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Cervical Microleakage in MOD Restorations: *In Vitro* Comparison of Indirect and Direct Composite

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Clinical Relevance

One of the advantages reported for indirect composite restorations is the reduction of polymerization shrinkage, which could produce better marginal sealing. Although sealing of cervical enamel margins was slightly better for the indirect systems used, no difference between indirect and direct restorations was found for cervical margins in cementum/dentin.

SUMMARY

This study compared microleakage between indirect composite inlays and direct composite restorations. Forty-eight standard inlay MOD cavities, with cervical margins located either in enamel or dentin, were prepared in extracted human third molars. The specimens were randomly divided into 3 groups (n=16). In the control group, the cavities were restored with the composite Filtek Z250 (3M ESPE). For the experimental groups, indirect restorations were made with the Artglass (Heraeus-Kulzer) or Belleglass HP (Kerr Laboratories) systems and cemented with the dual curing cement RelyX ARC (3M ESPE). The adhesive system Single Bond (3M ESPE) was applied on all groups. The specimens were submitted to thermolcycling, coated with nail varnish, then immersed in 2% basic fuchsine aqueous solution for 24 hours. The teeth were then sectioned and leakage scores were evaluated (40x), based on a standard ranking. Data were submitted to statistical analysis (Mann-Whitney and Kruskal-Wallis tests) with a 95% confidence level. No statistical difference was found between substrates (p=0.595), and the materials performed similarly in dentin (p=0.482). Direct restorations showed higher leakage than indirect restorations at the enamel margins (p=0.004). Within the limitations of this experimental design, overall leakage was similar between both substrates, while the indirect systems provided a better sealing than direct composites only in enamel.

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INTRODUCTION

In recent years, there has been an increased demand for aesthetic treatments; therefore, resin composite restorations have become a popular alternative for anterior and posterior teeth. Despite their success in anterior teeth, direct composite restorations have exhibited more leakage[1] and post-operative sentitivity[2] when applied to posterior teeth, due to polymerization shrinkage. In addition, there are some problems in obtaining adequate proximal contact.[3]

Indirect composite restorations could present several advantages: better anatomic contour and proximal contact, improved polishing and better esthetics.[4] Additionally, since a higher degree of conversion is obtained, improved mechanical properties can result.[5] Also, polymerization shrinkage of these restorations is only reduced related to the kind of cement used.[6]

Recently, a second generation of indirect composites (glass polymers) has been made available to clinicians. These new materials are reported as hybrid materials between composite and ceramic; however, they are composed of a resinous matrix with different inorganic fillers.[7]

The development of fiber-reinforced or glass-reinforced composites, also known as ceromers,[8] and the simplification of the laboratory technique, have made these new materials very popular for inlay, onlay, overlay, veneer, crown and partial fixed prostheses.[9] Some of the advantages reported include a reduction in occlusal wear, a simple fabrication technique and the possibility of low-cost repair when compared to ceramic restorations.[10-11]

Artglass was introduced in 1995 as a “polyglass.” This material is comprised of 70% (by weight) fillers and 30% resinous matrix. The fillers are mostly composed of barium-aluminum silicate glass (average = 0.7 µm) and colloidal silica. Also, there is a new methacrylate multifunctional monomer, allowing for a higher degree of conversion and a higher level of cross-linked chains when polymerized, thus, improving the mechanical properties of the restoration.[12] Yet, curing of the material is performed with a xenostroboscopic light, which is similar to a halogen light curing unit, but with higher intensity (4.5W).

Another material that has recently been introduced is Belleglass HP, marketed since 1996. There are conventional monomers in the matrix (urethane and aliphatic dimethacrylate). The material used to replace dentin presents 78% (by weight) of barium glass, with 0.6 µm mean filler size, while for enamel, there is 74% (by weight) borosilicate glass.[10] The polymerization mechanism is under pressure, with 140°C of temperature in a nitrogen environment. This increase in temperature enhances the degree of conversion, and the nitrogen prevents the oxygen-inhibition layer, thus, improving the mechanical properties.[10]

Microleakage remains a concern in restorative dentistry and has been related to postoperative sensitivity and secondary caries,[13-15] which was determined to be the primary reason for resin restoration replacement.[16] For indirect composite restorations, polymerization shrinkage is restricted to resin cement; therefore, better marginal sealing could be expected.[13] However, in addition to fracture, the marginal opening, secondary caries and postoperative sensitivity have been singled out as causes for failure of these restorations.[16]

This study evaluated the microleakage of 2 indirect composite materials when compared to direct composite restorations in margins located in enamel and dentin. The null hypothesis tested in this study is that indirect composite systems and direct composite restorations will produce similar marginal sealing in the enamel or dentin interface.

