Comparison of physical properties of three commercial composite core build-up materials

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Various materials have been used for core build-up when restoring the coronal portion of the tooth. Currently, bulk-fill resin composites have been produced to restore a large posterior cavity in single increment. This study aimed to evaluate the compressive strength, flexural strength, and microhardness of three commercial composite core build-up materials. All data were analyzed by one-way ANOVA and Tukey test methods (α=0.05). Flexural strength data were subjected to Weibull statistics analysis. All three groups presented significant differences in the compressive strength, flexural strength, and Knoop hardness. Filtek™ Z350 XT had the greatest compressive strength (MPa) and Knoop hardness while Filtek™ bulk fill had the highest flexural strength. MultiCore Flow had the lowest properties; however, it revealed the highest Weibull modulus (m) value. With regard to the properties tested in this study, bulk-fill resin composite can be used as an alternative to conventional resin composite for core build-up material.

Keywords: Flexural strength, Weibull statistics, Core build-up material, Bulk fill, Resin composite
Table 1  Materials used in this study

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
<th>Fillerload (wt%/vol%)</th>
<th>Manufacturer</th>
<th>Batch Number (lot number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtek™ Z350</td>
<td>Light cure composite: Bisphenol-A-glycidyl methacrylate (Bis-GMA), Ethoxylated bisphenol-A dimethacrylate (Bis-EMA), Urethane dimethacrylate (UDMA) with small amounts of Triethylene glycol dimethacrylate (TEGDMA) non-agglomerated/non-aggregated, 20 nm nanosilica filler, and loosely bound agglomerated zirconia/silica nanocluster</td>
<td>78.50/59.5</td>
<td>3M ESPE, St.Paul, MN, USA</td>
<td>N708953</td>
</tr>
<tr>
<td>Filtek™ Bulk fill</td>
<td>Light cure composite: Bis-GMA, Bis-EMA, Aromatic urethane dimethacrylate (AUDMA), UDMA and 1, 12-dodecane-DMA non-agglomerated/non-aggregated 20 nm silica filler, a non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, an aggregated zirconia/silica cluster filler and a ytterbium trifluoride filler</td>
<td>76.5/42.5</td>
<td>3M ESPE</td>
<td>N682084</td>
</tr>
<tr>
<td>MultiCore® Flow</td>
<td>Dual cure composite: Bis-GMA, UDMA, TEGDMA Inorganic fillers (barium glass, Ba-Al-fluorosilicate glass, silicon dioxide, and ytterbium trifluoride)</td>
<td>54.65/46</td>
<td>Ivoclar Vivadent, Schaan, Leichtenstein</td>
<td>T35741</td>
</tr>
</tbody>
</table>

by bulk technique up to 3 mm and each layer was cured for 20 s. Dual-cured core build-up materials was placed in one bulk and then cured for 20 s. All specimens were irradiated at the top and bottom surfaces. They were stored in distilled water at 37°C for 24 h with 100% humidity. Test specimens were subjected to the compressive strength tests using a universal testing machine (LR10K, LLOYD Instrument, UK) at a cross head speed 0.5 mm/min. The stress at fracture (S) was calculated according to the following equation:

\[ S = \frac{F}{(d/2)^2 \pi} \]

Where \( F \) is the load at fracture (N), \( d \) is the mean diameter of the specimen (mm)

**Flexural strength**

Flexural strength (\( \sigma \)) was determined by a three-point bending test. Thirty-five specimens in each group were fabricated using a stainless steel split mold with dimensions of 25±0.1 mm (length)×2±0.1 mm (height)×2±0.1 mm (width), as specified in ISO 4049:2009 standards10. The specimens were photo-polymerized using LED curing unit (Elipar S10, 3M ESPE). The center of the specimen was cured first and then the polymerization was performed by curing overlapping regions between right and left from the center until the entire specimen surface were polymerized. Each area was cured for 20 s and irradiation was performed at the top and bottom of the specimens. All specimens were stored in distilled water at 37°C for 24 h with 100% humidity. Then they were submitted to the universal testing machine (EZ-S, SHIMADZU, Kyoto, Japan) at a cross head speed of 0.75 mm/min until fracture occurred. All data were calculated according to the following equation:

\[ \sigma = 3\frac{F}{2bh^2} \]

Where \( F \) is the maximum load (N), \( l \) is the distance between the supports (mm), \( b \) is the width of the specimen (mm), and \( h \) is the height of specimen (mm)

**Knoop microhardness**

The Knoop microhardness test was performed in order to determine the microhardness of resin composite, which can predict the clinical performance of restorations. The specimens were made in a stainless steel split mold size 2 mm (height)×3 mm (diameter). All specimens were then stored in distilled water at 37°C for 24 h prior to testing. The specimens were submitted to the Knoop hardness test (KHN) using a load of 10 g with dwell time of 20 s when using a digital microhardness tester (FM-ARS-900, Future-test, Kanagawa, Japan). The specimens were positioned beneath the indenter of a digital microhardness tester and five indentations were measured on each specimen surface.

