International Journal of Medical and Health Research
ISSN: 2454-9142; Impact Factor: RJIF 5.54
Received: 06-04-2019; Accepted: 09-04-2019
www.medicalsciencejournal.com
Volume 5; Issue 6; June 2019; Page No. 24-28

Comparative evaluation of shear bond strength of different core build-up materials with zirconia using a self-adhesive resin cement: An *in vitro* study

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Abstract
Aim: To evaluate the shear bond strength of three different core build up materials Glass ionomer, Zirconomer and Luxacore with Zirconia using a self-adhesive resin cement.
Materials and Methodology: Thirty zirconia specimens were CAD-CAM milled with 6 mm in diameter and 10 mm in length. Core specimens were made of the same dimensions. The Zirconia specimens were luted to the core specimens using self-adhesive resin cement. These samples were tested for shear bond strength.
Results: ANOVA test revealed that the *P* value was significant between the groups ($P < 0.001$). While the highest mean shear bond strength value was noted in Group 3 (16.31 MPa), the lowest value was noted in Group 1 (9.06 MPa).
Conclusion: From this study, it was concluded that Composite resin core material luted with Zirconia with a self-adhesive resin cement possessed the highest shear bond strength.

Keywords: shear bond strength, self-adhesive resin cement, zirconia, zirconomer, luxacore

1. Introduction

A core build-up is a restoration placed in a severely damaged tooth in order to restore the bulk of the coronal portion of the tooth [1]. It is suggested that the placement of a core is needed when more than 50 percent of the coronal portion of the tooth is severely damaged [2]. Thus, core material is an important factor in the success of an indirect restoration. Important factors related to the success of a restoration are the design and quality of the core and the accuracy of the crown. Other factors that contribute to longevity and success include (i) the type of core material to which the crown is cemented (ii) the biophysical characteristics of the luting medium and (iii) the degree of bond strength between the cement and core materials. It is equally important that the bond strength of luting agents to various core materials be within the range of clinical acceptability [3]. Various materials have been used as core build up materials such as cast cores, silver amalgam, composite resin, glass ionomer, porcelain and compomer [3]. The core build-up material should have desirable properties such as sufficient compressive strength, flexural strength, biocompatibility with surrounding tissues and should also have good bond with the tooth structure, pins, posts and luting cements [4]. In the last two decades, ceramic materials have been widely used in restorative dentistry for their esthetic characteristics. Yttrium -Stabilized tetragonal zirconia polycrystal (Y-TZP) holds a prominent position featuring good biocompatibility and mechanical properties. It also shows high fracture resistance, good chemical and dimensional stability, high hardness and high compression resistance [5]. Zirconia has found various uses in different clinical scenarios as a material of choice for the fabrication of copings and structures of all-ceramic prosthesis.

Zirconia has been considered to be difficult to bond to tooth or core material, when compared to traditional ceramics, which contain silica in their composition. To improve bonding to ceramics, hydrofluoric acid is applied for micromechanical retention. This is ineffective in zirconia due to the absence of vitreous phase [5]. Applying a silane-based primer which increases the bonding in silica - based ceramics, also has no effect on untreated zirconia surface because of its low chemical reactivity [5]. To improve bonding of luting agent to zirconia, different approaches have been described in literature such as the use of phosphate acid ester monomers, zirconia coupling agents [6] and organic silanes [7]. A common practice to improve the bonding of zirconia is to perform surface conditioning before applying the adhesive system, using methods, such as sand blasting with aluminium oxide particles followed by silica coating [7], and even plasma sprays [8]. Regarding bonding, it has not been established which type of core build up material will make the zirconia - adhesive system present the best clinical performance. Thus, a study, which investigates which type of core material is best suited for zirconia restorations to be successful, will have immediate clinical applicability. The purpose of this in-vitro study was to evaluate the bond strength of zirconia to luting agent with three different types of core build up materials that are commonly used in clinical practice.

2. Materials and Methods

2.1 Fabrication of Zirconia Block Specimens

A metal die of 6 mm in diameter and 10 mm in length was made mimicking the exact dimensions of the zirconia specimens to be milled. The metal die was sprayed with an illuminant and then scanned by a 3D scanner (Amman Girrbach Ceramill 300). Following this, they were processed by a CAD Cam milling machine (Amman Girrbach Ceramill Motion 2) to manufacture thirty exact zirconia specimens required for the shear bond strength testing. All zirconia specimens were sand blasted.

2.2 Fabrication of Core Material Specimens

The same metal die was used to make a mould from PVS impression material. The different core build-up materials i.e. GIC, Zirconomer and Luxacore were packed into this mould to produce the exact dimensions as the zirconia specimens. GIC (GC Gold Label) and Zirconia reinforced GIC (Shofu) were mixed according to manufacturer's instructions and packed respectively into the mould to obtain the core samples. Luxacore (DMG) was added incrementally into the mould and each resin layer was light cured for 40 seconds with a curing unit. Ten samples of each core material were made in the exact dimensions as the zirconia specimens. A total of 60 specimens were made, of which, 30 were zirconia specimens, 10 were GIC samples, 10 were Zirconomer samples and 10 were Luxacore samples (Figure 1).

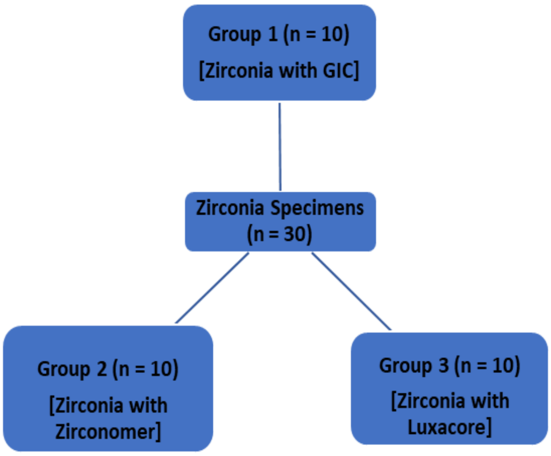

Fig 1: Grouping of Specimens

2.3 Fabrication of Acrylic Hold

An acrylic block was made for holding the specimens as they were subjected to shear bond strength test in the universal testing machine. A wax block was made (20 mm x 20 mm) on which the centre point was marked. Following this, a circle with 6 mm in diameter was marked on the block. The wax in the corresponding region was removed to 5 mm depth. This slot was prepared to make sure that specimen was centred within the acrylic block. Once the wax block was ready, a mould was made using PVS impression material. Acrylic was poured into the mould and the blocks were prepared. The specimens were placed within the slot with a small amount of acrylic and held in position until the material set.

2.4 Luting Procedure and Testing of Shear Bond Strength

The core sample and zirconia samples were luted using a self-adhesive resin cement (G-CEM LinkAce). The luting was carried out under a constant load of 100 grams. After initial self-polymerization, 40 seconds of light irradiations using a curing unit from each side of the block was performed to ensure optimal polymerization. The shear bond strength was tested using a computer controlled universal testing machine (Instron 2710-103). All specimens were placed on the machine and stressed to failure with a 50 kg load cell at a cross head speed of 1 mm/min. From the load values obtained, the shear bond strength value was calculated using the formula: Shear bond strength = Load/Area, where Area is πr^2 and load is the value obtained from the universal testing machine (Table 1).

Table 1: Load values with the corresponding shear bond strength of Group 1, Group 2 and Group 3

Zirconia-GIC		Zirconia-Zirconomer		Zirconia-Luxacore	
Load	**Strength (MPa)**	**Load**	**Strength (MPa)**	**Load**	**Strength (MPa)**
257.18	9.12	356.44	12.64	448.94	15.92
245.62	8.71	372.52	13.21	464.17	16.46
262.26	9.3	347.42	12.32	446.68	15.84
243.64	8.64	335.29	11.89	440.48	15.62
255.21	9.05	393.1	13.94	478.27	16.96
263.38	9.34	360.11	12.77	479.68	17.01
256.90	9.11	367.16	13.02	432.87	15.35
252.67	8.96	366.03	12.98	461.63	16.37
268.18	9.51	368.29	13.06	455.14	16.14
250.69	8.89	346.01	12.27	492.93	17.48

2.5 Statistical Analysis

The obtained data was statistically analysed using the software Statistical Package for Social Sciences (SPSS) version 16.0. The mean shear bond strength values obtained for each group are represented in Table 2 whereas the ANOVA test performed to the mean shear bond strength values are described in Table 3. In the present study, *P* value less than < 0.001 was considered to be significant. Tukey HSD (Honest Significance Difference) test was applied for the comparison of mean shear bond strength values obtained in different groups (Table 4).

3. Results

Among the different core build up materials, the mean shear bond strength value was found to be highest for Group 3 (Luxacore-16.31 MPa), followed by Group 2 (Zirconia reinforced Zirconomer-12.81 MPa). The lowest shear bond strength value was noted in Group 1 (GIC-9.06 MPa). The mean values, standard deviation and maximum and minimum range values of shear bond strength of each group are summarized in Table 2. One-way ANOVA test revealed significant differences between the groups for shear bond strength (Table 3).

Table 2: Descriptive Analysis of the Mean Shear Bond Strength

Core Build Up Material	N	Mean (MPa)	Std. Deviation	Std. Error	95 % Confidence Interval for Mean		Range	
					Lower Bound	Upper Bound	Minimum	Maximum
Zirconia GIC	10	9.063	± 0.27536	± 0.087	8.8660	9.2600	8.64	9.51
Zirconia Zirconomer	10	12.810	± 0.57552	± 0.182	12.398	13.221	11.89	13.94
Zirconia Luxacore	10	16.315	± 0.67551	± 0.213	15.831	16.798	15.35	17.48
Total	30	12.729	± 3.05595	± 0.557	11.588	13.870	8.64	17.48

Table 3: One Way ANOVA Analysis for Shear Bond Strength

	Sum of Squares	Degrees of Freedom	Mean Square	F Value	*P* Value
Between Groups	263.055	2	131.528	457.030	0.000*
Within Groups	7.770	27	0.288	-	-
Total	270.825	29	-	-	-

* Significant at $P < 0.05$ Level

Table 4: Tukey HSD Test for the Comparison of Shear Bond Strength between the Groups

Luting Agent	Core Build Up Material (I)	Comparison (J)	Mean Difference (I-J)	Std Error (±)	*P* Value	95% Confidence Interval	
						Lower Bound	Upper Bound
G-CEM LinkAce	Zirconia GIC	Zirconia Zirconomer	-3.74700	0.239	0.000*	-4.3418	-3.1522
		Zirconia Luxacore	-7.25200	0.239	0.000*	-7.8468	-6.6572
	Zirconia Zirconomer	Zirconia GIC	3.74700	0.239	0.000*	3.1522	4.3418
		Zirconia Luxacore	-3.50500	0.239	0.000*	-4.0998	-2.9102
	Zirconia Luxacore	Zirconia GIC	7.25200	0.239	0.000*	6.6572	7.8468
		Zirconia Zirconomer	3.50500	0.239	0.000*	2.9102	4.0998

* The mean difference is significant at the 0.05 level

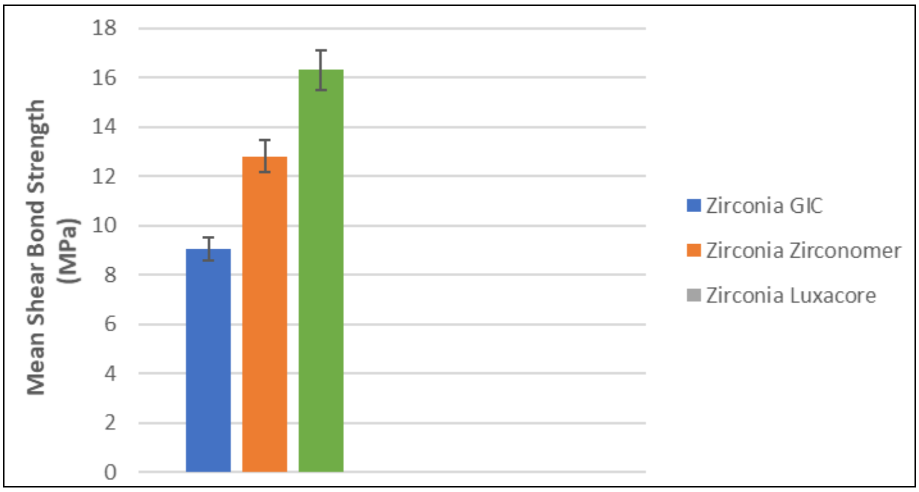

Fig 2: Bar Chart Representation

Using the Tukey HSD test, the core build-up materials in G-CEM LinkAce luting agent were compared (Table 4). As observed earlier (Table 2), Zirconia Luxacore material showed the highest shear bond strength followed by Zirconia Zirconomer and Zirconia GIC core materials. The difference was statistically significant ($P < 0.05$) for all the aforementioned groups (Table 4). A graphical representation of the mean shear bond strength values existed between the groups are given in Figure 2.

4. Discussion

The aim of this study was to evaluate the shear bond strength of different core build up materials when luted with zirconia using a self-adhesive resin cement. The bond strength of a luting agent to core build up material is one of the important factors in the success of a restoration and it should be within the range of clinical acceptability. As most of the failures of indirect restorations occur in the shear stress, in this study, it was used to assess the bond strength as previously described by Tezvergil A *et al.* and Padipatvuthikul P *et al.* [9-10]. The direct core materials used in the present study comprises of glass ionomer cement (GC Gold Label), zirconia reinforced glass ionomer cement (Shofu Zirconomer) and Composite resin cement (DMG Luxacore) because of their advantages like reduced chair side time, ease of manipulation and reduced cost. Zirconia block specimens were luted to the core material block specimens using a common self-adhesive resin cement (GC

G-Cem LinkAce).

Bond strength is affected by several factors, one of which is the luting cement type [11]. The bond between core build up material and the crown are based on the adhesions of the luting cement with the core material as well as with the crown. In the present study, the self-adhesive resin cement used was G CG-Cem LinkAce. It exhibited highest shear bond strength values in Group 3 (Zirconia-Luxacore) with a mean value of 16.31 MPa followed by Group 2 (Zirconia reinforced GIC-Zirconia) with a mean value of 12.81 MPa. The least shear bond strength was noted in Group 1 (GIC-Zirconia) with a mean value of 9.06 MPa. Frattes *et al.* [5], evaluated the bond strength of zirconia with different core materials (Silver alloy, Copper alloy, Composite resin, Zirconia, Enamel and Dentin) where they concluded that the composite based core material yielded a better shear bond strength. Hewlett *et al.* [12], concluded that resin luting cement had the highest shear bond strength to most foundation substrates. The bond between composite foundation and resin luting cement was also the most durable on immersion in lactic acid. Zirconium oxide has gained attention as a bio material due to superior mechanical properties, compared to alumina, chemical and biological inertness that makes it very bio-compatible. Zirconia has been considered a suitable choice for dental restorations due to its good mechanical properties, tooth-coloured and natural appearance and low plaque accumulation [13].

As it is essentially inert and nonpolar, chemical conditioning techniques commonly used in ceramics that have silica in their composition are ineffective on zirconia surfaces, unless they are pre-treated [14]. In this sense, various methods to increase mechanical retention have been investigated. It has been reported that blasting the zirconia surface treatment with aluminium oxide particles, followed by silicatization, i.e. blasting with alumina particles coated with silica layer, significantly improves bonding [15]. When sandblasted with high speed alumina particles, zirconia surface loses material in a relatively even way which causes an increase of its roughness, and thus of its contact area, allowing for a better flow of the luting material and providing micromechanical interlock [16]. There are several authors who have investigated the different surface treatments of zirconia. Derand *et al.* [8], stated that pre-treatment of zirconia ceramic surfaces with plasma spraying or sparsely fused glass pearls can successfully increase the bond strength to composite resin cements compared to untreated surfaces. In this study, sandblasting was performed to form surface roughness and irregularities which increases the surface area and wettability, thus allowing resin cement to flow into the surface. Although sandblasting improves bonding, it can affect the mechanical properties of zirconia [17] due to phase transformation which can cause fatigue in the material structure [18]. However, there are also reports that state that sandblasting strengthens the mechanical characteristics of zirconia [19, 20].

5. Conclusion

The following factors were considered to be the limitations in the current study. Thermocycling, a procedure to simulate aging of the materials was not carried out to test the durability of the bond formed between the zirconia and the core materials. Immersion of the specimens in lactic acid buffer solution, to evaluate the effect of acidic media on cement, was not performed. Effect of Primer application on surface of Zirconia prior to cementation using GC G-Cem LinkAce (though not instructed by the manufacturer) on the Shear bond strength was not taken into consideration. Specimen dimensions conforming to actual configuration of clinical crowns could have been used. To conclude, amongst all the core build up materials, Zirconia Luxacore exhibited the highest shear bond strength followed by Zirconia Zirconomer and Zirconia GIC core materials.

6. Acknowledgement

None Declared.

7. References

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