METHODS AND MATERIALS

Tooth Selection and Preparation

This research protocol had the approval of the Federal University of Pelotas Ethic Committee. Forty-eight human third molars, which were recently extracted for clinical reasons, were selected. After soft tissue removal, the teeth were stored in 1% chloramine solution for 72 hours and refrigerated in distilled water until testing. Also, the teeth were free of cracks under magnification (10x).

Cavity Preparation

The teeth had their roots embedded in a PVC matrix until 2 mm below the cement-enamel junction, using a die stone (Durone, Caulk/Dentsply, Petrópolis, Brazil). Standard Class II MOD inlay cavities were prepared. Diamond burs #4138 (KG Sorensen, Alphaville, Brazil) were mounted in a Galloni Machine (S Colombano, Milano, Italy) to obtain a standardized cavity preparation. The burs were replaced after 4 cavity preparations to ensure high cutting ability. The occlusal box was 2-mm deep and 2-mm across in the buccal-lingual dimension. The mesial-cervical wall was located in enamel (1-mm above the cementoenamel junction), with the distal surface located in cementum/dentin (1-mm below CEJ). The axial wall was placed in dentin, with a distance of 1.5-mm from the external tooth surface. The buccal and lingual walls were tapered (6°) and the internal angles rounded.

Inlay Fabrication

Impressions were made from each cavity preparation using condensation silicone (Silon, Caulk/Dentsply) to produce stone dies (Durone, Caulk/Dentsply) that were used to prepare the composite inlays.

Polymerization of the indirect restorations was performed following the manufacturer’s instructions. For Artglass, the UnixS (Heraeus Kulzer, Hanau, Germany) system was used. This system is composed of 2 xenostroboscopic lights in a polished aluminum chamber with a 320- to 520-nm wavelength and a stroboscopic frequency of 20Hz. Each 2-mm increment of indirect resin was polymerized for 180 seconds.

For Belleglass HP, the TekLite unit (Kerr, Orange, CA, USA) was used. This unit provides a high intensity light using a halogen light of 80W (wavelength of 400-500 nm) for 60 seconds. Then, one additional polymerization procedure was performed using an HP Curing Unit (Kerr) under nitrogen pressure (60 psi) at 140°C for 20 minutes. The insertion technique was similar to that used for Artglass.

The Microetcher treatment (Microetcher Model II—Danville Engineering Inc, San Ramon, CA, USA) was made in the internal surface of all inlay restorations. The silane coupling agent was also applied (Caulk/Dentsply).

Restorative Procedures

The materials used during the study are described in Table 1.

The teeth were randomly divided into 3 groups (n=16) according to the restorative materials used. Before luting or restoration, the specimens were cleaned with bristles and polishing paste.

Control Group: The entire cavity was conditioned with 35% phosphoric acid for 15 seconds. Following washing and gentle drying to leave a moist dentin surface, the adhesive system Single Bond (3M ESPE) was applied in 2 coats and light-cured for 20 seconds. The cavity was filled with oblique increments using a direct posterior resin composite (Filtek Z250, 3M ESPE). Tofflemayer metal matrices were used to reestablish the proximal surface of the restorations.[17-18] The polymerization of each increment was performed for 40 seconds from the occlusal aspect. A XL3000 light-curing unit (3M ESPE), with energy higher than 470mW/cm^2, was used for the polymerization procedures. Prior to starting each new restoration, the light source intensity was measured with a radiometer (Curing Radiometer Model 100, Demetron Research Corporation, Danbury, CT, USA).

Indirect Restoration Luting: For both indirect systems, luting was performed with RelyX ARC resin cement (3M ESPE). Tooth surfaces were conditioned with 35% phosphoric acid (3M ESPE) etching for 15 seconds. The surface was washed and gently dried, keeping it moist. Two coats of the adhesive system Single Bond (3M ESPE) were applied and photo-cured for 20 seconds. RelyX ARC (3M ESPE) was dispensed, mixed and applied to the internal surface of the inlay. The inlays were maintained in place for 8 minutes under pressure (1Kg of loading, using one adapted Vicat needle). Excess cement was removed with scalers before light curing the interfaces for 40 seconds. The same light-curing unit used for the control group was used for the indirect restorations.

