ORIGINAL RESEARCH

Comparative Evaluation of Fracture Toughness and Flexural Strength of Four Different Core Build-up Materials: An *In Vitro* Study

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Abstract

Aim: To evaluate and compare the fracture toughness and flexural strength of four different core build-up materials.

Materials and methods: A total of 60 samples were divided into four groups ($n = 15$) group I: dual cure composite resin reinforced with zirconia particles (Luxacore Z), group II: light cure composite resin (Lumiglass DeepCure), group III: zirconia reinforced glass ionomer cement (GIC) (Zirconomer Improved), and group IV: chemically cure composite resin (Self Comp) respectively. All the core build-up materials were manipulated according to the manufacturer's instructions and poured into the mold. A universal testing machine applied a central load to the specimen in a 3-point bending mode. Fracture of the specimen was identified and the reading was recorded by the universal testing machine. The data were analyzed statistically using one-way analysis of variance (ANOVA) and then compared.

Results: Group I showed the highest flexural strength (48.65 MPa) among all the groups while group IV showed the lowest flexural strength (17.90 MPa). Group I showed the highest fracture toughness (99.12 MPa) among all the groups while group IV showed the lowest fracture toughness (36.41 MPa.cm$^{-0.5}$). When mean flexural strength and fracture toughness values of all four groups were compared by using one-way ANOVA, the compared data was highly significant.

Conclusion: Based on the findings of this study, dual cure composite resin was the material of choice in terms of flexural strength and fracture toughness for core build-up material followed by light cure composite resin.

Clinical significance: The core buildup material serves to strengthen the tooth structure, allowing it to withstand the forces of chewing and preventing the risk of tooth fractures. This material is essential in restoring damaged or decayed teeth, as it provides a stable foundation for further dental work. By reinforcing the tooth structure, the core buildup material ensures that the tooth can function properly and remain healthy for years to come.

Keywords: Core build-up, Flexural strength, Fracture toughness.

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Introduction

A lot of teeth often show considerable coronal hard tissue defects, frequently requiring a core buildup as a preprosthetic treatment.[1] This pretreatment is necessary before the fabrication of subsequent extracoronal prosthesis. The core consists of restorative material placed in the coronal area of a tooth. This material replaces a carious, fractured, or otherwise missing coronal structure and retains the final crown. The core is anchored to the tooth by extending into the coronal aspect of the canal or through the endodontic dowel. The attachment between the tooth, dowel, and core is mechanical or chemical, or both, because the core and dowel are usually fabricated of different materials.[2]

The materials that are used for core build-up are gold, amalgam, resin-modified glass ionomer cement (GIC), and composite resin.[3] Each core build-up material has different properties and therefore advantages and disadvantages. Enamel–dentin bonding using adhesive materials such as composite resin or glass ionomer materials allows a more conservative technique compared to amalgam and is also possible for immediate tooth preparation. The use of amalgam is now replaced with the above adhesive materials. Composites bond to tooth structure by micromechanical bond and have compressive strength similar to dentine and high tensile and flexural strength.

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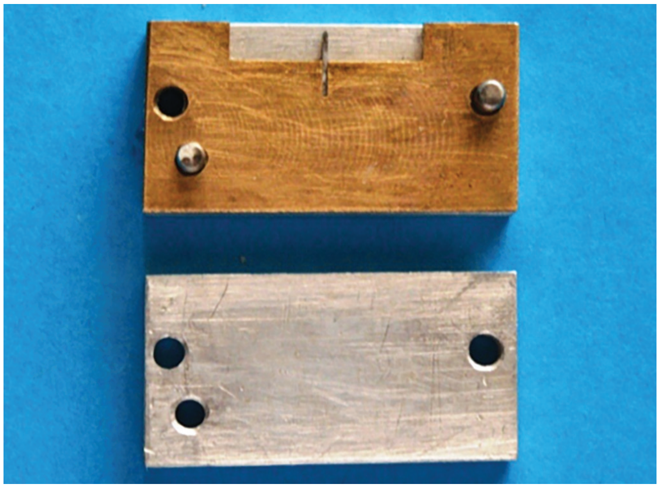

Fig. 1: Brass and aluminum die with a sharp steel blade to form the centrally located notch

