# Comparative Study Regarding the Compressive Strength of Different Composite Resins Used for Direct Restorations

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*The aim of this study was to evaluate and to compare the compression behavior under identical mechanical tests, of three different composite resins, by determining Young's modulus for compression, ultimate compressive strength and ultimate compressive strain. The studied materials were: Filtek Z250 Universal Restorative, Filtek Z550 and Filtek Bulk Fill Posterior Restorative (3M ESPE, St. Paul, MN, USA). Fifteen cylindrical samples, having 6 mm in height and 5 mm in diameter, were made from each material, using plastic molds. The samples were subjected to quantitative analysis of the compression behavior after mechanical tests. The fractured fragments of the samples were subjected to qualitative surface evaluation by scanning electron microscopy. Results were statistically analyzed using one-way analysis of variance (ANOVA) with Tukey's post hoc test. Filtek Z250 had the lowest value of Young's modulus for compression and the results were statistically significant (p<0.05) when compared to Filtek Bulk Fill Posterior Restorative and Filtek Z550. There were no statistically significant differences between all three materials regarding ultimate compressive strength (p>0.05). The lowest value for ultimate compressive strain was recorded for Filtek Bulk Fill.*

*Keywords: composite resins, Young's modulus, compressive strength, compressive strain, SEM*

Mechanical properties of composite resins play a central role in the longevity of the restoration. Since most of the masticatory forces are in fact compressive forces, the assessment of materials behavior under related conditions is of great importance [1]. In recent years, the considerable progress in the field of nanotechnology has led to the emergence of nano-composites. These materials have superior mechanical and optical properties that recommend them for direct restorations both of the anterior and the posterior teeth. However, micro-hybrid composites, through their optimal mechanical behavior, remain a reliable option for direct restorations in the posterior area. The new class of bulk fill composites poses a great challenge to existing composites on the market by simplifying clinical steps and increasing working time efficiency, and by comparable mechanical properties to conventional composite materials [2, 3].

A major problem is the fact that none of the available dental composite resins are able to meet both esthetic requirements for anterior teeth and functional needs of posterior ones. Thus, manufactures are trying to increase the filler content and decrease the size of particles to improve the physical properties [4, 5].

The aim of this study was to evaluate and to compare the compression behaviour under identical mechanical tests, of three different composite resins, by determining Young's modulus for compression, ultimate compressive strength and ultimate compressive strain.

## Experimental part

The studied materials were: Filtek Z250 Universal Restorative, Filtek Z550 and Filtek Bulk Fill Posterior Restorative, all manufactured by 3M ESPE, St. Paul, MN, USA.

Filtek Z250 Universal Restorative (3M ESPE) is a micro-hybrid composite, frequently used for restoration in the frontal area, as well as in the posterior ones. Its organic matrix is made from a mixture of Bis-GMA, TEGDMA, UDMA and Bis-EMA. The inorganic component of the of Filtek Z250 consists in zirconia and silica particles with a dimension ranging from 0.01 μm and 3.5 μm and an average filler particles size of 0.6μm. The inorganic filler loading is 84.5% by weight and 60% by volume.

Filtek Z550 Universal Restorative (3M ESPE) is a universal nano-hybrid composite resin, with high viscosity. It is recommended for direct restoration both in frontal and posterior area. The organic matrix is based on the resin system, represented by BIS-GMA, UDMA, BIS-EMA, PEGDMA and TEGDMA. The inorganic component is a combination of non-agglomerated/ non-aggregated particles of silica oxide with dimensions of 20 nm and modified zirconium and silicon oxides and clustered aggregates of zirconium/silicon oxides with dimensions of approximately 3μm. The loading with inorganic filler is of about 82% by weight respectively 68 % by volume.

Filtek Bulk Fill Posterior Restorative (3M ESPE) is a restorative material indicated for direct anterior and posterior restorations, including occlusal surfaces. It comes to help the practitioners by simplifying the restorative stratified technique up to one increment of 5 mm thickness. The organic matrix of Filtek Bulk Fill Posterior Restorative composite contains two new methacrylic monomers, AUDM and AFM, which have a synergic action towards the reduction of the polymerization shrinkage and stress. The organic component also contains DDDMA (1, 12 - Dodecanediol di-methacrylate) and UDMA (urethane di-methacrylate), a monomer with an increased molecular weight which reduces the viscosity of the resin and the polymerization shrinkage. The fillers are a combination of a 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 (comprised of 20 nm silica and 4 to 11 nm zirconia particles) and a ytterbium trifluoride ($YbF_3$) filler consisting of agglomerate 100 nm particles, with the role of increasing the radio opacity of the material. The inorganic filler loading is about 76.5% by weight, equivalent to 58.4 % by volume.

Details about composite resins type, producer and chemical composition are presented in table 1.