Finishing procedures were completed with the Enhance system (Caulk/Dentsply). The specimens were stored in distilled water for 7 days, and the teeth were then removed from the PVC matrixes. The direct restorations and margins from the indirect inlays were polished using a felt disc and polishing paste (Diamond, FGM Produtos Odontológicos, Joinville, Brazil).

Microleakage Test

The specimens were thermocycled between 5°C and 55°C (dwell time of 30 seconds) for 500 cycles using a thermal cycling machine (Ética Odontológica, São Paulo, Brazil). Two coats of nail varnish were then applied to the entire surface of each tooth, except for the margins of the restorations and 1 mm around them. The teeth were immersed in 2% basic fuchsine solution for 24 hours. Upon removal from the dye solution, the teeth were washed in tap water for 12 hours. The nail varnish was removed and the teeth embedded in a clear acrylic resin (Artigos Odontológicos Clássico Ltda, São Paulo, Brazil). Two sections were cut across the restorations with a band saw (Buhler Inc, Lake Bluff, IL, USA), allowing for evaluation of 4 surfaces.

Leakage was assessed by 3 examiners using a standardized scoring method for dye penetration: 0–no penetration; 1–restricted to the cervical wall; 2–restricted to the axial wall and 3–reaching the pulpal wall.[18] If the examiners showed disagreement in relation to the leakage scores, a consensus was obtained. The highest leakage observed on one

Table 1: *Materials Used, Manufacturers, Batch Numbers and Chemical Compositions*

Material	Manufacturer	Batch #	Composition
Filtek Z250 (direct composite)	3M ESPE (St Paul, MN, USA)	1KB	Bis-GMA, UDMA, Bis-EMA, TEGDMA, silica, zirconia dioxide and aluminium dioxide (82%–weight)
Artglass (indirect composite)	Heraeus Kulzer (Hanau, Germany)	010113	Bis-GMA, TEGDMA, barium-aluminium-silicate glass (69%–weight)
BelleGlass HP (indirect composite)	Kerr Laboratories (Orange, CA, USA)	204966	Bis-GMA, UDMA, barium-aluminium-silicate glass (74-78%–weight)
RelyX—ARC (resin cement)	3M ESPE (St Paul, MN, USA)	3415A3	Bis-GMA, TEGDMA, silica and zirconia glass (67.5%–weight)
Single Bond system)	3M ESPE (St Paul, MN, USA)	3HL	Water, ethanol, HEMA, Bis-GMA, (adhesive dimethacrylates, polyalkenoic acid, copolymers, initiator

of the surfaces evaluated for each restoration was assumed to be leakage into that specimen.

Statistical Analysis

Data were submitted to non-parametric statistical analysis (Mann-Whitney and Kruskal-Wallis) at the 95% confidence level.

RESULTS

Scores of dye penetration for different groups in the enamel and dentin margins are shown in Table 2. The non-parametric test (Mann-Whitney) disclosed similar performances for the enamel and cementum/dentin margins (p=0.595).

When comparing leakage in the enamel margins (Kruskal-Wallis), indirect inlays presented similar performance and both systems exhibited better marginal sealing than composite restorations (p=0.004). No direct restoration was able to completely prevent dye penetration. For Artglass and Belleglass HP, the percentages of completely sealed restorations were 50% and 37.5%, respectively. However, no restoration exhibited a score of 3 for dye penetration, and only one specimen exhibited a score of 2. In fact, in most of the specimens, dye leakage was absent or minimal.

For the dentin interface (Kruskal-Wallis), no statistically significant difference was found among groups (p=0.482); however, when observing the effective sealing, Belleglass HP completely sealed the interface in 50% of the specimens, while the other 2 groups were similar (37.5%). Also, at this interface, no specimens exhibited a score of 3 for dye penetration and few specimens exhibited a score of 2. In the majority of specimens, dye penetration was due to failures at the dentin-adhesive interface.

DISCUSSION

Polymerization shrinkage remains an important shortcoming for composite restorations. Shrinkage produces stress at the adhesive interface and could lead to bonding failure with gap formation. Microleakage at this interface could lead to marginal staining, postoperative sensitivity and secondary caries.[19]

When a direct composite restoration is made, polymerization shrinkage occurs directly at the dental structure, and the stress generated could reach up to 10 MPa, leading to a marginal breakdown and gap formation.[20] Nevertheless, when polymerization occurs indirectly, shrinkage is limited to the width of the luting space, which could reduce the deleterious effects at the interface.[18] The production of restorations in a laboratory allows for appropriate proximal contours and contacts and control of the anatomic form. Also, post-curing with heat, pressure and/or light increases the degree of conversion, thus improving the mechanical properties of the composite, resulting in better wear resistance.[16]

Generally, microleakage has been evaluated using *in vitro* models, with dye penetration as the most frequently used method.[14,21] This test presents some limitations, such as subjectivity of reading and high diffusability of dyes due to their small molecular weight.[22] However, since new materials constantly appear, and considering clinical evaluations are time-consuming and expensive, *in vitro* methods for microleakage are important tools in evaluating the possible performance of materials regarding sealing ability.[18]

For leakage measurements, a qualitative scale was selected, and basic fuchsine was used as the disclosing agent. These decisions were based on literature reviews that verified the most frequent methods used in microleakage studies,[14,21] while also considering that the choice of dye or tracer molecule used does not appear to influence results.[14] A thermocycling protocol was used to simulate the effects that restorative materials and adhesive systems are subjected to in the mouth, because of stresses at the adhesive interface generated by the difference in coefficients of thermal expansion between materials and dental structure.[14]

While the 2 indirect systems have different chemical compositions and mechanisms, behavior that influences their fit, interfacial gaps and curing mechanisms, these systems have produced a similar sealing ability in both substrates, with no or minimal leakage in most of the specimens. Some investigations have demonstrated that indirect composite systems may have similar capacities to resist dye penetration[4] and similar marginal adaptation.[23] Many factors influence polymerization shrinkage and marginal sealing in indirect restorations: adhesive/resin cement combinations and their ability to withstand interfacial stress; the ability of indirect restorations or the tooth to deform during cement polymerization; gap size and, consequently, interfacial cement volume.[13] A correlation between marginal adaptation and microleakage could be expected, since poor adaptation could facilitate the penetration of fluids, bacteria and bacterial by-products.[24] Nevertheless, Romão and others[25] demonstrated no correlation between cement thickness and microleakage. In the current study, a shoulder finish line that reduce poor marginal adaptation of ceromers when compared to marginal gaps produced by chamfer finish line specimens was used.[26]

Table 2: *Microleakage Scores Observed for Enamel and Dentin Margins in Each Tested Group*

	Enamel				Cementum/Dentin			
	0	1	2	3	0	1	2	3
Filtek Z250	0	15	1	0	6	6	4	0
Artglass	8	8	0	0	6	10	0	0
Belleglass HP0	6	10	0	0	8	7	1	0

For inlay cementation, a dual cure resin cement (RelyX ARC) was used. This cement presents a high degree of monomer conversion either in the presence or absence of light,[27] thus, decreasing the problems related to postoperative sensitivity, microleakage and secondary caries.[28]

Only in enamel did indirect systems produce slightly better sealing than direct composite restorations. Previous reports in the literature have demonstrated similar findings.[29-31] One possible reason is the lower level of polymerization shrinkage stress produced in indirect restorations, which is restricted to the small quantity of resinous material (resin cement).

Achieving a strong, durable seal to dentin has proved to be a greater challenge for adhesive dentistry.[13] In this study, dye penetration was minimal or absent in the majority of specimens for the 3 materials tested, and the specimens performed similarly. Similarities in relation to marginal leakage have been exhibited between direct and indirect composite restorations.[4] While indirect restorations would help to reduce the polymerization shrinkage effects by decreasing the resin total volume undergoing polymerization, the cavity configuration for inlay preparation represents a high C-factor, which could be particularly important in dentin margins.[13] Therefore, the beneficial effect of reduced polymerization shrinkage could be counteracted by stress generated by the high C-factor, which could explain the similar sealing achieved in dentin.

Comparing leakage in both substrates, no significant difference was observed. Several studies have demonstrated better sealing ability in enamel than in dentin margins.[6,32-33] However, according to Eick and others,[34] with the evolution of adhesive systems, similar bonding values could be achieved in enamel and dentin, primarily after hybridization of the dentin tissues. In Class II composite restorations, no significant difference was found for margins located in enamel or dentin, regarding the sealing ability or microtensile bond strength of the interfaces.[17]

Despite better sealing obtained with indirect restorations in enamel, leakage of direct restorations was minimal (score 1) in almost all specimens. Not only should sealing ability be considered when selecting a restorative material, but the amount of dentin structure removed (minimal intervention dentistry), the complexity of the technique and the cost of treatment should also be taken into account, where the direct restoration takes advantage.

Longitudinal clinical evaluations provide the most relevant guidelines for dental practice. After an 11-year evaluation, Pallesen and Quist[35] observed no difference in failure rates between direct composite restorations and composite inlays. Recently, in a survey of the literature, Manhart and others[16] found a similar annual failure for direct restorations and indirect composite restorations. Despite the relevance of clinical trials, these studies are more expensive and time-consuming, and ethical concerns may limit clinical evaluations. Therefore, there is a need for laboratory evaluation of dental materials that provide a faster response and can predict clinical performance.[36]

The null hypothesis tested was partially rejected, because indirect composite restorations showed better performance than direct restorations in enamel margins.

CONCLUSIONS

Cervical margins in enamel and cementum performed equally well for the investigated combinations of indirect resin/luting systems and direct resin composite restorations. While the sealing of enamel margins was slightly better for the indirect systems used, no difference between indirect and direct restorations was found in cementum.

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References

1. Manhart J, Kunzelmann KH, Chen HY & Hickel R (2000) Mechanical properties and wear behavior of light-cured packable composite resins *Dental Materials* **16(1)** 33-40.
2. Plasmans PJ, van't Hof MA & Creugers NH (1992) Fabrication times for indirect composite resin restorations *Journal of Dentistry* **20(1)** 27-32.
3. Loguercio AD, Reis A, Rodrigues Filho LE & Busato AL (2001) One-year clinical evaluation of posterior packable resin composite restorations *Operative Dentistry* **26(5)** 427-434.
4. Hasanreisoglu U, Sonmez H, Uctasli S & Wilson HJ (1996) Microleakage of direct and indirect inlay/onlay systems *Journal of Oral Rehabilitation* **23(1)** 66-71.
5. Wendt SL Jr (1987) The effect of heat used as secondary cure upon the physical properties of three composite resins. II. Wear, hardness, and color stability *Quintessence International* **18(5)** 351-356.
6. Liberman R, Ben-Amar A, Herteanu L & Judes H (1997) Marginal seal of composite inlays using different polymerization techniques *Journal of Oral Rehabilitation* **24(1)** 26-29.
7. Mandikos MN, McGivney GP, Davis E, Bush PJ & Carter JM (2001) A comparison of the wear resistance and hardness of indirect composite resins *Journal of Prosthetic Dentistry* **85(4)** 386-395.
8. Leinfelder KF (1997) New developments in resin restorative systems *Journal of the American Dental Association* **128(5)** 573-581.
9. Trushkowsky RD (1997) Ceramic optimized polymer: The next generation of esthetic restorations—Part 1 *Compendium of Continuing Education in Dentistry* **18(11)** 1101-1106.
10. Peutzfeldt A (2001) Indirect resin and ceramic systems *Operative Dentistry* **(Supplement 6)** 153-176.

