



# Flexural Strength and Depth of Cure of Single Shade Dental Composites

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## Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

## Article Information

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## ABSTRACT

**Aims:** This work aims to assess the flexural strength and depth of cure of Optishade, Omnichroma and Z350 dental resin composites.

**Study Design:** Experimental Laboratory Study.

**Methods:** To assess flexural strength as per ISO standards, 15 samples of each of the three materials were made (n=5) with the dimensions 25x2x2 mm. They were then subjected to 3 point bending testing on a universal testing machine. To assess depth of cure as per ISO standard, 15 cylindrical samples 4 mm in diameter and 6 mm in height were created (n=5) and scraping test was performed.

**Results:** There was a significant difference between the 3 materials in both flexural strength and depth of cure. Z350 had the lowest depth of cure and the highest flexural strength.

**Conclusion:** Within the limitations of this study, all three tested materials fell within the ISO requirements for dental resin composites for both flexural strength and depth of cure.

**Keywords:** Optishade; Omnichroma; Flexural strength; depth of cure; single shade composites; group shade composites

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## 1. INTRODUCTION

Dental resin composites are currently considered the material of choice for many dental practitioners [1,2]. Good esthetics and constantly improving physical properties play a large part in the increase of their usage [3]. In the quest for a perfectly camouflaged restoration, several composite systems have a large variety of shades available to help match multiple teeth. These shades are often layered in an attempt to get the best match to the adjacent tooth structure.. Unfortunately, even with the existence of a plethora of shades in several composite systems, the creation of an imperceptible restoration is not always achieved in clinical situations. This is due to several material and operator-related factors [4]. In an effort to simplify the process of shade selection and improve the final esthetic results, manufacturers have recently introduced “single” and “group shade” dental composites. These materials are meant to camouflage into the tooth structure once they have been placed [5]. Simply defined, “single shade” dental resin composites are those that use only one shade for all restorations.. Similarly, “group shade” dental resin composites have a narrower group of shades to replace the wide array frequently found in esthetic restorative materials. These materials have been shown to camouflage very well into the surrounding tooth structure [6,7].

While esthetic properties are undeniably important in anterior restorations, all direct restorative materials are subjected to a significant mechanical challenge during function. A composite restoration needs to be strong enough to withstand the mastication process. Flexural tests are often used to measure composite strength [8]. The International Organization for Standards (ISO) states that the flexural strength should be determined using a 3-point bending test for polymer-based restorative materials [9]. This will give clinicians an indication of the material's ability to withstand deformation and fracture [8,10]. Another important material property is the depth of cure. A well-cured restoration will have the optimal properties possible for that material. It follows that under-curing a restoration will result in suboptimal properties. Under-cured restorations may result in secondary caries, less wear resistance and restorative failure [11,12]. Furthermore, chemicals are more likely to be leached into the oral cavity by under-polymerized resin dental composites [13]. The ISO has a

standardized testing regimen for depth of cure measurement [9]. Measuring depth of cure, as per the ISO standard, aims to ensure the clinician knows the maximum increment size which will be adequately polymerized during restoration placement.

There are several papers in the current literature assessing the esthetic qualities of single and group shade dental resin composite materials [14-20]. However, the literature discussing the physical and mechanical properties of these materials is limited at this time [15,21]. This work aims to assess the flexural strength and depth of cure of a single shade and group shade dental resin composite compared to a conventional one. The tested null hypotheses are:

1. There is no difference between the flexural strength of the three materials tested
2. There is no difference between the depth of cure of the three materials tested

## 2. MATERIALS AND METHODS

The details of the materials used in this study are listed in Table 1.