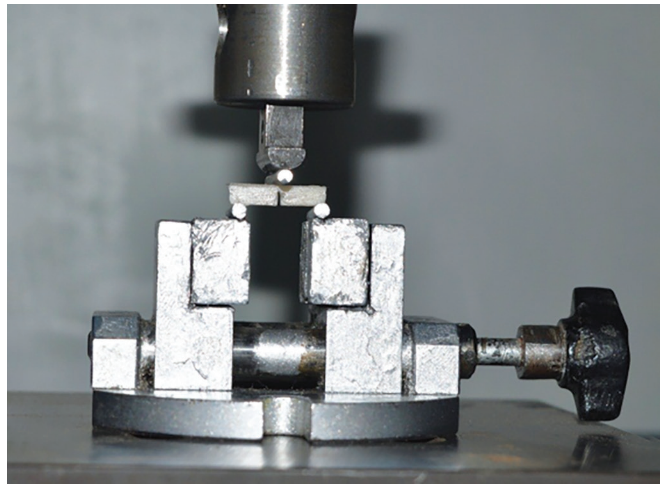

Fig. 2: Core build-up specimen is being tested under a universal testing machine with reading noted by computer screen

The goal in restoring endodontically treated teeth is the design and fabrication of the final restoration. Two following two factors influence the choice of technique: The type of tooth and the amount of remaining tooth structure. The latter is probably the most important indicator when determining the prognosis. Different clinical techniques have been proposed to solve these problems, and opinions vary about the most appropriate one.

The objective of restoration can be stated as reinforcement of remaining tooth structure, replacement of missing tooth structure is achieved with core and retention supplied by post for the core and for the final restoration.

The final configuration of the restored tooth includes the following four parts: Residual tooth structure, dowel material located within the roots, core material located in the coronal area of the tooth, and definitive coronal restoration.[4] There is a dire need to conduct a study that focuses on the development of sturdy core build-up materials for teeth that have undergone endodontic treatment. This is a critical area of research that requires attention, as the success of endodontic treatment is heavily dependent on the quality of the core build-up material used, with this we can improve the overall success rate of endodontic procedures and amplify the life of treated teeth. Therefore, this study aims to evaluate and compare the fracture toughness and flexural strength of four different core build-up materials and provide material that has the highest strength which will reinforce tooth structure.

Materials and Methods

The study was conducted in the Pune's metallurgic laboratory and samples were prepared at the relative humidity and temperature. The samples of each material were placed in tightly sealed plastic bags and tested 24 hours after preparation and the study was completed within a period of 7 days.

A standard hollow well finished and polished die was fabricated which was made up of brass with a sharp stainless-steel blade to form the centrally located notch. The dimensions of the specimens obtained from this mold were according to the American Society for Testing Materials (ASTM) guidelines for such a specimen (Standard E-399).[5] These were 1.8 mm in width, 4.2 mm in height, and 20 mm in length with a 3-mm long notch on one edge. The width of the notch was 0.5 mm (Fig. 1).

A total of 60 samples were divided into four groups ($n = 15$): Group I: Dual cure composite resin reinforced with zirconia particles (Luxacore Z), group II: Light cure composite resin (Lumiglass DeepCure), group III: Zirconia reinforced GIC (Zirconomer Improved), and group IV: Chemically cure composite resin (Self Comp) respectively. The metallic die was first seated onto the metallic base properly. The inner surface of the die was coated with petroleum jelly for ease of removal of the specimen from the die. All the core build-up materials were manipulated according to the manufacturer's instructions and poured into the mold. A glass slab was placed over the material to form a flush surface with the top of the mold. The light-cured specimens were subjected to curing through open parts of the die.

After complete setting, the plates were detached and the specimens were removed from the die by removing the walls of the die. After removing from the die, the specimen was inspected for the presence of any voids or irregularities. The specimens with any void or surface irregularities were discarded. All excess flash was trimmed gently with a Bard–Parker knife.

The fracture toughness and flexural strength were tested by using a universal testing machine (STAR testing system, IndiaModel No. STS 248, Accuracy: ±1%) (Fig. 2). Each of the test samples was loaded on the universal testing machine and subjected to load at a constant speed and the results obtained on the computer screen along with the plotted graph. The universal testing machine provides reading for which the sample was broken at applied load. On that force value, the computer screen provides fracture toughness and flexural strength with a preset formula for both tests. All four groups were compared by using one-way analysis of variance (ANOVA) and *post hoc* Tukey's honestly significant difference (HSD) test was applied to evaluate significant differences with the help of statistical package for the social sciences (SPSS) and SigmaPlot software.

