Comparison of Flexural Strength of Several Composite Resins available in Iran

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Abstract

Objective: Despite great advances made in dental composite resins, their use is associated with some concerns regarding their mechanical properties such as their flexural strength. Considering the introduction of different composite resins into the market, there is a need to compare their mechanical properties and particularly flexural strength. This study aimed to compare the flexural strength of 12 types of composite resins.

Methods: In this in-vitro experimental study, 120 specimens were fabricated of 12 different composite resins using a mold according to ISO 4049 standard. Samples were then subjected to 3-point flexural test in Surface Mount Technology (SMT) device with a crosshead speed of 0.75±0.25 mm/min. Obtained data were analyzed using one-way ANOVA and Scheffe’s test. P<0.05 was considered statistically significant.

Results: Flexural strength of understudy composite specimens was significantly different (P<0.0001). Pair-wise comparison of groups revealed significant differences between the following composite resins: Artemis and Swiss TEC (P<0.004), Venus and Swiss TEC (P<0.02), Charisma and Swiss TEC (P<0.0001), Charisma and Spectrum (P<0.03), Artemis and Z250 (P<0.0001), Synergy and Z250 (P<0.007), Point 4 and Z250 (P<0.02), CermaX and Z250 (P<0.02), Venus and Z250 (P<0.001), Charisma and Z250 (P<0.0001) and Charisma and Tetric Ceram (P<0.03).

Conclusion: All under study composite resins had the minimum required flexural strength according to ISO 4049 standard. Their flexural strength ranged from 134.0 MPa for Charisma to 263.0 MPa for Z250. Use of Tetric Ceram, Spectrum, Swiss TEC and Z250 is recommended for restorations in high stress-bearing areas due to their high flexural strength.

Key words: Flexural strength, Composite resin, Mechanical properties

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Introduction:

Dental composite resins are among the most commonly used restorative materials for esthetic purposes. They bond to tooth structure including enamel and dentin via the bonding agents and reinforce the remaining tooth structure. However, similar to other dental materials, composite resins have some drawbacks such as polymerization shrinkage and low fracture and wear-resistance (1, 2). Such disadvantages can cause complications especially in posterior composite resin restorations. Attempts have been made to enhance the mechanical and physical properties of composite resins and several techniques have been proposed for this purpose such as increasing the filler amount, changing the polymerization mechanism and type of filler, improving the type of polymer matrix, achieving a better bond between the filler and matrix and changing the orientation/distribution of fillers (3). Despite the advancements in this respect, toughness, strength and stability of composite resins in high stress-bearing areas require further investigations (4-6). Flexural strength indicates the stability and
survival of a restorative material. Composite restorations are subjected to high flexural stresses in the anterior and posterior regions during clinical service (7). Flexural properties highly depend on the intended clinical application of restorative materials. For instance, in Class V restorations composite resins require low flexural strength because they have to bend when the tooth is in function (8). But teeth that are subjected to high amounts of stress due to masticatory forces (Class I and Class II restorations) require higher flexural strength. In case of inadequate flexural strength, the restoration undergoes deformation due to masticatory stress leading to the loss of marginal seal between the composite resin and tooth structure (9).

Different types of composite resins manufactured by different companies are now used in Iran. Flexural strength plays a major role in their mechanical and clinical success. The present in-vitro study aimed to evaluate the flexural strength of 12 composite resin types available in Iran.

**Methods:**

In this in-vitro experimental study, 12 composite resin types available in Iran were evaluated. Characteristics of understudy composites are demonstrated in Table 1.

