

# Compressive Strength of Bulk-Fill and Conventional Nano-hybrid Composite Resins: An in Vitro Study

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**Objectives** Evaluation of the properties of recently introduced bulk-fill composite resins from different aspects is important. We aimed to evaluate the compressive strength of two bulk-fill composite resins with different viscosities compared with one conventional composite resin.

**Methods** This in vitro study evaluated two different bulk-fill composite resins and one conventional composite resin. Twelve samples were prepared for each group in a mold, measuring 4 mm in diameter and 6 mm in height. In group 1, x-tra fil bulk-fill composite resin was light-cured with 4-mm thickness for 40 seconds. Then, a 2-mm thick increment of composite resin from the same brand was placed over it and light-cured. In group 2, x-tra base composite resin was light-cured with 4 mm thickness. Then, Grandio conventional composite resin was placed over it with 2-mm thickness and light-cured. In group 3, Grandio conventional composite resin was placed in 2-mm thickness using the incremental technique and light-cured. The samples were stored in distilled water at 37°C for 48 hours, followed by the compressive strength test in a universal testing machine at a crosshead speed of 1 mm/minute. The data were analyzed with SPSS 21 using one-way ANOVA and post hoc Tukey's test. Statistical significance was set at  $P < 0.05$ .

**Results** There were no significant differences in compressive strength values of the three study groups ( $P > 0.05$ ).

**Conclusion** The bulk-fill composite resins evaluated in the present study exhibited compressive strength values similar to that of the conventional composite resin, indicating favorable compressive strength, with decreased working time.

**Keywords** Dental materials; Composite Resins; Natural Flow Composite Resin; X-tra fil composite resin; Grandio; Compressive Strength; Mechanical Tests

## Introduction

Light-cure composite resins have attracted attention for tooth restoration due to their esthetic appearance, optimal strength, and low abrasivity in posterior areas, due to improvements in their characteristics. However, their placement and incremental light-curing procedure are time-consuming. Therefore, bulk-fill composite resins were introduced, and it is claimed that they can be placed in one thick layer up to 4 mm and light-cured. These materials are available in flowable and paste forms<sup>1</sup>, and their mechanical properties vary in a broad spectrum, depending on their filler content.<sup>2</sup> The mechanical properties and degree of conversion of bulk-fill composite resins are the same in the entire thickness of the 4-mm-thick increment.<sup>3, 4</sup> Besides, the advantages of these materials include lower polymerization stresses due to lower polymerization shrinkage<sup>5, 6</sup>, decreased cuspal flexure in standard class II cavities<sup>7</sup>, forming a proper bond irrespective of the cavity shape or filling technique<sup>8</sup>, and improved self-leveling ability for materials with low viscosity.<sup>9</sup> It has been reported that the increase in curing depth of bulk-fill composites is possibly due to their greater translucency<sup>10</sup>, and their low polymerization shrinkage is due to their filler content or organic matrix.<sup>1</sup>

The restorative materials in the oral cavity should be highly resistant to masticatory forces; therefore, it is necessary to restore teeth with restorative materials that can withstand occlusal loads. In this context, the mechanical properties, including the compressive strength, of these materials are of importance. The bulk-fill composite resins' manufacturers

claim that they are the restorative material of choice for posterior teeth subjected to the highest occlusal loads. No studies are available on the compressive strength of bulk-fill composite resins, and there is a lack of consensus on the subject.

Therefore, the present study was undertaken to determine the compressive strength of one high-viscosity bulk-fill composite resin (x-tra fil, Voco, Germany) and one low-viscosity bulk-fill composite resin (x-tra base Voco, Germany) veneered by a conventional composite resin (Grandio, Voco, Germany) and compare them with a conventional composite resin (Grandio, Voco, Germany) with a high filler content for restoration of posterior teeth with the incremental technique. The null hypothesis was that there would be no difference in the compressive strength values of the composite resins evaluated in this study.

