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Bonding of Adhesive Resin Luting Agents to Metal and Amalgam

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Abstract - *The shear bond strength of three adhesives, Panavia 21, Superbond, All Bond C&B Cement, and a dual cure resin (Variolink), to Ni-Cr-Be (Rexillium III), Midigold (Type III gold) and Amalgam (Sybraloy) were determined. Fifteen samples were prepared using 800 grit abrasive papers for Ni-Cr and Midi-Gold, and 100 grit papers for amalgam. Ni-Cr-Be and Midi-Gold samples were sandblasted for 30s and steam cleaned for 10s. The adhesives were bonded to the samples using gelatine capsules and were matured for 24h in water at 37°C. The samples were debonded in shear using an Instron at a cross-head speed of 1 mm/min. The data was analysed using ANOVA and a Tukey test. The bond strength of Superbond to both metal alloys was significantly higher (P<0.05) than any of the materials tested, with the exception Panavia 21 to gold. The bond strength of All Bond C&B cement had shown to be not significant difference from those of Panavia 21 and Variolink, when bonded to Rexillium and Midi-Gold, respectively. The bond strength of All Bond C&B Cement to amalgam was significantly greater (P<0.05) than those of the other materials tested. The shear bond strength to gold showed lower bonding for all adhesives when compared with Rexillium (P<.001). The ranking of bond strength to both alloys was as follows: Superbond>Panavia21>All Bond C&B>Variolink. The nature of substrate to be used for bonding and the adhesive material itself are important factors in bonding which can be achieved between cast metals and prepared teeth with amalgam filling. Superbond should be successful as an adhesive for the attachment of all substrates tested, with the possible exception of amalgam, for which All Bond C&B Cement gives the best result.*

KEY WORDS: Bond strength, luting , amalgam bonding, alloy bonding, adhesives

INTRODUCTION

Recently, significant improvements in polymer chemistry have led to the development of several adhesive materials. These adhesives can give chemical adhesion not only to tooth structure[1] but also to non-precious alloys[2,3] and precious alloys with surface treatment[4]. They also have the potential of effectively bonding to amalgam restorations[5], particularly when the amalgam is placed as a core prior to the metal crown cementation. These advantages may improve resistance to separation at the interface between the adhesive and various substrates, such as amalgam and metals, and may ensure greater longevity of the crowns and bridges[6]. However, the current adhesives produce a less reliable bond to metal restorations[7]. In addition, the amalgam-adhesive resin interface is still the limiting factor for the bond strength[8]. Many workers apply adhesive resins between substrates to determine their bond strengths to the intended substrate. These substrates can be metal alloys, metal alloy and tooth, metal alloy and amalgam or amalgam and tooth.

Such an application would have increased or decreased the bond strength, and therefore obscured the real value of the bond strength of the adhesives with the intended substrate, which is considered to be more critical. One way to study this complex more thoroughly is to eliminate the complicating factors of having several interfaces and to investigate each interface in isolation from the other applications. This work would help the clinician to select the most favourable adhesive/substrate combination for use in particular crown and bridge situations. In recent years, several adhesive resin luting agents have been introduced. However, few studies have been conducted to assess the influence of their bond to various substrates, including alloy and amalgam, on crown and bridge retention by using shear bond strength measurements as the criteria for judgement. Therefore, the aims of this in vitro project were: to investigate and compare the shear bond strength of several adhesive luting agents to alloys (non-precious and precious) and amalgam; to determine the single multipurpose adhesive system that provides the highest shear bond strength to the various substrates tested and to determine the mode of failure using a stereomicroscope.

MATERIALS AND METHODS

Shear test specimens were prepared by bonding each of the four adhesive luting agents, Superbond, Panavia 21, All-Bond C&B cement and Variolink, to Ni-Cr-Be alloy (Rexillium III), Midi-Gold (precious alloy) and amalgam.