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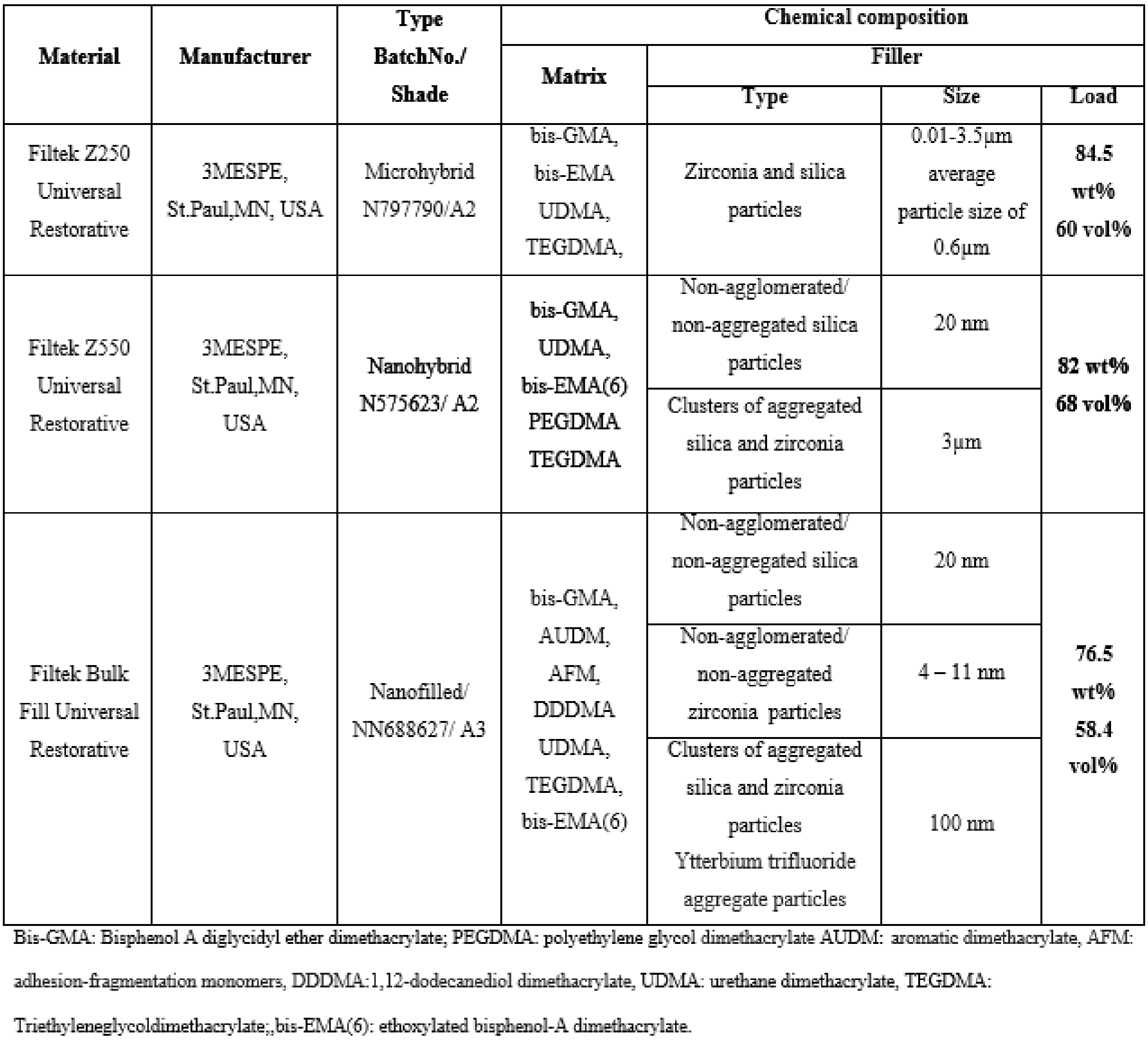
**Table 1**

DETAILS ABOUT TESTED MATERIAL



| Material | Manufacturer | Type BatchNo./ Shade | Chemical composition | | | |
|---|---|---|---|---|---|---|
| | | | Matrix | Filler | | |
| | | | | Type | Size | Load |
| Filtek Z250 Universal Restorative | 3MESPE, St.Paul,MN, USA | Microhybrid N797790/A2 | bis-GMA, bis-EMA UDMA, TEGDMA, | Zirconia and silica particles | 0.01-3.5μm average particle size of 0.6μm | **84.5 wt% 60 vol%** |
| Filtek Z550 Universal Restorative | 3MESPE, St.Paul,MN, USA | **Nanohybrid N575623/ A2** | **bis-GMA, UDMA, bis-EMA(6) PEGDMA TEGDMA** | Non-agglomerated/ non-aggregated silica particles | 20 nm | **82 wt% 68 vol%** |
| | | | | Clusters of aggregated silica and zirconia particles | 3μm | |
| Filtek Bulk Fill Universal Restorative | 3MESPE, St.Paul,MN, USA | Nanofilled/ NN688627/ A3 | bis-GMA, AUDM, AFM, DDDMA UDMA, TEGDMA, bis-EMA(6) | Non-agglomerated/ non-aggregated silica particles | 20 nm | **76.5 wt% 58.4 vol%** |
| | | | | Non-agglomerated/ non-aggregated zirconia particles | 4 – 11 nm | |
| | | | | Clusters of aggregated silica and zirconia particles<br>Ytterbium trifluoride aggregate particles | 100 nm | |

Bis-GMA: Bisphenol A diglycidyl ether dimethacrylate; PEGDMA: polyethylene glycol dimethacrylate AUDM: aromatic dimethacrylate, AFM: adhesion-fragmentation monomers, DDDMA:1,12-dodecanediol dimethacrylate, UDMA: urethane dimethacrylate, TEGDMA: Triethyleneglycoldimethacrylate;,bis-EMA(6): ethoxylated bisphenol-A dimethacrylate.

