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ADHESIVE PROPERTIES OF AN AMALGAM AND A POSTERIOR COMPOSITE RESTORATION AN IN-VITRO INVESTIGATION ON SHEAR BOND STRENGTH

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ABSTRACT

This study investigated shear bond strengths of an amalgam (Dispersalloy) and a composite resin (Z-100) to bovine dentin, mediated by five dentin adhesives (Amalgambond Plus, Scotchbond Multi Purpose, PQ1, All-bond 2 and One-step). Flat labial dentin surfaces were prepared from bovine lower incisor teeth. An 8 mm diameter area for amalgam and 6 mm diameter area for composite were bonded according to each manufacturer's directions before placement of the amalgam and composite to dentin. The bonds were stressed in shear at a cross head speed of 0.5 mm/min. The mean shear bond strengths were analyzed using one-way ANOVA and Tukey's test. The results showed no significant difference among the bond strengths of Amalgambond Plus (6.01 Mpa), Scotchbond Multi Purpose (4.96 Mpa), PQ1 (5.90 Mpa), All-Bond 2 (4.94 Mpa) and One -step (5.01 Mpa) when bonded to amalgam. However, there were significant differences among the bond strengths of Amalgambond Plus (12.76 Mpa), Scotchbond Multipurpose (13.72 Mpa), PQ1 (8.45 Mpa), All -Bond 2 (6.85) and One-step (4.32 Mpa) when bonded to composite.

It was concluded that Scotchbond Multi Purpose and Amalgambond Plus have higher bond strengths to composite resin, when compared to the other dentin adhesions.

INTRODUCTION

In spite of efforts to find an acceptable replacement, dental amalgam remains the most widely used material in restorative dentistry, providing longevity, ease of manipulation, relatively low cost, good wear resistance and less technique sensitivity. (Leinfelder, 1983; Jordan et. al., 1985). Balanko and Harris (1992) showed that amalgam lacks the ability to bond to tooth structure, and therefore has traditionally been retained in prepared cavities by retentive features that often require the removal of sound tooth structure. However, in badly destroyed teeth, these modifications may weaken the remaining tooth structure and lead to fractures

or endanger the pulp. Composite resins, on the other hand, are well established as capable of effectively bonding to both enamel and dentin. In addition, some manufacturers developed adhesive resins for bonding amalgam to tooth structure. (Staninec and Holt, 1988; Charlton et al, 1992; Vargas et al, 1994 and Turner et al, 1995).

Eakle et al (1992) and Ianzo et al (1993) showed that the use of an amalgam bonding agent may help overcome the need for additional retentive features. It has been found that some of these bonding agents strengthen the restored tooth. Edgren and Denehy, 1992; Cooley et al, 1991; Charlton et al, 1992; Shimizu et al, 1986; Staninec

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and Holt, 1988; Turner et al, 1995; Gwinnett et al, 1994 have also reported a reduction in micro-leakage when bonding agents are used in conjunction with amalgam as the restorative material. Gendusa (1992) reported that the bond formed between the resin and amalgam is a micro-mechanical bond. The alloy is condensed against the adhesive resin before polymerization, allowing the amalgam to surround the resin and lock into it as both the alloy and the resin set.

Furthermore, several studies have been conducted to evaluate the bond strength of amalgam to enamel and dentin with the use of different bonding agents. DeSchepper et al (1991) reported that the mean tensile bond strengths of amalgam to dentin using All-Bond 2 ranged from 10 to 11 Mpa. However, Roeder et al (1991) showed that the bond strength of All-bond 2 to amalgam was 3.4 to 8.8 Mpa. Vargas et al (1994) reported a bond strengths of 4.0 to 9.3 Mpa between amalgam and dentin when All-Bond 2 is used. Moreover, Hasegawa et al (1992) studied the shear bond strength of freshly mixed amalgam to dentin using Amalgambond. He found that it was 5.1 ± 1.7 Mpa. Covey and Moon (1991) tested the shear bond strength of four dentin bonding agents. They found that the mean shear bond strengths for Amalgambond, Panavia, Ketac-Cem and Scotchbond 2 were 3.5, 3.4, 3.2 and 4.8 Mpa respectively. Vargas et al (1994) reported that the mean shear bond strengths of amalgam was 11.9 Mpa when Amalgambond plus was used. Prati et al (1991) found that Amalgambond bond resin composite to dentin was 62% better than Scotchbond 2 and 66% better than a glass ionomer material. Cooley and Tseng (1991) evaluated Amalgam bond's ability to bond a resin composite and two type of amalgam (spherical and admixed) to dentin. The shear bond strengths of the spherical and admixed alloys were 3.3 and 3.8 Mpa, respectively and for the resin composite, it was 22.3 Mpa. They concluded that resin composite has significantly higher bond strength to dentin than amalgam alloys when amalgambond is used. Nakabayashi et al. (1992) evaluated the tensile bond strength of Amalgabond to ground bovine dentin. The measured tensile bond strengths of resin composite (9.4 Mpa)