The adherends used for alloy samples were Rexillium III (Ni-Cr-Be alloy) and Midi-Gold (Type III gold). The latter is composed of 50.0% Au, 35.0% Ag, 3.5% Pd and 9.5% Cu. To prepare the samples of both alloys, discs, 8 mm in diameter and 5 mm thick, each with a shaft extending vertically from the centre of one surface, were cast in alloy. These were embedded centrally in cylindrical polyester

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resin blocks, and placed in the fume cupboard. After 24h, the resin blocks were removed from the cupboard. To facilitate bond strength testing, 800 grit wet and dry carborundum papers were used by hand to expose a flat area of each alloy sample. Fifteen samples of Ni-Cr-Be alloy and of Midi-Gold were prepared for bonding with each of the four materials tested, and re-used throughout the study. Immediately prior to bonding, the alloy samples were sandblasted (with 50 μm aluminium oxide for 30 s, at a line pressure of 5Kg/cm^2 and a distance of 3 cm), and steam cleaned for 10s.

The amalgam alloy used was Sybraloy a spherical alloy. The amalgam alloy capsules were triturated for 12s, according to the manufacturer's instructions. For each sample, the mixed amalgam was manually condensed into a cavity of 5 mm diameter and 2 mm depth, prepared centrally in polyester resin cylinder block. The 15 samples were reused throughout the study for bonding the four resin cements tested. All the samples were stored in distilled water at 37 °C for 24h prior to testing. After 30 days storage in water, the fully set specimens were lapped by hand on wet 100-grit silicon carbide paper, which closely matched the surface profile created by a finishing diamond bur used to prepare teeth for the crown and bridge applications[9]. Then, the amalgam surface of each cylinder was thoroughly rinsed and dried using the air syringe.

To prepare of the test specimens for Rexillium, Midi-Gold and amalgam, a circular hole, 5 mm in diameter was punched in adhesive tape (made from PVC) backed with cellulose acetate sheet, and the tape was attached centrally to the ground surface of the adherend to demarcate the bonding area. The margins of the tape were punched to ensure adaptation of the tape to the surface.

The test specimens were prepared using the gelatine capsule technique (#5 gelatine capsules from Eli Lilly and Company Indianapolis, USA, 4.6 mm diameter). Capsules were vented and pre-loaded with composite as a space filler (any brand - time expired was used for this purpose) but leaving a 1 mm space for the test adhesive system. The capsule was finally filled with the mixture of the resin luting agent under consideration. All adhesives were used in accordance with the manufacturer's instructions, including conditioning, rinsing and drying of the prepared alloy surfaces. Details of the compositions are provided in Table 1.

After the capsule was seated on the bonding site, a vertical loading apparatus was used to hold the specimens under a constant pressure, and, more importantly, to prevent the specimen from sliding away from the bonding site during polymerisation of the resin. In accordance with the manufacturer's instructions, the prepared surfaces of both alloys were not primed before the application of the resin

Table 1. *Adhesive resins used in this study*

Adhesive	*Composition*	*Bat. No*	*Manufacturer*
All Bond C&B Cement	BIS-GMA self-cured Luting composite and Quartz filler	049297	Bisco Inc., Itasca USA
All Bond 2	Etchant: 10% H_3PO_4 Primer A: NTG-GMA Primer B: BPDM Adhesive: BIS-GMA, UDMA, HEMA	880016	Bisco Inc., Itasca USA
Panavia 21	MDP monomer, Catalyst, Inorganic Fillers Tooth Primer: (liquid A+liquid B)	41205	J. Morita USA and Kuraray Co. Japan
Superbond	Monomer (liquid): MMA, 4-META Polymer (powder): PMMA Catalyst: TBB G reen Activator: an aqueous solution of 10% citric acid + 3% ferric chloride	60802	Sun Medical Co. Kyto, Japan
Variolink	Dimethacrylate, Fine Particle Glass filler Email Preparator: etching gel. Syntac Primer: TEGDMA Syntac Adhesive: PEGDMA Heliobond: BIS-GMA TEGDMA	814578 (Catalyst) 803085 (Base) 811339 810826 814325 803798	Vivadent Ets. Liechtenstein Germany

