

# Effect of Luting Cements On the Bond Strength to Turkom-Cera All-Ceramic Material

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## Abstract

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**BACKGROUND:** The selection of the appropriate luting cement is a key factor for achieving a strong bond between prepared teeth and dental restorations.

**AIM:** To evaluate the shear bond strength of Zinc phosphate cement Elite, glass ionomer cement Fuji I, resin-modified glass ionomer cement Fuji Plus and resin luting cement Panavia-F to Turkom-Cera all-ceramic material.

**MATERIALS AND METHODS:** Turkom-Cera was used to form discs 10mm in diameter and 3 mm in thickness (n = 40). The ceramic discs were wet ground, air - particle abraded with 50 -  $\mu$ m aluminium oxide particles and randomly divided into four groups (n = 10). The luting cement was bonded to Turkom-Cera discs as per manufacturer instructions. The shear bond strengths were determined using the universal testing machine at a crosshead speed of 0.5 mm/min. The data were analysed using the tests One Way ANOVA, the nonparametric Kruskal - Wallis test and Mann - Whitney Post hoc test.

**RESULTS:** The shear bond strength of the Elite, Fuji I, Fuji Plus and Panavia F groups were:  $0.92 \pm 0.42$ ,  $2.04 \pm 0.78$ ,  $4.37 \pm 1.18$ , and  $16.42 \pm 3.38$  MPa, respectively. There was the statistically significant difference between the four luting cement tested ( $p < 0.05$ ).

**CONCLUSION:** the phosphate-containing resin cement Panavia-F exhibited shear bond strength value significantly higher than all materials tested.

## Introduction

The main purpose of the luting agent is to seal the gap at restoration-prepared tooth interface and retain the restoration in place to prevent its displacement during function [1].

Dental luting agent provides a connection between the indirect fixed restorations and the supporting prepared tooth structure [2]. The type of connection can be in the form of mechanical, chemical, micromechanical, or combination. These luting materials may be used for provisional or permanent cementation depending on their physical properties and planned longevity of fixed dental prosthesis [3] [4].

A strong and permanent bond between hard dental tissues and restorative materials provides improved marginal adaptation, thereby preventing microleakage resulting in pulpal sensitivity or penetration of bacteria and toxic substances and discolouration [5].

An adequate adhesion between ceramic and tooth substance is required for the successful function of ceramic restorations over the years [6]. Bond strengths are influenced by some factors one of which is the type of luting cement [7].

In vitro studies have documented the rationale for using conventional luting cement with the all-ceramic restorations including Turkom-Cera system

[5] [8] [9] [10]. Clinical trials on full - coverage high-strength ceramic restorations have also reported acceptable success rates with conventional luting agents [11] [12]. However, in the event of compromised retention or marginal seal, even high - strength ceramic crowns might benefit from adhesive bonding with a composite resin luting agent. Several in vitro and in vivo studies on this topic recommended adhesive cementation of ceramic and even high - strength ceramic restorations [4] [13] [14] [15] [16].

The integrity of the dental luting cement to ceramic surfaces plays an important role in the durability of the restorations; the failures originating from cementation surfaces acknowledged the need for a strong cement to improve the bonding at this critical area [17].

The bond strength of different luting agents to Turkom - Cera™ all - ceramic material has not been studied. Therefore, the objectives of this study were:

1. To determine the shear bond strength of Turkom - Cera luted with different types of cement.
2. To examine the association between shear bond strength and failure modes.

## Materials and Methods

### Materials used

Four types of luting agents were used; zinc phosphate cement (Elite, GC Corporation, Tokyo, Japan), glass ionomer cement (Fuji I, GC Corporation, Tokyo, Japan), resin-modified glass ionomer cement (Fuji Plus, GC Corporation, Tokyo, Japan) and resin luting cement (Panavia-F, Kuraray Medical Inc., Okayama, Japan) with its silane coupling agent. Also, forty Turkom - Cera (Turkom - Ceramic (M) Sdn Bhd, Puchong, Malaysia) discs 10 mm in diameter and 3 mm thick were prepared and used in this study.

### Specimen preparation

Perspex split mould with five circular openings of 10 mm diameter and 3 mm thickness was used for the preparation of the Turkom - Cera disc specimens. A total of forty Turkom - Cera ceramic discs with 10 mm diameter and 3 mm thickness were prepared according to manufacturer instructions.

