The Influence of Sonic and Ultrasonic Vibration on the Shear Bond Strength of a Selected Resin Luting Cement

ABSTRACT:

Purpose: This study determined the effect of sonic and ultrasonic instrumentation on the shear bond strengths of Panavia 21, a popular cement for the luting of resin-bonded restorations. Methods: 84 Ni-Cr cylinders were cemented to randomly selected resin composite substrates using Panavia 21 following the manufacturer's instructions. The Ni-Cr-composite specimens were divided into 7 groups of 12 specimens each based upon the procedure used for removing the excess cement. For Group 1 (Co) specimens the excess cement was removed with microbrushes immediately after cementation. Groups 2 through 7 were based on the use of vibrating instrument and the time period after which the excess material was removed. These included the cement, Panavia 21, three vibrating instruments, Sonic with a universal tip (So), Piezoelectric ultrasonic with a USP1S tip (Pu), Magnetorestrive ultrasonic with a FS1-100 tip (Mu) and two different time periods, soon after cementation (9m) and one hour after cementation (1h). Once excess cement removal was completed, the specimens were subjected to shear testing.

Results: Mean Shear Bond strengths ranged from 16.03 MPa (Co) to 19.91 MPa (So 1h). Statistical analysis demonstrated that interaction of the main effects were significant ($F= 4.27$, $p=0.042$). Post-hoc analysis demonstrated that the effect of timing was significant in all the instrumented groups. The majority of the tested specimens failed cohesively compared to mainly adhesive failures for the control group.

Conclusions: The effect of type of instrumentation immediately following polymerization setting had no effect on the shear bond strengths however a delay of 1 hour for all types of instrumentation had a beneficial effect of improving observed shear bond strengths.

INTRODUCTION

The provision of resin-bonded bridges is an accepted treatment modality in the replacement of teeth in a short edentulous span in the short to medium term.[1] Success is dependent on appropriate patient selection, design features of the retainer and the bonding cement and technique utilized. The dental literature has shown that ultrasonic vibration from the use of an ultrasonic scaler may lead to the breakdown of dental materials.[2,3,4,5] It is postulated that ultrasonic vibration can induce crack formation and propagation with brittle luting cements such as zinc phosphate and glass ionomers, which may cause separation between a casting or post and the underlying tooth structure.[2] Various authors have reported on the use of ultrasonics to remove adhesive retainers cemented with resin luting cements.[3,4,5] Conversely, other investigators have questioned the ability of

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ultrasonic vibration to loosen other types of restorations, such as posts, when cemented with resin- based cements.[6,7]

There is little evidence in the literature on the effect of vibration produced by sonic and ultrasonic instruments on the shear bond strengths of resin luting cements when applied early after initial setting of such materials.

The aim of this study was to determine the effect of sonic and ultrasonic instrumentation on the shear bond strengths of resin luting cements. The simulated clinical situation was the removal of excess cement from around a metallic prosthesis immediately and 1hour after setting. A substrate of resin composite sample and Nickel-Chromium (Ni-Cr) metallic cylinder was employed to mimic the tooth structure and the metal prosthesis respectively. The null hypothesis stated that the effect of instrumentation type and timing would have no effect on the shear bond strength of the selected resin luting cement.

MATERIALS AND METHODS

Panavia 21 resin luting cement indicated for cementing resin-bonded bridges was evaluated in this study. Cylinders of nickel chromium alloy measuring 4.5 mm X 5 mm and samples of P60 posterior composite with dimensions 8mmX8mmX2mm were used to mimic the metallic prosthesis and the prepared tooth structure. A sonic scaler, a piezolelectric ultrasonic unit and a 25 K magnetostrictive ultrasonic unit were used to evaluate the effects of vibration. Ninety four composite specimens were light cured for 20 seconds using a Biolite 2100 halogen unit in Teflon coated stainless steel molds and Mylar strips on the top surface of the specimens. Following polymerization the composite substrates were finished manually with wet 600 grit silicone carbide paper for 30 seconds and then embedded in individual cylinders of Acratray autopolymerizing polymethyl methacylate

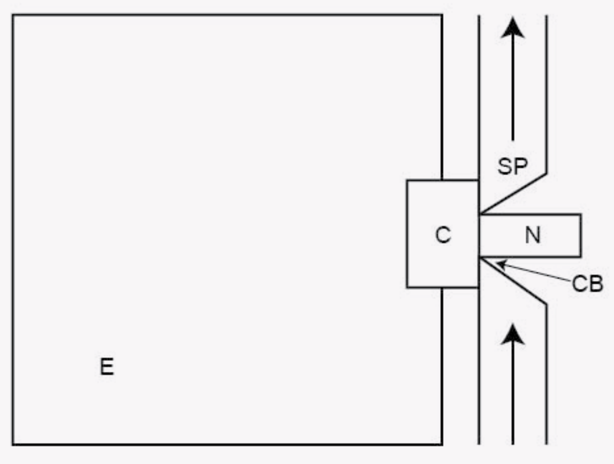

Figure 1: Schematic cross sectional representation of specimen in shear testing jig [C-composite, R- Ni-Cr rod, E-embedding resin, P- shear probe, CS- beveled countersink] Arrow indicates direction of movement of shear probe.