### 2.1 Flexural Strength Testing

Specimens of Filtek Z350 [lot NA06044, shade A2, 3M/ESPE, St Paul MN, USA], Omnichroma [lot 134S3, Tokuyama, Japan] and Optishade [Lot 7946593, Light Shade, Kerr, CA, USA] were prepared, with 5 specimens per group. A stainless steel split mold with the dimensions 25mm x 2 mm x 2mm [New Age Research, USA] was used to prepare the samples according to ISO 4049/2019 specifications [9]. For the setup, a glass slide and Mylar strip were placed under the mold. The material to be tested was then placed into the mold as a single increment. Next, a Mylar strip was placed over the test material and pressed with a glass slide, effectively sandwiching the mold between the glass slides/Mylar strips. This removed excess material prior to light curing. Each specimen was light cured on both the bottom and top surfaces using five overlapping exposures of 20 seconds each, by a LED light curing unit (LCU) (3M ESPE Elipar, St Paul, MN, USA). The irradiation was measured with a hand held radiometer (Bluephase Meter II, Ivoclar, Amherst, NY, USA) at 1000 mW/cm<sup>2</sup> immediately before specimen preparation. 320 grit abrasive paper was used to finish the

specimens. Samples were then stored in for 24 hours in distilled water at 37°C.

Flexural Testing was done on a universal testing machine 5944 (Instron, Norwood, MA, USA) with a crosshead speed of 0.5 mm/min. As per the ISO standard [9], the formula used to calculate flexural strength is:

$$\sigma = \frac{3Fl}{2bh^2}$$

Where

“F = maximum load exerted on the specimen in Newtons (N)

l = distance between the supports (in mm)

b = width at the center of the specimen (in mm), measured immediately before testing

h = height at the center of the specimen (in mm), measured immediately before testing”

## 2.2 Depth of Cure

Specimens of Filtek Z350, Omnichroma and Optishade were prepared, with 5 specimens per group. These specimens were made by using a stainless steel cylindrical split mold [New Age Research, USA]. The internal dimensions of the mold were 6 mm in length and 4 mm in diameter.

For specimen preparation, the mold was positioned on a glass slide with a transparent Mylar strip on it. The mold was then filled with the desired dental resin composite material and covered with another Mylar strip and then a glass

slide. The mold and strips were pressed between the slides in order to displace excess material. The mold was then placed on filter paper, the upper glass slide removed and the material light cured as per manufacturers’ recommendations. The LCU irradiation was measured with a hand held radiometer at 1000 mW/cm<sup>2</sup> immediately before specimen preparation. The specimen was removed from the mold directly after curing was completed. A plastic spatula was used to remove any uncured material. A digital micrometer [Mitutoyo Co, Kawasaki, Japan] was used to measure cured cylinder height. The measured value was divided by two to obtain the depth of cure.

The results were analyzed using one-way analysis of variance (ANOVA) followed by pairwise comparison using Bonferroni method. Tests were conducted to test the effect of the material on the flexural strength and depth of cure. Statistical software SPSS Ver. 17 [IBM, Armonk, NY, USA] was used at 0.05 significance level.

## 3. RESULTS

### 3.1 Flexural Strength

There was a statistically significant difference between the 3 materials tested (p= 0.00132). The mean flexural strength of all the materials (in MPas) along with their standard deviations is shown in Fig. 1