From each material, 15 cylindrical samples were made using plastic molds, having 6 mm height and 5 mm diameter, according to ISO standards 4049 and ANSI / ADA No. 27. The material was placed in molds by layering technique (for Filtek Z250 and Z550 4 layers of 1.5mm and for Bulk Fill 2 layers of 3mm), each layer being light-cured for 40s. To provide a perfectly flat surface of the first and last layers, the polymerization was proceeded trough a transparent Mylar strip placed on a 2 mm thickness glass plate. To ensure complete polymerization of the material, a light source emitting diode (LED) type Dentmate LedexTM , with a wavelength between 440 nm and 480 nm and a maximum power of 1000 mW/cm$^2$, was used.

For the quantitative analysis of the compression behavior of the three composite materials presented above, the samples were subjected to mechanical tests immediately after they were produced. We used INSTRON 3382 Norwood, MA, USA, servo-hydraulic traction/ compression test equipment, characterized by the following technical parameters: a load capacity of maximum 100 kN, a maximum speed of 500 mm/min, a minimum one of 5x10$^{-3}$ mm/min, a maximum force at maximum speed of 50 kN, a maximum speed at maximum force of 250 mm/min, a recovery speed of 600 mm/min, and Bluehill® Lite software for data recording and computing. The compression load in our experiments was on axial direction, with a constant forward speed of 0.5 mm/min at ambient temperature. In order to define the behavior of the composite materials subjected to mechanical compression tests, the characteristic curve of the material were obtained. Thus, we recorded the applied force curves (N) - absolute deformation (mm) for the 15 samples of each material. These curves give us information about the behavior of the tested material and the possibility of deriving the characteristic parameters of the studied material. Using the initial geometric dimensions of the samples (length and section), the stress ([Pa]) - strain ([%]) curves were obtained. The Young's Modulus for compression, the ultimate compressive strength and the stress–strain parameters were calculated. The Kolmogorov-Smirnov normality test was used to determine the distribution of data in groups. One-way ANOVA and Tukey post hoc statistical tests were used to compare the results in groups.

After performing the mechanical tests, the fractured fragments of the samples were subjected to qualitative surface evaluation using scanning electron microscope VEGA II LSH TESCAN (Czech Republic) to identify the possible causes that lead to micro-cracks and fracture.

## Results and discussions

*Quantitative analysis of materials compression behavior*

In figure 1a the stress–strain curves for 15 samples of Filtek Z250 material are represented. The overall appearance of the curves indicates a brittle fracture without showing an area of plasticity. There is a *jagged* aspect of these dependencies determined by the growing and expanding of some micro-cracks, up to samples break-down. In the stress range of 100-200 (MPa) it was found that there is a linear dependence stress-strain curves, which allowed the determination of the Youngs modulus for compression (*E*). Maximum applied forces up to breakage were determined to be ranging between 3000 N and about 6000 N, which resulted in the ultimate stress between 180 MPa and 360 MPa. One sample (no.11) showed a particular behavior, breaking at very small forces, due to multiple longitudinal micro-cracks which are formed. In our opinion this behavior was given by possible errors during the sample preparation and the data obtained in this case was eliminated. Other three samples (no. 7, 13, and 14) did not show linear region of stress–strain curves and thus was not possible to calculate the Young's modulus. However, in these particular cases, the recorded data allowed estimations of ultimate compressive strengths and strains.

For the Filtek Z550, in figure 1b are plotted the compressive stress-strain curves for 15 samples. For this material, higher ultimate strengths were determined, when compared to Filtek Z250, but the corresponding strains had similar values. One sample (no.5) broke at very small forces, possibly due to some initial micro-holes. For two samples (no.7 and 9) non-linear dependences were recorded, and thus the modulus of elasticity was not possible to be determined. The jagged aspect of the curves was also present for this material, but it was less pronounced.

For Filtek Bulk Fill Posterior Restorative, Fig.1c) shows the compressive stress-strain curves also for 15 samples. The ultimate stress values were lower than those of the above presented materials and the jagged appearance of the curves was rarely observed. The values of the elasticity modulus were higher than that of the previous materials. Note that again one of the samples (no. 6) broke at much lower forces than the others, and the resulted value of the ultimate compressive strength was removed from the subsequent calculations. Samples 9 and 11 showed a stress-strain non-linear character and the value of Young's modulus was not calculated.

The average values and the absolute measurement errors were calculated, in order to compare the parameters determined in the compression test for the three materials (table 2).

The measurement errors were in the 10-15% range, being mostly determined by two factors: structural non-homogeneities (micro-holes) of the samples and the parallelism between the two faces of the cylindrical samples, on which the compression forces were applied.

The results were statistical analyzed using Kolmogorov-Smirnov normality test which showed that all data were normally distributed. In order to compare the results between all three materials, ANOVA and Tukey post hoc statistical tests were used.