Nickel-Chromium cylinders were cast using a lost wax technique. Following de-vestment, one end of each cylinder was sandblasted with 50 μm Al_2O_3 for 5 seconds to yield an oxide layer, which facilitated the bonding process. The cylinders were stored in distilled water for 1 week prior to the bonding procedure.

The cylinders were cemented to randomly selected resin composite substrates using Panavia 21 following the manufacturer's instructions and precluding the use of oxygen by the use of Oxyguard on the extruded cement. A specialized jig applied a 5 N load to the opposing end of the Ni-Cr cylinder during the setting reaction to standardize the film thickness of the luting medium.

A power analysis determined that each test group required 12 specimens for statistical significance. One group of 12 specimens served as the control group that received no vibration, where excess cement was removed using micro-brushes. Excess cement of the remaining specimens was left in place and removed at two different time intervals: 9 minutes and 1 hour following setting, using various powered instruments. A pilot study determined the minimum amount of time luting cements should be allowed to set prior to instrumentation. The pilot investigation demonstrated that fifty percent of all specimens debonded when both sonic and ultrasonic vibration was attempted 1 to 9 minutes following the manufacturer's guidelines for setting. Hence, vibration was only attempted 9 minutes following completion of the setting reaction. Allocation of specimens is described below. The total of 84 Ni-Cr cylinders specimens were divided into 7 groups of 12 specimens each based upon the procedure used for removing the excess cement. For Group 1 (Co) specimens the excess cement was removed with microbrushes immediately after cementation. Groups 2 through 7 were based on the use of vibrating instrument and the time period after which the excess material was removed. These included the cement, Panavia 21, three vibrating instruments, Sonic with a universal tip (So), Piezoelectric ultrasonic with a USP1S tip (Pu), Magnetorestrive ultrasonic with a FS1-100 tip (Mu) and two different time periods, soon after cementation (9m) and one hour after cementation (1h). The various instruments were used for as long as necessary to remove all excess cement. Following removal of the cement with the respective instruments all the specimens were stored in distilled water for 7 days and then subjected to shear testing.

A tensometer testing machine was used to facilitate shear testing. Each specimen [composite (C) - Ni-Cr rod (R)] in its embedding resin (E) was placed in a specialized mounting jig that allowed the applied load to be perpendicular to the composite-Ni-Cr rod (*Figure 1*). The shear probe (P) consisted of a rod of stainless steel with a machined opening and a beveled countersink (CS) that fit over the diameter of the Ni-Cr rod. The beveled edge acted as a knife-edge probe that allowed direct contact with the luting cement interface.

Shear force was applied with a load cell of 500N at a crosshead speed of 0.5mm/min. Shear force was calculated using the following formula:

$$\text{Shear Force (MPa)} = \frac{\text{Peak load at Failure (N)}}{\text{Cross sectional area of cylinder (mm}^2\text{)}}$$

Debonded surfaces were observed using a light microscope to classify the modes of failure as: (a) Cohesive (b) Adhesive or (c) Mixed depending on relative amounts of cement remaining on the composite surface or the Ni-Cr surface. Type of failure was categorized as cohesive when cement was evenly found on both composite and alloy substrate, adhesive failure when the majority of cement was left on either the alloy or composite substrate and mixed when equal amount of resin remained on the composite and alloy surfaces.

Data were analyzed using SPSS software version 21. The means and standard deviations were calculated for each group. The two factor ANOVA was used to assess differences in bond strength. Included factors in the model were vibrating instrument type, time and their interaction.

RESULTS

Mean Shear Bond strengths ranged from 16.03 MPa (Co) to 19.91 MPa (So 1h). Means and standard deviations are presented in Table 1. Results demonstrated that interaction of the main effects were significant ($F= 4.27$, $p=0.042$). Post-hoc analysis demonstrated that the effect of timing was significant in all the instrumented groups. Mean shear bond strengths were significantly higher for all specimens in the instrumented groups at 1h compared to immediate removal and the control group. Distribution of failure patterns is presented in Table 2.

DISCUSSION

The use of resin composite substrate to mimic tooth structure eliminated the problems with tooth quality associated with variations in dentine quality, storage conditions, storage time and age of teeth at extraction.[8,9,10] When considering resin-bonded prostheses, Aboush and Jenkins demonstrated that non-precious metal retainers bonded to enamel surfaces had similar tensile bond strengths when bonded to composite substrates hence the use of composite as the selected adherend instead of natural tooth structure.[11]

An unexpected result was the similar values obtained for shear bond strength of the Panavia when excess cement was immediately removed with either microbrushes (Co) or various instruments- So, Pu, Mu. The beneficial effect of delayed instrumentation on excess cement was clearly demonstrated, with a delay of one hour significantly improving values of shear bond strength.