was significantly greater than that of amalgam (2.8 Mpa).

With the continual introduction of new and improved adhesive resin systems, as well as increasingly bond claims by dental manufacturers, it has become difficult for clinicians to decide which materials are most compatible and effective.

The purpose of this present study was to compare the shear bond strengths between two posterior restorations, amalgam and composite to dentin, using five different adhesive resin bonding agents.

MATERIALS AND METHODS

A total of 50 bovine incisor teeth were used in this study. The roots of the teeth were cut and removed. The teeth were stored in deionized water for further use. The facial surfaces were ground flat to expose dentin with 240 and 400 grit silicon carbide abrasive mounted on a grinding wheel with copious amount of water (Jean Wirtz Automat A polishing machine Dusseldorf, West Germany). The flattened surfaces of each tooth were centered flush horizontally in 35 mm diameter and 25 mm depth teflon molds with cold cure acrylic resin. Before the bonding procedure, the teeth were again ground slightly using 600-grit silicon carbide abrasive paper to assure clean and fresh surfaces for bonding and to remove any acrylic flashes from the dentin surfaces.

In such a manner, a total of 50 specimens were prepared. They were then divided into two groups of 25 teeth each, and the bonded specimens from each group of materials were divided into five treatment groups of five specimens each for testing.

In the first group, an amalgam alloy (Disperalloy) was used with similar 5 dentine bonding agents (Table 1) and was applied to the treated tooth surface with a split teflon mold 8 mm in diameter and 4 mm in thickness, which was attached to the tooth with a metal ring.

In the second group, a restorative composite resin (Z-100) was used with 5 bonding agents (Table 1) and applied to the treated dentinal surface through a split teflon mold, 6 mm in diameter, that

contacted the surface and extended approximately 3 mm from the surface, which was firmly attached to the tooth with a metal ring.

The dentin bonding agents tested were: Amalgambond Plus; Scotchbond Multi Purpose; PQ1; All-Bond 2 and One-Step (Table 1).

The dentin bonding agents were applied ac-

ording to the manufacturer instructions. For amalgam specimens the split teflon mold were split and removed 20 minutes after condensation. However, in case of composite specimens, they were removed immediately after curing of the restoration (ESPE Dental Elipar Highlight, Seefeld, Germany). All specimens were then stored in distilled water for 24 hours at 37°C.

Table 1: Materials, Manufacturers and Procedures

A. Restorative Materials:

Materials	Procedure
Amalgam (Dispersion Alloy) (Dentsply Caulk International Inc. Milford, DE 19963-0359 USA)	After condensation leave undisturbed for 20 minutes.
Composite (Z-100) (3 M Dental Products, St Paul, Illinois MN55144, 1000)	After application cure it for 60 seconds.

B. Adhesive Materials:

Amalgambond Plus (Parkell products Farmingdale, NY 11735)	Dentin Activator: apply 10 seconds, rinse and dry. Adhesive: thin layer, blow with gentle air, leave undisturbed. For 30 seconds. Base and Catalyst: 2:1 drop apply thin layer condense amalgam immediately for composite cure, for 90 seconds.
Scotchbond Multi Purpose (3M Dental Products St Paul, MN 55144, 1000)	Etchant: apply 5 seconds, rinse and dry Activator: apply and dry 5 seconds for amalgam only. Primer: apply, dry 5 seconds Adhesives: apply, cure 10 seconds for composite. Mix it with catalyst then apply, don't dry for amalgam.
All-Bond 2 (Bisco Inc., Illinois 60193)	Conditioning: apply 15 seconds, rinse and dry Primer: apply 5 coats, dry 5 seconds Resin: * D/E for composite apply a thin layer and cure 20 seconds * D/E and pre-bond for amalgam apply a thin layer then resinomer apply.
PQ1 (Ultradent product, South Jordan, Utah 84095)	Conditioning: apply 15 seconds, rinse and dry. Bond: apply 15 seconds, air thinning and light cure 20 seconds.
One-step (Bisco Inc., Illinois 60193)	Conditioning: apply 15 seconds, water rinse and dry. Adhesive: apply 2 drop, 2 coats, dry for 10 seconds and light cure for 10 seconds. Resinomer: thin layer for amalgam only