BIS-GMA: Bis-phenol glycidyl methacrylate;
NTG: Nitroglycerin
BPDM: Bi-Phenyl dimethacrylate
UDMA: Urethane dimethacrylate
HEMA: 2-Hydroxyethyl methacrylate
MDP: Methacryloyloxydecyl dihydrogen Phosphate
MMA: Methyl-methacrylate;
4-META: Methacryoxyethyl trimellitate anhydride;
PMMA: Polymethyle-methacrylate
TBB: Tri-n-Butyle borane;
TEGDMA: Tetra ethylene glycol dimethacrylate
PEGDMA: Poly (ethylene glycol) dimethacrylate

luting agents, except with All-Bond C & B Cement. For this adhesive, Primer A and B were mixed and two coats were applied to the bonding surface and dried for 5s with an air syringe, before the final application of the luting resin. For All-Bond C & B Cement, the amalgam surfaces were primed with Primer A and Primer B in a similar way to the preparation of the metal surfaces. For the other products, the prepared surfaces of the amalgam were not primed before the application of the resin luting agents, according to the manufacturer's instructions. Following a storage period of 24h at 37°C, the specimens were allowed to come to room temperature.

To determine the shear bond strength, each test specimen was positioned in a shear test jig, to provide a base for testing, and debonded using the tensile testing machine at a cross head speed of 1 mm/min and full scale deflection of 1 KN. The data on the mean and the standard deviation was received by the computer after the fracture of the specimens occurred. The shear bond strength was calculated (in MPa) from the load required to cause fracture of the bond (in Newtons) divided by the nominal area of the bonding circle (in mm^2).

On completion of the bond tests, all specimens were examined with a light stereomicroscope to determine whether failures were adhesive (at the adhesive/substrate interface) or cohesive (within adhesive or substrate) or a combination (mixed) of both types of failures. For specimens showing mixed failures, the proportion of adhesive and cohesive fractures was estimated visually.

The values of the shear bond strength for each material tested at superficial, middle and deep dentine (5 samples each), and combined dentine depths, Rexillium, Midi-Gold and amalgam (15 samples each), were obtained using statistical analysis of data. The values were subjected to a one-way analysis of variance (ANOVA) and Tukey's pairwise comparisons testing, using the Minitab Statistic Computing Package. The Tukey test was used to provide confidence intervals for all pairwise comparisons between mean values for all groups tested in this study. Test results at levels of $P>0.05$ were regarded as non-significant. To determine whether significant differences ($P< 0.05$) existed between the bond strength values for the Rexillium and Midi-Gold alloys, the data were subjected to a two-way ANOVA.

RESULTS

The value of bond strength of Superbond to Rexillium was significantly higher than any of the other adhesive materials (Table 2). There was no significant difference between Superbond and Panavia 21 when bonded to Midi-Gold (Table 3). Although Variolink produed the weakest bond for both alloys there was no significant difference between All Bond C&B Cement and Variolink for gold. A two-factor ANOVA (Table 4) revealed that the effects of both substrates and adhesive systems and their interactive effect on shear bond strength were highly significant ($P<0.001$). The mean Rexillium shear strengths (16.8 ± 3.9 MPa) were higher than the mean Midi-Gold shear strength (13.8 ± 3.1 MPa), and were significantly different from each others ($P<0.001$). For amalgam (Table 5), the value of bond strength of All Bond C&B Cement was significantly higher than any of the other adhesive materials. The value of bond strength of Panavia 21 was not significantly different from that of Variolik and Superbond.. The types of modes of adhesive failure for substrates tested are given in Tables 2, 3 and 5).

DISCUSSION

In the present study, the superiority of Superbond, when bonded to both metals, may be due to different factors. Firstly, the nature of the adhesive mechanism of Superbond, which occurs due to ionic bonding[10] as well as hydrogen bonding[11] may be a factor. Secondly, the direction of shrinkage during polymerisation of Superbond, which occurs towards the adhesive-metal interface[12], may also have had an advantageous effect on the bond strength of Superbond. For Midi-Gold, the value of Panavia 21 (16.5 ± 4.1 MPa) is similar to that (17.7 ± 1.7 MPa) previously reported[13]. These latter workers used the sandblasting and tinplating methods to bond Panavia 21 to gold (Type III) and comparison of the results suggest that there is no advantage in tinplating although comparisons of this type should be treated cautiously as the experimental methods are not identical.

Munksgaard et al. reported a value of 16.8 MPa to be considered as the minimum value required for resisting contraction forces that occur during polymerisation of the resin[14]. In the present study, products such as Superbond

Table 2. *The shear bond strength (MPa) of adhesive resins to Rexillium*

Adhesive	*Shear Bond Strength (MPa)*	*Mode of Failure (N=15)*				
	Mean ± SD	*A*	*C/M*	*C/R*	*Mixed*	*Mixed Area (%) For Combined Results. Mean ±SD*
Superbond	23.8 ± 3.5	10			5	52.0 ± 21.7 C/R 48.0 ± 21.7 A
Panavia 21	18.3 ± 5.4	9			6	50.0 ± 20.2 C/R 50.0 ± 20.2 A
All Bond C&B	15.8 ± 3.5	6			9	55.6 ± 19.4 C/R 44.4 ± 19.4 A
Variolink	9.5 ± 3.0	2			13	27.7 ± 12.2 C/R 72.3 ± 12.2 A

Means that are not significantly different [P > 0.05 (ANOVA and Tukey)] are indicated by vertical lines. Mode of failure: A: Adhesive, C/M: Cohesive in metal, C/R: Cohesive in resin.

Table 3. *The shear bond strength (MPa) of adhesive resins to Midi-Gold*

Adhesive	*Shear Bond Strength (MPa)*	*Mode of Failure (N=15)*				
	Mean ± SD	*A*	*C/M*	*C/R*	*Mixed*	*Mixed Area (%) For Combined Results. Mean ±SD*
Superbond	19.3 ± 2.6	10			5	66.0 ± 13.4 C/R 34.0 ± 13.4 A
Panavia 21	16.5 ± 4.1	6			9	58.9 ± 14.5 C/R 41.1 ± 14.5 A
All Bond C&B	11.1 ± 2.8	6			9	38.9 ± 10.5 C/R 61.1 ± 10.5 A
Variolink	8.3 ± 2.9	15				

Means that are not significantly different [P > 0.05 (ANOVA and Tukey)] are indicated by vertical lines. Mode of failure: A: Adhesive, C/M: Cohesive in metal, C/R: Cohesive in resin.

Table 4. *Two- way ANOVA of the test results showing the difference between the* Ni-Cr alloy and the Midi-Gold alloy when bonded with adhesive resins

Source	*Df*	*Sum of Square*	*Mean of Square*	*F-value*	*P-value*
Alloy	1	273.2	273.2	21.2	<0.001
Adhesive	3	2627.3	875.8	202.9	<0.001
Interaction	3	74.8	24.9	12.9	<0.001
Error	112	1436.2	12.8		

The result show the type of alloy and the adhesive which have a significant effect on shear bond strength values (P<0.001).

