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Comparative evaluation of compressive strength of three different core build up materials on fiber reinforced composite post after 24 hours and 1 week- an *in vitro* UTM study

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Abstract
Background: A core build-up is a restoration placed in a badly broken down tooth to restore the coronal portion of the tooth. This facilitates subsequent restoration of the broken down tooth by means of extra-coronal restoration. Compressive strength of core materials is thought to be important because core usually replaces the large bulk of the tooth structure and must resist multidirectional forces. In this study compressive strength of three different core materials was investigated on Fiber Reinforced Composite post at different time intervals.
Objective: The purpose of the study undertaken was to determine the compressive strength of self-cured, photo cured and dual cured core build up materials on Fiber Reinforced Composite post after 24 hours and 1 week.
Methodology: Cylindrical specimens measuring 6mm in height and 4mm in diameter were prepared using a machined plexiglass mold and core build up was done around the fiber post. Ten specimens were prepared in each group (n=30); Group A: Restorative Glass Ionomer Cement-GC Gold, Japan; Group B: Light-cured composite-Magma NT, Prevest Denpro, USA and Group C: Dual-cure core-build up composite resin-Para Core, Coltene whaledent, USA, which were further subdivided into five specimens per group according to the time intervals of 24 hours and 1 week. Compressive strength was determined using a universal testing machine. The maximum load applied to fracture the specimens was recorded and compressive strength calculated in MPA. The data obtained was analyzed using parametric one way ANOVA test and Bonferroni post-hoc procedure.
Results: The mean compressive strength was significantly higher ($p<0.05$) in Para Core group as compared to GC Gold and Magma NT. The differences in compressive strength observed were statistically significant.
Conclusion: Within the limitations of this study, 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.

Keywords: Restorative GIC, GC Gold, MAGMA NT, para core, compressive strength, core-build up

Introduction
Modern restorative therapy has provided dentistry with the ability to retain fractured teeth that would have been extracted without hesitation just a few decades ago. It is well known that with proper endodontic treatment and an adequate post endodontic restoration, pulp less teeth can serve indefinitely as an integral part of the dental apparatus provided the supporting structures are not compromised.
A core build up is done on a badly damaged tooth to restore the coronal portion of the tooth and facilitates subsequent restoration of the broken down tooth by means of extra coronal restoration [1]. In general, the core can be thought of as a supra gingival extension of the post. The main functions of the core are to provide a visible and accessible platform to improve the retention and to strategically manage the transfer of forces from the final restoration [2]. They are contraindicated in persistent periapical lesions, poor periodontal health, poor crown: root

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ratio, teeth with heavy occlusal contact, economic factors and inadequate skills. Ideal requirements of core build up materials are ease of manipulation, natural tooth color, adequate compressive and flexural strength, dimensional stability, insolubility and inhibition of dental caries.

Core build-up materials are basically those which are used to repair the damaged tooth structure before the tooth preparation is done and stabilize the weakened parts of the tooth. So it can be stated that they are a key part of the preparation for an indirect restoration. Cores provide retention and resistance form for crowns and behave as transitional restorations before tooth preparation [3].

An ideal core build-up material must possess excellent mechanical properties in order to resist the stresses that may be produced during function providing unbiased stress distributions of forces and decreasing the probability of tensile and compressive failures. Strength is not the only criteria for selection of core material but it is crucial. If other variables are considered to be equal, the strongest core material is indicated [4].

Compressive strength is considered to be a crucial indicator of success because a high compressive strength is necessary to resist masticatory and para functional forces. According to Philips [5], compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. It provides data of force versus deformation for the conditions of the test method.

Various materials like amalgam, Glass Ionomer Cement (GIC) and composites have been used for core build up. Amalgam is dimensionally stable and is readily available. It requires a prolonged setting time and is difficult to prepare immediately after placement. It is aesthetically unpleasant too. On the other hand, GIC's are weaker than desirable to be used as core build up materials but are excellent as fillers when less than one half of the coronal structure is missing.

