Effect of cement film thickness on shear bond strengths of two resin cements

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Abstract

Objective: The purpose of this study was to determine the effect of cement thickness on the shear bond strength of two commercial adhesive resin cements, Panavia-F and Super-Bond C&B when used to bond nickel-chromium alloy to bovine dentine.

Materials and methods: Ni-Cr alloy discs, Ø5x3 mm and bovine teeth (120 pairs) were bonded together by two different resin cements (Super Bond C&B and Panavia F) at four different film thicknesses (50, 100, 150 and 200 micrometers). After bonding, they were stored in 37°C water for 24 h. Shear bond test at a crosshead speed of 0.5mm/min was performed. The fracture surfaces of the specimens were observed by scanning electron microscope.

Results: Panavia F showed the shear bond strength ranged from 4.02±1.44 MPa to 9.32±2.40 MPa, whereas Super Bond C&B showed a shear bond strength ranging from 5.01±1.38 MPa to 7.10±2.70 MPa. Both cements showed maximum shear bond strength to Ni-Cr alloy at 100 micrometers. In general, Panavia F showed higher bond strength than Super Bond C&B. Both cement thickness and cement type, and their interaction were found to have an effect on the shear bond strength of nickel-chromium alloy to bovine dentine. No significant differences were found when the film thickness was less than 150 micrometers for Panavia F ($P>0.05$) while those of Super Bond C&B were not significantly different at any film thickness ($P>0.05$). When the thickness of cement increased, more voids in the cement were found especially in Super Bond C&B.

Conclusions: Within the limitations of this study, the shear bond strength between 50 and 150 micrometers was not significantly affected by the cement thickness.

Key words: panavia, super bond, film thickness, Ni-Cr alloy, shear bond strength, resin cement bovine dentine

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Introduction

The film thickness of cement is one of the critical factors essential to the clinical success of fixed prostheses. The theory of the thin layer of the cement to obtain a great either mechanical or chemical bond strength has been well accepted[1,2]. International Standards for Water-based cement (ISO9917-1, 2007) established the critical thickness of the cement at 25 micrometers. However, some resin cement cannot form the cement thickness less than 25 micrometers due to several factors such as filler addition, resin consistency. International Standards for Polymer-based restorative materials (ISO4049, 2009) were established separately and increased the critical thickness of the cement up to 50 micrometers. Several theories focusing on the disadvantages of thicker cement layers on bond strength have been proposed[3-5]. Thicker cement can cause a greater amount of polymerization shrinkage, which increases interfacial stresses. Moreover, the large number of voids can be found in thicker cement, which results in decreasing the bonding area, causing higher stresses in the cement layer as well as stress concentrations that will promote crack initiation and propagation[3,5]. These disadvantages may affect the cement bond strength. It is hypothesized that an optimal cement thickness for resin cement that will provide the highest bond strength can be determined. The objective of this study was to determine the effect of cement thickness on the shear bond strength of two commercial adhesive resin cements, Panavia-F and Super-Bond C&B used to bond nickel-chromium alloy to bovine dentine.

Materials and methods

A total of 120 nickel-chromium alloy (Sankin NNB®, Sankin Industry Co., Japan) discs, size 5 mm in diameter and 3 mm in thickness, were prepared by lost-wax technique. The discs were polished with silicon carbide paper, 600 grits, then blasting with 50 micrometers of aluminum oxide powder under 4 bar pressure. The discs were cleaned ultrasonically with water for 5 min then kept dry and clean, ready for cementation.

120 bovine teeth were prepared by cutting the root, removing the pulp tissue and filling the cutting root orifice with glass-ionomer cement. The teeth were embedded in acrylic block by exposing the flat buccal surface on the top of the block. The embedded teeth were polished with silicon carbide paper, 600 grits, and then cleaned in water with ultrasonic cleanser for five minutes. The prepared teeth blocks were kept in distilled water at 37 ± 2 °C.

The bovine teeth were randomly bonded to alloys discs (15 specimens per group) by two different adhesive resin cements; Panavia F (Kurarey Co., Japan) and Super Bond C&B (Sun Medical Co., Japan) and four different cement film thicknesses (50, 100, 150 and 200 micrometers). The detailed information of the materials used in this study is showed in Table 1. The cement film thickness was controlled by adhesive tape (50 micrometers per layer) and measuring micrometer jig (Figure 1). The adhesive tape was punched to obtain a 3 mm diameter hole as the bonding area then the tape was placed on the center of the exposed tooth surface and the demarcated tape was cut for easy removal. The cementation technique followed the manufacturer instructions.