Table 5. **T***he shear bond strength (MPa) of adhesive resins to amalgam*

Adhesive	*Shear Bond Strength (MPa)*	*Mode of Failure (N=15)*				
	Mean ± SD	*A*	*C/M*	*C/R*	*Mixed*	*Mixed Area (%) For Combined Results. Mean ±SD*
Superbond	4.2 ± 1.3 “	15				
Panavia 21	6.4 ± 1.9 * “	15				
All Bond C&B	12.4 ± 4.7	7			8	53.8 ± 22.6 C/R 46.2 ± 22.6 A
Variolink	8.6 ± 3.8 *	15				

Means that are not significantly different [P > 0.05 (ANOVA and Tukey)] are indicated by similar superscripts. Mode of failure: A: Adhesive, C/M: Cohesive in metal, C/R: Cohesive in resin.

and Panavia 21 attained bond strength values higher than the value of 16.8 MPa to both alloys. Although the value of All Bond C&B Cement (15.8 MPa) did not reach 16.8 MPa it was only slightly short of the minimum value when bonded to Rexillium. Accordingly, the products with these reported values are more likely to be clinically accepted for crown and bridgework, although it has been reported that adhesives, such as Superbond and Panavia 21 produced poor bonding to certain gold alloys, such as Au-Ag-Pd-Cu[15]. In the present study, the bond strengths of all adhesive tested were higher than that of Variolink when bonded to the Ni-Cr-Be alloy or Midi-Gold alloy. This could result from the adhesive components incorporated within the adhesive cements enabling the adhesive to chemically bond to the metal oxide. These components are: an organic ester groups in Panavia 21, 4-META in Superbond and Primer A (NTG-GMA) and Primer B (BPDM) in All-Bond C&B Cement. The variations in these adhesive components and their ability to wet and penetrate into the surface irregularities may also account for the differences noted in the bond strength values obtained in this work. In spite of the fact that Variolink has no Metal Primer, this cement showed some success in bonding to both alloys tested and its bond strength to Midi-Gold was similar to that of

All Bond C&B Cement. This finding could be due to the lower film thickness and the flow properties of Variolink[16], which allowed complete penetration into the sandblasted metal surface, with minimal shrinkage stress, thus forming a relatively strong bonds.

Reports have shown that adhesive resins such as Panavia Ex (Panavia 21 without ED Primer) and Superbond adhere better to non-precious alloys than to Midi-Gold[4,17]. These reports are in agreement with the present work, since all the adhesives tested, produced higher bond strength to Ni-Cr alloy than to Midi-gold. This observation may indicate that the selection of the type of alloy is also important, as well as the adhesive, for bonding metal restorations to abutment teeth. The apparent decrease in the bond strength of the adhesives to the Midi-Gold alloy compared with Ni-Cr-Be alloy may be due to different factors. These factors are the low amounts of basic metal in the composition of the gold and the differences in the wet ability of sandblasted metal surfaces caused by the adhesives. The active monomers within the adhesives may have a lower affinity to the oxidising surface of the Midi-Gold alloy than to Ni-Cr-Be alloy. The softness of gold alloys, such as Midi-Gold, which can result in the erosion of the sandblasted surfaces and therefore the reduction of the surface area for bonding[7], is also an important factor.

Resins, such as Superbond and Panavia Ex are designed to bond metals. However, several workers have found that these adhesives produce less favourable results when bonded to amalgam[18-22]. For example, Barzilay et. al. found that the bond strength values for Superbond and Panavia Ex are with in the range of 4.5 and 4.3 MPa, respectively[20]. These values are notably lower in comparison with the value 12 MPa reported by Souza et al., when they bonded All Bond C&B cement to amalgam[5]. In the present study the bond strength of Panavia 21, Superbond and All Bond C&B Cement were found to be 6.4, 4.2 and 12.4 MPa, respectively.