Use of sonic and ultrasonic dental devices have been shown to be associated with increased surface roughness and voids of restorative dental materials.[12,13,14] Surface defects, characterized as voids may be attributable to the vibratory motion of the instrument together with the minimal effects of the cavitation at the tip of the instrument for ultrasonic devices.[15]

Fonseca *et al* demonstrated a beneficial effect of time on the hardness of Panavia.[16] Newly set chemically cured resin cement, with suboptimum hardness values is easily prone to the development of voids at the interface as a result of vibratory instrumentation. Under testing conditions such defects may behave as the starting point for the propagation of cracks and ultimate early failure. A post polymerization delay of 1-hour may potentially reduce the amount and size of defects introduced at the luting cement interface caused by vibratory motion, thereby improving the quality of the bond achieved.

The strength of brittle solids is dramatically decreased by surface damage.[17] This was clearly demonstrated by the majority of the specimens failing cohesively, following all types of instrumentation. It is noteworthy to emphasize that the control groups showed more specimens failing adhesively, demonstrating inherent deficiencies with the bonding mechanism between the resin luting cement and either of the selected

Table 1:

Means shear bond strengths and standard deviation of composite bonded to Ni-Cr cylinders with Panavia 21 (the same superscript common letters show no significant differences between values for shear bond strengths. Significant differences between instrument groups are indicated by the variation in the case of the same letter)

	Panavia 21	Mean (+S.D) (MPa)
Group 1	Co	16.03 (6.22)[a]
Group 2	So-9m	16.32 (5.34)[ab]
Group 3	So-1h	19.91 (5.13)[B]
Group 4	Pu-9m	16.39 (3.09)[ac]
Group 5	Pu-1h	19.26 (5.07)[C]
Group 6	Mu-9m	17.04 (6.31)[ad]
Group 7	Mu-1h	19.24 (8.79)[D]

Table 2:

Modes of specimen failure by instrumentation type and timing of instrumentation.

Type of Failure	Adhesive	Cohesive	Mixed
Group 1: Co	7	5	
Group 2: So-9m	3	9	
Group 3: So-1h	4	8	
Group 4: Pu-9m	2	8	2
Group 5: Pu-1h	2	10	
Group 6: Mu-9m	4	8	
Group 7: Mu-1hr	3	9	

adherends instead of suboptimum material properties, which one may expect with cohesive failure. This reinforces the concept that obtained data for shear bond strengths may actually mirror fracture toughness measurements.

The ultrasonic instruments were used according to clinical use by applying to the cement. The motion of the instruments were not evaluated and the angle of the tip to the cement was not standardized. Furthermore the load applied was not standardized at a set level. Time may have also been a factor as this was not fully controlled. All these variables may have a contribution to the outcome of the results and merit further research.

CONCLUSION

The null hypothesis had to be partially rejected. While the effect of type of instrumentation immediately following polymerization setting had no effect on the shear bond strengths, a delay of 1 hour for all types of instrumentation had a beneficial effect of improving shear bond strengths. In the clinical setting, when using Panavia 21 to cement resin bonded prostheses and set excess cement needs to be removed to prevent plaque retention a delay of 1 hour is recommended.

MANUFACTURERS' DETAILS

- Panavia 21- -
- Nickel Chromium alloy - Soft Non-Precious Ceramic Alloy, Meta Dental Corp, Elmhurst, NY, USA
- Posterior composite - P60, 3M ESPE, St. Paul, MN, USA
- Sonic scaler -Rand 6400 Orbital Air Scaler JR Rand Co, Freeport, NY, USA
- Piezolelectric ultrasonic unit (Biosonic S1, Coltene/ Whaledent Inc, Cuyahoga Falls, OH, USA)
- Magnetostrictive ultrasonic unit -Gnosis SC-1, Medeco International, Inc., Miami, FL, USA
- Biolite 2100 halogen unit- Medeco International, Inc., Miami, FL, USA
- Sandblaster- Henry Schein Inc, Melville, NY, USA
- Autopolymerizing polymethyl methacylate- Acratray, Henry Schein Inc, Melville, NY, USA
- Al_2O_3 - NorthStar Dental Inc, Ogdensburg, WI, USA
- Oxyguard- Kuraray Co Ltd, Tokyo, Japan
- Tensometer- Tinius Olsen, Horsham, PA, USA
- Light Microscope -Stero Star Zoom, Reichert Inc, Depew, NY, USA
- Panavia- Kuraray Co Ltd, Tokyo, Japan

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