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ORIGINAL ARTICLE

Determination of Shear Bond Strength of Nanocomposite to Porcelain and Metal Alloy

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ABSTRACT

Objective: To compare porcelain and metal repair done with both nanocomposite and conventional composite. **Material and Methods:** A total of 30 cylinders were fabricated from Porcelain (I), Porcelain fused to metal (II), and metal (III) substrate each. Control group (A) was bonded with conventional micro-hybrid composite and experimental group (B) was bonded with nanocomposite in a 2 mm thickness. All specimens were thermocycled and stored in distilled water at 37 °C for 7 days. A universal testing machine was used to measure the Shear bond strength (SBS). The difference between bond strengths of the groups was compared using an independent t-test. **Results:** In all three groups, the SBS was higher in the experimental group as compared to the control group. The use of nanocomposite of metal alloy presented maximum shear bond strength, followed by samples of porcelain fused to metal and finally porcelain, showing the lowest values of SBS. **Conclusion:** Porcelain and alloys bonded with nanocomposite exhibit enhanced adhesiveness as well as aesthetic and mechanical properties. This subsequently would translate into providing higher clinical serviceability and durability and hence a cost-effective and accessible repair option for human welfare.

Keywords: Dental Porcelain; Tooth Fractures; Nanostructures.

Introduction

A major foundation for the replacement of restorations is porcelain and metal fracture [1]. Porcelain fracture incidence ranges from 5 % to 10 % during service life of ten years [2]. Fractures transpire due to flaws in porcelain restorations and result in a compromise in the tooth esthetics and subsequent tooth structure loss. Researchers report that repair materials should be such that they restore both color and structure of teeth in fracture areas [3]. Previous literature has proposed the use of adhesive materials in weak and brittle ceramic restorations to provide good esthetics and strength [3,4].

Porcelain restorations offer strength and excellent esthetics due to their superior physical and mechanical properties. But on the other hand, it can inevitably crack or get chipped off [5,6]. Nevertheless, it is cost-effective, so it is widely used. In addition, its manufacturing is fast and easy, and has tooth color matching ability [7]. In 2008, O' Brien reported that there are three types of fractures that need to be repaired; the one which involves only porcelain structure, the one which involves both metal and porcelain, and the fracture which leads to massive exposure of metal. An inappropriate design, improper method in Porcelain manufacturing, trauma, and improper surface treatment for metal fused to porcelain are all some porcelain veneer fracture causes [8]. As previous studies show, the main cause of fractures and chipping of zirconia porcelain are mainly mismatch in coefficient of thermal expansion among zirconia and porcelain veneer, the thickness of porcelain as well as intrinsic low fracture hardiness, and decreased thermal conductivity [9].

Resin-Based Composites are a suitable choice of material to fix fractured sites [10]. Strong and durable resin bond material has superior retention with good marginal seal and reduced microleakage and increases fracture resistance of not only the repaired tooth but also the restoration [10].

Several methods are followed to get the high-quality resin veneers to cast alloys bond. These include mainly; silicoater system [11], adhesive metal primer [12], adhesive heat-cured opaque resin [13], light-cured 4-META opaque resin [14], silane coupling agent [15], self-curing 4-META/MMATBB opaque resin, and various commercial adhesive bonding promoters [16].

Selection of a strong resin bond and accurate surface handling is required when there is intraoral fracture and chipping of the ceramic veneers. Porcelain-based prosthesis repair considerably increases the cracked prosthesis life and gives patients and dentists economical ease, instead of making prostheses again [17]. Over the years, researchers worked to develop inorganic fillers in resin-based composites and the modern trend is to decrease the size of filler particles from micrometer to nanometer [18]. The present study aim was to rule out whether this applies in the case of porcelain repair.

This study aimed to measure the shear bond strength of nanocomposite to porcelain and metal alloy and compare it with that of conventional composite to porcelain and metal alloy. We also aimed to evaluate the efficiency of nanocomposite as efficient interim porcelain and metal repair material. We hypothesize that the shear bond strength of nanocomposite to porcelain and metal alloy is more than that of conventional micro-hybrid composite to porcelain and metal alloys.