## Methods and Materials

The present in vitro study evaluated low-viscosity x-tra base (Voco, Germany) and high-viscosity x-tra fil (Voco, Germany) bulk-fill composite resins and Grandio (Voco, Germany) universal nanohybrid composite resin. Table 1 presents the characteristics of the composite resins used in this study. According to a study by Mozzyzadeh et al,<sup>11</sup> a cylindrical aluminum mold with 6 mm height and 4 mm diameter was used to fabricate composite resin samples in three groups ( $n=12$ , a total of 36 samples). The sample size was calculated to be 12 in each group according to Mozzyzadeh et al,<sup>11</sup> assuming  $\alpha=0.05$  and study power of

0.9.

Group 1: x-tra fil composite resin was applied with 4 mm thickness and light-cured with a LED curing unit (LITEX 695; Dent America, USA) with a minimum light intensity of 650 mW/cm<sup>2</sup> for 40 seconds. Then, a 2-mm-thick increment of the same composite was applied over it and light-cured.

Group 2: x-tra base composite resin was applied with 4 mm thickness and light-cured similar to group 1, and then a 2-mm-thick increment of Grandio composite resin was placed over it and light-cured similar to that in group 1.

Group 3: Conventional composite resin (Grandio) was placed using the incremental technique and light-cured similar to that in group 1 until the mold was filled.

The samples were retrieved from the molds and stored in distilled water at 37°C for 48 hours. Each sample was then placed in a universal testing machine (STM-400; Santam Co., Tehran, Iran). Load was gradually applied vertically at a crosshead speed of 1 mm/minute. The force application continued until the sample broke (breaking point), and the force was recorded at breakage in Newtons (N). The mean compressive strength of the samples was calculated in megapascals (MPa).

**Table 1-** Composite resins used in the present study and their characteristics

Material type	Brand name	Manufacturer	Organic or inorganic matrix	Filler content percentage
Bulk-fill composite resin with high viscosity	X-tra fil	Voco, Germany	Methacrylate matrix Bis-GMA, UDMA, TEG-DMA	86wt%, 70.1vol%
Bulk-fill composite resin with low viscosity	X-tra base	Voco, Germany	Methacrylate matrix Bis-GMA, UDMA, TEG-DMA	75wt%
Conventional composite resin	Grandio	Voco, Germany	Methacrylate matrix Bis-GMA, TEG-DMA	87wt%, 71.4vol%

#### Statistical analysis:

The data were analyzed with SPSS version 21 using one-way ANOVA and post hoc Tukey's test at a significance level of  $P < 0.05$ . The Kolmogorov-Smirnov and Levene's tests were used to assess the normality of data distribution and equality of variances, respectively.

#### Results

Table 2 presents the mean, standard deviation, minimum and

maximum compressive strength values of different groups. The mean compressive strength of Grandio was higher than that of other groups, with x-tra fil and x-tra base composites ranking second and third, respectively, but the groups were not significantly different in this respect ( $P > 0.05$ ). Besides, for more reassurance and since the sample size was small due to the existing limitations, the data were analyzed by the Kruskal-Wallis test as a nonparametric test as well, which showed no significant difference ( $P = 0.104$ ).

**Table 2.** Mean and standard deviation of the study groups

Composite resin groups	Mean (MPa)	Mean (kN)	SD (Mpa)	95% confidence interval for the mean (MPa)		Minimum (MPa)	Maximum (MPa)
				Lower bond	Upper bound		
Group 1	251.53	3.159	36.33	228.45	247.62	176.10	322.53
Group 2	249.48	3.133	32.18	229.02	269.93	193.21	302.47
Group 3	287.27	3.608	47.08	257.35	317.18	212.87	352.13