The shear bond strengths were determined using an Instron Universal Testing Machine (Instron Cor. 8500 Canton, Massachusetts, USA) at across-head speed of 0.5 mm per minute. Knife-edge shear probe was attached to the cross head until fracture occurred. Shear forces were recorded in megapascals, and obtained directly from the computer software.

Data analysis was completed using the Statistical Package for Social Science System (SPSS). The mean (and standard deviation) shear bond strength was calculated for each treatment group

and compared using a two-way Analysis of Variance (ANOVA). Calculations indicated statistically significant F-ratios ($P < 0.05$) (Table 2). The data were further analyzed by one-way Analysis of Variance (ANOVA) and Tukey HSD (Post Hoc Test).

RESULTS

The mean shear bond strength of amalgam to dentin using five different bonding agents ranged from 4.94 to 6.01 Mpa (Table 3), however for the composites they ranged from 4.32 to 13.72 Mpa (Table 4). It was evident from the present study, when using ANOVA and Tukey's Test, that there

Table 2: Two-Way Analysis of Variance

Source	Df	Type III SS	F. Value	Pr>F
Restorative Materials	1	185.424	47.607	0.000
Adhesives	4	174.426	11.196	0.000
Rest. Materials *Adhesives	4	146.474	9.402	0.000
Error	40	155.795		

Table 3: Amalgam Shear Bond Strengths to Dentin (Mpa)

Group	Mean	SD	Range
Amalgambond Plus	6.01	1.58	3.71-7.67
Scotch bond Multi Purpose	4.96	2.16	2.53-7.73
PQ1	5.90	2.40	2.76-8.76
All -Bond 2	4.94	1.00	3.23-5.70
One -Step	5.01	1.36	2.79-6.42

Values connected by the line are not significantly different ($\alpha=0.05$) at 5% significant level.

Table 4 : Composite Shear Bond Strengths to Dentin (Mpa)

Group	Mean	SD	Range
Amalgambond Plus	12.76	2.77	9.82-15.72
Scotch bond Multi Purpose	13.72	3.03	10.47-16.84
PQ1	8.45	2.28	5.33-11.57
All -Bond 2	6.85	0.97	5.34-7.78
One -Step	4.32	0.27	3.98-4.62

Values connected by the line are not significantly different ($\alpha=0.05$) at 5% significant level.

Table 5 : Shear Bond Strengths (Mpa) for the Different Groups.

Group	Number	Mean	SD	Range	Significance
Amalgam * between groups	25	5.37	1.70	2.53-8.76	0.766
Composite * between groups	25	9.22	4.12	3.98-16.84	0.000

