The Effect of Two Adhesive Agents on Shear Bond Strength Between Fresh Dental Amalgam and Resin Composite

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Abstract

Objective: To assess and compare the results on the bond strength of two adhesive agents that bond fresh amalgam to two types of composite restorations, and to check the mode of bond failure.

Methods: Sixty standardized circular cavities were prepared in a block of polymethyl methacrylate with standardized dimensions. Fresh amalgam was condensed to fill the cavity, then a gelatin mold with standardized dimensions was placed over the fresh amalgam, and the composite resin was bonded to the amalgam. Samples were assigned into three main groups, each containing (20) samples. G1: Amalgam bonded to composite without adhesive agent, G2**:** Amalgam bonded to composite by single bond universal adhesive, G3: Amalgam bonded to composite by scotch bond MPP, and each group was divided into two subgroups of (n=10) (Nanofill and Nanohybrid composite) to measure shear bond strength, which was followed by evaluation of debonding in all samples under a stereomicroscope to assess the mode of failure.

Results: The results showed that G3 has higher shear bond strength than G1 and G2, and this is statistically significant at (p=0.001, p=0.005) respectively, while G1 has the lowest shear bond strength and a statistically non-significant difference from G2 at (p=0.539). It was also found that the type of composite resin has no effect on bond strength and statistically non-significant difference was found for any of the sub-groups. Following debonding of all the samples, they were examined under a stereomicroscope, and the adhesive failure present was about (%65), and mixed failure present about (%35), while cohesive failure was (%0).

Conclusions: Highest bond strength was found with Scotch bond multi-purpose plus (SBMPP) agent compared to other groups. The strength of the fresh amalgam bonding to the composite resin without an adhesive agent was low. The bond strength with single bond universal adhesive was lower than with the SBMPP system.

Keywords: *Fresh amalgam, Composite resin, Adhesive agent, Shear bond strength.*

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Introduction

A restoring material for direct dental restorations characterized by simplicity of manipulation, that minimizes the amount of tooth reduction, low cost, highly aesthetic, with the ability to bond to the tooth structure and improved mechanical property would be the best choice for clinicians interested in conservative dental treatment. Hence, the most preferred materials for such situations are dental amalgam and composite resin[1]. Dental amalgam is characterized by high strength, high wear resistance, and greater dimensional stability. Additionally, it is less affected by moisture and considered as the only material which has self-sealing ability with time, but because of its lack of aesthetic appearance and bonding ability there is a preference for composite resin which is characterized by both good aesthetics and bonding ability[2,3], but despite the improvement in its mechanical properties it still has some limitations regarding its use in large cavities and deep margins. Moreover, because of its sticky nature, achieving perfect bonding, isolation, and achieving a light curing in deep margins is still highly difficult. Besides, polymerization shrinkage of the material is still an unresolved issue[4-7]. Therefore, to achieve a combination of the perfect properties of these materials for use in restorations, combined amalgam-composite restorations by adhesive agent have been recommended by many researchers[8].

The study aimed to evaluate and compare the effect of two adhesive agents (SBMPP, and Adper™ and Single Bond ™ Universal Adhesive) on the shear bond strength with fresh high copper amalgam material bonded to two types of composite resins (Filtek™ Z350 XT, Filtek™ Z250 XT), and to evaluate the mode of bond failure: whether adhesive, cohesive or mixed.

Materials and methods

Specimen preparation

Sixty standardized cylindrical blocks were prepared from cold cure acrylic (PMMA) with dimensions of (13mm in diameter, 12 in height). A dental surveyor was used to align the acrylic mold in vertical alignment with an angled handpiece. The cavity was prepared at the surface of the acrylic cylindrical block with standardized measurements of (diameter; 7.5mm, depth; 4mm)[9] Figure 1.

Figure 1: Standardized measurement of the cavity prepared inside the acrylic cylindrical block: Diameter (7.5mm) and Depth (4mm).

Capsulated Amalgam (High Copper non-gamma-2 alloy) was triturated, carried, and placed according to the working time and technique specified in the manufacturer's instructions[7]. After 5 minutes the adhesive agent was added to the amalgam surface, skipping the etching steps[10]. The Scotchbond™ Multi-Purpose Plus (SBMPP) adhesive agent was added in steps according to the manufacturer's instructions, while the Adper™ Single Bond ™ Universal Adhesives was applied in one step according to the manufacturer's instructions. Following the adhesive placement, a gelatin mold with a standardized internal diameter of 4.9 mm and height of 5 mm[11] was placed on the amalgam surface and was fixed by the adhesive agent (Figure 2).