The reason for the superiority of All-Bond C&B Cement over the other materials may be due to the hydrophilic nature of the mixed primers, used before the application of All-Bond C&B Cement. This improves surface coverage, allows better wetting of the amalgam surface, and therefore ensures intimate contact between the adhesive monomer and the amalgam surface. Variolink has no metal primer, and therefore its bond is purely micromechanical. However, the bond strength of Variolink to amalgam was similar to that of Midi-Gold and. was notably higher than that of Superbond and Panavia 21, although it was not statistically different from than for Panavia 21. The strong bond between this adhesive and amalgam and the metal as well could be explained by its lower film thickness and the better flow property[16]. This may allow the adhesive to flow and enter the roughened surfaces, created by 100-grit silicon carbide papers, completely and optimize the interlocking between the amalgam and the resin. The decrease in the bond strength demonstrated by Superbond when bonded to amalgam may be attributed to the worsened flow property of this adhesive[16]. This may lead to an inability of the resin to seal and fill the gap between the amalgam and the resin[23]. These findings suggest that the ability of a resin to wet and penetrate the irregular surface of amalgam could be considered as a critical factor in the retention of metal crowns luted to teeth restored with amalgam and may explain some clinical failures.

The value of the bond strength may have a profound influence on the type of the mode of failure. In this study, all of the samples tested have appeared to be either adhesive or mixed (adhesive and cohesive within the resin) in nature (Tables, 2, 3, 5). It is observed that the proportion of the cohesive resin failure, within the mixed area, increased with increasing the bond strength value, for most of the samples tested.

This work would suggest that the nature of substrate to be used for bonding and the adhesive material itself are important factors in bonding which can be achieved between cast metals and prepared teeth with amalgam fillings. The simpler treatment of the metal surfaces by sandblasing with AL_2O_3 (no priming, silicoating or tin-plating), used in this study, would help to remove an expensive, sophisticated or complicated treatment in various clinical situations. This is particularly important for alloys with a high noble content such as Midi-Gold. Superbond could prove highly beneficial for cementing metal crowns (fabricated from precious or non-precious alloys) in clinical bridgework. Panavia 21 can also prove highly successful for bonding gold crowns to abutment teeth. For attaching crowns and bridges to teeth presented with existing amalgam restorations at the bonding sites, All Bond C&B Cement may be the most appropriate choice of material. Superbond and Panavia 21 could not be considered reliable for bonding crowns to amalgam restorations unless further improvements in the adhesive systems are made. The bond strength values of these adhesives were relatively low and the observed mode of failure was 100% adhesive.

MANUFACTURER'S DETAILS

- All Bond C&B Cement. Bisco Inc., Itasca, Illinois, USA
- All Bond 2. Bisco Inc., Itasca, Illinois, USA
- Panavia 21. Kuraray Co., Osaka, Japan
- Superbond. Sun Medical Co. Kyoto, Japan
- Variolink. Vivadent Ets, Schaan, Liechtenstein
- Rexillium III. Jeneric Pentron, Wallingford, Conn, USA
- Midi-Gold. Ivoclar North America, Inc.
- Sybraloy. Kerr, Romulus, MN, USA
- #5 gelatine capsule. Eli Lilly and Company, Indianapolis, USA