Each specimen was embedded in a die stone (Densite, Shufo, Japan) using plastic mould 30 mm in diameter and 30 mm high. The bonding surface of the specimens was at the same level of the embedding medium to form one flat surface.

After hardening for 24 hours at room temperature, the bonding surface of the specimens

were sanded with a series of silicon carbide (SiC) abrasive papers in sequence (No. 400, 600, 800 and 1000 grit, Buehler) using a water - irrigated lapping machine (Metaserv® 2000, Buehler, UK) until the ceramic disc was perfectly flushed with the mounting mould and a flat surface was attained. All specimens were rinsed under running water and dried before bonding procedure. The ground bonding surface was examined under a microscope (Zoom Stereo EMZ - 1, MEIJI Techno Co., Ltd., Saitama, Japan) at 30x magnification to ensure that no abrasive particles were left on the surface.

### Sample distribution and bonding procedure

According to the Four luting cement (Elite, Fuji I, Fuji Plus & Panavia F) used, four different groups were evaluated.

Group 1: Sandblasting + Zinc Phosphate cement.

Group 2: Sandblasting + Glass ionomer cement.

Group 3: Sandblasting + Resin-modified glass ionomer cement.

Group 4: Sandblasting + Resin cement.

### Bonding procedure

All samples were mounted and secured on the shear bond test apparatus recommended by ISO/TS 11405/2003 [18] to bond a uniform amount of cement onto the Turkom-Cera bonding surface. The alignment apparatus consists of a holder for the specimen, a cylindrical split brass mould resulting in samples with a defined bond area of 3 mm diameter and 3 mm height, a silicone pad and an added load of 1 kg.

Sandblasting was performed with 50 - µm aluminium oxide (Al<sub>2</sub>O<sub>3</sub>) particles at an air pressure of 2.5 bars for 13 seconds from a distance of 10 mm. The discs were then steam cleaned and air dried. The brass split mould was carefully adapted to the bonding surface by raising the mounted specimen using the screw at the bottom of the mounted specimen. The split mould together with the mounted specimen was then quickly secured on to the bonding apparatus and tightly screwed. All cement were mixed according to manufacturer's instructions at room temperature (24°C). The cement were placed, using a plastic instrument, into the 3 mm diameter hole in the brass split mould while it was slightly raised to ensure a uniform flow onto the bonding surface and to avoid trapping of air bubbles (Figure 1). A sharp blade was used to remove the excess cement before setting from the top of the brass split mould. A layer of

Oxyguard II (oxygen - blocking gel) was applied in the case of Panavia F.



Figure 1: The hole in the brass mould adapted to the bending jig

Specimens were allowed to set under a constant load of 1 kg for 15 minutes using a polyvinylsiloxane (Express putty, 3M ESPE, St. Paul, MN, USA) putty mould that was placed over the brass split mould and held in place by the weight (Figure 2). The 1 kg load was removed, and the samples were allowed to sit at room temperature for an additional 30 minutes with the polyvinylsiloxane mould still in place.



Figure 2: Load application during bonding

The samples were carefully removed from the apparatus, and the brass split mould was separated using a sharp blade, and the excess cement was removed with a scalpel blade to standardise the bonding area. Then, the specimens were stored in distilled water at 37°C for 24 h before testing.

### Testing procedure

The bonded specimens were mounted in the shear test jig recommended by ISO [15] and tested using a universal testing machine (Instron® Corp., England) at a crosshead speed of 1 mm/min (Figure 3).



Figure 3: Specimen during shear bond strength testing

The maximum load at failure was recorded in Newton, and the SBS of each specimen was calculated and expressed in MPa by dividing the force (N) at which the bond failure occurred by the bonding area (mm<sup>2</sup>).

### Assessment of mode of failure

The bonded surfaces were observed under a microscope (Zoom Stereo EMZ - 1, MEIJI Techno Co., Ltd., Saitama, Japan) at 30X magnification to evaluate adhesive and cohesive failure modes. According to Piwowarczyk et al., (2004), failures were categorised as follows [19]:

1. Adhesive failure at the ceramic-cement interface.
2. Cohesive failure within the cement or ceramic.
3. Mixed failure: a combination of adhesive and cohesive failures.