For Panavia, the exposed dentine was treated with ED primer for 60 s then gently air dried. Cement pastes were mixed within 20 s and applied on the alloy surface then placed on the dentine surface and the thickness was aligned on the micrometer within 40 s. The excessive cement was removed with a brush. The cement was cured with a light curing unit on the left and right sides for 20 s then the Oxyguard was applied and left for 3 min before Oxyguard and vinyl tape were removed.

Table 1 The materials used in this study

Materials	Brand name	Lot no.	Manufacturer	composition
Ni-Cr alloy	Sankin NNB	J50033	Sankin Industry Co., Japan	Ni: 63%,Cr: 28%,Mo: 5%, others 4%
Resin cement	Panavia F	51536	Kurarey Co., Japan	**Paste A**: Dimethacrylate (DMA), 10-Methacryloyloxy-decyl dihydrogen phosphate **(MDP)**, silanized silica, photoinitiator, dibenzoyl-peroxide **Paste B**: Dimethacrylate (DMA), N,N-diethanol-*p*-toluidine, accelerator, functionalized sodium fluoride, silanated barium glass
	Superbond C&B	P1941	Sun Medical Co., Japan	**Powder**: Polymethyl Methacrylate (PMMA) **Liquid**: Methyl Methacrylate (MMA), 4-Methacryloxyethyl trimellitate anhydride (4-META) **Initiator**: Tri-n-butyl borane (TBB)

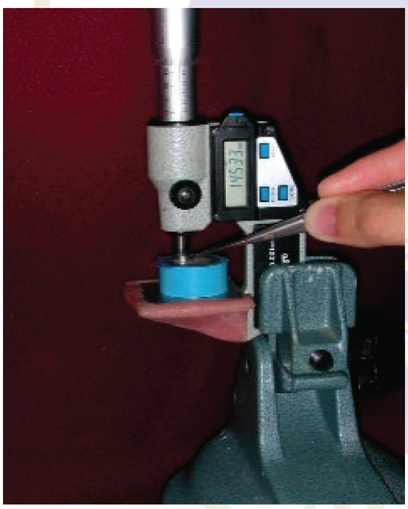


Figure 1 The cement film thickness measuring jig.

For Superbond C&B, the Green Activator was painted on the dentine surface for 10 s, rinsed with water and gently air-dried. One drop of catalyst and four drops of monomer were lightly mixed and one small scoop of polymer powder was put in the activated liquid. The mixed cement was applied on the alloy surface, placed on the dentine surface and the thickness was aligned on micrometer. The excess cement was removed with a brush and left for 8 min before vinyl tape was removed.

After cementation, all specimens were immersed in distilled water and kept in the incubator at 37 ± 2°C for 24 h before bond test. The bonded specimens were mounted in a shear test jig and subjected to a shear test using a knife-edge blade in a universal testing machine (Instron 5566, Instron Corp., Buckinghamshire, UK.) at a crosshead speed of 0.5 mm/min. The maximum load was recorded and the bond strength was calculated by dividing the maximum load by bonded surface area, and reported in MPa (Pa = N/m^2).

The data were statistically analyzed by Two-way ANOVA then post-hoc multiple comparison was performed by Games-Howell test. The fracture surfaces of all specimens were observed by scanning electron microscope (JSM-5410LV, JEOL LTD, Tokyo, Japan) at x35 magnification. The mode of failure was classified as adhesive when the cement totally detached from either alloy or bovine dentine surface and complex failure when the cement was found both on alloy or bovine dentine surface. Complex failure was analyzed using the percentage of cohesive failure (fracture occur in the cement layer) by the program Image Pro Plus (Media Cybernetics, Inc., MD, USA)

Results

Table 2 shows the mean shear bond strength and standard deviation of nickel-chromium alloy bonded to bovine dentine with two adhesive resin cements at different film thicknesses. The higher mean shear bond strength of Panavia F and Super Bond C&B was recorded in the 100 micrometers group and the mean values were simply lower for the 50, 150, and 200 micrometer cement layers respectively compared with the samples with a 100 micrometer thick cement layer for Panavia F and 150, 200 and 50 micrometers for Super Bond C&B.