Material and Methods

Study Design and Procedures

A comparative study was conducted in de 'Montmorency Dental College, Lahore & Mechanical Laboratory) from January to May 2021. Two stages were included in the study: Stage 1: Fabrication and aging of the samples, and Stage 2: measurement and evaluation of Shear Bond Strength (SBS) between porcelain/metal / composite border. In Group I, 20 cylinders were made from porcelain in a customized brass

split mold. The porcelain was condensed into the holes and ablaze at 940 ºC in a calibrated porcelain oven. In Group II, 20 porcelain fused to metal cylinders were fabricated by inlay wax cylinders having 1.0 cm diameter and half of the cylinder height (of 0.4 cm) and another half 0.2 cm. They were invested and cast with Ni-Cr alloy. The surface of metal was air abraded with 50 µm aluminium oxide. After application of porcelain layer and firing, final prepared surfaces were air abraded and finished with finishing burs. In Group III, the metal cylinders were made by flowing inlay wax into a cylindrical silicone mold with a diameter of 1.0 cm and a height of 0.4 cm. The wax cylinder was invested and cast with Ni-Cr and finally cleaned with an ultrasonic unit in distilled water. They were divided into group A (Control) and B (Experimental) and bonded with conventional microhybrid composite and nanocomposite, respectively. The surface to be bonded was ready by wet sanding with 240 grit and then 600 grit silicon carbide abrasive. Then surface treatment with 50 µm aluminium oxide was carried out in an air abrasive unit. Samples were cleaned in distilled water for 10 mins ultrasonically before their use; they were kept in distilled water for 24 hours [19].

Application of the Resin Composite Material

Group (A): Control Group: The 60 samples of the three subgroups, namely (A-I, A-II, and A-III), were taken and given 15 seconds for application of etchant gel. Then, a 10-second wash, followed by thorough drying, was done for 10 seconds. Next, the silanization of all substrates was carried out as ceramic primer was applied at the etched surface and allowed to dry. Then two coats of 3M single bond adhesive were applied to silane treated substrates. The material was gently dried for 2-5 seconds and light cured for 10 seconds. Finally, the microhybrid composite with a thickness of 2.0 mm was applied at the porcelain, porcelain-metal/metal interface following manufacturer's directions and light-cured for 20 sec with 500mw/cm² (Belle glass, HP Teklite, Belle de St Claire, USA) [20]. Group (B): Experimental Group: The 60 samples of the three subgroups, namely (B-I, B-II, and B-III) were taken and etchant gel was applied for 15 seconds. The samples were rinsed for 10 seconds and dried for 2-5 seconds. For silanization of all substrates, the ceramic Primer was applied to the etched surface and allowed to dry. Then, two consecutive coats of 3M single bond adhesive were applied to silane-treated substrates. The samples were dried gently for 2-5 seconds and light-cured for 10 seconds.

Finally, nanocomposite was applied with 2.0 mm thickness at porcelain-metal/metal-interface following manufacturer's directions and light-cured for 20 seconds with a 500mw/cm² output hand-held curing light (Belle glass, HP Teklite, Belle de St Claire, USA) [20].

PMMA Base/Mount Preparation

The cylindrical samples were mounted with self-cured acrylic bases individually. Powder and liquid were blended and then manipulated per the producer's recommendation. Square blocks were prepared manually for the fixation of porcelain/composite samples. These samples were mounted in the partially polymerized bases and the whole assembly was allowed to polymerize completely at room temperature for 24 hours, after which they were removed. After storage in distilled water for 24 hours at 37 ºC, the specimens were thermocycled between 5 and 55 ºC at 200 cycles for 30 sec. The specimens, after thermocycling, were stored in distilled water at 37 ºC for 7 days before being tested for shear bond strength [20].

Testing and Measurement of SBS

The PMMA moulds holding the porcelain/composite samples were placed in the fixture of the standardized Universal testing machine (AGS-X series, Shimadzu Corp., Kyoto, Japan,). The shear force was calculated at the point of failure/debonding in Mpa.

Data Analysis

The data was statistically entered and evaluated with SPSS version 23.0 (SPSS Incorporated, Chicago, IL, USA). Mean ± SD values were given for the quantitative variable "Shear bond strength". One-way ANOVA was applied to compare the shear bond strength of subgroups I, II, and III in Groups A and B, respectively. A p-value of less than 0.05 was considered significant.

Ethical Approval

This study was approved by the Ethical Review Committee of the concerned institution (ERB/IRB/No. 5081/PGMI).

Results

The mean SBS porcelain (I) in the control group was 13.74±0.77, and in the experimental group, it was 18.67±0.54, respectively. The minimum SBS porcelain in the control and experimental group was 12.60 and 18.00, respectively. In contrast, the maximum SBS in the control and experimental group was 15.00 and 19.60, respectively (Table 1). The p-value shows a significant association between porcelain (I) with the experimental and control groups. Shear bond strength was higher in the experimental group than in the control group.

Table 1. Descriptive statistics for shear bond strength of porcelain (I) in the control and experimental group.