<table>
<thead>
<tr>
<th>Raw</th>
<th>Name/ Composite type</th>
<th>Resin</th>
<th>Batch no.</th>
<th>Filler</th>
<th>Factory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Artemis/ Hybridfine particle</td>
<td>BisGAMA, TEGDMA, UDMA</td>
<td>E00247</td>
<td>Barium glass, ytterbium trifluoride Ba-Al-FL-silicate, Silica glass</td>
<td>Ivoclar Vivadent, Schaan, Liechtenstein</td>
</tr>
<tr>
<td>2</td>
<td>InTen-S / Hybrid</td>
<td>BisGAMABisEMA, UDMA</td>
<td>H29977</td>
<td>Barium glass, ytterbium trifluoride</td>
<td>Ivoclar Vivadent, Schaan, Liechtenstein</td>
</tr>
<tr>
<td>3</td>
<td>Synergy/ Hybrid fine particle</td>
<td>BisGAMABisEMA TEGDMA</td>
<td>0206616</td>
<td>Strontium glass Barium glass, Amorphous silica</td>
<td>Coltèn, whale dent AG., Genf, Switzerland</td>
</tr>
<tr>
<td>4</td>
<td>CeramX / nanofill</td>
<td>Polymerized Dimethacrylate</td>
<td>708000501</td>
<td>Ba-Al-Boron-Silicate Amorphous Silicon dioxide</td>
<td>DENTSPLY, DeTrey GmbH, Konstanz, Germany</td>
</tr>
<tr>
<td>5</td>
<td>Quixfil / Hybrid</td>
<td>Polymerized Carboxylic acid dimethacrylate</td>
<td>611000259</td>
<td>Strontium Al-Na-Fl Phosphate silicate</td>
<td>Dentsply, DeTrey GmbH, Konstanz, Germany</td>
</tr>
<tr>
<td>6</td>
<td>Tetricceram/ Micro hybrid Fine particle</td>
<td>BisGMA UDMA TEGDMA</td>
<td>H29498</td>
<td>Ba-Al-Borosilicate Silica</td>
<td>Ivoclar Vivadent, Schaan, Liechtenstein</td>
</tr>
<tr>
<td>7</td>
<td>minifill /Filtek Z250</td>
<td>TEGDMA BisGMA</td>
<td>7AK</td>
<td>Zirconia Silica</td>
<td>3M ESPE, St.Paul, MN, USA</td>
</tr>
<tr>
<td>8</td>
<td>Micro hybrid /Venus</td>
<td>BisGMA</td>
<td>010036</td>
<td>Ba-Al-Boron-Fl silicate</td>
<td>Heraus Kulzer GmbH, Hanau, Germany</td>
</tr>
<tr>
<td>9</td>
<td>Micro hybrid /Charisma</td>
<td>BisGMA TEGDMA</td>
<td>081</td>
<td>Ba-Fl Silicate</td>
<td>Heraus Kulzer GmbH, Hanau, Germany</td>
</tr>
<tr>
<td>10</td>
<td>Fine hybrid /Swiss TEC</td>
<td>BisGMA BisEMA TEGDMA</td>
<td>0234T</td>
<td>Barium glass Amorphous Silica</td>
<td>Coltène, Whaledent AG (Manufacturer) Feldwiesenstrasse Alistätten, Switzerland</td>
</tr>
<tr>
<td>11</td>
<td>Spectrum Hybrid / submicron TPH</td>
<td>BisGMA BisEMA Polymerized Di and trimethacrylate</td>
<td>0406000884</td>
<td>Ba-Al- Boro Silicate Ba-Fl-AI- Silicate</td>
<td>DENTSPLY (UK) Ltd</td>
</tr>
<tr>
<td>12</td>
<td>Micro hybrid /Point4</td>
<td>BisGMA</td>
<td>204B31</td>
<td>Ba-Al Boro Silicate</td>
<td>Kerr Manufacturing, Inc, Orange, CA, USA.</td>
</tr>
</tbody>
</table>

Ten specimens were evaluated in each group and their flexural strength was assessed according to ISO 4049 standard (10). Specimens were fabricated by applying composites to a stainless steel mould measuring 2x2x25 mm. The mould was placed on a clear polyester film (50±30 μm)
and fixed on a metal plate. The moulds were filled with composite resin and a glass slide was placed over them. Adequate pressure was applied to eliminate any possible void and for the excess material to leak out. Specimens were then light cured (Skylight Dmetec, 1200 mW, LED). The mould surface was divided into three equal segments. First the central part and then the lateral parts were cured for 20s each to complete polymerization. Specimens were then immersed in water at 37±1 °C for 15 min. Next, they were separated from the mould and their appendages were removed using a paper disc. Surface of specimens was then ground with 400, 600 and 800 grit abrasive papers for 30s under running water with a circular motion to achieve a smooth surface. Specimens were immersed in distilled water and stored in an incubator at 37±1 °C for 24h. The thickness and diameter of specimens were then measured twice using a digital caliper with 0.1 mm readability. Samples underwent 3-point flexural test in SMT device (Iran) with a loading rate of 50±16 N/min. Applied force at failure for each specimen was measured, recorded and converted to MPa using the equation below:

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

Where F is the applied force, L is the distance of the two supports, b is the width of specimen and h is the thickness of specimen.