Regarding the Young's Modulus, One -Way ANOVA statistical test showed that there are significatnt differences between the materials ($p < 0.05$, table 3). Significant results were obtained when comparing the values for Filtek Z250 to Filltek Z550 and Filtek Bulk Fill ($p < 0.05$). The results for Filtek Bulkfill were not statistically significant when compared to Filtek Z550 ($p > 0.05$, table 4).

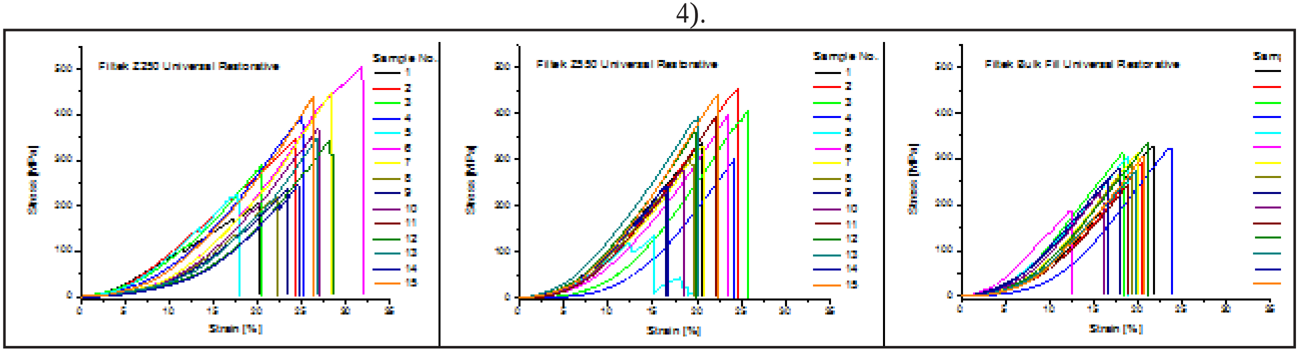


Fig. 1. The stress–strain compressive curves: a. Filtek Z250; b. Filtek Z550; c. Filtek Bulk Fill Posterior

**Table 2**
AVERAGE VALUES OF YOUNG'S MODULUS FOR COMPRESSION, ULTIMATE COMPRESSIVE STRENGTH AND ULTIMATE COMPRESSIVE STRAIN FOR TESTED MATERIALS ± STANDARD DEVIATION

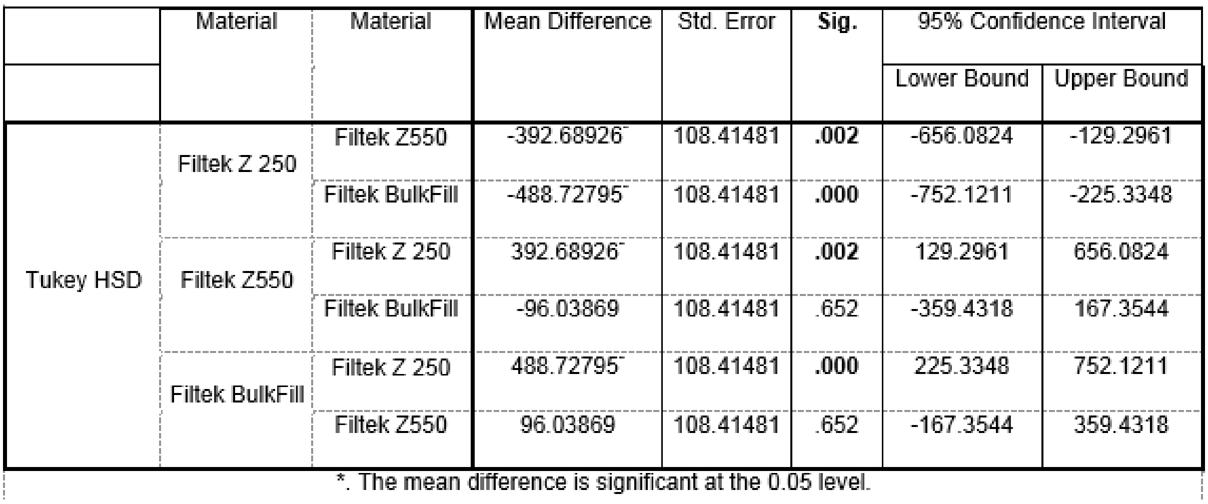
| Material | Young's Modulus for compression, *E* (MPa) | Ultimate compressive strength (MPa) | Ultimate compressive strain (%) |
|---|---|---|---|
| Filtek Z250 | 953.01±87.55 | 254.31±18.46 | 28.21±1.34 |
| Filtek Z550 | 1369.36±113.99 | 267.67±19.48 | 23.37±0.95 |
| Filtek Bulk Fill Posterior | 1460.22±97.20 | 234.17±8.03 | 21.07±0.88 |

**Table 3**
ANOVA STATISTICAL TEST RESULT FOR YOUNG'S MODULUS

ANOVA Young's Modulus for compression

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2011416.455 | 2 | 1005708.227 | 11.409 | .000 |
| Within Groups | 3702438.020 | 42 | 88153.286 | | |
| Total | 5713854.474 | 44 | | | |