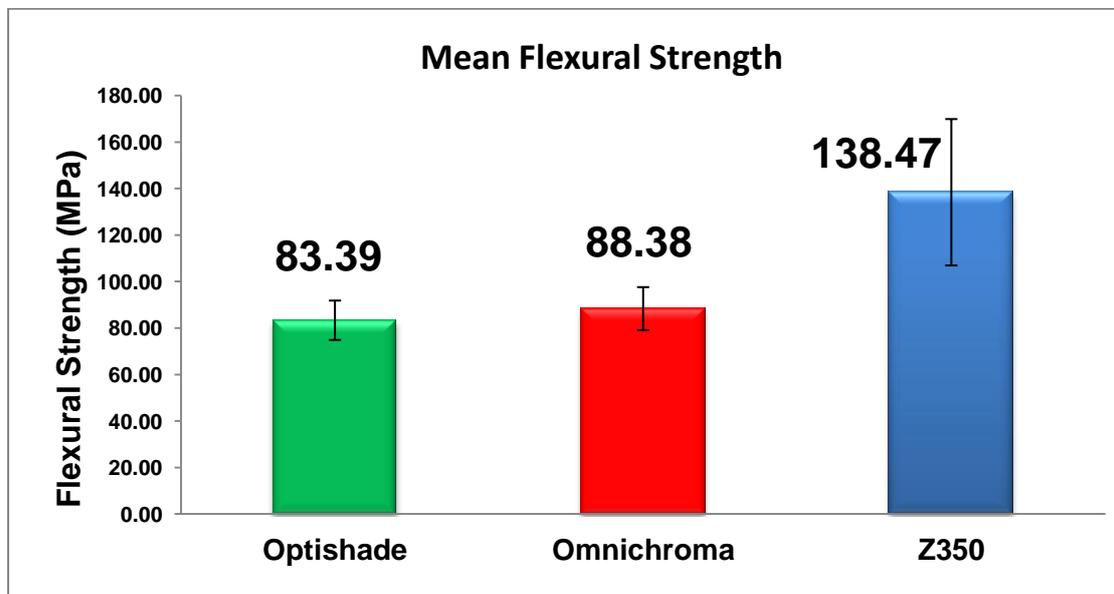


Fig. 1. Mean flexural strength

**Table 1. The components of the materials used in this study, as described by manufacturers**

<b>Material</b>	<b>Lot, shade &amp; manufacturer</b>	<b>Organic Matrix Composition</b>	<b>Inorganic Filler Composition</b>
Omnichroma	Lot 134S3 Tokuyama Dental)	<ul style="list-style-type: none"> <li>• UDMA</li> <li>• TEGDMA</li> </ul>	<ul style="list-style-type: none"> <li>• Filler loading 79 % by wt (68% by vol)</li> <li>• Uniform sized supra-nano spherical filler (260 nm spherical SiO<sup>2</sup>-ZrO<sup>2</sup>)</li> <li>• Composite filler (include 260 nm spherical SiO<sup>2</sup>-ZrO<sup>2</sup>)</li> </ul>
Optishade	Lot 7946593 Light Shade Kerr, CA, USA )	<ul style="list-style-type: none"> <li>• BisGMA</li> <li>• BisDMA</li> <li>• TEGDMA</li> </ul>	<ul style="list-style-type: none"> <li>• Filler loading 81% by wt (64 % by vol) of spherical silica and zirconia particles formed from a molecular suspension (effective particle size 5 – 400 nanometers) and 400 nm barium glass particles</li> <li>• Adaptive Response Technology (ART) with zirconia/silica nanoparticles and rheological modifiers</li> </ul>
Z350	lot NA06044 shade A2 3M/ESPE, St Paul MN, USA	<ul style="list-style-type: none"> <li>• BisGMA</li> <li>• UDMA</li> <li>• TEGDMA</li> <li>• PEGDMA</li> <li>• bis-EMA(6) resins.</li> </ul>	<ul style="list-style-type: none"> <li>• Filler loading 78.5% by weight (63.3% by volume) of non-agglomerated/non-aggregated silica fillers (20 nm), non-agglomerated/non-aggregated zirconia fillers (4 – 11 nm) and aggregated zirconia/silica cluster fillers (20 nm silica and 4 – 11 nm zirconia). The average cluster particle size is 0.6 - 10 microns.</li> </ul>

Bonferroni pairwise comparison revealed the difference was between Optishade and Z350 ( $p=0.00238$ ) as well as Omnichroma and Z350 ( $p=0.00487$ ). There was no statistically significant difference between Omnichroma and Optishade ( $p=1$ ).

### 3.2 Depth of Cure

One way ANOVA revealed a statistically significant difference between all three materials ( $p=0.00011$ ). The mean depths of cure, along with their SD are shown in Fig. 2.

