Original Research

A Comparative Evaluation of the Compressive Strength of Two Core Build-Up Materials Reinforced with Zirconia: An In-Vitro Study

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Abstract
Problem: Core building requires high strength, bonding, and aesthetics. GIC and composite resin are the gold standards, but the requirement for increased strength never diminishes. In this study, the compressive strengths of GIC and composite resin with their zirconia-reinforced alternatives were compared. **Approach:** 48 extracted molars that met the inclusion criteria were collected, and a square cavity of selected measurement, including one cusp of the tooth, was prepared to receive the restoration. 10% zirconia was added to the GIC and composite resin. Teeth with a prepared cavity were allotted to four different groups according to the restorative material: Group 1: GIC; Group 2: zirconia-reinforced GIC; Group 3: composite resin; and Group 4: zirconia-reinforced composite resin, tested for compressive strength using the Instron testing machine. **Findings:** ANOVA and post-hoc Tukey tests were used for the comparison of various groups. The composite resin group was found to have the highest compressive strength, followed by zirconia-reinforced GIC. **Conclusion:** It can be concluded that the addition of zirconia can increase the strength of GIC to some extent but reduce the strength and bonding of composite resin.
Keywords: Glass Ionomer Cement; Composite Resin; Zirconia-Reinforced Glass Ionomer Cement; Zirconia-Reinforced Composite Resin; Compressive Strength; Restorative Material

Introduction

Any dental restoration's longevity is influenced by the characteristics of the dental materials used, the patient's age, and the pace at which cavities develop in the restored tooth. As a restoration tends to transfer stress differently than an intact tooth, where the occlusal biting loads are transferred to dentin as compression that is distributed over a large internal volume of tooth structure, reducing local stress, an ideal core build-up material should have a variety of properties. These properties include strength near the enamel and dentin and expansion near the enamel and dentin. The bonding of such materials to dentin and enamel is another topic of discussion if strength is taken into account.

Composite resin and amalgam both have significant bonding issues with the tooth's structure, but glass ionomer cement has lower strength but stronger bonding. In order to change the qualities of already-existing materials, various resins and other components are added. One of these is the addition of zirconia particles to GIC. Research is being done on various zirconia addition rates to GIC and composite resin. 10% Yttria-stabilised zirconia powder was utilized as filler in this in vitro research and the compressive strength of the glass ionomer cement and composite resin was evaluated.[1]

Materials and Method

48 non-carious molar teeth that had recently been extracted were included in the study. Samples that had been severely damaged or demineralized were excluded. All teeth were completely cleaned, and any calculus or debris was eliminated. They were mounted in an acrylic block measuring 1.5 cm by 1.5 cm by 2 cm up to cemento-enamel junction (Figure. 1). The occlusal surface was made flat to standardise the depth. The next step was to create a square cavity on a corner for each sample, which had dimensions of 5 mm in length, 2 mm in depth, and one cusp (Figure. 2). A flat-end straight fissure bur with a 2 mm marking on it was used to prepare the cavity.

All 48 teeth were prepared and divided into 4 groups for core build up material as shown in Table 2. 12 samples were assigned to each group. The samples were assigned randomly after the cavity preparation. Finely ground zirconia powder was obtained from a zirconia block (Dental Direkt).

According to the manufacturer's instructions, Group 1 (G) samples were restored with GIC type 9 mixed using an agate spatula on a mixing pad.

For Group 2 (ZG), 10% zirconia powder was weighed compared to the amount of powder, added to the powder, and mixed thoroughly as shown in Figure 3. The powder-liquid ratio was taken as per the manufacturer’s instructions, and manipulation was done similarly as for Group 1.

For Group 3 (C), 37% phosphoric acid (Total Etch by Ivoclar Vivadent) was applied on prepared tooth surface for 15 seconds for etching, followed by a thorough washing with distilled water, drying, and the application of a bonding agent (Tetric N Bond by Ivoclar Vivadent). The bonding agent underwent a 20-second light cure. A Teflon-coated filling tool was used to take the necessary amount of composite from the syringe and fill it directly. It was exposed to wireless curing blue light (LED-B woodpecker, wavelength: 420–480 nm) for 40 seconds to cure it.

For Group 4 (ZC), all teeth were etched and bonded first. Then, according to the weight of a 3.5-g syringe of a composite, 10% powder of zirconia was pre-weighted and mixed just before restoring. A large brown-coloured dappen dish with its sides covered with black paper was taken, all the composite was removed from the syringe, and the pre-weighted powder was directly added to the composite (as shown in Figure 4) and mixed well using a Teflon-coated instrument. All 12 samples were then immediately filled in and light-cured.

All samples were finished, polished, and stored in distilled water for 24 hours.