GICs for restorative dentistry were developed by the end of the 1960's and were first described by Wilson and Kent in 1970 [6]. Many properties of GICs such as fluoride release, adhesion to tooth structure, ease of placement and biocompatibility made these materials attractive for their use in practice.

Recently core build up materials such as flowable composites have been introduced. There are however concerns that the mechanical properties of these materials which incorporate less filler content are reduced to allow flowability since fillers have been reported to improve the mechanical properties of Bis-GMA based dental resins. This suggests that flowable materials with less filler content might be mechanically weaker than their more filled counterparts [7].

Para Core is a fiber reinforced, dual cured and radiopaque core build up material. It exhibits a stackable, non slumpy consistency and is formulated to cut similar to dentin allowing the bur to move smoothly between natural tooth structure and the material without creating troughs and grooves. It incorporates glass particles that impart high strength [8].

In this study, an attempt was made to determine the compressive strength of commonly used core build-up materials, i.e. between self-cured, photo cured and dual cured core build up materials on Fiber Reinforced Composite (FRC) posts after 24 hours and 1 week to determine the most clinically appropriate material. The materials used were:

- Restorative GIC- Label 2 (GC Gold, Japan)
- Light cured composite-Magma NT (Prevest Denpro, USA)
- Dual-cure core builup composite-Para Core (Coltene Whaledent, USA)

Methodology

A total of 30 specimens were made. In Group A, there were 10 samples of Restorative GIC- GC Gold, in Group B, there were 10 samples of Magma NT and in Group C there were 10 samples of Para Core which were further subdivided into 5 samples per group according to the time interval of 24 hours and 1 week. The experimental variables of specimen size, shape, testing configuration, fabrication procedure, temperature, humidity, storage time, storage temperature, strain rate and set time were all standardized in this study. All specimens were treated identically throughout this study, which is based on American Dental Association (ADA) Specification No. 66 (GIC) and 27 (Direct filling resins).
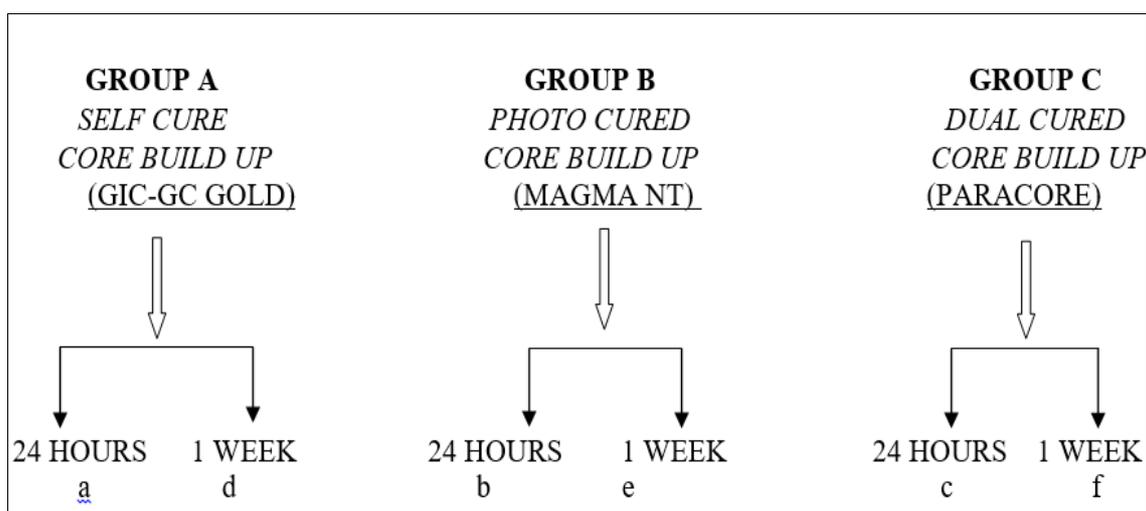
a1, a2, a3, a4, a5- Restorative GIC after 24 hours
b1, b2, b3, b4, b5- Magma NT after 24 hours
c1, c2, c3, c4, c5- Para Core after 24 hours
d1, d2, d3, d4, d5- Restorative GIC after 1 week
e1, e2, e3, e4, e5- Magma NT after 1 week
f1, f2, f3, f4, f5- Para Core after 1 week