Sample grouping

The sixty samples were divided into three main groups of (N=20/group) according to the type of adhesive agent treatment and a control group that had not received adhesive agents, and each group was subdivided into two subgroups of (n=10) (a) Amalgam bonded to Nanofill composite (b) Amalgam bonded to Nanohybrid composite.

G1: n= 20 Amalgam bonded to composite without an adhesive agent

G2: n=20 Amalgam bonded to the composite by single bond universal adhesive

G3: n=20 Amalgam bonded to the composite by scotch bond MPP.

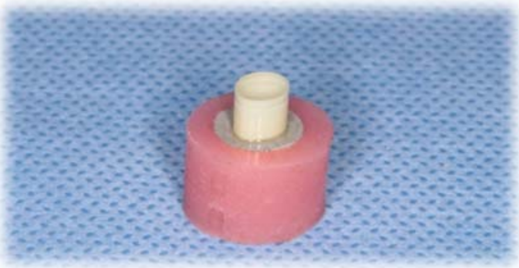

Figure 2: Gelatin capsule placement on fresh amalgam surface following adhesive agent placement.

Then the packable resin composite (Filtek™ Z350, and Filtek™ Z250 XT) was applied, inserted, and cured following the manufacturer's instructions; after completion of adding the composite resin and polymerization, the gelatin mold was removed. The specimens were stored in an incubator at (37°C and 100% humidity) in a light-proof container for one week to ensure final setting of the amalgam[12,13].

Shear bond strength testing

Shear bond strength testing was carried out by direct shear strength universal testing machine at a crosshead speed of 0.5 mm/min. Necessary modifications of the machine were carried out, including construction of a special jig to hold and stabilize the polymethyl methacrylate mold inside and construction of a special chisel crosshead to exert a shear force (Figure 3). The bond strength was calculated in Megapascals (Mpa) by dividing force (Newton) into the surface area of composite $(mm)^2$, yielding the result at (Mpa)[13,14] as in the following equations;

Shear Strength [MPa]=maximuim force [Newton]/area $[mm]^2$

Max f = took it from data recorded, Area =area of the circle.

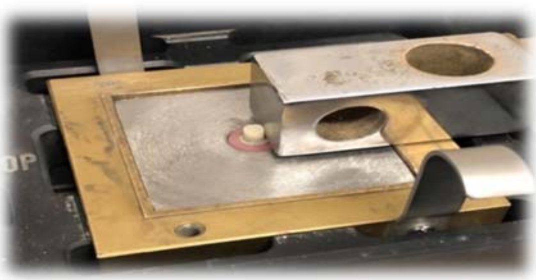

Figure 3: Direct shear strength universal testing machine.

Analysis of failure mode

After shear bond strength testing, each debonded sample was evaluated under a stereomicroscope. Adhesive failure means complete separation of the amalgam from the composite resin, cohesive failure occurs either within the amalgam or within the composite resin, while mixed failure means a combination of adhesive and cohesive failure.

Statistical analysis

Student s t-test of two independent samples was used to compare the mean of two groups. One way analysis of variance (ANOVA) was used to compare the three means, A p-value of ≤ 0.05 was considered statistically significant.

Results

Shear bond strength testing

The bond strength in the sub-groups according to the composite filling material was measured. The results were predicted as shown in Table 1 that the mean shear bond strength was not significantly different between G1a and G1b at (p= 0.5). Also, no significant difference was found between G2a and G2b at (p=0.4). Moreover, statistically, there was no significant difference between G3a and G3b at (p= 1).

Concerning the adhesive agent used in each group, the lowest shear bond strength was with G1, at about (1.201±0.78 Mpa), however the G2 had a slightly higher mean bond strength of about (2.031±1.2 Mpa) compared to G1 but the difference was not significant at (p=0.539) as shown in Table 2, while G3 had the highest mean shear bond strength (5.929±7.2 Mpa), which was significantly higher than G1 and G2 at (p = 0.001, p = 0.005) respectively as shown in Table 2.