SD: Standard deviation

#### Discussion

Various composite resins have been introduced based on nanotechnology, aiming to combine the advantages of hybrid and microfilled restorative materials. Nano-composite resins have the esthetic appearance necessary for anterior restorations, with good mechanical properties for posterior restorations to withstand masticatory forces, and are currently used as conventional composite resins.<sup>10</sup> In the present study, Grandio universal nanohybrid composite resin was used as a conventional composite resin. However, placing composite resins in 2-mm conventional increments is time-consuming, with a risk of air bubble entrapment and contamination between the layers.<sup>12</sup> Currently, the interest in

using bulk-fill composite resins and their placement in bulk for direct restoration of posterior teeth has increased because they can be placed in 4-mm thick layers, increasing the speed of the clinical procedures compared with placing 2-mm increments of conventional composite resins, in addition to other advantages, including an increase in the curing depth and a decrease in polymerization shrinkage.<sup>13, 14</sup> Bulk-fill composite resins are available with high and low viscosities, and it has been reported that those with low viscosity have inferior mechanical properties and higher polymerization shrinkage than those with high viscosity.<sup>13</sup> Therefore, it is advisable to veneer them with a final layer of conventional composite resin, which has been introduced as the material of choice for veneering of low-viscosity bulk-fill composite

resins.<sup>12, 15</sup> In the present study, the x-tra base bulk-fill composite resin was veneered with Grandio conventional composite resin.

Since the compressive strength is one of the most important physical properties of composite resins and most masticatory forces in the posterior area are compressive, it is crucial to evaluate the restorative materials' efficacy under such conditions.<sup>16</sup> However, controversy exists regarding the mechanical properties of composite resins.<sup>17</sup> Considering all the above, in the present study, the compressive strength of two different types of bulk-fill resins with high viscosity (x-tra fil) and low viscosity (x-tra base) and one universal nano-hybrid conventional composite resin (Grandio) was compared. The null hypothesis of the study was accepted according to the results, and it was shown that there was no significant difference in the compressive strength of bulk-fill and conventional composite resins using the bulk-fill and incremental application techniques. Furthermore, it has been reported that bulk-fill composite resins are not significantly different from the conventional composite resins in marginal adaptation; they are also stronger in terms of mechanical and physical properties and are equally reliable in terms of mechanical properties. Bulk-fill composite resins with regular viscosity have been reported to be the best choice.<sup>15</sup> In a study by Irina et al, each composite resin exhibited a characteristic behavior during the compressive strength test with the universal testing machine. In their study, Filtek Z250 (micro-hybrid), Filtek Z550 (nano-hybrid), and Filtek bulk-fill composite resins were compared for their compressive strength. Filtek bulk-fill composite resin exhibited the highest elastic modulus, indicating that it was the hardest material with minimum deformability. Besides, this composite resin exhibited the poorest mechanical properties except for its flexural strength compared with micro-hybrid and nano-hybrid composite resins; however, there were no significant differences in the final compressive strength of the three composite resins.<sup>18</sup>

Pradeep et al. evaluated the compressive strength of bulk-fill and nano-hybrid composite resins and reported that bulk-fill composite resins had superior compressive strength than nano-hybrid composite resins. Both SDR (Dentsply) and Filtek bulk-fill (3M ESPE) showed higher compressive strength than nano-hybrid composite resin. They also reported no statistically significant difference in compressive strength between SDR and Filtek bulk-fill.<sup>19</sup> The results of the present study are consistent with the studies above.

Strength is not an inherent property of materials. The mechanical strength of composite resins is affected by several factors, including the nature of the organic matrix, the material's state, the status of reinforcing elements, filler size and content, and the technique used to evaluate strength.<sup>18, 20</sup> The main factor for the success of bulk-fill composite resins in deep restorations is to increase their curing depth because inadequate polymerization of composite resins compromises their mechanical properties.<sup>21</sup> Adding photo-initiators such as Ivocerin in addition to camphorquinone to the materials increases the curing depth