### Statistical analysis

Descriptive statistics of shear bond strength were performed. To compare shear bond strength between the four groups tested, One Way ANOVA and the nonparametric Kruskal - Wallis tests were conducted. A post hoc test using Mann - Whitney Post hoc test was performed to test which pair of groups differ from each other significantly.

Regarding the association between shear bond strength and modes of failure, descriptive statistics for modes of failure and shear bond strengths were recorded, and the result was descriptively analysed. The Statistical Package for the Social Sciences, version 19 (SPSS, SPSS Inc., Chicago, IL) software was used to perform the statistical analysis. Statistical significance was set at  $\alpha = 0.05$ .

## Results

Descriptive analysis was performed, and the mean and median shear bond strength for all groups is presented in Table 1.

**Table 1: The mean and median shear bond strength (MPa) for the four luting types of cement used**

Cement	n	Mean (SD)	Median (IQR)	95% Confidence Interval	
				Lower Bound	Upper Bound
Elite	10	0.92 (0.42)	0.95 (0.59)	0.62	1.22
Fuji I	10	2.04 (0.78)	2.11 (1.21)	1.48	2.60
Fuji Plus	10	4.37 (1.18)	4.22 (1.06)	3.52	5.22
Panavia F	10	16.42 (3.38)	15.92 (4.20)	14.01	18.84

Since the distribution of shear bond strength was not normally distributed as indicated by histogram and Shapiro - Wilk test, nonparametric Kruskal - Wallis Test was then done to compare the shear bond strength between Elite, Fuji I, Fuji Plus and Panavia F. Results were shown in Table 2. There was a significant difference in shear bond strength between the four groups ( $p < 0.001$ ).

**Table 2: Comparison of shear bond strength (MPa) between Elite, Fuji I, Fuji Plus and Panavia F by Kruskal Wallis Test**

Cement	n	Mean (SD)	Median (IQR)	Chi-Square (df)	P value
Elite	10	0.92 (0.42)	0.95 (0.59)	34.837 (3)	<0.001
Fuji I	10	2.04 (0.78)	2.11 (1.21)		
Fuji Plus	10	4.37 (1.18)	4.22 (1.06)		
Panavia F	10	16.42 (3.38)	15.92 (4.20)		

<sup>a</sup> Kruskal - Wallis Test was used. Significant level was set at 0.05.

Further analysis using Mann - Whitney Post hoc test with Bonferroni correction as multiple pairwise comparisons revealed that there were significant differences between shear bond strength of Elite and Fuji I ( $p = 0.018$ ), Elite and Fuji Plus ( $p < 0.001$ ), Elite and Panavia F ( $p < 0.001$ ), Fuji I and Fuji Plus ( $p < 0.001$ ), Fuji I and Panavia F ( $p < 0.001$ ) and also between Fuji Plus and Panavia F ( $p < 0.001$ ).

### Testing mode of failure

A cross-tabulation was performed between the four treatment groups (Elite, Fuji I, Fuji Plus and Panavia F) and modes of failure. It was noticed that with Elite, Fuji I and Fuji Plus, the modes of failure were 100 % adhesive mode. While for Panavia F, the modes of failure were 30 % mixed and 70 % adhesive mode.

Descriptive summary for modes of failure and shear bond strengths was performed. The identified modes of failure were: adhesive and mixed. The shear bond strength for the adhesive mode of failure was in ascending order; Elite (0.92 MPa), Fuji I (4.04 MPa), Fuji Plus (4.37 MPa) and Panavia F (14.79 MP). In general, the shear bond strength for the mixed mode of failure (20.25 MPa) was higher compared to that of the adhesive mode (0.92 to 14.79 MPa).

## Discussion

This study was carried out to evaluate the shear bond strength of different luting cement (zinc phosphate cement Elite, glass ionomer cement Fuji I, resin-modified glass ionomer cement Fuji Plus and resin luting cement Panavia F) to Turkom-Cera all - ceramic discs.

The results of the current study indicated that the bond strength of resin luting cement Panavia F ( $16.42 \pm 3.4$  MPa) to sandblasted Turkom-Cera discs was higher to that obtained by zinc phosphate cement Elite ( $0.92 \pm 0.4$  MPa), glass ionomer cement Fuji I ( $2.04 \pm 0.8$  MPa) and resin-modified glass ionomer cement Fuji Plus ( $4.37 \pm 1.2$  MPa). Statistical analysis showed the statistically significant difference between the four luting types of cement tested. The mean shear bond strength of Panavia F was significantly higher than Elite, Fuji I and Fuji Plus ( $p < 0.05$ ).