Flexural strength values were statistically analyzed using SPSS version 15 software. The mean, SD and 95% CI were calculated. One-way ANOVA and Scheffe’s multiple comparison test were applied to compare flexural strength of composite resins. $p<0.05$ was considered statistically significant.

**Results:**

Diagram 1 shows the mean and SD of flexural strength of specimens.

Comparison of flexural strength of specimens with one-way ANOVA revealed significant differences in this respect among groups ($p<0.0001$). The highest flexural strength in a descending fashion belonged to the following composites:

Z250 > Swiss TEC > Spectrum > Tetric Ceram > Quixfil > InTen-S > CeramX > Point4 > Synergy >...
Venus > Artemis > Charisma

The highest and lowest flexural strengths belonged to Z250 and Charisma, respectively. For pairwise comparison of groups, Scheffé's multiple comparison test was used. The difference in flexural strength between the following groups was statistically significant: Swiss TEC and Artemis ($p<0.004$), Swiss TEC and Venus ($p<0.02$), Swiss TEC and Charisma ($p<0.03$), Charisma and Spectrum ($p<0.03$), Z250 and Artemis ($p<0.001$), Z250 and Synergy ($p<0.007$), Z250 and Point4 ($p<0.02$), Z250 and CermaX ($p<0.02$), Z250 and Venus ($p<0.001$), Z250 and Charisma ($p<0.0001$) and Tetric Ceram and Charisma ($p<0.03$). No other significant differences were noted.

**Discussion:**

Characteristics of the restorative materials can be assessed with different tests. These tests include compressive strength test, axial tensile strength test and flexural strength test. During the recent years, flexural strength testing has become increasingly popular as a suitable method to assess the strength of materials. In flexural strength testing, specimens are subjected to horizontal loads and failure occurs as the result of application of tensile stress (11). Thus, this test can better manifest the current clinical status. Cattani-Lorente et al. in 1993 demonstrated that flexural strength tests had higher sensitivity for evaluation of superficial defects. Furthermore, 3-point flexural test could better signify the differences between materials than the axial tensile strength test (12). Thus, in our study, flexural strength test according to ISO 4049 standard was used which has been used in several studies (13-17).