11. Cesar PF, Meyer Faara PM, Miwa Caldart R, Gastaldoni Jaeger R & da Cunha Ribeiro F (2001) Tensile bond strength of composite repairs on Artglass using different surface treatments *American Journal of Dentistry* **14(6)** 373-377.
12. Freiberg RS & Ferracane JL (1998) Evaluation of cure, properties and wear resistance of Artglass dental composite *American Journal of Dentistry* **11(5)** 214-218.
13. Hilton TJ (2002) Can modern restorative procedures and materials reliably seal cavities? *In vitro* investigations. Part 1 *American Journal of Dentistry* **15(3)** 198-210.
14. Hilton TJ (2002) Can modern restorative procedures and materials reliably seal cavities? *In vitro* investigations. Part 2 *American Journal of Dentistry* **15(4)** 279-289.
15. Thordrup M, Isidor F & Hörsted-Bindslev P (1994) Comparison of marginal fit and microleakage of ceramic and composite inlays: An *in vitro* study *Journal of Dentistry* **22(3**) 147-153.
16. Manhart J, Chen H, Hamm G & Hickel R (2004) Buonocore Memorial Lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition *Operative Dentistry* **29(5)** 481-508.
17. Cenci M, Demarco F & de Carvalho R (2005) Class II composite resin restorations with two polymerization techniques: Relationship between microtensile bond strength and marginal leakage *Journal of Dentistry* **33(7)** 603-610.
18. Mota CS, Demarco FF, Camacho GB & Powers JM (2003) Microleakage in ceramic inlays luted with different resin cements *Journal Adhesive Dentistry* **5(1)** 63-70.
19. Barros GK, Aguiar FH, Santos AJ & Lovadino JR (2003) Effect of different intensity light curing modes on microleakage of two resin composite restorations *Operative Dentistry* **28(5)** 642-646.
20. Nash RW (2002) Processed composite resin—a versatile restorative material *Compendium of Continuing Education in Dentistry* **23(2)** 142-144, 146, 148 passim.
21. Raskin A, D'Hoore W, Gonthier S, Degrange M & Dejou J (2001) Reliability of *in vitro* microleakage tests: A literature review *Journal Adhesive Dentistry* **3(4)** 295-308.
22. Alani AH & Toh CG (1997) Detection of microleakage around dental restorations: A review *Operative Dentistry* **22(4)** 173-185.
23. Soares CJ, Martins LR, Fernandes Neto AJ & Giannini M (2003) Marginal adaptation of indirect composites and ceramic inlay systems *Operative Dentistry* **28(6)** 689-694.
24. Awliya W, Oden A, Yaman P, Dennison JB & Razzoog ME (1998) Shear bond strength of a resin cement to densely sintered high-purity alumina with various surface conditions *Acta Odontologica Scandinavica* **56(1)** 9-13.
25. Romao W Jr, Miranda WG Jr, Cesar PF & Braga RR (2004) Correlation between microleakage and cement thickness in three Class II inlay ceramic systems *Operative Dentistry* **29(2)** 212-218.
26. Cho L, Choi J, Yi YJ & Park CJ (2004) Effect of finish line variants on marginal accuracy and fracture strength of ceramic optimized polymer/fiber-reinforced composite crowns *Journal of Prosthetic Dentistry* **91(6)** 554-560.
27. Braga RR, Cesar PF & Gonzaga CC (2002) Mechanical properties of resin cements with different activation modes *Journal of Oral Rehabilitation* **29(3)** 257-262.
28. el-Mowafy OM, Rubo MH & el-Badrawy WA (1999) Hardening of new resin cements cured through a ceramic inlay *Operative Dentistry* **24(1)** 38-44.
29. Douglas WH, Fields RP & Fundingsland J (1989) A comparison between the microleakage of direct and indirect composite restorative systems *Journal of Dentistry* **17(4)** 184-188.
30. Milleding P (1992) Microleakage of indirect composite inlays. An *in vitro* comparison with the direct technique *Acta Odontologica Scandinavica* **50(5)** 295-301.
31. Robinson PB, Moore BK & Swartz ML (1987) Comparison of microleakage in direct and indirect composite resin restorations *in vitro Operative Dentistry* **12(3)** 113-116.
32. Monaco C, Baldissara P, dall'Orologio GD & Scotti R (2001) Short-term clinical evaluation of inlay and onlay restorations made with a ceromer *International Journal of Prosthodontics* 14(1) 81-86.
33. Santini A, Plasschaert AJ & Mitchell S (2001) Effect of composite resin placement techniques on the microleakage of two self-etching dentin-bonding agents *American Journal of Dentistry* **14(3)** 132-136.
34. Eick JD, Gwinnett AJ, Pashley DH & Robinson SJ (1997) Current concepts on adhesion to dentin *Critical Reviews of Oral Biology and Medicine* **8(3)** 306-335.
35. Pallesen U & Qvist V (2003) Composite resin fillings and inlays. An 11-year evaluation *Clinical Oral Investigations* **7(2)** 71-79.
36. Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, Van Landuyt K, Lambrechts P & Vanherle G (2003) Buonocore Memorial Lecture. Adhesion to enamel and dentin: Current status and future challenges *Operative Dentistry* **28(3)** 215-235.