In interpreting the results of this study, one has to take into account the internal strength of the cement used. Ultimately, cement with a bond strength that competes with the strength of the cement or one of the substrates to be bonded to can be used. The bond strength of zinc phosphate and glass ionomer cement is much lower than that of resin-modified glass ionomer cement, which have a lower strength compared to resin composite cement [20]. This fact is reflected in the highest shear bond strength value of the resin cement tested in this study. In general, the ranking of the bond strength results increased up from zinc phosphate cement to glass ionomer cement to resin-modified glass ionomer cement to resin luting cement. This trend may be related to the intrinsic strength of the cement. The higher the resin contents, the higher the strength [21] [22].

The results of this study are in agreement with the results of other in vitro studies [19] [23]. Piwowarczyk et al., (2004) found that the shear bond strengths between sandblasted high - strength aluminium oxide ceramic and resin cement were significantly higher than those of zinc phosphate, glass ionomer and resin-modified glass ionomer cement [19]. Another in vitro study found that the shear bond strength of aluminium oxide-reinforced glass ceramic material increases significantly from conventional glass ionomer cement, resin-modified glass ionomer cements to resin cement [23].

In vitro studies on bonding strengths of cement to dental ceramics differ within a wide range and assessment of their clinical significance is difficult. Since the all-ceramic restoration is cemented to dentine, is not only the cement - ceramic interface important, but also the dentine - cement interface can be an important factor that determines the longevity of the restoration.

The shear bond strength of human dentine was found to be 13.4 MPa [24]. It has also been

suggested that 10 - 13 MPa is the minimum strength needed for clinical bonding [23] [25]. On the other hand, the in vitro bond strengths to acid - etched human dentine of various commercial resin composite bonding cement, which have been in clinical use for a relatively long time, are reported to range from 1.1 MPa to 14.8 MPa [26]. The shear bond strength of dentine to Panavia F and Fuji Plus were 7.7 MPa and 7.0 MPa, respectively [24] [27]. Due to variation in the experimental set - up or preparatory procedures, the shear bond strengths reported in the literature are difficult for comparison. Nevertheless, the shear bond values reported are much lower than the shear bond strength values found for the ceramic - cement interface. A microtensile bond strength test of dentine and a Cerec 2 inlay cemented with Panavia F showed a similar result; debonding occurred more often at the cement-dentine interface than at the cement - inlay interface [28]. This finding was also supported by another study which found that the resin composite had the higher bond strength to the ceramic material than to the prepared dentine [29].

In short, based on the previous considerations the use of the resin cement Panavia F will give the most reliable bond to the ceramic material, and fracture will most probably occur at the cement - dentine interface.

For conventional zinc phosphate cement, one study reported tensile bond strength to dentine of 0.6 MPa, whereas another study reported 0.9 MPa [30] [31]. Although these values seemed to be very low, and are considerably inferior to those suggested as the minimum acceptable strength for clinical bonding, zinc phosphate cements have been successfully used clinically for a very long time to lute cast dental restorations and currently recommended for luting high - strength ceramics (eggs: Procera AllCeram and Turkom - Cera) [11] [12] [13]. To assess the clinical performance of bonding systems, in vitro studies should, therefore, be supplemented with clinical studies with long-term follow-up.

The current study also addressed the issue of failure modes. About the luting cement used with sandblasted Turkom-Cera ceramic, failure modes for zinc phosphate, glass ionomer and resin-modified glass ionomer cement were completely adhesive between the cement-bonding substrate interface for all specimens. However, the Panavia F has shown a complex adhesive and cohesive failures in 30 % of specimens which was in agreement with another study conducted by Ayyildiz et al. in 2015 [33]. This complex mode of failure may explain the higher bond strength of Panavia F to Turkom-Cera specimens obtained in this study.

In conclusion, within the limitations of this in vitro study, it was found that the mean shear bond strength between sandblasted Turkom-Cera ceramic and Panavia F was significantly higher than those of zinc phosphate, glass ionomer and resin-modified

glass ionomer cement. This study has given rise to the tentative conclusion that higher bond strength values increase complex (adhesive and cohesive) failure modes.

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