Evaluation of the mode of bond failure

There were 65% adhesive failures as follow: 35% mixed failures, and none was cohesive failure (Table 3).

Table 1: Mean shear bond of all experimental groups.

Groups	Number of samples	Mean shear bond strength	(±SD)	p
G1a: Nano fill composite bonded to amalgam, without adhesive agent	10	1.326	(1.090)	0.488
G1b: Nano hybrid composite bonded to amalgam, without adhesive agent	10	1.076	(0.240)	
G2a: Nano fill composite bonded to amalgam, single bond universal adhesive	10	2.247	(1.000)	0.445
G2b: Nano hybrid composite bonded to amalgam, single bond universal adhesive	10	1.815	(1.433)	
G3a: Nano fill composite bonded to amalgam, scotch bond multi-purpose plus	10	5.983	(8.632)	0.974
G3b:Nano hybrid composite bonded to amalgam, scotch bond multi-purpose plus	10	5.874	(5.966)	

Table 2: Comparison of shear bond strength according to the presence or absence of adhesive agent and type of adhesive agent.

Groups	N	Mean shear bond strength	SD	P (ANOV)	LSD (groups)	P (LSD)
G1	20	1.201	0.779		1*2	0.539
G2	20	2.031	1.223	0.002	1*3	0.001
G3	20	5.929	7.222		2*3	0.005

Table 3: The mode of failure for each sample of the study

Groups	**Adhesive failure %**	**Mixed failure %**	**Cohesive failure%**
G1	75	25	0
G2	55	45	0
G3	65	35	0
Total	65	35	0

Discussion

Although the amalgam and composite widely used as direct restoration, each one has its advantage, disadvantage, and limitation. In this study placement of a layer of amalgam under the composite resin will reduce the thickness of the composite so that simultaneously that will reduce the polymerization shrinkage. Placement of the composite resin in a deep margin near the cementoenamel junction has some limitations such as difficulties in isolation, getting the light cure to reach the deep margins and difficulties with getting adequate bonding, all of which lead to an improper seal. However, placement of the amalgam layer in the base of the deep cavity will improve the marginal seal[(3)]. Furthermore, a recent in vivo study demonstrated better retention, contour and contact for combined (amalgam-composite) restorations compared to the conventional composite resin or amalgam restorations(8).

The bonding of amalgam to the composite resin can be achieved by mechanical means [micro-mechanical] or chemical means or a combination of mechanical and chemical means. Macro-mechanical bonding can be achieved by creating undercuts, grooves and also using a self-threading pin. Micromechanical bonding can be achieved by sandblasting with such as alumina oxide. Chemical bonding can be achieved by placing an adhesive agent between the amalgam and the composite resin. The macro-mechanical method is unsuitable for the fresh amalgam(15). Also the sandblasting for the fresh amalgam has an adverse effect because small particles become embedded in the fresh amalgam and affect the amalgam- composite interface(16). Although the macro-micro mechanical method has an adverse effect on the fresh amalgam surface of compromising the amalgam and weakening it, the placement of the adhesive agent on the fresh amalgam surface will enhance the bonding between amalgam and the composite and that will also improve the mechanical properties including (increasing fracture resistance, decreasing the leakage rate at the amalgam composite interface and masking the unpleasant appearance of amalgam)(7-17).

Shear bond strength testing is a convenient method of testing adhesive interfaces that are well established in biomaterials research. Although in vitro tests may not reflect the intraoral conditions, findings under controlled conditions are still helpful and can be applied to predict the clinical performance(18). Different laboratory and mechanical evaluations were made to evaluate bonding strength. Bonding strength in this study was measured by using a macro-shear test because it is closer to the clinical situation and also manipulation and alignment of the samples can be easily done, and it is specialized for measuring large bonded surface areas of more than [3mm²](19).

The shear bond strength is the measurement most commonly used to evaluate the bond strength, however, several different configurations are used to exert shear force, including wire loops, chisels, notched chisels, and knife edges, which have significant influence on stress distribution and are an essential source of variability in shear bond measurement, besides which the speed at which a load is applied to a sample (crosshead speed) influences the results of bond strength tests. For these reasons, making exact comparisons between other studies and the current study is slightly difficult but possible(20).

In (G1a, G1b), (G2a, G2b), (G3a, G3B) it was concluded that the type of composite resin does not affect shear bond strength because both types are similar in microstructure as they belong to the nanocomposite family. This also confirms the finding of another study by Bedini et al.(21). However, they used two micro filled resin composites and two hybrid resin composites which are completely different from each other in their application, shape and filler features. The microfill composite is specifically used in the anterior region because the lower rate of filler and size makes it more aesthetic. On the other hand, the hybrid resin composite is characterized by a combination of the small and large size of filler material and has more strength and better aesthetics than the microfill resin composite and can be used in the anterior and posterior region(22).

Meanwhile, nanocomposite restorative material is characterized by improved mechanical properties and good aesthetic properties and is nowadays considered a more widely used material which is suitable for all situations; for these reasons, it was used in this study(23). The explanation for this result: The basic chemical formula of Composite resin in any types mainly consists of (organic component as resin matrix, inorganic component as filler, and coupling agent) and no major change was made to this formula except to reduce the size of the filler and the shape of filler to improve the mechanical properties, and it was classified as microfill, hybrid and nanofiller composite resin. In this case, the type of composite resin appeared to have no effect on the shear bond strength because all types consist of the same chemical formula(24). G1 showed the weakest shear bond strength of about (1.201Mpa). This confirms the finding in the study by Özcan et al.(11).

Composite resin and dental amalgam are two different materials, and there are no interactions between them, which explains the similarity in the results of this study and other studies. The mechanism of bonding amalgam to composite resin was gained by mechanical means (macro-mechanical) or chemical means or a combination of mechanical and chemical means. The fact that the amalgam was bonded to the composite resin without any preparation of the amalgam surface or adding an adhesive agent would account for this weak shear bond strength(9).

The selection of Scotch bond multi-purpose plus adhesive system as an intermediate layer between the fresh amalgam surface and two types of composite resin was based on the previous study by Caradash et al.(25), also Demarco et al.(11), and Sharafeddin and Moradian(26). They conclude that even with high strength of the bond of composite resin to tooth structure this does not ensure that the microleakage rate will be low. In addition, these studies all agree that even with improvement of the mechanical properties of composite resin to be used in the posterior region it still has limitations because of the polymerization shrinkage, wear and stickiness nature of the material as well as the difficulty in achieving a tight bond in deep margins located near the cementoenamel junction and the difficulty of achieving light intensity. They further agreed that the combined amalgam/composite technique demonstrated less microleakage than the composite resin only. The G3 showed the highest shear bond strength (5.929 Mpa) which was statistically significant at (p= 0.001) compared to the G1. This result is in agreement with the study by Fruits et al.(16). This high bonding strength was gained because the Scotch bond multi-purpose plus is specifically constructed to be used with fresh amalgam surfaces and its ability in wetting and penetrating the amalgam surface enhances the bonding, creating an intimate mechanical bonding with the composite material which enhances the bond strength(26).

The selection of the single bond universal adhesive agent was based on previous studies which studied two types of adhesive agent, one from the total-etch system while the other was from the self-etch system(3,7,27,28). Therefore, a single bond universal adhesive agent was used in this study which was characterized as a combination of both systems in a single bottle to be used as required, either in the total etch or self-etch system(29). G2 showed slightly higher shear bond strength than G1 by (0.83 Mpa) but statistically, there was no significant difference from G1, and this agreed with the study by Hadavi et al.(30). The possible explanation for this result is that placing the acid etching on the amalgam surface before placement of the adhesive agent decreased the shear bond(30). The single bond universal agent could be used in the self-etch or total-etch system even without application of acid etching, but the acidic monomer that is present in their composition may affect bond strength(31).

The Scotch bond multi-purpose plus adhesive system has higher shear bond strength than the single bond universal adhesive of about (3.898 Mpa) and the difference was statistically significant at(p= 0.005), which does not agree with a study by Sharafeddin and Moradian(26), which concluded that there was no statistically significant difference between the two systems when placed on the fresh amalgam surface. The discrepancy in results may be because in the present study the two systems of adhesive agents intermediated between the fresh amalgam and composite resin without surrounding the tooth structure, which meant there was an absence of adhesive agent interaction with the tooth structure. In addition, the present study evaluated the shear bond strength in the absence of tooth structure,whereas the previous studies conducted microleakage testing of the two systems of adhesive agents intermediated between fresh amalgam and composite resin inside the tooth structure and that would affect the result because the bonding agents would interact with the surrounding tooth structure(26).