Preparation of specimens

The specimen dimensions for each property were selected according to International Standards Organization (ISO) 4049 (ISO, 1992). Compressive strength was measured from cylindrical specimens, 4×6 mm which were mounted on FRC posts embedded in an acrylic base model at an angle of

45^0 such that 5mm of the post will be surrounded by core build up material. The acrylic base was angled at 45^0 to keep the specimens at the ideal angle during the mechanical test. The oblique incidence of loading aims at reproducing a critical stress distribution during the sample testing. A plexiglass mold was used to prepare the core build up specimens. The mold was placed on the acrylic base with the post in the center. Core build up materials were applied in the mold layer by layer for Magma NT and light curing was done with light curing unit for 40 seconds per layer. Para Core was flowed within mold space via auto mix tip, light cured for 30s and kept at room temperature for 5 min, to allow adequate polymerization via self-cure. Molds were then removed from all specimens and samples were stored in distilled water at 37 ± 1 °C prior to testing.

Measurement of properties
The machine used in this study was a Computerized Universal testing Machine (UTM) [Banbros Engineering Pvt. Ltd., India [Model No. WDW- 5; Serial No. 20070802]. Like other universal testing machines, it was capable of recording tension, compression, bend, flexure, peel, shear, stress relaxation, creep and provided a range of cross head speeds which could be set from 0.5 mm/min to 15 mm/min. The samples prepared in this study were placed in the machine between the grips (Figure 1). Accuracy of the machine was +/-1%. Cross head speed was set at 1 mm/minute. Throughout the tests the control system and its associated software recorded the load and extension of the samples when a sudden drop was experienced.
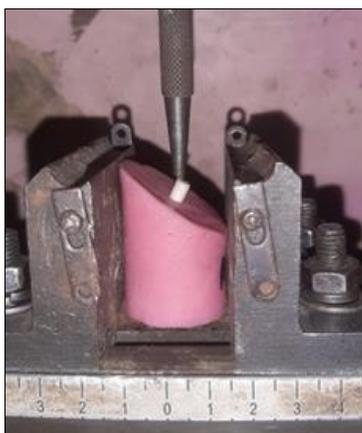

Fig 1: Sample testing

Compressive strength was calculated by the use of formula:
$T=F/\pi r^2$
Where, F=Load applied in Newton, r=Radius of the specimen, $\pi=3.141$
The values obtained were tabulated and subjected to statistical analysis. The mean compressive strength value with its standard deviation was calculated for each core material. One way ANOVA and Bonferroni post Hoc test were used to determine whether statistically significant difference existed among core build up materials.

Result
The observed compressive strength (MPA) of three groups is summarized in Table 1. It shows that the mean compressive strength of Para Core was the highest followed by Magma NT and Restorative GIC being the least (Para Core > Magma NT > Restorative GIC).