**Table 4**
TUKEY POST HOC STATISTICAL TEST RESULT.FOR YOUNG'S MODULUS
Multiple Comparisons
Dependent Variable: Young's Modulus for compression



| | Material | Material | Mean Difference | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Tukey HSD | Filtek Z 250 | Filtek Z550 | -392.68926* | 108.41481 | .002 | -656.0824 | -129.2961 |
| | | Filtek BulkFill | -488.72795* | 108.41481 | .000 | -752.1211 | -225.3348 |
| | Filtek Z550 | Filtek Z 250 | 392.68926* | 108.41481 | .002 | 129.2961 | 656.0824 |
| | | Filtek BulkFill | -96.03869 | 108.41481 | .652 | -359.4318 | 167.3544 |
| | Filtek BulkFill | Filtek Z 250 | 488.72795* | 108.41481 | .000 | 225.3348 | 752.1211 |
| | | Filtek Z550 | 96.03869 | 108.41481 | .652 | -167.3544 | 359.4318 |

*. The mean difference is significant at the 0.05 level.

For compressive strength, One -Way ANOVA statistical test showed that there are no significant differences between the materials ($p>0.05$, table 5). Tukey post hoc statistical test results support this observation that there were no statistically significant differences when compared the materials one to each other ( $p > 0.05$, table 6).

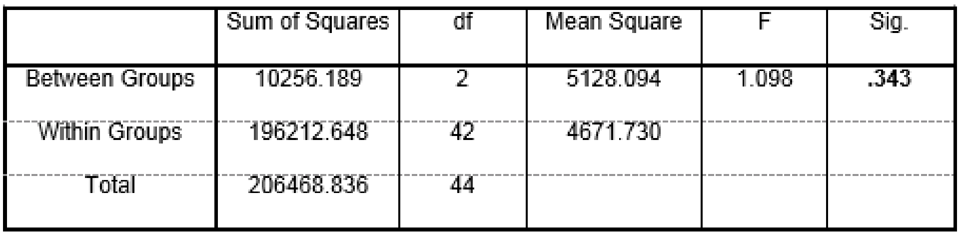
Regarding the compressive strain, One -Way ANOVA statistical test showed that there are significant differences between the materials ($p<0.05$,table 7). Tukey post hoc statistical test shows significant results only when comparing the values for Filtek Z250 to the ones for Filtek Bulk Fill ($p<0.05$, table 8).

It can be noticed that from the three studied materials, Filtek Bulk Fill composite has the highest value of the Young's modulus for compression (1460 MPa, but the lowest value of the ultimate compressive strength (234 MPa) and the corresponding ultimate strain (21.07%). Filtek Z250 had the smallest modulus of elasticity (953 MPa) and the highest ultimate compressive strain (28.21%). For Filtek Z550 was obtained the highest compressive strength of 268 MPa.

*SEM Evaluation of fractured surfaces*

Figure 2 shows fracture area images from a fragment of a Filtek Z250 composite sample at 100X, 200X, 500X, and 1000X magnifications (fig. 2 a-d). A characteristic of this material is the presence of micro-holes caused by the extraction of the micrometric filler particles from the resin

**Table 5**
ANOVA STATISTICAL TEST RESULT FOR COMPRESSIVE STRENGTH
ANOVA Compressive Strength

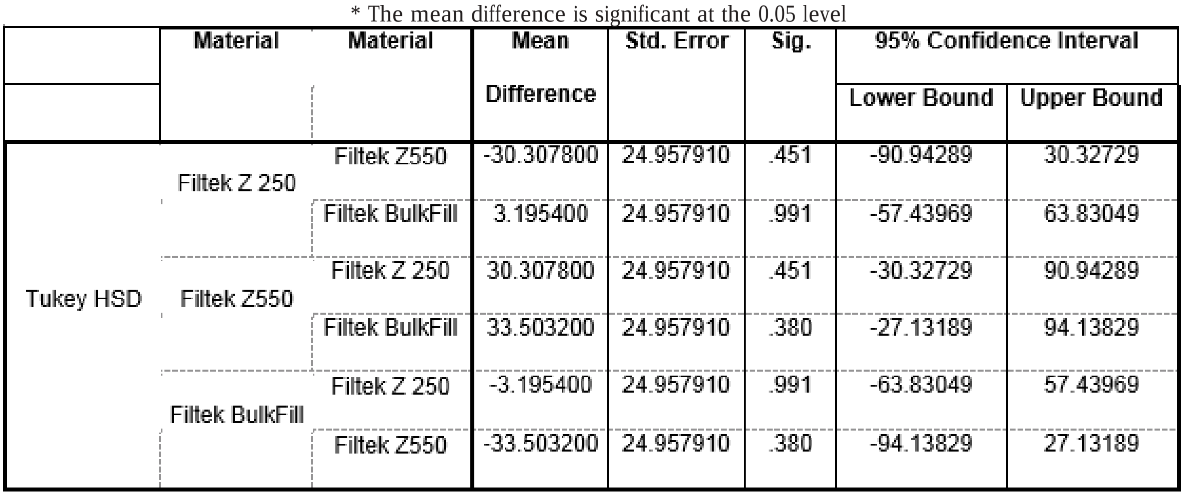


| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 10256.189 | 2 | 5128.094 | 1.098 | .343 |
| Within Groups | 196212.648 | 42 | 4671.730 | | |
| Total | 206468.836 | 44 | | | |