Bonferroni pairwise comparison revealed the difference was between Optishade and Z350 ( $p=0.00018$ ) as well as Omnichroma and Z350 ( $p=0.00069$ ). There was no statistically significant difference between Omnichroma and Optishade ( $p=1$ ).

## 4. DISCUSSION

Dental restorative materials are subjected to a multitude of stress types, which must be considered when evaluating a dental filling material. Some examples of these stresses are compressive, tensile and shear. These simple stresses form the foundation of other, more complex, patterns such as flexural stress [22]. Flexural strength has been correlated to clinical wear of composites [23,24]. Currently, the ISO

standard uses a 3-point flexural testing for resin-based filling materials [9]. As both Optishade and Omnichroma are relatively new to the dental marketplace, the current standard ISO testing procedures were used to measure their flexural strength and depth of cure. The results were then compared to Z350, which is a conventional composite and has been in the marketplace for longer.

At present, the majority of the published work on single and group shade dental resin composites focus mainly on their esthetic properties [6,7,16-18,20,25,26]. There is very limited published work available in the literature regarding any other physical or mechanical properties of these materials [15,21]. This work aims to begin filling that gap.

The null hypotheses were both rejected in this work. The alternate hypotheses were accepted as there was a significant difference between the materials tested in both flexural strength and depth of cure results.

Regarding the flexural strength of the materials tested, all 3 materials were above the ISO's standard of 80 MPa. Z350 exhibited a significantly higher flexural strength than either Optishade or Omnichroma. While all three materials are highly filled, Z350 has the lowest filler loading of any of the materials tested in

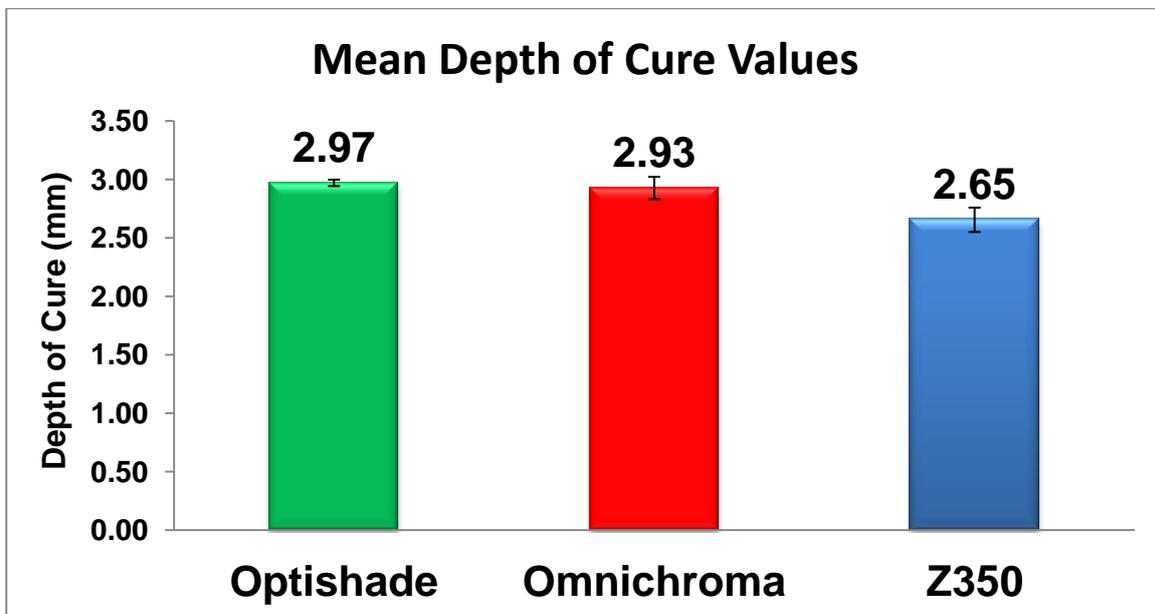


Fig. 2. Mean depth of cure values (mm)