After 24 hours, on applying Bonferroni post Hoc test, mean difference was highest i.e. 78.00 between the group A versus group C followed by mean difference between group A versus Group B i.e. 42.80 and least difference, 35.20 was observed between group B versus group C respectively. Overall p values for all the groups during comparison were found to be ≤0.001 which is statistically significant. (Table 2)
After 1 week, the results obtained were statistically significant. On applying Bonferroni post Hoc test, least mean difference calculated was 49.60 between group B and C, and the highest difference 119.20 was calculated among group A versus group C followed by mean difference of 69.60 among group A versus Group B respectively. (Table 3 and figure 2)
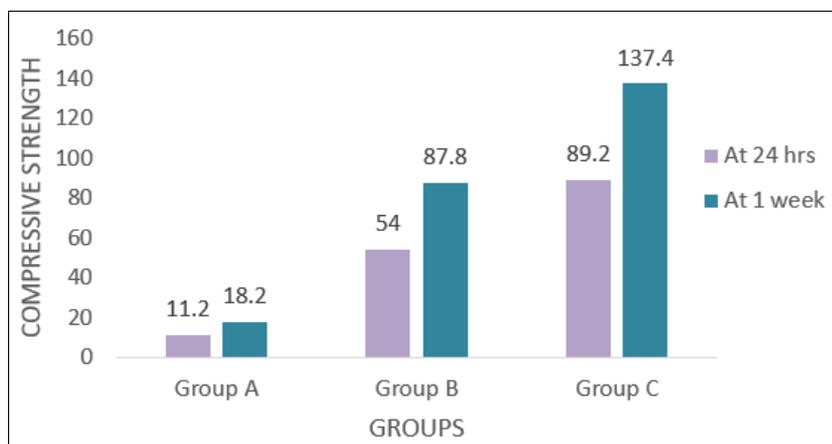

Fig 2: Comparison of compressive strength of different core build up materials at different time intervals.

Table 1: Summary statistics of compressive strength (MPA) of three groups.

Sr. No.	Group A		Group B		Group C	
	24 h	1 week	24 h	1 week	24 h	1 week
	F (MPA)	F (MPA)	F (MPA)	F (MPA)	F (MPA)	F (MPA)
1	11.86	20.72	55.80	83.15	95.46	121.33
2	12.06	18.38	44.74	92.70	82.56	157.88
3	13.05	15.47	60.85	85.80	85.56	125.38
4	12.08	19.27	50.05	87.45	90.45	135.48
5	9.01	18.47	58.05	89.80	92.35	147.85
Mean	11.20	18.20	54	87.8	89.20	137.40
SD	1.64	2.16	6.44	3.83	4.76	15.53

Table 2: Mean differences of compressive strength of three different core build up materials on FRC post at 24 hours.

Comparison of groups	Mean difference	p-value
A versus B	42.80	≤ 0.001*
A versus C	78.00	≤ 0.001*
B versus C	35.20	≤ 0.001*

Test applied: Bonferroni post Hoc test;
*p-value ≤0.05 statistically significant

Table 3: Mean differences of compressive strength of three different core build up materials on FRC post at 1 week.

Comparison of groups	Mean difference	p-value
A versus B	69.60	≤ 0.001*
A versus C	119.20	≤ 0.001*
B versus C	49.60	≤ 0.001*

Test applied: Bonferroni post Hoc test;
*p-value ≤0.05 statistically significant

Discussion

The present study was undertaken to find out the best core build up material with respect to their curing mechanisms and time intervals. The three core build up materials were manipulated according to manufacturer's instructions.

The specimens were mounted vertically between disk plates of UTM and load was applied at 45^0 to fracture the specimens using a rod having diameter of 1.5 mm. A continuous compressive force was applied at a crosshead speed of 1 mm/min until failure. The highest fracture load of each specimen was measured by a sudden drop in load magnitude, recorded in Newton. The maximum load applied was recorded and compressive strength (MPA) was calculated.

In dentistry, the loss of material due to non-antagonistic contacts have been defined as occlusal contact free area (CFA) wear. GIC exhibits a CFA wear five times higher than amalgam and three times higher than resin composite materials [9]. However, the fracture resistance load of Magma NT and Para Core groups was significantly higher than that of Restorative GIC-GC Gold group. On the basis of their mechanical properties, dual cure core build up resin composites with nanofillers may be used as alternatives to Restorative GIC.