Results

Group I showed the highest flexural strength (48.65 MPa) among all the groups while group IV showed the lowest flexural strength (17.90 MPa). The mean flexural strength for group II and group III were 40.18 MPa and 28.18 MPa, respectively, which was intermediate between groups I and IV (Table 1; Fig. 3). When mean flexural

Table 1: Comparison of flexural strength and fracture toughness between groups I, II, III, and IV

	N	*Mean*	*SD*	*F*	*df*	*p-value*	*Inference*
Flexural strength (MPa)							
Group I	15	48.65	13.11	30.14	3	0.0001 (<0.001)	Highly significant
Group II	15	40.18	10.73				
Group III	15	28.18	8.17				
Group IV	15	17.90	2.82				
Total	60	33.73	14.98				
Fracture toughness (MPa.cm$^{-0.5}$)							
Group I	15	99.12	26.71	30.15	3	0.0001 (<0.001)	Highly significant
Group II	15	81.83	21.90				
Group III	15	57.59	16.60				
Group IV	15	36.41	5.73				
Total	60	68.74	30.53				

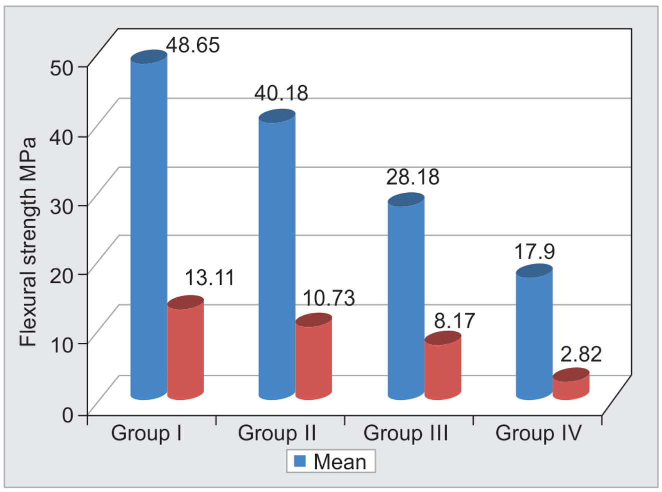

Fig. 3: Comparison of flexural strength between groups I to IV

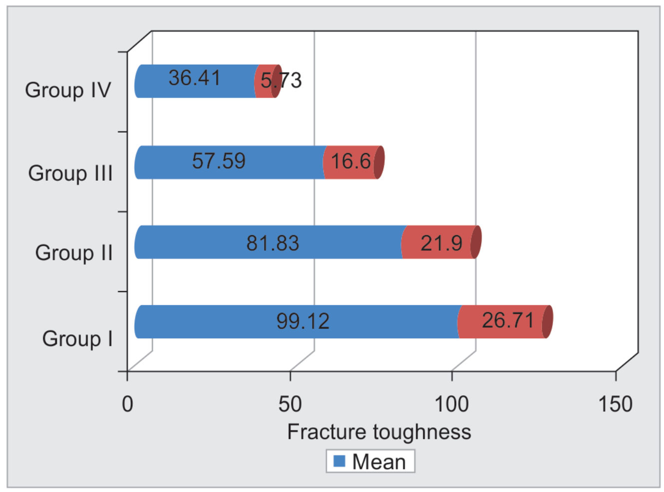

Fig. 4: Comparison of fracture toughness between groups I to IV

strength values of all four groups were compared by using one-way ANOVA, the data were highly significant. *Post hoc* Tukey's HSD test showed that no significant difference was found between groups I and II. It also showed that a significant difference was found between groups I and III; groups I and IV; groups II and III; groups II and IV; and groups III and IV.

Group I showed the highest fracture toughness (99.12 MPa) among all the groups while group IV showed the lowest fracture toughness (36.41 MPa.cm$^{-0.5}$). The mean fracture toughness for groups II and III were 81.83 MPa.cm$^{-0.5}$ and 57.59 MPa.cm$^{-0.5}$, respectively, which was intermediate between groups 1 and IV. When mean fracture toughness values of all four groups were compared by using one-way ANOVA, the compared data was highly significant (Table 1; Fig. 4). *Post hoc* Tukey's HSD test showed that no significant difference was found between groups I and II. It also showed that a significant difference was found between groups I and III; groups I and IV; groups II and III; groups II and IV; groups III and IV. Group I shows the highest fracture toughness and flexural strength.

Discussion

A core build-up is a restoration placed to provide the foundation for a restoration that will endure the masticatory stress that occurs in the oral cavity for prolonged periods and to provide satisfactory strength and resistance to fracture before and after crown preparation. It forms an integral part of the tooth. Cores are usually retained by pin, post, and/or a bonding system to facilitate their retention and to restore the tooth to the extent necessary to support a crown or bridge abutment.