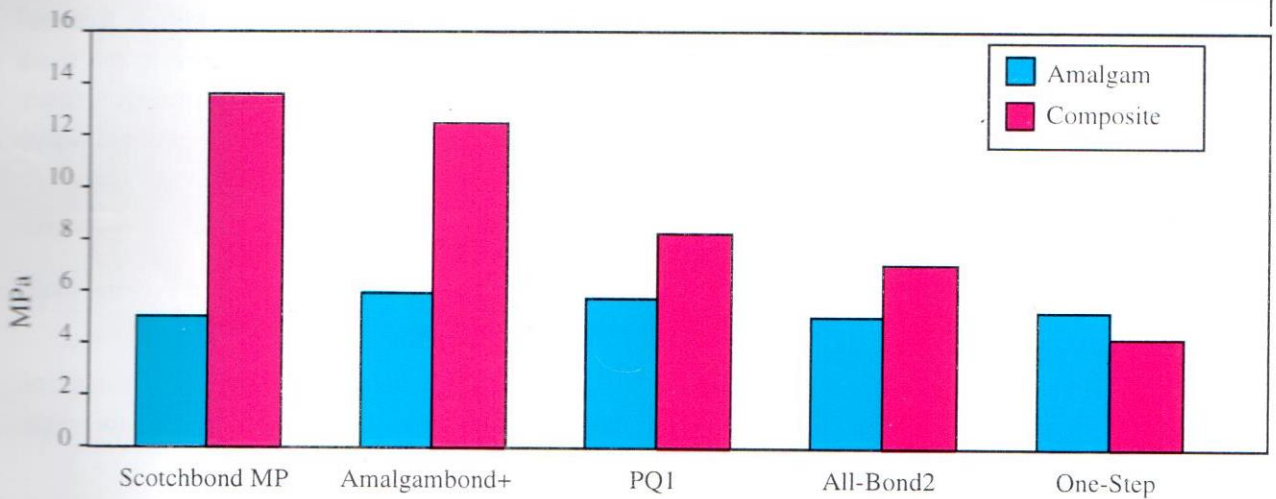


Fig. 1 : Mean shear bond strengths of amalgam and composite with different adhesives.

were no statistical significant difference in the shear bond strengths of amalgam, irrespective of the type of the bonding system used (Table 3,5) and [Fig.1].

In the case of composites there were statistical significant differences in the shear bond strengths between all bonding systems. However, for Amalgambond Plus and Scotchbond Multi-purpose there were no statistical differences (Table 4, 5) and [Fig. 1].

DISCUSSION

In the present study, bovine teeth were used as a substrate and alternative to human teeth in dentin adhesion tests (Nakamichi et al., 1983; Saunders, 1988 and Fowler et al, 1992). Bonding of restorative dental materials to dentin has been a long-standing predictable procedure. Dentin bonding has traditionally involved more steps than enamel bonding. Most of the available adhesive systems used three steps: (1) Acid conditioning for dentin surface, (2) Priming the conditioned surface, and

(3) Application of a resin adhesive agent. Depending on these systems, the priming and/or application of the adhesive resin may also require several applications.

Attaining high bond strengths to dentine has continued to be a challenge when compared to enamel bonding (Barkmeier and Erickson, 1994). The early systems (First -generation) yielded bond strengths in the range of 1 to 3 Mpa (Huget et al, 1979; Solmon and Beech, 1983; Barkmeier and Coolye, 1991, 1992). The bond strengths for second generation systems were in the range of 6 to 13 Mpa (Barkmeier and Cooley, 1992, 1989; Erickson, 1992). As adhesive systems have evolved, bond strengths to dentin now approach or equal previously reported enamel bond values (14-23 Mpa) (Barkmeier and Erickson, 1994; Los and Barkmeier, 1994; Triolo et al, 1995).

In an effort to simplify dentin bonding, manufacturers have recently introduced systems that combine the primer and adhesive agent. These systems have generally been referred to as "one-

component systems". However, most of these newer systems still require multiple application and curing sequences, and thus are not single procedure systems. Tay et al. (1996) have also suggested that one-component systems have a narrow "window of opportunity" for optimum bonding, which is dependent on residual surface moisture.

The present study compared two restorative materials, amalgam and composite, with different adhesive systems: the first three bonding systems (Table 1) were multiple components, while the last two were one component. Of the five bonding agents tested, Amalgabond Plus was self-cured, PQ1 was light-cured and All-Bond 2, Scotchbond Multipurpose and One-step were dual-cured systems. Most of the researchers showed that placement of amalgam before curing the adhesive resin bond gives better result than if it is placed after polymerization (Gendusa, 1992; Diefenderfer and Reinhardt, 1997). Perhaps, this may explain the manufacturer recommendation for Amalgabond Plus, Scotchbond Multi-purpose, All-Bond 2 and One-Step, and this is in agreement with the results of the present study. It could be claimed that condensing amalgam into the unset resin facilitates the formation of a mechanical union between amalgam and resin as the resin sets. Although PQ1, being light polymerized, should be cured before the addition of amalgam. However, the results of the present investigation reveals no significant differences in shear bond strength of amalgam when compared with the other adhesive systems. This may explain the importance of precisely following the manufacturer direction in using these bonding systems.