this work at 78.5% by weight. Omnichroma has 79% by weight and Optishade has 81% by weight. It has been found that while strength increases with an increase in filler loading, strength declines at very high filler levels [22]. Another possible reason for the increase in Z350's flexural strength may be the presence of the aggregated zircona/silica cluster fillers. Nanoclusters have been found to significantly increase the strength of nanohybrid dental resin composites [27]. The cause is believed to be that the nanoclusters absorb and dissipate crack propagation [28]. The polymer matrix composition of Z350 differs to that of the other two materials in this work. While Omnichroma has a BisGMA free matrix, both Optishade and Z350 have BisGMA and TEGDMA in their matrixes. Both Z350 and Omnichroma have UDMA. Z350 is the only material tested which has Bis-EMA in its polymer matrix. Although Bis-EMA's structure is similar to Bis-GMA, Bis-EMA has a lower viscosity and is more flexible, which could result in higher overall conversion [29]. Studies have found that polymers with Bis-EMA had a high flexural strength [30]. The result of this work was not in agreement with that of Takuma *et al*, who found that Omnichroma had a flexural strength of similar value or greater than the other dental resin composites tested [21]. However, none of the comparative materials they tested had nanoclusters. The comparators were esthetic, group shade or giomer resin composite materials. Thus, the results of that work are expected to be different from the ones in this study. Schweppe *et al*. reported flexural strength results of 86.4 MPa for Omnichroma, which is similar to what was found in this work [15].

Adequate curing is a requirement for dental resin composite restorations to achieve their optimal properties, while a multitude of restorative failures have been reported due to under-curing [12]. Dental resin composite restorations which are inadequately cured have less than optimal physical and mechanical properties [31,32]. Several factors affect the polymerization of dental resin composites, among which are the wavelength of the dental curing light [33]. The light cure used in this work was the same for all materials prepared. The light cure unit's irradiance was measured prior to sample preparation and found to be 1000 mW/cm<sup>2</sup> at each reading. This effectively eliminated the effect of variations within the LCUs such as type of light cure unit, wavelength emitted, etc. The factors which remain are all material related. They include material shade, filler type and volume [34].

Darker material shade and larger filler size have both been shown to decrease light penetration into the dental resin composite, while smaller particles and lighter shades allowed more light penetration from the LCU [35]. The depth of cure was positively correlated with the light penetration through the dental resin composite [36].

Both Optishade and Omnichroma had significantly higher depths of cure when compared with Z350. This may be due, in part, to the higher translucency of both these materials in comparison to shade A2 Z350. Both Optishade and Omnichroma are marketed as translucent materials which are capable of reflecting the shade of the surrounding tooth structure. The depth of cure of Z350 was in agreement with other published work [32,37,38]. While all three materials tested may be classed as nanocomposites due to the size of their fillers, both Optishade and Omnichroma have smaller particles than Z350. As mentioned earlier, Z350 also has nanoclusters which increase the filler size. Thus, it follows that Z350 had the lowest depths of cure measured. Despite the differences found, each of the materials cured above the 2 mm depth recommended by their manufacturers. This meant that each of the materials had a depth of cure which was more than 1.5 mm and thus they all conformed to the current ISO requirement [9]. Ensuring that 2 mm increments are used while placing the esthetic restorations will allow each material to polymerize satisfactorily, all else being equal. This knowledge will help guide dental clinicians during incremental placement of dental resin composites, ensuring adequate polymerization of each increment and increasing the chances of the final restoration's success and longevity.

## 5. CONCLUSION

In conclusion, within the limitations of this study, both Optishade and Omnichroma showed a higher depth of cure and a lower flexural strength than Z350. All the materials tested conformed to the ISO requirements for both flexural strength and depth of cure.

## CONSENT

It is not applicable.

## ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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