Composite increments should not be thicker than 2 mm in order to provide adequate polymerization (18). Also, since we light cured specimens from the central and lateral directions, it seems that specimens were adequately polymerized. To eliminate or minimize the role of confounding factors, specimens were matched in terms of dimension, light intensity and duration of exposure. The distance of the two supports for measurement of flexural strength was considered 20 mm similar to previous studies. Based on the obtained results, Z250 composite resin had the highest flexural strength and thus the highest difference with other understudy composites. Swiss TEC ranked second after Z250 followed by Spectrum and Tetric Ceram. High flexural strength in the understudy composites can be attributed to their high filler content and reactions between resin compounds after the light curing process. Fillers used in the understudy composites are shown in Table 1. Venus and Charisma are both microhybrid composites and showed lower flexural strength than other composites but this difference was not significant. Cluster particles in these composites are comprised of fine (0.4-3 μm) and microfine (0.04-0.2 μm) particles. Application of these composites in high stress-bearing areas is associated with high risk of treatment failure. Hybrid composites namely InTen-S and Quixfil had similar flexural strength. Two hybrid fine particle composites namely Artemis and Synergy had similar flexural strength as well. The highest flexural strength belonged to Z250; which is a mini fill composite. The filler size in this composite ranges from 0.01 to 3.5 μm. Composite resins with higher flexural strength (Z250, Swiss TEC, Spectrum and Tetric Ceram) had higher filler volume as well (60%, 58.5%, 57% and 64.6%, respectively). Previous studies have also reported that these composites have higher flexural strength. In a study by Chung et al. (2004), Z100 and Z250 composite resins that had higher filler volume showed higher flexural strength (15). It seems that application of these composites for restorations in high stress-bearing areas such as CL II, CL I and CL IV restorations is associated with greater success.
Some studies have mentioned that filler volume is the main cause of different flexural strengths of composite resins (14, 19). In a study by Yap et al. (2003) Z100 composite resin with 66% filler volume had the highest and Silux with 40% filler volume had the lowest flexural strength (14). In our study, the highest flexural strength belonged to Z250 with 60% filler volume while the lowest flexural strength was observed in Charisma with 64% filler volume. These findings are different from those of previous studies; which may be attributed to the presence of fluoroalumino silicate in Charisma. In a study by Masouras et al. in 2008 it was demonstrated that ideal strength, hardness and flexural modulus are obtained by incorporation of a specific amount of fillers and by further increasing the filler amount composite properties either remain the same or decrease in quality (20). Llie et al. (2009) stated that by increasing the amount of filler up to 60%, flexural strength and MOE increased. However, raising the filler content over 60% increased defects and void formation and thus, did not further enhance favorable properties of resins. Therefore, increasing the filler content does not necessarily improve the flexural strength of composite resins (21). In our study, all understudy composites had filler volumes over 51%. This contradiction indicates that type of filler, resin and composite plays a more important role than the filler volume in justifying the results of flexural strength test.

Three groups of understudy composite resins namely CeramX, Quixfil and Spectrum had polymerized resins in their composition. They did not show significant differences in flexural strength with one another although the flexural strength of Spectrum was slightly higher than that of the other two groups.

In our study, only one nanofill composite resin was evaluated (CeramX) which had a flexural strength equal to that of hybrid composites. This composite showed a significant difference with Z250 with the highest flexural strength (P<0.02). Garoushi et al. (2011) reported that composite resins with nanometer and micrometer scale particulate fillers had lower flexural strength than microfilled composites (22). This may be due to the presence of agglomerated clusters of nanometer scale particulates that propagate crack formation. Other researchers found that percentage of agglomerates in nanofilled reinforced polymers negatively affects the optimal properties of nanofilled composites because under force application fracture initiates at the agglomerated areas (23, 24). SEM images of nanoparticle agglomerates obtained by Rutetrmann et al. in 2008 showed a clearly porous structure that confirmed the theory of fracture with in the agglomerates (23). Addition of nanofillers to composite resins decreases their degree of conversion because nanofillers increase the refractive index and enhance the formation of agglomerates that interfere with light penetration or cause light scattering; consequently, the light intensity decreases (25, 26). Also, the oxygen present in agglomerates inhibits the polymerization of free radicals in the specimen. This phenomenon has been observed in some composite types (27).

InTen-S, despite having the lowest filler volume, ranked 6th among the 12 understudy composite resins in terms of flexural strength (51%). Its high flexural strength may be attributed to the presence of a co-polymer that increases the total filler content. The remaining 6 composites had the lowest flexural strengths (Charisma< Artemis< Venus< Synergy) despite their high filler volume which may be due to the presence of fluoroalumino silicate in their composition. Furthermore, Quixfil ranked 5th in terms of flexural strength despite having the highest filler volume among the 12 understudy composite resins (66.4%) which may be explained by the presence of CDMA oligomer in its composition. To obtain more definite results, further studies
are required to assess the role of each possible variable such as filler type, resin type, filler volume, filler size and etc. in flexural strength of composite resins.

**Conclusion:**

The obtained results demonstrated that all understudy composite resins had the minimum required flexural strength according to ISO 4049 standard (flexural strength over 80 MPa). The mean flexural strength of Charisma was 134.0 MPa while this rate was 263.0 for Z250. Z250, Swiss TEC, Spectrum and Tetric Ceram composites are recommended for use in high stress-bearing areas due to their high flexural strength.

**Conflict of Interest:** “None Declared”

**References:**

15. Chung SM, Yap AU, Chandra SP, Lim CT. Flexural strength of dental composite restoratives: