



ISSN Print: 2394-7489  
ISSN Online: 2394-7497  
IJADS 2020; 6(2): 282-286  
© 2020 IJADS  
[www.oraljournal.com](http://www.oraljournal.com)  
Received: 01-02-2020  
Accepted: 03-03-2020

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## **An *in vitro* comparative evaluation of the depth of cure and flexural strength of four tooth colored direct core build-up materials**

**Roshan Sadiya, Utkarsh Piyush Shah and Mrudhula Kamal**

### **Abstract**

The purpose of this study was to comparatively evaluate the depth of cure and flexural strength of 4 tooth colored direct core build-up materials- a nanocomposite, microhybrid composite, resin modified GIC and a modified composite.

**Materials and Methods:** 240 samples of 4 tooth colored core build-up materials were prepared from polytetrafluoroethylene molds to assess the depth of cure and flexural strength. Samples were divided equally into 4 groups (n=60) [Group I- nanocomposite, Group II-micro hybrid composite, Group III- resin modified GIC and Group IV-modified composite-Cention N]. Each group was further divided into 2 subgroups. Subgroup A (n=40) for measuring depth of cure by Vickers' hardness number and Subgroup B (n=20)- for measuring flexural strength. Subgroup A of each group was further divided equally into 4 divisions according to thickness of the restorative material placed into the designated mold (1mm, 2mm, 3mm and 4mm). The results were statistically analyzed using ANOVA, multiple comparisons (post-hoc test) were carried out using Bonferroni test.

**Results:** At different heights of the specimen, Group IV recorded the highest mean micro hardness followed by Group II, Group I and Group III. Higher mean micro hardness was recorded by all the core build-up materials in the radiated surface compared to non-radiated surface. Higher mean flexural strength was recorded in Group IV followed by Group II, Group I and Group III respectively.

**Keywords:** Core build-up material, nanocomposite, micro hybrid composite, resin modified glass ionomer cement, flexural strength, depth of cure

### **1. Introduction**

Teeth undergoing endodontic treatment are more often severely compromised by decay, previous restorations, or excessive wear, resulting in a significant loss of coronal tooth structure [1]. Hence, a successful endodontic therapy should be complemented with an adequate post endodontic restoration of the pulp less tooth to function indefinitely as an essential part of the masticatory apparatus [2].

Post endodontic restorations are placed to restore the endodontically treated tooth back to its original form, function and aesthetics [3]. Coronal restorations directly influence the survival and success of endodontically treated teeth by reducing bacterial microleakage into the recently treated root canal system; re-establishing proximal contacts and occlusal stability as well as protecting the tooth from future breakdown, both carious and non- carious [3].

Depending on the amount of tooth structure to be restored a number of direct and indirect materials have been used in core build-up procedures. 4 Direct core build-up materials include high copper amalgam, visible light cured resin composite, polyacid modified composite, resin modified glass ionomer cement and silver cermet cement [4]. These materials should have compressive strength to resist intraoral forces and flexural strength to prevent core dislodgement during function which in turn, is dependent on the adequacy of setting or polymerization of the material [5].

With the advent of newer materials for use in core build-up procedures, it may be apt to compare the mechanical properties with older materials, thereby identifying a suitable material that can achieve optimal results. Depth of cure is the depth to which the light is able to harden the material [6]. The depth of polymerization is a crucial factor not only in order to achieve optimum physical and mechanical properties but also to ensure that the clinical problems do

not arise due to the partially polymerized material. 7 Depth of cure and shrinkage stresses induced during polymerization affects the mechanical properties and marginal integrity of restorations [7].

Strength values often serve as indicators of structural performance of brittle materials [8]. The three-point flexural strength test that has been used to measure mechanical properties of a material has been selected by ISO for screening resin based materials [8]. Flexural strength is defined as the maximum stress that a material can resist before failure when subjected to a bending load [9]. High flexural properties are desirable where heavy masticatory stresses are encountered clinically [9].