Flexural strength is used to evaluate the strength of the material and the amount of distortion expected under bending stress. Flexural strength tests are considered to be sensitive to surface imperfections such as cracks, voids, and related flaws which can influence the fracture strength of brittle materials. High flexural strength values reflect a limited tendency to crazing and high resistance to surface defects and erosion. Fracture toughness is an intrinsic property of a material and is a measure of the energy required to propagate a crack from an existing defect. Flexural strength and fracture toughness are considered to be the most important properties of core build-up materials.

Several materials including amalgam, GIC, hybrid GIC, composite resin, and cast metal alloys have been used so far for core build-up with various degrees of success. Initially, amalgam was the best material for core build-up with high mechanical properties,[6,7] but the recent advances in the composite resins and GICs have improved the mechanical properties.[8] Composite resin core build-up materials have been widely used, owing to their high compressive strength, good adhesive properties, low modulus of elasticity, and their economic affordability. The resin composite core build-up materials showed better mechanical properties than the silver amalgam core, which is similar to the results of a study done by Cho et al.[9] and Bonilla et al.[10] have found that some resin composites exhibited more compressive strength than that of amalgam and could be used as alternatives to amalgam. Capp and Warren[11] also stated that, composite and acrylic resins can be used as alternatives to amalgam for core structures and that GIC is the weakest core build-up material.

Agrawal A and Mala K[12] showed that, on the basis of their mechanical properties, dual cure core build-up resin composites with nanofillers may be used as alternatives to amalgam core, which is similar to the results of a study done by Mitra et al.[13] have found that, nanocomposites to be superior to hybrid, microhybrid or microfill composite resins.

The result of the present study stated that dual cure composite resin (Luxacore Z) has more fracture toughness (99.12 $\pm$ 26.71 MPa.cm$^{-0.5}$) than light cure composite resin (Lumiglass DeepCure) (81.83 $\pm$ 21.90 MPa.cm$^{-0.5}$). This is in accordance to a study done by Kumar L et al.[14] It may be because of its composition. The type of fillers in dual cure composite resin (Luxacore Z) is aluminoborosilicate glass, zirconia–silica nanofillers, fumed silica, and titanium oxide, which could be the reason for their high strength. When a microcrack is initiated in a dental composite, zirconia–silica nanofibers remain intact across the crack planes and support the applied load. The stress-induced phase transformation of zirconia contributes to the toughening effect.

In the present study, the light cure composite resin (Lumiglass) was superior to GIC (Zirconomer improved) in terms of flexural strength. This is in accordance with the study done by Kumar G and Shivrayan A.[8]

Steven G et al.[15] suggested that the fracture strength of composite resin (900 N)was at least 1.9 times that of glass ionomer-based core build-up materials (500 N), similar to the studies done by Lloyd and Butchart.[16] The result of the present study was in consistent with the results shown by Bonilla ED et al.[10] They concluded that the highest fracture toughness values were shown by dual cure composite resin (166.0 $\pm$ 9.2 MPa.cm$^{-0.5}$) while the lowest fracture toughness values were shown by chemically cure composite resin (72.32 $\pm$ 7.2 MPa.cm$^{-0.5}$).

Goldman[17] concluded that fracture toughness values of glass ionomer materials were lower than the composite resins. In the present study, the fracture resistance of zirconia-reinforced glass ionomer core build-up was superior to chemically cure composite resin. This was in accordance with the study done by Shah et al.[18] The main reason for the improved strength was the incorporation of nanofiller particles and zirconia filler particles which prevents crack propagation.

When choosing the core build-up material, the amount and mode of stress must be considered because it affects the stress transmission to the core. As the firmness increases, the stress goes more directly to the root and less to the core. It is also important to choose a core that has similar physical properties to the tooth structure because of the favorable strong interface and lower risk of microleakage and failure. The results of our study indicate that, on the basis of fracture toughness and flexural strength, dual cure composites resin with zirconia filler particles may be used as a material of choice for core build-up. Further clinical studies are required to overcome the limitations of the present study such as the bonding mechanism with tooth structure, biocompatibility, role of saliva contamination on strength.

Conclusion

Within the limitations of the study, the following conclusion can be drawn:

Dual cure composite resin exhibited higher flexural strength and fracture toughness followed by light cure composite resin; however, these findings were statistically insignificant. Dual cure composite resin exhibited highest flexural strength and fracture toughness than zirconia reinforced GIC and chemically cure composite resin (Self Comp) and the difference was statistically significant. Dual cure composite resin was the material of choice in terms of flexural strength and fracture toughness for core build-up material.

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