Although the Scotch bond multi-purpose plus adhesive had higher shear bond strength, it was considered low, weak and a failure(13,15,16), when compared with the shear bond strength of composite resin to the tooth structure which was about (17-30 Mpa), considering variance according to the adhesive system used and dental tooth structure either enamel or dentine(32).

The mode of bond failure

In the present study, stereomicroscope observation on debonded surfaces of the samples was conducted in order to report failure mode frequencies in adhesive, cohesive and mixed failures. Adhesive failure means complete separation of amalgam and composite resin, cohesive failure occurs either within the amalgam or with composite resin, while mixed failure is a combination of adhesive and cohesive failure. In general, when mixed and adhesive failures were observed more frequently, that means the shear bond strength was low. Likewise, when the frequency of cohesive failure increased, the mean of shear bond strength also increased(33). Stereomicroscope observation on debonded surfaces in the present study detected adhesive failures in about (65%) of samples, and a combination of adhesive-cohesive failures only in (35%) of samples, no cohesive failure was present either with amalgam or composite resin. This confirms the findings of studies by Bichacho et al.(13) and Pilo et al.(15). In the present study, it appears that adhesive strength cannot exceed the cohesive strength. This result is due to the fact that dental amalgam and composite resin are two different materials and there is no interaction between them.

Conclusions

- Even the highest bonding strength, provided by the scotch bond multi-purpose plus adhesive system group, is still low compared to the values reported when it is used for bonding composite to the tooth structure.
- Fresh amalgam bonded to the composite resin without any adhesive agent has the lowest bonding strength, and cannot be dependable. The bonding

strength provided by the single bond universal adhesive agent is lower than that of the Scotch bond multipurpose plus adhesive agent.

- The adhesive strength cannot exceed the cohesive strength.

References

1. Demarco F, Corrêa MB, Cenci MS, Moraes RR, Opdam NJ. Longevity of posterior composite restorations: not only a matter of materials. Dent Mater. 2012;28(1):87-101.

2. Udoye C, Aguwa E. Amalgam safety and dentists' attitude: a survey among a Subpopulation of Nigerian dentists. Oper Dent. 2008;33(4):467-71.

3. Firouzmandi M, Doozandeh M, Jowkar Z, Abbasi S. Effect of composite/amalgam thickness on fracture resistance of maxillary premolar teeth, restored with combined amalgam-composite restorations. J Clin Exp Dent. 2016;8(3):e268-72.

4. Polydorou O, König A, Hellwig E, Kümmerer K. Long-term release of monomers from modern dental-composite materials. Eur J Oral Sci. 2009; 117(1):68-75.

5. Moraes RR, Gonçalves LdS, Lancellotti A, Consani S, Correr-Sobrinho L, Sinhoreti M. Nanohybrid resin composites: nanofiller loaded materials or traditional microhybrid resins?. Oper Dent. 2009;34(5):551-57.

6. Chan KH, Mai Y, Kim H, Tong KC, Ng D, Hsiao J. resin Composite Filling. Materials: a review. Materials. 2010;3(2):1228-43.

7. Tolidis K, Boutsiouki C, Gerasimou P. Microleakage in combined amalgam/composite resin restorations in MOD cavities. Braz J Oral Sci. 2013;12(2):100-104.

8. Kaur G, Singh M, Bal C, Singh U. Comparative evaluation of combined amalgam and composite resin restorations in extensively carious vital posterior teeth: An in vivo study. J Conserv Dent. 2011;14(1):46-51.

9. Portugal J, Marques P, Jardim L, Leitão J. Shear bond strength of aged dental amalgam repaired with composite. Revista Portuguesa de Estomatologia, Medicina Dentária e Cirurgia Maxilofacial. 2008;49(2):69-74.

10. Demarco F, Ramos O, Mota C, Formolo E, Justino L. Influence of different restorative techniques on microleakage in class II cavities with gingival wall in cementum. Oper Dent. 2001;26(3):253-259.

11. Özcan M, Vallittu P, Huysmans M-C, Kalk W, Vahlberg T. Bond strength of resin composite to differently conditioned amalgam. J Mater Sci Mater Med. 2006;17(1):7-13.