However, despite the many studies that have been conducted to compare the fracture loads of core materials, studies on the depth of cure and flexural strength of the newer materials are limited [4]. Therefore, an attempt was made to comparatively study and evaluate the depth of cure and the flexural strength of newer direct core build-up materials that would help the clinician select better restorative materials for the long term clinical success of post endodontic restorations.

**2. Materials and methods**

240 samples of 4 tooth colored core build-up materials were prepared to assess the depth of cure and flexural strength. The test samples were divided into 4 groups (Group I- nanocomposite, Brilliant NG (Coltene/Whaledent AG); Group II- micro hybrid composite, Swiss TEC (Coltene/Whaledent AG); Group III- resin modified glass ionomer cement, GC Fuji II LC Universal restorative material (GC Corp) and Group IV- a modified composite, Cention N (Ivoclar Vivadent) with 60 samples in each group (n=60). Each group was further divided into 2 subgroups (Subgroup A [n=40]- for measuring depth of cure by Vickers’ hardness number and Subgroup B [n=20]- for measuring flexural strength by three point bending test using Universal testing machine). The Subgroup A of each group was divided equally into 4 divisions (1mm, 2mm, 3mm and 4mm thickness of restorative material packed into the designed mold).

**2.1 Test for depth of cure:** Polytetrafluoroethylene hollow cylindrical molds with an inner diameter of 8mm and outer diameter of 10mm, measuring different heights of 1, 2, 3 and 4mm were used for the study. To prepare each specimen, the mold was placed on a clear glass slide; the materials were placed in the mold and covered with a mylar strip. 1mm thick glass slide was placed on top of it and was held by finger pressure to extrude excess material. Only the top side of the specimen was irradiated with a light curing unit for 60 seconds. The head of the light curing unit was in contact with the glass slide and around 1mm away from the mold during exposure. The samples were removed from the mold and the bottom surfaces were marked to distinguish them from the top surfaces. The samples were stored at room temperature in light proof containers for 24 hours. The bottom and top hardness were determined using Vickers’ hardness tester with 200gf load application for 15 seconds. For each sample, 3 VHN readings were recorded for the top irradiated and bottom non irradiated surfaces. Then for each thickness the mean value and standard deviation of VHN were measured. A bottom to top VH was determined and a value of 80% was used to indicate acceptable curing.

**2.2 Flexural strength testing:** 80 specimens, 20 for each group as mentioned before were subjected to flexural strength

testing as follows. Specimens using rectangular polytetrafluoroethylene molds of dimensions 25±2 mm x 2±0.1 mm x 2±0.1 mm (ISO 4049 and ANSI/ADA Specification no. 27) were prepared. The base and mold were lubricated with a thin layer of separating medium. All specimens were packed into the mold cavity, covered by a polyester strip and gently pressed using a glass slide to extrude the excess material. The specimen cements were light cured for 60 seconds through the glass slide. Thereafter, the specimens were removed from the mold, flashes were eliminated using silicon carbide paper and using low speed diamond coated disks with copious water irrigation. The test specimens were stored in distilled water at room temperature for 24 hours prior to testing. Flexural three point bending test was carried out using Universal testing machine. The maximum load exerted on the samples was recorded and the flexural strength at failure was calculated by the following formula:  $\sigma = 3Fl/2Bh^2$

Where, F= maximum load exerted on the specimens in Newton; l= distance (mm) between the supports ± 0.01mm; B= width (mm) of the specimen immediately prior to testing; h= height (mm) of the specimen measured immediately prior to testing.

**3. Results**

The results were statistically analyzed using ANOVA, multiple comparisons (post-hoc test) were carried out using Bonferroni test.

- Mean Microhardness recorded in the different core build-up materials was as follows: Group I- Nanocomposite (Brilliant NG)- 63.31; Group II- Micro hybrid composite (Swiss TEC)- 69.77; Group III- Resin modified GIC (GC Fuji II LC universal restorative material)- 36.45; Group IV -Modified composite (Cention N)- 74.18
- Mean Microhardness recorded in the different Surfaces was as follows: Radiated- 65.88; Non- Radiated- 55.98
- Mean Microhardness recorded in the different Specimen Heights was as follows: 1mm- 64.18; 2mm- 62.60; 3mm- 60.42; 4mm- 56.51

**Table 1:** ANOVA (Microhardness)

Source of Variation	P-Value
Core build-up material	<0.001*
Specimen Ht	<0.001*
Surface	<0.001*
Core build-up material x Specimen Ht	0.733
Core build-up material x Surface	<0.001*
Specimen Ht x Surface	<0.001*
Core build-up material x Specimen Ht x Surface	0.428

\*denotes significance

Pair-wise significant differences were determined using Bonferroni multiple comparisons for composites as well as for the different specimen heights.