**Table 6**
TUKEY POST HOC STATISTICAL TEST RESULT FOR COMPRESSIVE STRENGTH
Multiple Comparisons

Dependent Variable: Compressive Strength

* The mean difference is significant at the 0.05 level



| | Material | Material | Mean Difference | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Tukey HSD | Filtek Z 250 | Filtek Z550 | -30.307800 | 24.957910 | .451 | -90.94289 | 30.32729 |
| | | Filtek BulkFill | 3.195400 | 24.957910 | .991 | -57.43969 | 63.83049 |
| | Filtek Z550 | Filtek Z 250 | 30.307800 | 24.957910 | .451 | -30.32729 | 90.94289 |
| | | Filtek BulkFill | 33.503200 | 24.957910 | .380 | -27.13189 | 94.13829 |
| | Filtek BulkFill | Filtek Z 250 | -3.195400 | 24.957910 | .991 | -63.83049 | 57.43969 |
| | | Filtek Z550 | -33.503200 | 24.957910 | .380 | -94.13829 | 27.13189 |

**Table 7**
ANOVA STATISTICAL TEST RESULT
FOR COMPRESSIVE STRAIN

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 228.059 | 2 | 114.030 | 4.065 | **.024** |
| Within Groups | 1178.174 | 42 | 28.052 | | |
| Total | 1406.233 | 44 | | | |

**Table 8**
TUKEY POST HOC STATISTICAL TEST RESULT FOR COMPRESSIVE STRAIN
Multiple Comparisons
Dependent Variable: Compressive strain

| | Material | Material | Mean Difference | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Tukey HSD | Filtek Z 250 | Filtek Z550 | 3.18733 | 1.93397 | .237 | -1.5112 | 7.8859 |
| | | Filtek BulkFill | 5.49067* | 1.93397 | **.019** | .7921 | 10.1892 |
| | Filtek Z550 | Filtek Z 250 | -3.18733 | 1.93397 | .237 | -7.8859 | 1.5112 |
| | | Filtek BulkFill | 2.30333 | 1.93397 | .465 | -2.3952 | 7.0019 |
| | Filtek BulkFill | Filtek Z 250 | -5.49067* | 1.93397 | **.019** | -10.1892 | -.7921 |
| | | Filtek Z550 | -2.30333 | 1.93397 | .465 | -7.0019 | 2.3952 |

*. The mean difference is significant at the 0.05 level.

matrix in which they were incorporated (fig. 2 a-b). The previously assumed mechanism of blocking the cracks by the microparticles is highlighted for Filtek Z250 composite in figure 2 c. A micro-crack which is stopped from advancing through the material by relatively large particle of about 40 μm can be seen.

Figure 3 shows images of fractured area of a Filtek Z550 composite sample at 100X, 200X, 500X, and 1000X magnifications (fig.3 a-d). The analysis of these surfaces reveals a fragile fracture of the material, with the propagation of micro-cracks along the rupture planes. It is obvious on micrographs that the direction of material fracture is through overlapping material planes and the major cracks are following the same direction.

Detailed images present the linear propagation of a crack (fig. 3 c), with adjacent areas of not affected material (fig. 3 d).

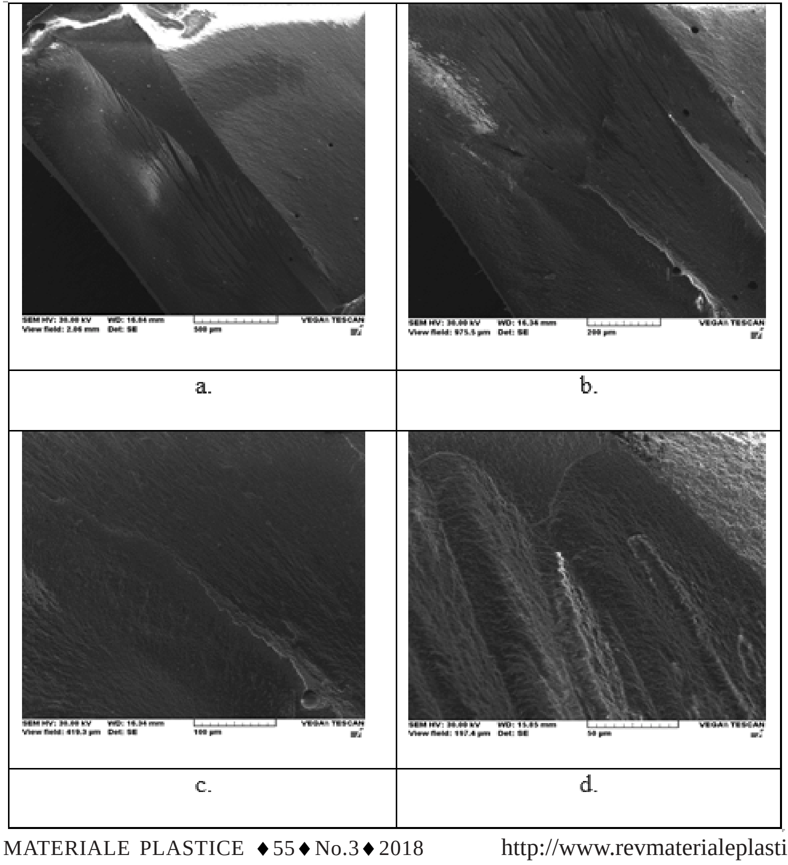

a. b. c. d.