**Fracture analysis**

The fracture surfaces of the specimens were coated with gold for 60 s in Quorum Q150R ES (serial no. 15112, Quorum Technologies, East Sussex, UK) at a sputter current of 25 mA. They were observed in a scanning electron microscope (SEM; JSM-IT300LV, serial no. MP1372001500150, JEOL, Tokyo, Japan)

**Statistical analysis**

Data obtained from the compressive, flexural, and Knoop hardness tests were analyzed by One-way ANOVA and Tukey's test (\( \alpha=0.05 \)). Reliability of materials and
probability of failure were analyzed by Weibull analysis using the flexural strength data. The following equation was used to evaluate the cumulative probability of failure, \( P_f \):
\[
P_f = 1 - \exp\left(\frac{-\sigma}{\sigma_0}m\right)
\]
Where \( P_f \) is the probability of failure, \( \sigma \) is the flexural strength, \( \sigma_0 \) is the characteristic strength (\( P_f = 63.2\% \)), \( m \) is the Weibull modulus. Plotting \( \ln[\ln(1-P_f)] \) against \( \ln \sigma \) will provide a slope with the value of the Weibull modulus.

### RESULTS

The results from the ANOVA analyses indicated that there were significant differences at the 95% level (\( p<0.05 \)) in the mean compressive strength, flexural strength, and Knoop hardness of three materials (Table 2). Filtek™ Z350 had the greatest compressive strength and Knoop hardness, which were 283.43 MPa and 66.22 respectively, followed by Filtek™ Bulk fill (239.75 MPa, 48.99) and MultiCore® Flow (193.25 MPa, 40.69). On the other hand, Filtek™ Bulk fill had the greatest mean flexural strength (142.43 MPa), followed by Filtek™ Z350 (125.22 MPa) and MultiCore® Flow (114.71 MPa).

The result from the Weibull analyses (Fig. 1) showed that...
showed that MultiCore® Flow had the greatest Weibull modulus (16.60), followed by Filtek™ Bulk fill (15.76) and Filtek™ Z350 (11.38). The characteristic strengths of Filtek™ Bulk fill, Filtek™ Z350 and MultiCore® Flow were 147.21, 131.83 and 114.71 MPa, respectively.

The SEM images (Fig. 2) show the defects associated with the fracture sites. Filtek™ Z350 had the largest porosity size, while MultiCore® Flow had the lowest size of such defects.

**DISCUSSION**

Mechanical properties are important factors for the success of core build-up restorative dental materials. This is because they must withstand the forces due to mastication and para-function. This study evaluated some of the properties, including compressive strength, flexural strength, and Knoop hardness (KHN) of three resin composite materials. The null hypothesis of this study was rejected, since there were statistically significant differences in the properties of the three groups. The results of this study demonstrated that Filtek™ Z350 had the greatest compressive strength and Knoop hardness, whereas Filtek™ Bulk fill had the greatest flexural strength. These results confirm an earlier conclusion that bulk fill resin-based composites show lower mechanical properties (except for flexural strength) than nanohybrid and microhybrid resin-based composites.

It is known that the mechanical properties of the composites are related to their filler contents and to the type and size of filler. From the composition (Table 1), Filtek™ Z350 has a higher filler content (78.5 wt%, 59.5 vol%) than Filtek™ Bulk fill (76.5 wt%, 42.5 vol%) and MultiCore® Flow (54.65 wt%, 46 vol%). For the filler types, silica and zirconia fillers are found in Filtek™ Z350 and Filtek™ Bulk fill, whereas MultiCore® Flow contains barium glass and silicon dioxide fillers. Bulk fill composite materials have been developed to offer low polymerization shrinkage, easy use and improved depth of cure. When it is necessary to increase the depth of penetration of the light initiating the cure, the amount of filler particles has to be reduced. Therefore, Filtek™ Bulk fill has lower compressive strength and hardness compared to Filtek™ Z350. MultiCore® Flow has the lowest filler content and also has no zirconia in its composition. Consequently, it has the lowest strength. Nevertheless, all three materials tested were found to have compressive strength values (>100 MPa) greater than the minimum value (50 MPa) recommended for dental amalgam, which is clinically well-proven for core build-up.