The results of two-way ANOVA showed the shear bond strength between nickel-chromium alloy bonded to bovine dentine was significantly influenced by both cement type and cement thickness including their interaction ($p<0.05$).

Since the homogeneity of variance was not assumed, the comparisons of shear bond strength among material and thickness groups were tested by The Games-Howell multiple comparison test. The mean shear bond strength of Panavia F was not significantly different when the film thickness was less than 150 micrometers ($p>0.05$) and the mean shear bond strength of Super Bond C&B was not significantly different at any film thickness ($p> 0.05$).

Table 3 shows the percentage of bond failure on the alloy site. Almost all specimens failed in the complex failure type. All adhesive failure was found only on the cement-dentine interface. The percentage of adhesive failure of Panavia F occurred more frequently than Super Bond C&B at all levels. The greater cement thickness of both specimens increased the number of complex failure patterns. These complex failures showed more cohesive failure than adhesive failure.

The SEM micrograph presented in Fig. 2 shows the fracture surface on alloy sites at 50-micrometer (a) and 200-micrometer specimens (b) of both cements. Complex failure, more voids and crack lines were found in greater cement thicknesses and predominately in Super Bond C&B.

Discussion

The optimum thickness for the highest shear bond strength in this study was 50 to150 micrometers for Panavia F. However, the shear bond strength was not significantly different in any thickness for Super Bond C&B. Moreover, regarding overall shear bond strength, Panavia F showed higher bond strength than Super Bond C&B at every film thickness except at 200 micrometers. This may be due to the difference in filler added formula and the two-paste system of Panavia F that contained more filler than 70 wt%[6] showing better mechanical properties than Super Bond C&B containing no filler. Yoshida et al.[7] found that the shear bond strength of luting agents to metal was

Table 2 The shear bond strength of two resin cements at different film thickness.

Cement	Shear bond strength (MPa ± SD) Film thickness			
	50 µm	100 µm	150 µm	200 µm
Panavia F	9.05 ± 3.10^{a}	9.32 ± 2.40^{a}	$8.25 \pm 3.32^{a,b}$	4.02 ± 1.44^{d}
Super Bond C&B	$5.01 \pm 1.38^{c,d}$	$7.10 \pm 2.70^{a,b,c}$	$7.07 \pm 1.50^{a,b,c}$	$5.83 \pm 2.90^{b,c,d}$

Note: The same superscript letter indicated no significant differences ($p > 0.05$)

Table 3 The percentage of bond failure on alloy site.

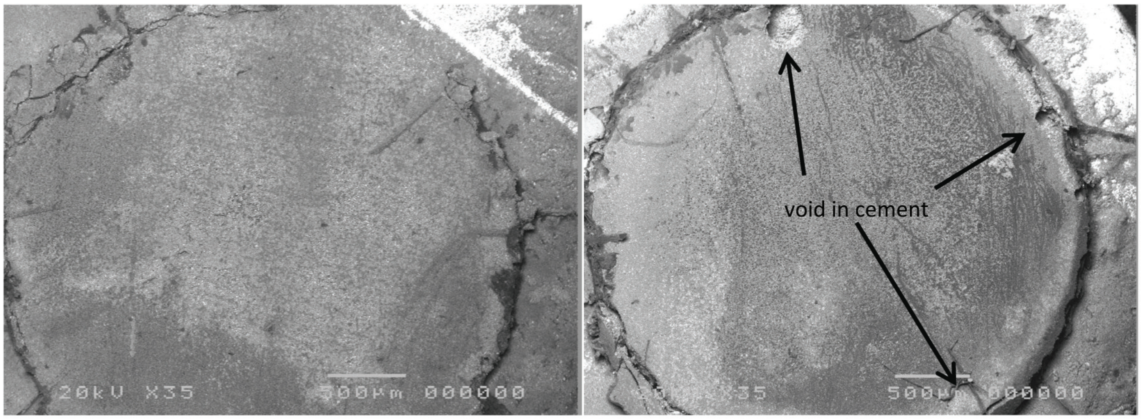
Cement	Cement thickness (micrometer)	Adhesive Failure (cement-dentin)	Complex failure	
		n (%)	n (%)	Adhesive (%) Cohesive (%)
Panavia F	50	15 (100)	0 (0)	- -
	100	15 (100)	0 (0)	- -
	150	10 (66.67)	5 (33.33)	87.94 12.06
	200	7 (46.67)	8 (53.33)	78.43 21.57
Super Bond C&B	50	12 (80.00)	3 (20.00)	99.01 0.99
	100	7 (46.67)	8 (53.33)	84.67 15.33
	150	6 (40.00)	9 (60.00)	84.76 15.24
	200	3 (20.00)	12 (80.00)	83.54 16.46