Fig. 2 SEM aspect of fractured area for a Filtek Z250. a. 100X; b. 200X; 500X; 1000X

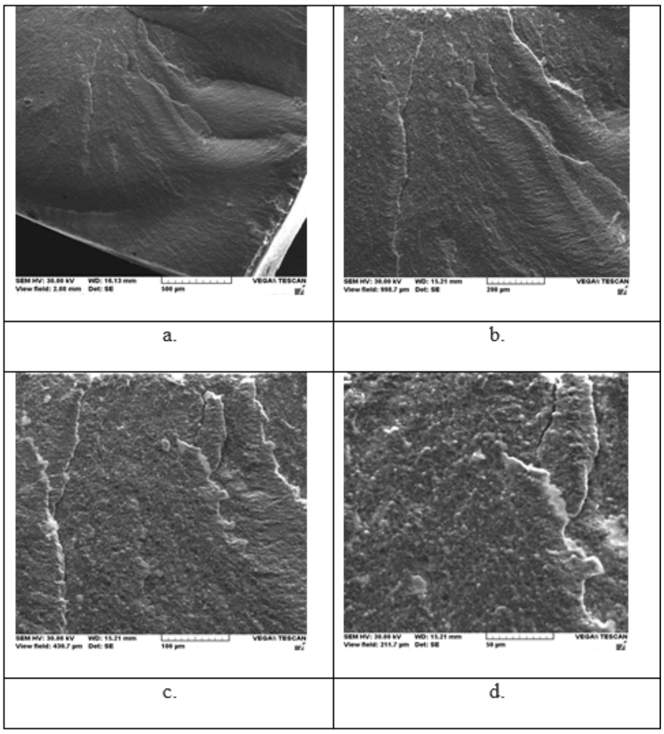

a. b. c. d.

Fig. 3 SEM aspects of fractured area for a sample of Filtek Z550: a. 100X; b. 200X; 500X; 1000X

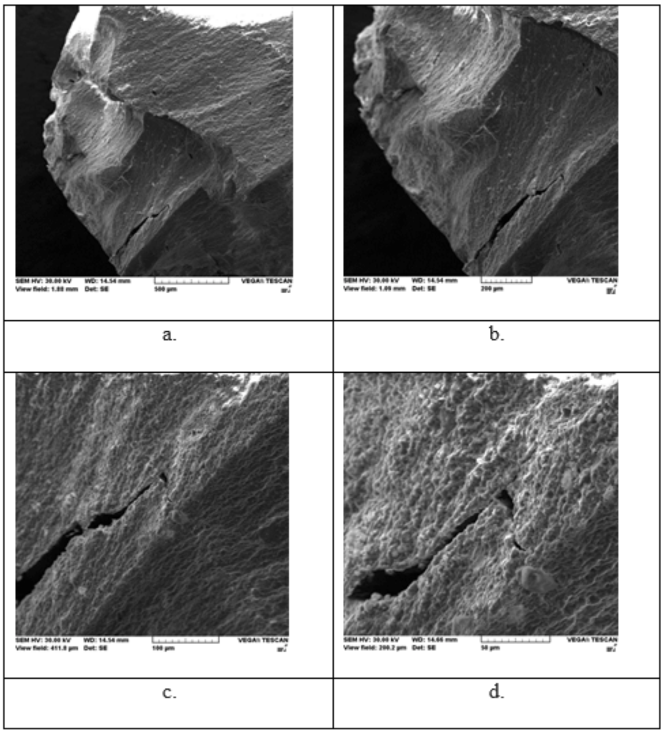

a. b. c. d.

Fig. 4 SEM aspects of fractured area for a sample of Filtek Bulk Fill Posterior: a. 100X; b. 200X; 500X; 1000X

Figure 4 shows fracture area images from a fragment of a Filtek Bulk Fill Posterior composite sample at similar magnifications as previously mentioned. In the case of this material, there are observed large cracks propagated in the material volume (fig. 4 a-b). Compared to the other two materials for Filtek Bulk Fill, the cracks are fewer but wider indicating a typical fracture behavior when broken (fig.4 c-d). Practically, the material suddenly yields to a certain amount of force applied without micro-cracks in overlapping planes.

In the present study the quantitative determinations were made on the universal testing machine until the samples were cracked. Each material had a particular behavior under compression tests. For Filtek Z250 was recorded the lowest value of the Young's modulus,($E$ =953 MPa), indicating a greater deformability of this composite material. This is confirmed by the highest strain value of 28.21%. At the same time, Filtek Z250 had a tensile strength of 254 MPa, comparable to 227±53 MPa determined in other studies [6]. Filtek Z550 composite was highlighted by the fact that it had the highest compressive strength, which may be a consequence of the fact that it has the highest filler load, of approximately 68% vol.

Recent studies have shown that the mechanical strength of composite materials is influenced by a series of factors, such as the nature and state of the organic matrix, the nature and condition of the reinforcement element and the bulk fraction of the reinforcement element [7-10]. Both materials remain a viable option for direct posterior restorations.