Statistics	Porcelain (I)		Total
	Control	Experimental	
N	20	20	40
Mean	13.74	18.67	16.20
Std. Deviation	0.77	0.54	2.580
Range	2.40	1.60	7.00
Minimum	12.60	18.00	12.60
Maximum	15.00	19.60	19.60

p-value= 0.000 (Significant: p-value<0.05).

In the control group, the mean SBS of porcelain fused to metal (II) was 15.70±0.55; in the experimental group, it was 19.55±0.66, respectively. It is quite clear in the above table that the mean SBS of porcelain fused to metal (II) was higher in the experimental group compared to that of the control group. Furthermore, p-value shows that the mean shear bond strength of porcelain fused to metal was higher in the experimental group than in the control group (Table 2).

Table 2. Descriptive statistics for shear bond strength of porcelain fused to metal (II) in the control and experimental group.

Statistics	Porcelain Fused to Metal (II)		Total
	Control	Experimental	
N	20	20	40
Mean	15.70	19.55	17.62

Std. Deviation	0.55	0.66	2.03
Range	2.00	2.30	6.00
Minimum	14.60	18.30	14.60
Maximum	16.60	20.60	20.60

p-value= 0.000 (Significant: p-value<0.05).

In the experimental group, the mean SBS of metal alloy (III) was 21.12±0.73; in the control group, the mean SBS of the metal alloy was 17.56±0.68, respectively. In the control group, the minimum and maximum SBS of metal alloy were 16.60 and 18.60, respectively. The minimum and maximum SBS of metal alloy in the experimental group was 20 and 22. P-value showing that mean metal alloy was statistically different in both groups. In the experimental group, the mean Shear bond strength of metal alloy to nanocomposite was higher than in the control group (Table 3).

Table 3. Descriptive statistics for SBS (shear bond strength) of metal alloy in control & experimental group.

Statistics	Metal Alloy (III)		Total
	Control	Experimental	
N	20	20	40
Mean	17.56	21.12	19.34
Std. Deviation	0.68	0.73	1.93
Range	2.00	2.00	5.40
Minimum	16.60	20.00	16.60
Maximum	18.60	22.00	22.00

p-value= 0.000 (Significant: p-value<0.05).

Discussion

Multifactorial reasons contribute to porcelain fractures. It can be concluded that excessive stresses or irregular parafunctional habits play a vital role [21]. A repair is a good option compared to a complete prosthesis replacement as it is a cost-effective, patient-compliant, time-saving, and less traumatic procedure [22].

Ceramic restorations bond strongly with composite resins, and wherever replacement is needed at the fractured site, composite can be successfully employed [23]. Approximately thirty years back, few studies reported that by making undercuts, ceramic restorations bond to composite. The ceramic's surface conditioning was done by using silane coupling agent, which makes a good stable resin-ceramic bond with high shear bond strength [24]. Research has already documented that hydrofluoric etching combined with silane coupling agents increases the ceramic-composite bond by establishing micromechanical retention [25]. A 35% phosphoric acid etchant gel was used in this study to overcome the corrosive and tissue injurious effect of hydrofluoric acid [26].

The emphasis of this research was to encourage nanocomposite usage for porcelain and metal alloy restoration. However, past literature has shown that the composite and porcelain bond strength, and surface treatments, also used bonding /adhesive agents for enhanced results. Therefore, this study focused on the comparison between bond strengths of porcelain and metal alloy to nanocomposite and compared with that of conventional micro-hybrid to porcelain and metal substrates.

It was concluded that repair of metal samples resulted in the highest shear bond strength values, followed by samples of porcelain fused to metal and porcelain. These results were also concluded from previous studies, which showed that using different composites and substrates, the highest values were obtained with metal alloys [27,28]. Repairs made on multiple substrates may perform differently than those made on a single

ceramic surface. In this study, three different substrates were used to determine the shear bond strength relevance to the type of substrate being repaired along with the type of resin composite being used, i.e., conventional microhybrid and nanocomposite. The bonding system used and procedure for surface preparation were common to both groups. Concerning all the previous studies on porcelain-composite bonding and the success of porcelain repair with composites, it can be safely concluded that this technique can be made common in our clinical practices where applicable and cost-effective. The findings of this study will set the basis for the induction of nanocomposites in prosthetic dentistry, which could enhance prostheses repair in an economical way. However, translating the results of this study into a clinical scenario would require further investigation. This study only focusses on one treatment method. Other methods should also be analyzed to give a conclusive decision.

Conclusion

Nanocomposite has shown better bonding with all three substrates, owing to higher shear bond strength values than conventional microhybrid composite. The differences were significant in all three cases.

Authors' Contributions

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All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

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None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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