Both filler morphology and filler loading influence the flexural strength, flexural modulus, and hardness. Moreover, the type of monomer in the matrix influences these properties. One study reported that monomer containing Bis-GMA or TEGDMA substituted by UDMA results in an increase in flexural strength. Also that substitution of Bis-GMA by TEGDMA reduces the flexural strength. In this study, TEGDMA monomer contained in Filtek™ Z350 and MultiCore® Flow leads to lower flexural strength compared to Filtek™ Bulk fill.

Weibull statistics relate to the reliability of the material in use. It does this by providing the probability of failure. Simple measurement of fracture strength alone cannot predict structure failure. That is because it provides an insight into only the stresses that the material will withstand for a given flaw size distribution. On the other hand, the Weibull modulus \( m \) is a parameter that describes the variability of the strength of brittle materials. A high Weibull modulus indicates higher reliability of materials. In addition, materials with a high Weibull modulus are more predictable and less likely to break at a stress much lower than a mean experimental value. The second parameter of the Weibull analysis is the characteristic strength \( \sigma \). This is a parameter that corresponds to the stress level giving a 63.2% probability of failure. Thus Weibull characteristic strength values \( (P_f=63.2\%) \) are slightly greater than the mean strength values \( (P_f=50\%) \).

In this study, MultiCore® Flow has a Weibull modulus \( m \) higher than other groups. This may be because of the lower viscosity of uncured Multicore® Flow. As a result surface defects within the material are reduced and crack propagation is minimized. SEM analysis confirms this result, showing the smallest defects on the fractured surfaces (Figs. 2C and F). Filtek™ Bulk fill has similar m value to Multicore® Flow while Filtek™ Z350 has the lowest m value. The result from SEM of the Filtek™ Z350 group (Figs. 2A and D) showed that there were the largest porosities on the fracture surfaces. These porosities may result from the placement technique that involves building up the material in multiple increments. This technique necessitates higher chair time and increases the risk of voids and contamination between layers. Another factor responsible for the gaps in the material is clinical skill of the operator. The operator that carefully performed and strictly followed according to the manufacturer’s instruction will give the good clinical outcome. One study revealed that operator skill and experience play a major role in the post-operative sensitivity outcome. Therefore, materials that use a bulk technique tend to provide smaller gaps than do conventional resin composites that using an incremental technique. Furthermore, in this study, Filtek™ Bulk fill had a similar m value as an earlier study which had \( m=14.21 \). On the other hand, it was higher than that found by Vidhawan et al. In addition, the m value of Filtek™ Z350 in this project \( m=11.38 \) is higher than that reported as \( m=8.3 \). These differences in m value could be due to the differences in methodology used in the earlier work.

Although the strength of core build-up material is the factor that influenced the fracture resistance of the abutment, the matching moduli between the material and the dentin is also important. If there is too mismatch of the elastic values, interfacial stress may occur from either thermal, mechanical, or shrinkage strain in the material. Therefore, core build-up material should
have high elastic modulus similar to tooth structure to withstand the forces of mastication and polymerization shrinkage stresses\(^8\). The elastic modulus values of Filtek\(^\text{TM}\) Z350, Filtek\(^\text{TM}\) Bulk fill and Multicore\(^\circ\) were reported approximately 14\(^{20}\), 10.1\(^{25}\) and 9\(^{26}\) Gpa, respectively. Flexural strength of dentin ranged from 245 to 280 MPa\(^{25}\), and modulus of elasticity of dentin ranged from 11–20 Gpa\(^{26}\). Therefore, Filtek\(^\text{TM}\) Z350 has strength and modulus value approaches to dentin’s more than other groups.

CONCLUSION

Three chosen core build-up materials have significant differences in compressive strength, flexural strength and Knoop hardness. Filtek\(^\text{TM}\)Z350 has the highest mean compressive strength and Knoop hardness whereas Filtek\(^\text{TM}\)Bulk fill have the highest flexural strength. MultiCore\(^\circ\)Flow and Filtek\(^\text{TM}\)Bulk fill have higher Weibull modulus than Filtek\(^\text{TM}\)Z350. Based on these results, Filtek\(^\text{TM}\) Z350 is the material of choice for core build-up. Another alternative for core material is bulk fill resin composite because it exhibited high strength and reliability. Importantly, it can be cured as a single placement, thereby reducing the patient chair time.

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REFERENCES