**Table 2:** Multiple comparisons amongst the different core build-up materials for significant differences:

Core build-up material (I)	Core build-up material (J)	P-Value
Group I	Group II	<0.001*
	Group III	<0.001*
	Group IV	<0.001*
Group II	Group III	<0.001*
	Group IV	<0.001*
Group III	Group IV	<0.001*

\*denotes significant difference

**Table 3:** Multiple comparisons amongst the different specimen heights for significant differences.

Specimen Ht (I)	Specimen Ht (J)	P-Value
1 mm	2mm	0.033*
	3mm	<0.001*
	4mm	<0.001*
2mm	3mm	0.001*
	4mm	<0.001*
3mm	4mm	<0.001*

\*denotes significant difference

Mean Flexural strength recorded in the different core build-up materials was as follows: Group I- Nanocomposite (Brilliant NG)- 90.52; Group II- Micro hybrid composite (Swiss TEC)- 105.67; Group III- Resin modified GIC (GC Fuji II LC universal restorative material)- 54.22; Group IV -Modified composite (Cention N)- 117.76.

**Table 4:** ANOVA (Flexural strength)

Source of Variation	P-Value
Between Groups	<0.001*
Within Groups	-----

\*denotes significant difference

The difference in mean flexural strength among the groups was found to be statistically significant ( $P < 0.001^*$ ). In order to find out among which pair of groups there exist a significant difference, we carry out multiple comparisons using Bonferroni test. The results are given below:

**Table 5:** Multiple comparisons (Flexural strength using Bonferroni test)

Group (I)	Group (II)	P-Value
Group I	Group II	0.001*
	Group III	<0.001*
	Group IV	<0.001*
Group II	Group III	<0.001*
	Group IV	0.013*
Group III	Group IV	<0.001*

\*denotes significant difference

#### 4. Discussion

Restoration of root canal treated teeth can be challenging due to structural differences such as dehydration of dentin, reduction of microhardness, collagen alteration between vital and non-vital root filled teeth [10]. The objectives of a restoration following root canal treatment and retreatment are to restore form, function and aesthetics, to prevent bacterial microleakage into the root canal space, to ensure adequate periodontal health and to protect the remaining tooth structure against fracture [15].

A core build-up is a restoration placed to provide foundation for a restoration that will withstand the masticatory stress that exists in the oral cavity for prolonged periods and to provide substantial strength and resistance to fracture before and after crown preparation [5]. The selection of these materials is primarily based on the ease of handling with due consideration being given for the mechanical properties and manipulative variables [5].

Recent modifications in post-endodontic restorations depend on the improvement of the adhesive techniques and the materials used [10]. Focusing on relevant advantages such as bio- economy of dental tissues and periodontal tissues, reinforcement of healthy residual dental tissues, aesthetic, ergonomic and economic advantages of the conservative

bonded techniques helps the clinician to choose the appropriate restoration [10]. Hence in the present study tooth colored direct core build-up materials have been selected.

Composites have become a popular choice for core build-up of teeth due to their rapid rate of polymerization and better strength properties [5]. Improvements in filler technology have allowed blends of submicron particles (0.04 microns) and small particles (0.1- 1.0 micron) to be incorporated into the composite formulation classifying them as micro-hybrid composites [15]. Nanotechnology is another advancement in the development of resin based composites [12]. These contain nanometric sized filler particles (0.005- 0.01 microns) throughout the resin matrix, in combination with a more conventional type filler technology. The nanofiller particles contribute to better polishability and higher aesthetical performance [12].