Under the conditions of this study, all of the bonding agents tested bonded amalgam and composite to dentin, however the bond strengths of composite were higher than with amalgam. This was in agreement with most previous investigators (Kanca, 1992; Miller et al, 1992). Notwithstanding, the use of adhesive bonding agents with amalgam restorations may play a major role for decreasing post-operative sensitivity.

Consequently, the clinical use of the amalgam bonded restorations may serve other purposes beside increasing bond strength. A microleakage study demonstrated a better hermetic seal with less microleakage in bonded amalgam than with composite resin (Staninec and Holt, 1988). In another study (Torri et al, 1989), the progression of artificial caries was inhibited along cavity walls in bonded amalgam restorations. In addition, teeth restored in vitro with amalgam bonded to the tooth were found to fracture at a significantly greater load than teeth restored with conventional amalgam (Eakle et al, 1992).

CONCLUSION

Based upon the findings of the present study, the following conclusions are made:

1. The shear bond strength of the restorations tested was improved by using any of the resin bonded adhesives.
2. Shear bond strength of the resin bonded composite restorations were higher than the resin bonded amalgam restorations.
3. No significant differences were evident in the shear bond strength between the amalgam and the 5 different adhesives used in this study.
4. There were significant differences in the shear bond strength between composite and the different adhesive systems used.

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REFERENCES

1. Balaznik M. Bonded silver amalgam restorations. *Journal of Esthetic Dentistry* 4 : 54 - 57 (1992).
2. Barkmeier W. W. and Cooley R. L. Resin adhesive systems: *In vitro* evaluation of dentine bond strength and marginal microleakage. *Journal of Esthetic Dentistry* 1 : 67-72 (1989).
3. Barkmeier W. W. and Cooley R. L. Current status of adhesive resin systems. *Journal of the American College of Dentists* 58 : 36-39 (1991).
4. Barkmeier W. W. and Cooley R. L. Laboratory evaluation of adhesive systems. *Operative Dentistry Supplement* 5: 50 - 61 (1992).
5. Barkmeier W. W. and Erickson R. L. Shear bond strength of composite to enamel and dentin using Scotchbond Multi -Purpose. *American Journal of Dentistry* 7 : 175-179 (1994).
6. Charlton D. G., Moore B. K and Swartz M. L. *In vitro* evaluation of the use of resin liners to reduce microleakage and improve retention of amalgam restorations. *Operative Dentistry* 17 : 112 - 119 (1992).
7. Cooley R. L., Tseng E. Y. and Barkmeier W. W. Dentine bond strengths and microleakage of a 4-Meta adhesive to amalgam and composite resin.. *Quintessence International* 22 : 979 - 983 (1991).
8. Cooley R. L., Tseng E. Y. Dentine bond strength and microleakage of 4-Meta to amalgam and composite. [abstract 1035]. *Journal of Dental Research* 70 : 395 (1991).
9. Covey D. A. and Moon P. C. Shear bond strength of dental amalgam bonded to dentin. *American Journal of Dentistry* 4 : 19-22 (1991).
10. DeSchepper E. J. Cailleteau J. G. , Roeder L. and Powers J. *In vitro* tensile bond strengths of amalgam to treated dentine. *Journal of Esthetics Dentistry* 3 : 117-120 (1991).
11. Diefelnderfer K.E. and Reinhardt J.W. shear bond strengths of 10 adhesive resin/amalgam combination. *Operative Dentistry* 22 : 50 - 56 (1997).
12. Eakle W. S., Staninec M. and Lacy A. M. Effect of bonded amalgam on the fracture resistance of teeth. *Journal of Prosthetic Dentistry* 68 : 257 - 260 (1992).
13. Edgren B. N. and Denehy G. E. Microleakage of amalgam restorations using amalgambond and copalite. *American Journal of Dentistry* 5 : 296 - 298 (1992).
14. Erickson R. L.. Surface interactions of dentin adhesive materials. *Operative Dentistry Supplement* 5 : 81-94 (1992).
15. Fowler C.S., Swartz M.L., Moore B.K. and Rhodes B.F. Influence of selected variable on adhesion testing. *Dental Materials* 8 : 265 - 269 (1992).
16. Gendusa N . Hydrolysis of 4-Meta/MMA-TBB resins: a myth. *Journal of Esthetic Dentistry* 4 : 58 - 60 (1992).
17. Gwinnett A. J., Baratieri L. N., Monteiro S and Ritter AV Adhesive restorations with amalgam: Guidelines for the Clinician. *Quintessence International* 25 : 687 - 698 (1994).
18. Harris R. K. Dental amalgam: Success or failure? *Operative Dentistry* 17 : 243 - 252 (1992).
19. Hasegawa T., Retief D. H., Russell C. M. & Denys F. R. A laboratory study of the Amalgambond Adhesive System. *American Journal of Dentistry* 5 : 181-186 (1992).
20. Huget E. F., Denniston J. C. and Vilca J. M. Dentine adhesives: A perspective *Military Medicine* 144: 619-620 (1979).
21. Ianzo J. A., Mastrodomenico J. and Gwinnett J. Strength of amalgam restorations bonded with Amalgambond. *American Journal of Dentistry* 6 : 10-12 (1993).
22. Jordan R. E., Suzuki M. and Boksmann L.. The new generation amalgam alloys: Clinical considerations. *Dental Clinics of North America* 29 : 341 - 358. (1985).
23. Kanca J. III. Resin bonding to wet substrate I. Bonding to dentin. *Quintessence International* 23 : 39 - 41 (1992).
24. Leinfelder K. The amalgam restoration. *Dental Clinics of North America* 27 : 685 - 696 (1983).
25. Los S. A. and Barkmeier W. W. Shear bond strength of composite to dentin using newer generation dental adhesive systems. *Esthetic Dentistry Update* 5 : 46-49 (1994).
26. Miller B.H. Arita K., Tamura N., Nishino M., Guo L. and Okabe T., bond strengths of various materials to dentin using Amalgambond. *American Journal of Dentistry* 5 : 272 - 276.

