction of this study.

Conflict of Interest: “None Declared”

References:

1. El-Korashy DI. Post-gel shrinkage strain and degree of conversion of preheated resin composite cured using different regimens. *Oper Dent* 2010; 35:172-179.
2. Knezevic A, Sariri K, Sovic I, Demoli N, Tarle Z. Shrinkage evaluation of composite polymerized with LED units using laser interferometry. *Quintessence Int* 2010; 41:417-425.
3. Heymann H, Swift EJ, Ritter AV, Sturdevants CM. Sturdevant's art and science of Operative dentistry. 6th Ed. USA. St. Louis: The C. V. Mosby Co. 2013; Chap 9: 221-222.
4. Summit JB, Rabbins JW, Schawartz RS. Fundamentals of operative dentistry. 3rd Ed. Quintessence Publishing Co. 2006; Chap 10: 293-295.
5. Barros GK, Aguiar FH, Santos AJ, Lovadino JR. Effect of different intensity light curing modes on microleakage of two resin composite restorations. *Oper Dent* 2003; 28: 642-646.
6. Yang JY, ZhangSHY, Chen SH, Feng L. Effect of two light-curing modes on marginal adaptation and microhardness of packable posterior resin-based composites. *J Clin Rehabil Tissue Engineering Res* 2010; 14: 8904-8907.
7. Yazici AR, Celik C, Dayangac B, Ozgunaltay G. Effects of different light curing units/modes on the microleakage of flowable composite resins. *Eur J Dent* 2008; 2: 240-246.
8. Friedl KH, Schmalz G, Hiller KA, Märkl A. Marginal adaptation of class V restorations with and without “softstart-polymerization”. *Oper Dent* 2000; 25: 26-32.
9. Yap AU, Soh MS, Siow KS. Effectiveness of composite cure with pulse activation and soft-start polymerization. *Oper Dent* 2002; 27: 44-49.
10. Ratih DN, Palamara JE, Messer HH. Minimizing dentinal fluid flow associated with gapformation. *J Dent Res* 2006; 85: 1027-1031.

11. Yap AU, Ng SC, Siow KS. Soft-start polymerization: influence on effectiveness of cure and post gel shrinkage. *Oper Dent* 2001; 26: 260-266.
12. Yap AU, Soh MS, Siow KS. Post-gel shrinkage with pulse activation and soft start polymerization. *Oper Dent* 2002; 27: 81-87.
13. Hakimeh S, Vaidyanathan J, Houpt ML, Vaidyanathan TK, Von Hagen S. Microleakage of compomer classV restorations: effect of loadcycling, thermal cycling and cavity shape differences. *J Prosthet Dent* 2000; 83: 194-203.
14. Bedran-de-Castro AK, Pereira PN, Pimenta LA, Thompson JY. Effect of thermal and mechanical loadcycling on nanoleakage of class II restorations. *J Adhes Dent* 2004; 6: 221-226.
15. Mitsui FH, Bedran-de-Castro AK, Ritter AV, Cardoso PE, Pimenta LA. Influence of load cycling on marginal microleakage with two self-etching and two one-bottle dentin adhesive systems in dentin. *J Adhes Dent* 2003; 5: 209-216.
16. Campos PE, Barceleiro Mde O, Sampaio-Filho HR, Martins LR. Evaluation of the cervical integrity during occlusal loading of Class II restorations. *Oper Dent* 2008; 33: 59-64.
17. Jang KT, Chung DH, Shin D, García-Godoy F. Effect of eccentric load cyclig on microleakage of Class V flowable and packable composite resin restorations. *Oper Dent* 2001; 26: 603-608.
18. Sarr M, Kane AW, Vreven J, Mine A, Van Landuyt KL, Peumans M, *et al.* Microtensile bond strength and interfacial characterization of 11 contemporary adhesives bonded to bur-cut dentin. *Oper Dent* 2010; 35: 94-104.