Resin modified glass ionomer cements also known as hybrid ionomers are conventional glass ionomer cements with the addition of HEMA.5 They overcame the drawbacks of conventional glass ionomer cements such as inferior physical properties not making them suitable for core build- up procedures as they are susceptible to moisture contamination and have low early strength.5 They are considered dual cure cements if a light cure or chemical cure polymerization mechanism is used [5].

A dual curing resin based composite containing alkaline fillers incorporated in a methacrylate resin matrix, classified as alkasites (CENTION N), focuses on bioactive properties and have been used in modern dentistry for core build- up and cementation [13]. The main factors to be considered apart from their caries protective ability are the length of the setting time, adequacy of mechanical properties and degree of conversion in depth and the impact of additional light curing on these properties [13].

The depth of polymerization is a crucial factor not only in order to achieve optimum physical and mechanical properties but also to ensure that the clinical problems do not arise due to the partially polymerized material [14]. Depth of cure and shrinkage stresses induced during polymerization affects the mechanical properties and marginal integrity of restorations [14]. Hence for this reason, investigation of the depth of cure is of scientific interest.

Depth of cure can be investigated by direct and indirect methods [15]. Direct methods include infrared microscopy and laser Raman which are complex, expensive and time consuming while the indirect methods include micro hardness testing, scratching and visual inspection [15]. The micro hardness testing appears to be the most popular method because the other indirect methods tend to overestimate the curing depth [15].

Surface micro hardness has been shown to be an indicator of the degree of conversion.15 To determine the depth of cure based on top and bottom measurements, the ratio of bottom/top hardness is calculated to give an arbitrary minimum value for this ratio.16 The bottom to top hardness ratios ranging from 0.80 – 0.85 have been used to consider the bottom surface as adequately cured which means that the bottom to top surface micro hardness ratio of 80% or more indicates adequate curing [15, 16].

The Vickers micro hardness test was selected for the study because it is the most accurate available simple test for measuring the micro hardness of a brittle material such as composite resin [17]. In the micro hardness test the magnitude of load has a significant effect on the results [15]. A range of 1grf (gram force) to 1 kgf (kilogram force) is considered

acceptable, the most common being 100grf - 500grf<sup>[15]</sup>. The indenter with a higher load penetrates deeper into the material, reaches the harder layer and therefore measures a greater hardness<sup>[15]</sup>. In the present study, the load was 200grf and the dwell time was 15 seconds<sup>[15]</sup>. Studies have shown that a dwell time of 15 seconds could be accepted as an actual time of load application time for a composite resin material<sup>[15]</sup>.

Variables affecting hardness and depth of cure include curing light irradiance, exposure time and the restorative material used. A study by Shakir suggested that a longer irradiation time was more efficient for polymerization than a shorter irradiation time<sup>[18]</sup>. In the present study although the manufacturers recommended different exposure times for adequate curing depth, an exposure time of 60 seconds was used in order to have maximum curing and to standardize the experimental conditions<sup>[15]</sup>.

Cellabos suggested that the depth of cure was not influenced by curing lights<sup>[15]</sup>. In the current study, LED curing unit was used as it can adequately cure the materials up to a thickness of 3mm which is accordance with a study conducted by Oglah *et al.*<sup>[19]</sup>. The spectral output of gallium nitride blue LED falls within the absorption spectrum of the camphoroquinone photo-initiator (400-500nm) introduced in most light activated resin composites and thereby produces effective polymerization<sup>[19]</sup>.