Magma NT is a low shrinkage composite and the nanosilica and zirconia (Zr) fillers improve its good physical properties and esthetics [10]. It is a light-curing hybrid composite with high translucency that show high depth of cure to 10 mm for opaque shade and 15 mm for other shades. Para Core is a dual-curing composite with glass-reinforced, radiopaque composite system that has low consistency which allows the mixing and application in root canal. According to the manufacturer's information, Para Core has the highest filler content (68 wt%), followed by Magma NT (58.8 wt%) and GIC. It can be noticed that the results of fracture resistance load had the same trend with the filler content in core

materials.

The observed increase of compressive strength in the samples of Restorative GIC, although not statistically significant, could be explained by the reduction of undesirable early water exchange [11]. In the present study the specimens were stored in distilled water before the compressive strength measurements were taken. After the acid-base reaction, clinically described as the initial setting, the maturation process takes place within the material until complete setting occurs [12]. The water absorbed in the maturation phase occupies coordination sites around metal cations or hydration regions around the polyanion chain within the set cement. This enables shrinkage compensation, and the proportion of loosely bound water decreases relative to the proportion of tightly bound water as the cement matures [13]. The maturation results in altered mechanical properties for GIC, and compressive strength increases asymptotically to a stable value higher than the one found at 24 hours [12].

Zirconia nano particle containing Magma NT showed significantly higher compressive strength than Restorative GIC. Multiple explanations can be presented in this regard. Zr has high strength and fracture toughness that is imparted in Magma NT [14]. In addition, micro and macro size filler particles are known to leave internal flaws in the composite materials, possibly affecting the resulting compressive strength of the material [15]. Use of nano particle size Zr fillers allows for a highly condensed filler component, whereby filling defects among macro and micro filler particles and enhancing the compressive strength [16]. It further improves the filler/polymer chain interaction with a favorable effect on internal stress development [17]. In a study by Hambire and Tripathi [18], it was concluded that adding Zr filler to a constant volume fraction of silica and glass particle containing composite significantly improved the compressive strength of the experimental composite material. They concluded that Zr was a significant contributing factor in compressive strength of composite materials.

Dual cure materials have been recommended for core build ups as they allow to bulk fill the cores with adequate working and setting time, while reducing the effect of light attenuation on the depth of cure and hence the mechanical properties of the material [19]. It has been reported that dual cured resin materials show similar mechanical properties as well as the depth of cure for bulk fill techniques than light cure resin composites and better properties (fracture toughness, depth of cure, hardness) than chemical cure composites [20]. Interestingly, compressive strengths among all three materials (Restorative GIC, Magma NT, Para Core) in the present study were significantly higher ($p<0.01$) at 1 week as compared to 24 hours indicating that the polymerization reaction continued for some duration after 24 hours of increasing the conversion of monomers to polymers. Degree of conversion of monomer to polymer has been linked to the better mechanical properties of dual cured composites and therefore could be the possible explanation for the findings in the present study [21].

Visual examination of the fractured parts was performed. Following fracture patterns were observed: (a) Core build up material fractured along with the post (b) Cohesive fracture of core build up material only took place (c) Adhesive fracture took place where the core build up material was debonded from the post (d) Fracture line within core build up material.

Conclusion

Within the limitations of this study, it can be concluded that

the compressive strength of Para Core was the highest and the strength increased with increase in time for each core build up material. Para Core achieves its strength through incorporation of glass particles and high filler content. In this study only the compressive strength of core build up material in relation to FRC post was studied. As a drawback, standard bonding protocol of fiber posts was not achieved in current study which may affect the compressive strength results of different core build-up materials used. Various other factors such as relation of core with cement used to lute the post, post-cement-core-dentin interface, elasticity of post in relation to dentin, etc. we're not considered. Further *in vivo* and Scanning Electron Microscope (SEM) studies can be done to find out the most appropriate core build up material.

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