consistently in bulk-fill composite resins with 4-5-mm depth leading to higher mechanical properties in the whole thickness (4-5 mm) of the restoration. Ivocerin initiator is considered to be more effective than camphorquinone alone.<sup>21</sup> Both filler morphology and filler loading influence the mechanical properties. Compared with conventional composite resins, bulk-fill composite resins have higher translucency which causes an increase in the depth of cure. The round shape of the fillers positively increases the translucency.<sup>22</sup> Another approach to improve the materials' translucency is to reduce the amount of fillers since translucency and the amount of filler particles correlate linearly.<sup>2</sup> The translucency of bulk fill composite resins is also influenced by the difference in the refractive indices between the filler particles and the resin matrix. Similar refractive indices of the components of a composite resin were shown to improve translucency.<sup>23</sup> A larger filler size improves translucency.<sup>1, 2</sup> The dimension of fillers was increased in many bulk-fill composite resins. The 20- $\mu$ m or larger size decreases the total filler surface and, consequently, the filler-matrix interface. Thus, small matrix-filler interface in bulk-fill composite resins decreases light-scattering, increasing the blue light's penetration depth.<sup>24</sup> Therefore, bulk-fill resin-based composites are adequately cured, and the mechanical properties within the incremental thickness are constant.

In some bulk-fill composite resins, such as SDR, using a stress-decreasing resin technology described as "polymerization modulator" in the backbone of the resin synergistically interacts with the camphorquinone photo-initiator and results in slower increase in elasticity modulus, allowing for stress reduction without a decrease in the rate of polymerization or degree of conversion compared with conventional nano-composite resins. Because of this technology, it has higher compressive strength than nanohybrid composites (Filtek Z 250XT). Bulk-fill composite resins use three types of fillers in their structure: I) conventional barium glass fillers, II) isofillers such as cured dimethacrylates + glass filler + ytterbium fluoride, and (III) spherical mixed oxides, each playing a special role in the composite resin. Isofillers increase physical properties by reducing polymerization stress, and spherical oxides improve mechanical properties.<sup>2</sup> Studies have shown that the amount and composition of fillers have a direct role in increasing the mechanical properties of composite resins.<sup>11, 16</sup> Braganca et al.<sup>25</sup> evaluated the mechanical properties of Tetric Evoceram bulk-fill (Ivoclar Vivadent, Schaan, Liechtenstein), Venus bulk-fill (Heraeus-luzer, Hanau, Germany), Filtek bulk-fill (3M ESPE, Saint Paul, MN, USA), and SDR flowable bulk-fill (Dentsply, Konstanz, Germany) composite resins and reported that SDR composite resin had the least compressive and tensile strength values, with inferior mechanical properties compared with other bulk-fill composite resins. In contrast, Filtek bulk-fill composite resin exhibited the highest compressive strength. The researchers attributed the low strength of SDR composite resin to its low filler content to decrease its viscosity.

Similarly, several studies<sup>13, 26, 27</sup> have reported a positive correlation between the filler content and increased flexural and compressive strength values. In a study by Didem et al, all the bulk-fill composite resins that were evaluated exhibited the required mechanical properties for application in the occlusal surface.<sup>26</sup> Therefore, it can be concluded from the results of previous studies that an increase in filler size and content increases the composite resins' compressive strength. The favorable compressive strength of bulk-fill composite resins evaluated in the present study might be attributed to the resin matrix used in their structure because it affects the mechanical properties. Replacing Bis-GMA and TEG-DMA with UDMA, which has a better curing depth and limits sliding of polymer segments on each other, improves the mechanical properties, including the tensile, flexural, and compressive strength values.<sup>11, 16</sup> The results achieved with these composite resins can be justified by the similarity of their monomers and almost similar filler percentages in their structure.

It is suggested that other properties of restorative materials, including microleakage, be evaluated in human teeth, in addition to cuspal flexure and tensile strength in future studies under the conditions of the present study. Evaluation of compressive strength in individuals with parafunctional habits, including bruxism and cleaning, can provide valuable information as well.

## Conclusion

The x-tra fil and x-tra base bulk-fill composite resins exhibited properties similar to Grandio conventional composite resin in terms of compressive strength under the present study's in vitro conditions.

## Conflict of Interest

No Conflict of Interest Declared ■

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