For imparting loads, a unique jig was created, as seen in Figure 5. It was square and 5 mm by 5 mm in size, or the same as the restoration's cross section. The materials were evaluated for compressive strength using the Instron universal testing apparatus after 24 hours at a crosshead speed of 1.0 mm/minute (Figure 5). The specimens that had fractured were examined for restoration fracture or bond

failure. The compressive strength was estimated from the load at which the restoration fractures using the following formula:
Compressive strength = failure load / area of the restoration.

Results

The load at which the restoration fractured was recorded, and the compressive strength of each cement at a 2 mm thickness was calculated by dividing that value by 25 mm^2. Table 3 below lists the findings for each material's compressive strength.

The compressive strength of composite resin was highest followed by zirconia reinforced GIC, GIC and Zirconia reinforced composite resin. When evaluated for fracture of the restoration, 4 bond failures were observed in zirconia reinforced composite resin. Mean and standard deviation are given below.

All Group wise distribution (One way ANOVA):

Statistically, significant difference was present in Comprehensive Strength among all groups as given in Table 4

Mean Comprehensive Strength (N/mm^2) was highest in Composite Resin Group (112.40 ± 2.77) followed by Zirconia Reinforced GIC Group (95.69 ± 0.99), GIC Group (85.36 ± 1.41) and Zirconia Reinforced Composite Resin Group (76.21 ± 19.29) respectively.

Bond Failure wise distribution

Bond failure was noticed in 33.3% of the samples in zirconia-reinforced composite resin only.

Discussion

If there is only minor to moderate tooth structure loss, the core buildup without posts can be used to treat broken teeth and teeth that have lost one or more cusps, preserving them without the requirement for endodontic therapy. Such teeth lose their vitality and vigour when they undergo endodontic treatment. Direct core building may be an option in some circumstances. The pulp and dentin should be shielded from microleakage and chemical or thermal impacts by the core material. Because high compressive strength is required to withstand masticatory and parafunctional stresses, compressive strength is regarded as a crucial success indicator.[3] Core building becomes essential for teeth with serious decay. In dentistry, a variety of core build-up materials are employed, including glass ionomer cement, auto-cured composite resin with titanium, resin-modified glass ionomer cement, and light-polymerized hybrid composite resin. Because of their tremendous strength, they are employed as core materials. The majority were not created expressly for core building, but their strength made them appropriate.[4]

A reliable primary building material is amalgam. Its use is decreasing as a result of its many drawbacks. According to Huysamanset et al.[5], amalgam has been regarded as the ideal material for cores. Amalgam cores have been shown to perform better than resin composite cores in mechanical tests and finite element analysis. However, the usage of amalgam as a primary building material has decreased due to its unattractive outcome and mercury disposal. The performance of composites has also improved due to the development of novel composite resins and bonding agents.

It has been demonstrated that glass ionomer cements are an effective treatment for such clinical problems. Although its low strength remains a drawback, its chemical bonding and fluoride-releasing qualities merit attention. However, because of its lower strength as compared to amalgam and composites, it is less frequently advised for core building, particularly when a crown is not to be used after.

But over time, it was thought to increase the strength of glass ionomer cement in order to prevent mechanical bonding. When resin was first put on it, little changed other than a tiny boost in strength. Glass nanoparticles were later added, along with resin; however, there were no discernible variations in strength between the nano and micro particles.[6] Additionally, experiments produced compomers, metal reinforcements, and the current trend in zirconia reinforcement.

In one study by Sharma et al.[7] in 2022, they compared the compressive strength of three different core build-up materials on fibre-reinforced composites after 24 hours and 1 week. They concluded that Para Core had higher strength compared to the other two core build-up materials, GC Gold and Magma NT, and the strength of each material increased after 1 week.

Gu Y. W. et al.[8] examined the characteristics of GIC in 2005 by strengthening it with 7% yttria-stabilised ZrO2 powder. According to Chalissery V. P. et al.[9], zirconomer's (zirconia-reinforced GIC by GC) strength is comparable to amalgam. In 2016, Wang et al.[10] reported that adding 1%, 3%, and 5% ziconia fillers to fibre-reinforced composite resin after silanization increased the material's fracture toughness and Vickers hardness. According to Guo G et al.[11], partial replacement of particulate glass filler (2.5%–5.0%) with zirconia/silica or zirconia/yttria/silica nanofibers can significantly improve the mechanical properties (flexural strength and fracture toughness) of the composites, even though it slightly lessens the degree of monomer conversion in the composites. a further rise in the content of nanofiber. But as the percentage of nanofibers increases (7.5% or more), the flexural strength will drop. Lower refractive index fibre materials will be required to further increase nanofiber content without lowering DC and strength.

In one of the study by Melavanki C et al[12], They came to the conclusion that there was no statistically significant difference ($p > 0.05$) between the groups Zirconia modified glass ionomer, DPI alloy, and Vitrimer, and that the mean compressive strength and flexural strength of glass-reinforced composites were statistically significant (p 0.05) when compared to other group levels. Glass-reinforced composite was deemed to be a superior core build-up material within the constraints of this investigation when compared to zirconia-modified glass ionomer, DPI alloy, and Vitrimer.

In their work, Fazelian et al.[13] added 5%, 10%, and 15% zirconium oxide particles in order to examine the mean compressive strength and microstructure of the light-cure and self-cure glass ionomers. Based on the findings of this study, it can be said that the mean compressive strength is increased by the 15% weight addition of zirconium oxide particles to light-cure glass ionomer.

Since their creation, glass ionomer cements have developed. Depending on their characteristics, GICs are available in nine different classes. For bulk filling restorations needing great strength, such as core build up restorations, the type 9 GIC is an extra-hard and viscous GIC. The GIC material utilised in this instance is a type 9 core-built Fuji 9. Along with strength, it provides a core with the benefits of fluoride release and chemical bonding. There is evidence that the properties of this class are superior to those of resin-modified systems.[14]

With little intervention or tooth preservation, composites offer a strong and beautiful restoration. Due to their high aesthetic value, they may also be positioned in a thin area of the aesthetic zone. However, they are rigid and mechanically connected. The bonding issue is still there with this. It is highly technique-sensitive and has a good isolation requirement. Dental composites made of resin are frequently used to restore carious teeth. The creation of dental composites that release more F, Ca_2+, and

PO_4 ions as anti-caries agents has been the subject of extensive investigation. The mechanical characteristics and fracture toughness of dental composites supplemented with particle fillers, particularly composites that release anti-caries agents, are still subpar.[15]

Initially, there were weaker microfilled composite resins with small amounts of filler particles. Later, the particles became more grounded, evolving into minifils, midifils, and finally "microhybrids[16]," which solely contained nanoscale particles. The majority of manufacturers have dubbed this class of microhybrids "nanohybrids[17]" after changing their formulations to include additional nanoparticles and perhaps pre-polymerized resin fillers, similar to those present in microfill composites. The nanofill and nanohybrid materials are state-of-the-art filler formulations made of hybrid organic-inorganic fillers and nanosized components.[18]

Tetric N Ceram (IvoclarVivadent), a light-curing, radiopaque nano-hybrid composite for direct restorative operations that is highly regarded for posterior high-strength restorations, was employed in this investigation.

This investigation found that composite resin continued to be the strongest substance. Although zirconia reinforcement made the GIC stronger, it was still inferior to composite resin. The zirconia-reinforced composite performed less well than we anticipated. Zirconia filler particles may not have adhered to one another properly in this instance.

The very thin thickness of the restoration is thought to be the reason for the extremely low compressive strength values obtained in this investigation. Zirconia powder has been discovered to greatly boost compressive strength when added to glass ionomer cement; however, it lowers when composite resin is used. Zirconia reinforcement has increased the strength of GIC, although it still falls short of composite resin in terms of strength. The strongest material for the core build-up in this instance is composite, but adding 10% zirconia to the composite causes problems.

Conclusion

Within the limitations of this study, it can be concluded that the strength of the GIC can be increased by adding zirconia particles directly to the GIC powder. However, it was not the same for composites. By adding zirconia powder directly to the composite, its strength as well as bonding are seen to be decreasing. The composite resin remains the strongest of all the ones tested. If used technically, it can give the best results as a core building material. Due to the small sample size and in vitro study, further research in this field is required. Moreover, masticatory cyclic loading and changes in oral temperature may also change the properties of the restorative material, which has to be considered.

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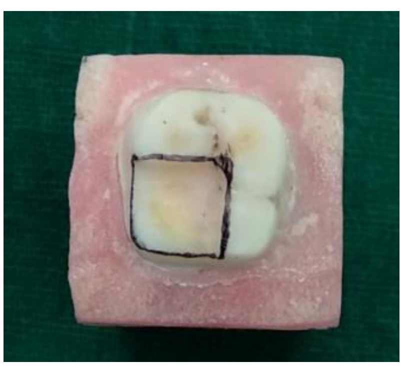