For Filtek Bulk Fill Posterior composite, the highest elasticity modulus was determined, ($E$ = 1460 MPa). This material proved to be the most rigid (less deformable). At the same time, this material had the lowest values of compressive strength and strain. The average compressive strength was 234 MPa. The highest force applied to 4.5 KN was supported by sample 1, with a maximum compressive strength limit of 264 MPa. This behavior was also observed by other authors, who have pointed out that Filtek Bulk Fill Posterior has lower mechanical properties compared to nanohybrid and micro hybrid composites, with the exception of flexural strength [11-13]. It should be noted that Filtek Bulk Fill has the lowest inorganic phase loading, of about 58.4%, compared to the other two materials analyzed in the present paper.

The appearance of the specific curves for the three studied materials reveals the typical behavior of fragile materials that have a nearly null plastic deformation before breaking. These results are in agreement with other studies that have shown, following the evaluation of various composite materials, including the Filtek Z250, that in compression tests all composites suffered a fracture when the stress applied equaled the material's elastic limit [14-16].

However, small differences in the appearance of the curves characteristic of each material can be observed. Thus, for some samples of Filtek Z250, it is possible to detect the areas corresponding to a slight plastic deformation. This correlates with the fact that this material had the lowest value of the elastic modulus and the largest specific deformation. This is in agreement to the principle that stated that the higher the E values, the smaller the deformations of the specimen s, at the same voltage. The plastic deformation areas are also observed on the specific curves for Z550 nano hybrid composite, but with smaller intervals. For Filtek Bulk Fill in one sample these plastic deformation intervals are missing, the material being non-deformable and being broked abruptly.

The microscopic appearance of materials fracture lines highlighted and supported the data previously obtained on the universal testing machine. All three tested composite materials showed a fragile breakage, but large differences occurred in the appearance of cracks and their propagation in the material mass. For Filtek Z250, there were several cracks in the tear area. The propagation of the cracks was made in plans, while at the same time it was found a blocking of the cracking of a microparticle, which was also emphasized in other studies [17]. For Filtek Z550 composite, cracks propagated more clearly in overlapping layers, giving a slight plastic deformation before full tearing. In the Filtek Bulk Fill composite, fewer cracks in the rupture area were observed but wider and sequential in the mass of the material, without propagation in overlapping planes, indicating that the sample had suddenly yielded.

Considering that the three evaluated composites have a similar chemical composition, the different compression stress behavior can be attributed to the inorganic phase loading differences. Micrometric agglomerations (nanoclusters) of nanometric particles determine particular microstructures such as for Filtek Z550. Nanoclusters determine a different mechanism of fracturing of the material compared to irregular or spherical micrometric particles [18-20]. They strengthen the structure and increase resistance to external forces through crack reflection. Nanoclusters have the ability to absorb and dissipate internal stress by propagating break lines between the fragments of clusters they have previously yielded [6]. This causes increased fatigue tolerance. Such a crack reflection mechanism on the surface of nanoclusters was also observed in the present study for the Filtek Z550 material by electronic scanning microscopy. The nanoclusters have a very pronounced internal porosity given by the large number of nanoparticles, including a secondary phase of infiltration with silane coupling agent. These structures would be expected to be less stress resistant compared to silica or zirconia particles of the same size as nanoclusters. However, studies have shown that nanoclusters, used as reinforcing elements of the polymeric matrix, considerably improved the behavior of mechanical tests on composites [21-24]. Stress applied to the surface of the material in a dry environment is transmitted inside the structure through the silane layer and causes deformation both inside and outside the nanoclusters. The presence of water in the resin matrix could diminish the internal concentration of the wiping and would allow the cracks to spread [25-28]. Moreover, when wet materials are tested, hydrolysis and polymerization of the silane phase inside the nanoclusters causes changes in stress transmission both inside and outside the nanoclusters. The major consequence would be the decrease of the mechanical deformation of the clusters which will induce the increase of the local tolerance to stress [29-34].

It is worth mentioning that in the present study the samples were evaluated immediately after preparation, at ambient temperature and in a dry environment. Even in an anhydrous environment, for Filtek Z550 nano-hybrid composite, the highest average compressive strength was determined, the nanoclusters in its structure allowing reflection and propagation of the micro-cracks in overlapping planes. Particular properties of nanoclusters provide to nanocomposite restorations optimal clinical performance in the humid environment of the oral cavity.

## Conclusions

Filtek Z250 had the lowest value of Young's modulus for compression, followed by Filtek Z550 and Filtek Bulk Fill Posterior Restorative. There were no statistically significant differences between all three materials regarding ultimate compressive strength. The lowest value for ultimate compressive strain was recorded for Filtek Bulk Fill Posterior Restorative followed by Filtek Z550 and Filtek Z250.

Analysis of stress-strain curves characteristics revealed a fragile material breakage, more obvious for Filtek Bulk Fill Posterior that suffered the smallest plastic deformation before tearing.

SEM evaluation revealed, for all three studied materials, the appearance of micro breakages in the compression area and some micro holes produced by the separation of the micrometric filling particles. For Filtek Z250 microhybrid composite, a crack blocking mechanism by the filler microparticles has been observed which can explain the optimal mechanical properties of this material.

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