In the present study, among the aesthetic core build-up material samples of 4 groups categorized into 4 divisions of 1mm, 2mm, 3mm and 4mm thicknesses that were subjected to depth of cure testing by Vickers micro hardness tester, the maximum values were demonstrated by Group IV (modified composite- Cention N) while the lowest values were demonstrated by the resin modified glass ionomer cement which was statistically significant ( $P < 0.001$ ) and is concurrent with a study done by Mazumdar *et al.* wherein the reason for increased microhardness is attributed to the nanoparticle size of the inorganic filling<sup>[20]</sup>. The resin modified glass ionomer cement showed the lowest microhardness values that could be attributed to more porosity with the manual mixing system which was reported in a study done by Taha *et al.*<sup>[21]</sup> The results also showed that amongst the different specimen heights, highest mean micro hardness was recorded in 1mm height samples followed by 2mm, 3mm 4mm samples respectively and the difference was statistically significant ( $P < 0.001$ ) indicating that the depth of cure decreased with the increase in thickness which was in agreement a study done by Rouhollahi *et al.*<sup>[15]</sup>. With light cured resins, measurements have shown that the depth of cure decreases continuously in areas deeper than approximately 0.5mm<sup>[16]</sup>. The depth of cure is highest at a depth of 0.5mm because of the uppermost inhibition layer<sup>[15]</sup>. From this layer downwards, the light intensity entering the material decreases steadily as filler particles scatter light and color pigments absorb it<sup>[16]</sup>.

In the current study, between the two surfaces, radiated surface recorded a higher mean micro hardness compared to non-radiated surface and highest values for microhardness was demonstrated by samples with 1mm thickness while the lowest values was denoted by samples of 4mm thickness which is concomitant with the findings of the studies by various researchers. A post light curing reaction tends to occur with the remaining radicals within 24 hours after initial polymerization, thus to determine the depth of cure, the test samples are usually stored for 24 hours before measurements

are made which is accordance with the current study<sup>[16]</sup>.

It must be noted that one of the major factors affecting the long-term clinical performance of a restorative material is their mechanical durability under complex stresses while chewing<sup>[9]</sup>. Strength is the most important aspect for selection of a core material as stronger the material better is the ability to resist deformation and fracture<sup>[5]</sup>. Flexural strength testing is increasingly popular as a suitable method to assess the strength of materials as it reflects resistance to compressive and tension stresses that act simultaneously<sup>[15]</sup>.

Flexural strength can determine the longevity of restoration towards chewing pressure and occlusal forces<sup>[23]</sup>. According to the ISO Specification 4049 the mechanical properties of a restorative material can be measured using the flexural three-point bending test thereby predicting their clinical performance. The ISO 4049 (ISO 2000) standard employed in the current study required rectangular shaped specimens with dimensions of 25mm length, 2mm width and 2mm thickness that is loaded at its center<sup>[9]</sup>. It has been stated that the ISO specifications for height and width are satisfactory because the dimensions of the specimens allow efficient polymerization<sup>[8]</sup>. The length of the rectangular shaped specimen exceeded the exit window diameter of the curing light tip, so an overlapping light curing exposure was required as curing progressed along the length of the specimen<sup>[8]</sup>.

In the present study Group IV (modified composite- Cention N) showed the highest flexural strength values while Group III (resin modified glass ionomer cement) reported with the lowest values. This could be attributed to the presence of a special patented filler (partially functionalized by silanes) in Cention N which is responsible for imparting adequate strength to withstand the stresses and strains that the restorative material may be subjected to in the oral cavity and to achieve acceptable clinical longevity<sup>[20]</sup>. It is generally assumed that as the filler loading is increased, the mechanical properties also increase. However, in the current study, Group I (nanocomposite) showed lower values for flexural strength testing when compared to Group II (microhybrid composite) which was in agreement with a study done by Sonwane *et al.* wherein the results were attributed to the fact that there is a great variety in manufacturing brands of nanocomposites which could result in differences in the volumetric content of the inorganic particles<sup>[11]</sup>.

## 5. Conclusions

Within the limitations of the present invitro study it can be concluded that:

1. Amongst the different core build-up materials, highest mean micro hardness was recorded in Group IV [modified composite (Cention N)] followed by Group II [micro hybrid composite (Swiss TEC)] and Group I [nanocomposite (Brilliant NG)]. Lowest mean micro hardness was recorded in Group III [resin modified glass ionomer cement (GC Fuji II LC universal restorative material)].
2. Amongst the different specimen heights, highest mean micro hardness was recorded in 1mm height followed by 2mm, 3mm and 4mm respectively.
3. Between the two surfaces, radiated surface recorded a higher mean micro hardness compared to non-radiated surface.
4. Higher mean flexural strength was recorded in Group IV followed by Group II, Group I and Group III respectively.

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