Fig. 1: Teeth Mounted on Acrylic block

Fig. 2: Creation of Space Cavity of 5 mm in length, 2 mm in depth

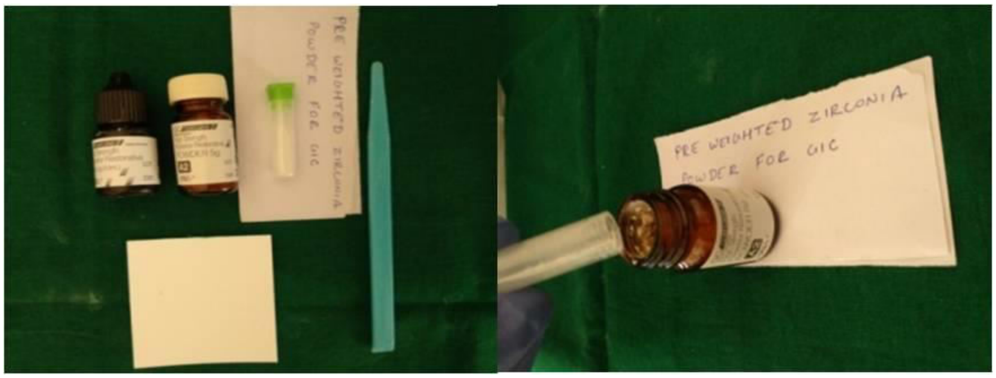

Fig. 3: Pre-Weighed 10% Zirconia powder added to GIC Powder

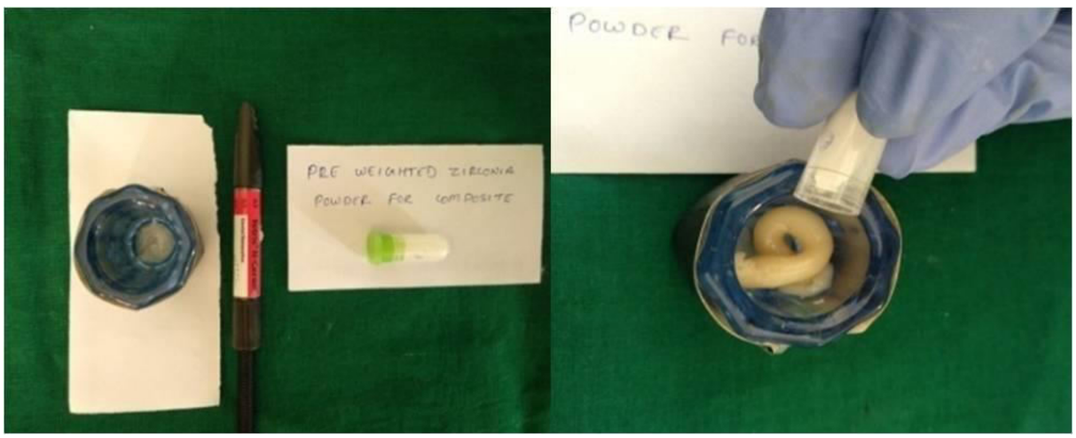

Fig. 4: Pre-Weighed 10% Zirconia powder added to Composite

Fig. 5: Unique Jig used in Universal Testing Machine

Table 1:- Materials used in the study

Sr. No.	Material	Brand name	Company
1.	Glass Ionomer Cement (GIC) Type 9	GC Gold Label (GC 9)	GC
2.	Composite Resin(Bulk Fill)	Tetric N-Ceram	Ivoclar Vivadent
3.	Etchant	Total Etch	Ivoclar Vivadent
4.	Bonding Agent	Tetric N Bond	Ivoclar Vivadent
5.	Self Cure Acrylic Resin	Rapid Repair	Pyrex Dental
6.	Zirconia Block	Ddcubex[2]	Dental Direkt

Table 2:- Group division

Group No.	Group Name	Core build up material
1	G	GIC
2	ZG	Zirconia reinforced GIC
3	C	Composite Resin
4	ZC	Zirconia reinforced composite Resin

Table 3:- Compressive strength for each group

Sr. no	Compressive strength for Group 1 (N/mm^2)	Compressive strength for Group 2 (N/mm^2)	Compressive strength for Group 3 (N/mm^2)	Compressive strength for Group 4 (N/mm^2)
1	83.64	94.28	107.8	84.20
2	84.12	94.64	108.72	88.32
3	84.48	96.88	111.72	43.76
4	86.36	95.48	111.16	85.52
5	86.68	96.08	112.08	80.64
6	83.88	96.96	112.56	93.84
7	84.12	94.16	116.32	54.16
8	86.24	96.16	114.60	96.48
9	86.56	96.28	109.76	56.24
10	84.88	94.80	114.36	88.96
11	86.36	96.52	116.44	49.92
12	87.56	96.04	113.28	92.48

Table 4:- All Group wise distribution (One way ANOVA)

Groups	Number	Compressive Strength (N/mm2)		F Value	P Value
		Mean	SD		
GIC	12	85.36	1.41	30.185	≤ 0.05 S
Zirconia Reinforced GIC	12	95.69	0.99		
Composite Resin	12	112.40	2.77		
Zirconia Reinforced Composite Resin	12	76.21	19.29		

Table 5: Bond failure in the groups

Groups	Number	Bond Failure	
		n	Percentages
GIC	12	0	0 %
Zirconia Reinforced GIC	12	0	0 %
Composite Resin	12	0	0 %
Zirconia Reinforced Composite Resin	12	4	33.3%