27. Nakabayashi N, Watanabe A and Gendusa NJ Dentin adhesion of "Modified" 4-Meta/MMA-TBB resin: Function of HEMA. *Dental Material* 8 : 259 - 264 (1992).
28. Nakamichi I., Iwaku M., and Fusayama T. Bovine teeth as possible substitutes in the adhesion test. *J. Dent. Res.* 62 : 1076 - 1081 (1983).
29. Prati C, Nucci C and Montanari G. Shear bond strength and microleakage of dentine bonding systems. *Journal of Prosthetic Dentistry* 65 : 401 - 407 (1991).
30. Roeder L., DeSchepper E.J. and Powers J.M. In vitro bond strength of repaired amalgam with adhesive bonding systems. *Journal of Esthetic Dentistry* 3:126-132 (1991).
31. Saunders W.P. The shear impact retentive strengths of four dentine bonding agents to human and bovine dentine. *J Dent* 16 : 233 - 238 (1988).
32. Shimizu A, UI T and Kawakami M. Bond strength between amalgam and tooth hard tissues with application of fluoride, glass ionomer cement and adhesive resin cement in various combinations. *Dental Material Journal* 5 : 225 - 232 (1986).
33. Solmon A. and Beech D. R. Bond strengths of composite to dentine using primers. *Journal of Dental Research* 62. Abstract of papers p. 677 Abstract 253 (1983).
34. Staninec C. M. and Holt M. Bonding of amalgam to tooth structure: tensile adhesion and microleakage tests. *Journal of Prosthetic Dentistry* 59 : 397 - 402 (1988).
35. Tay F. R. Jr., Gwinnett A. J. and Wei S. H. Micro-morphological spectrum from overdrying to over-wetting acid-conditioned dentin in water -free acetone-based, single-bottle primer/adhesives. *Dental Materials* 12 : 236 - 244 (1996).
36. Torri Y., Staninec M., Kawakami M., Imazato S., Torri M. and Tsuchitani Y. Inhibition in vitro of caries around amalgam restorations by bonding amalgam to tooth structure. *Operative Dentistry* 14 : 142 - 148 (1989).
37. Triolo P. T. Jr., Swift E. J. Jr. and Barkmeier W. W. Shear bond strengths of composite to dentine using six dental adhesive systems. *Operative Dentistry* 20 : 46 - 50 (1995).
38. Turner E. W., St Germain H.A. and Meiers J.C. Microleakage of dentin-amalgam bonding agents. *American Journal of Dentistry* 8 : 191 - 196 (1995).
39. Vargas A. M. , Denehy E. G. and Ratananakin T. Amalgam Shear bond strength to dentin using different bonding agents. *Operative Dentistry* 19 : 224-227 (1994).