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REFERENCES

1. Eick, J.D., Cobb, C.M., Chappell, R.P., Spencer, P. and Robinson, S.J. The dentinal surface: its influence on dentinal adhesion. Part I. *Quintessence. Int*., 1991; **22**: 967-77.
2. Tanaka, T., Nagata, K., Takeyama, M., Nakabayashi, N. and masuhara, E. 4-MMETA opaque resin – A New resin strongly adhesive to nickel-chromium alloy. *J. Dent. Res*., 1981; **60**: 1697-1701.
3. Tanaka, T., Fujiyama, E., Shimizu, H., Takaki, A. and Atsuta, M. Surface treatment of nonprecious alloys for adhesion-fixed partial dentures. *J. Prosthet. Dent*., 1986; **55**: 456-62.
4. Tanaka, T., Atsuta, M., Nakabayashi, N. and Masuhara, E. Surface treatment of gold alloys for adhesion. *J. Prosthet. Dent*., 1988; **60**: 271-79.
5. Souza, M.H., Retief, D.H., and Russell, C.M. Shear bond strength and microleakage of All Bond. *Am. J. Dent*., 1993; **6**: 148-54.
6. Ishijima, T., Caputo, A.A. and Mito, R. Adhesion of resin to casting alloys. *J. Prosthet. Dent*., 1992; **67**: 445-9.
7. Mukai, M., Fukui, H. and Hasegawa, J. Relationship between sandblasting and composite resin-alloy bond strength by a silica coating. *J. Prosthet. Dent*., 1995; **74**: 151-5.
8. Swift, E.J., Perdigao, J. and Heymann, H.O. Bonding to enamel and dentine: A brief history and state of the art. *Quintessence. Int*., 1995; **26**: 95-110.
9. Mojon, P., Hawbolt, E.B., MacEntee, M.I. and Belser, U.C. Maximum bond strength of dental luting cement to amalgam alloy. *J. Dent. Res*., 1989; **68**: 1545-9.
10. Rheinberger, V. and Beham, G. Adhesive bridges – New prosthetic possibilities. 1985; Ivoclar report No. 2.
11. Ohno, H., Araki, W. and Sagara, M. The adhesion mechanism of dental adhesive resin to alloy: Relationship between Co-Cr alloy surface structure analysed by ESCA and bonding strength of adhesive resin. *Dent. Mater.* 1986; **5**: 46-65.
12. Yoshida, K. and Atsuta, M. Effects of adhesive primers for noble metals on shear bond strengths of resin cements. *J. Dent.* 1997; **25**: 53-8.
13. Novelli, C., Lacy, M., Watanabe, L.G. Shear bond strength of adhesive resins to dental alloys. *J. Dent. Res.* 1995; **74**: 231, Abst 1759.
14. Munksgaard, E.C. and Asmussen, E. Dentine-polymer bond promoted by Gluma and various resins. *J. Dent. Res*., 1985; **64**: 1409-11.
15. Tsubota, Y., Kokubo, Y., Kobayashi, K. and Fukushima, S. (1993): Bond strength of adhesive resin cements to tooth structure. Transactions Second International Congress on Dental Materials., 1993; P-076 (Abst).
16. Saad, A. Osman., McCabe, J.F., Walls, A.W. Film thickness and rheological properties of luting agent for crown cementation. *Eur. J. Prosthodont. Res. Dent*., 2006; **14**: 23-7.
17. Watanabe, I., Matsumura, H. and Atsuta, M. Effect of two metal primers on adhesive bonding with type IV gold alloys. *J. Prosthet. Dent*., 1995; **73**: 299-303.
18. Cooley, R.L., McCourt, J.W. and Train, T.E. Bond strength of resin to amalgam as affected by surface finish. *Quintessence. Int*., 1989; **20**: 237-39.
19. Rueggeberg, F.A., Caughman, W.F., Gao, F. and Kovarik, R.E. Bond strength of Panavia EX to dental amalgam. *Inter. J. Prosthod*., 1989; **2**: 371-75.
20. Barzilay, A., Vassilas, G. and Graser, G.N. (1990): Panavia and 4-META bond to amalgam and Ni-Cr alloy. *J. Dent Res*., 1990; **69**: 2038 (Abst).
21. Aboush, Y.E. and Jenkins, C.B. The bonding of an adhesive resin cement to single and combined adherends encountered in resin-bonded bridge work: an in vitro study. *Br. Dent. J*., 1991; **171**: 166-69.
22. Bagley, A., Wakefield, C.W. and Robbins, J.W. In vitro comparison of filled and unfilled universal bonding agents of amalgam to dentin. *Oper. Dent*., 1994; **19**: 97-101.
23. McComb, D., Brown, J. and Forman, M. Shear bond strength of resin-mediated amalgam-dentin attachment after cyclic loading. *Oper. Dent*., 1995; **20**: 236-40.