12. Al-Jazairy YH. Shear peel bond strength of compomers veneered to amalgam. J Prosthet Dent. 2001;85(4):396-400.

13. Bichacho N, Pilo R, Brosh T, Berkovich M, Helft M .Shear bond strength of composite resin to fresh amalgam. Oper Dent.1995;20(2):68-73.

14. Dabas D, Patil AC, Uppin VM . Evaluation of the effect of concentration and duration of application of sodium ascorbate hydrogel on the bond strength of composite resin to bleached enamel. J Conserv Dent. 2011;14(4):356-60.

15. Pilo R, Brosh T, Shapinko E, Dodiuk H. Long-term durability of adhesive systems bonded to fresh amalgam. J Prosthet Dent. 1996;76(4):431-36.

16. Fruits TJ, Duncanson Jr MG, Coury TL . Interfacial bond strengths of amalgam bonded to amalgam and resin composite bonded to amalgam. Quintessence int. 1998;29(5):327-34.

17. Shafiei F, Memarpour M, Karimi F. Fracture resistance of cuspal coverage of endodontically treated maxillary premolars with combined composite-amalgam compared to other techniques. Oper Dent. 2011;36(4):439-47.

18. Özcan M, Koolman C, Aladag A, Dündar M. Effects of different surface conditioning methods on the bond strength of composite resin to amalgam. Oper Dent. 2011;36(3):318-25.

19. Van Meerbeek B, Peumans M, Poitevin A, Mine A, Van Ende A, Neves A. et al. Relationship between bond-strength tests and clinical outcomes. A review. Dent Mater. 2010;26(2):e100-12.

20. Salz U, Bock T. Testing adhesion of direct restoratives to dental hard tissue-. A review. J Adhes Dent. 2010;12(5):343-71.

21. Bedini R, Chistolini P, De Angelis G, Albergo G . Mechanical performance of dental amalgam-composite interfaces. Clin Mater. 1994;17(3):147-50.

22. Blackham J, Vandewalle K, Lien W. Properties of hybrid resin composite systems containing

prepolymerized filler particles. Oper Dent. 2009;34(6):697-702.

23. Beun S, Glorieux T, Devaux J, Vreven J, Leloup G. Characterization of nanofilled compared to universal and microfilled composites. Dent Mater. 2007;23(1):51-9.

24. Lien W, Vandewalle KS. Physical properties of a new silorane-based restorative system. Dent Mater. 2010;26(4):337-44.

25. Cardash HS, Bichacho N, Imber S, Liberman R. A. combined amalgam and composite resin restoration. J prosthet Dent. 1990;63(5):502-05.

26. Giannini M, Paulillo LA, Ambrosano GM. Effect of surface roughness on amalgam repair using adhesive systems. Braz Dent J. 2002;13(3):179-83.

27. Sharafeddin F, Moradian H. Microleakage of class II combined Amalgam-Composite restorations using different composites and bonding agents. J Dent Teh Univ Med Sci. 2008;5(3):126-30.

28. Shafiei F, Memarpour M, Karimi F. Fracture resistance of cuspal coverage of endodontically treated maxillary premolars with combined composite-amalgam compared to other techniques. Oper Dent. 2011;36(4):439-47.

29. McLean D, Meyers E, Guillory V, Vandewalle K. Enamel bond strength of new universal adhesive bonding agents. Oper Dent. 2015;40(4):410-17.

30. Hadavi F, Hey JH, Ambrose ER. Shear bond strength of composite resin to amalgam: An experiment in vitro using different bonding systems. Oper Dent. 1991;16(1):2-5.

31. Alex G. Universal adhesives: the next evolution in adhesive dentistry. Compend Contin Educ Dent. 2015;36(1):15-26.

32. Kournetas N, Kakaboura A, Giftopoulos D, Chakmachi M, Rahiotis C, Geis-Gerstorfer J. Marginal behavior of self-etch adhesive/composite and combined amalgam-composite restorations. Eur J Prosthodont Restor Dent. 2010;18(2):70-7.

33. Machado C, Sanchez E, Alapati S, Seghi R, Johnston W. Shear bond strength of the amalgam-resin composite interface. Oper Dent. 2007;32(4):341-46.