Note : All adhesive failure was found only on the cement-dentine interface.

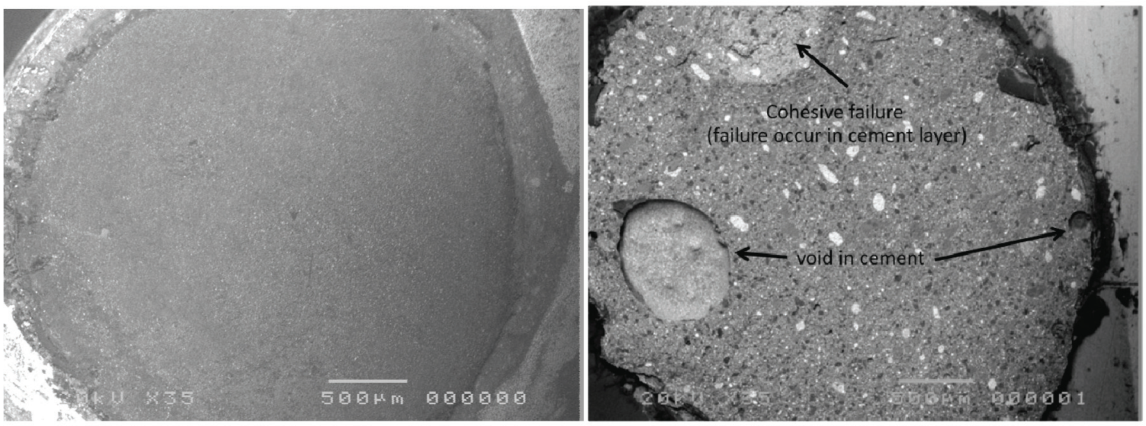
influenced by the luting agent's mechanical properties. They found the shear bond strength of non-primed specimens cemented by Panavia 21 exhibited greater strength than those cemented with Super Bond C&B. This was also in agreement with several studies[8,9].

The majority of bond failures in this study occurred on the cement-dentine interfaces. The SEM observation of Super Bond C&B failure found more voids than Panavia F. This may be due to the different preparations between both resin cements. Super Bond C&B is based on PMMA resin and non-filler addition which were weaker than Bis-GMA resin and high filler addition in Panavia F. Furthermore, Super Bond C&B was prepared in powder and liquid form while Panavia F was prepared in two-paste form. Mixing a powder-liquid material is more likely to introduce voids into the mixture, especially in the thicker cement of Super Bond C&B. The results of SEM observation in this study were similar to previous studies.[10,11]

The number and size of voids in the thick cement could lead to crack propagation at lower forces. The reason for crack propagation at a lower force is that those voids create stress concentrations, and thus act as local stress raisers leading to cracks in the bulk of the cement. This may be the reason why the fracture pattern was changed to more complex failure and more cohesive failure was found when the cement thickness increased. The thinner cement expelled the voids leading to more homogeneous cement that required greater force to break this bond[12]. The bond strength value from adhesive site failure of the thin cement seems to be higher than the cohesive and complex failure in the thick cement that presented more voids. These voids were weak points leading to the failure.



a-1. Panavia F; 50 micrometers   a-2. Panavia F; 200 micrometers



b-1. Super Bond C&B; 50 micrometers   b-2. Super Bond C&B; 200 micrometers

Figure 2 The SEM pictures of fracture surfaces on alloy site, whole alloy surface was covered by cement.

Therefore, cohesive and complex failures might not indicate the true bond strength of luting cement.

In conclusion, within the limitations of this study, the cement thickness of Panavia effected the shear bond strength of alloy to dentin only on 200 micrometer, while those of Superbond was not affected the shear bond strength

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