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The Evaluation of Flexural Strength of Composite Resin Materials with and without Fiber

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Abstract

The aim of the present study was to evaluate the effect of solutions, times of storage and reinforcement with fiber on the flexural strength of different composite materials. Nanofill and nanohybrid composite materials with and without fiber, a glass fiber and polyethylene fiber, were tested in the present study. 72 specimens (25×2×2 mm³) were prepared as following six groups; Group ECME: everStick Fibre / Clearfil Majesty Esthetics, Group EFU: ever Stick Fibre / Filtek Ultimate, Group RCME: Ribbond Fibre / Clearfil Majesty Esthetics, Group RFU: Ribbond Fibre / Filtek Ultimate, Group CME: Clearfil Majesty Esthetics, Group FU: Filtek Ultimate. The specimens were stored in distilled water and mouthwash and tested after 24 hours and 7 days. Data were analyzed using analysis of variance and Schefee test. It was found that the EFU group in distilled water for 24 hours had the highest flexural strength and the CME group in mouthwash for 7 days had the lowest flexural strength. The storage times and the solutions were not statistically significant factors affecting on the flexural strength. The mean flexural strength values of the RCME and the RFU groups were similar to the FU group.

Keywords: Composite resin materials; Fiber; Flexural strength

Introduction

Composite resins have found a wider area of utilization in the restoration of both anterior and posterior teeth as a result of the development of their esthetic and mechanical properties However, material properties must be further developed so as not to represent low fracture strength in the patients with parafunctional habits such as bruxism and under high stress areas such as cases requiring wide preparations including cusps, inlays or onlay restorations [1-5].

Fillers have been added to the composite resins to improve their esthetic and mechanical properties [5,6]. The amount and size of the filler, and the distribution of its particles affect physical and mechanical properties of composite resins [1,3,7]. Microfill composites have similar esthetical properties as enamel surface due to their low filler amounts. However, their mechanical properties are poor. Hybrid composites have superior mechanical properties than microfill composite resins because of their high filler amounts, and have acceptable esthetical properties [1,3,8]. Comparing the mechanical properties of nanohybrid and microhybrid composites showed that the nanohybrid had significantly superior properties [5]. Another method for improving the mechanical properties of dental polymers is addition of fibers [9,10].

Fiber reinforced composite resins (FRCs) have been extensively used since 1960 [11] and currently represent a choice for clinical applications such as reinforcement of complete dentures and removable partial dentures, fixed partial dentures, endodontic posts, periodontal splints and orthodontic treatment as a retention splint [12-15]. Mechanical properties of FRCs applications depend on some factors like fiber orientations, fiber amount, adhesion of fibers to polymer matrix, impregnation of fiber with the matrix polymer, fiber type, fiber's aspect ratio and volume loading [10,15,16].

There are several types of reinforcement fibers used in dental materials, but the most used are glass fiber, polyethylene fiber, kevlar, and carbon fiber [17-19]. These fibers are available pre- or non-impregnated system. Impregnation of fibers with dental monomer systems having high viscosity is difficult. Gap and cracks caused by insufficient impregnation of fibers and insufficient adhesion between fibers and matrix result in an increase in water storage by FRCs. Increased water absorption of FRCs applications in an aqueous environment such as oral cavity cause a reduction in not only mechanical properties but also bending properties of FRCs restoration [15,20] and hence affect its long term stability [21].

Properties of materials, such as fracture resistance and elasticity, under stress are evaluated by the determination of properties of flexural strength, flexural modulus, and fracture toughness [2]. While the failure stress of a material is called flexural strength, the stiffness of a material is called flexural modulus as both measured in bending [22]. Flexural strength is important for composite designers because composite resins, especially cavities under stress, are exposed to tension and compression forces [1,2]. Thus the aim of the present study was to investigate the effect of fiber reinforcement and time of storage in different solutions on the flexural strength of composite resin materials.

Materials and Methods

In the present study, nanofill composite resin, nanohybrid composite resin, glass fiber, and polyethylene fiber were used.

Producers and chemical composition of the materials were listed in Table 1. Rectangular specimens were prepared in stainless steel mold with internal dimensions of 25 (±2 mm) × 2 (±0.1 mm) × 2 (±0.1 mm), according to ISO 4049 Standard [23]. In the present study, 6 groups were formed, each having 12 specimens.

Material	Producer	Chemical Composition	Lot no.
Clearfil Majesty Esthetic (Nanohybrid)	Kuraray, Osaka, Japan	Matrix: Bis-GMA, hydrophobicaromatic dimethacrylates, and hydrophobicaliphatic dimethacrylates, dl-Camphorquinone Filler: 66 vol% (78wt%) Silanated barium glass (average particle size 0.7 μm) and pre-polymerized organic filler	0033AA
Filtek Ultimate (Nanofill)	3M ESPE, St.Paul, MN, USA	Matrix: Bis-GMA, UDMA, TEGDMA, PEGDMA and Bis-EMA resins Filler: Non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles)	N185323
everStick C&B	Stick Tech Ltd, Turku, Finland	E-glass fibers, PMMA, Bis-GMA	2101216-ES-279
Ribbond	Ribbond Inc, Seattle,Washington, USA	UHMWPE, Bis-GMA	416120

Bis-GMA, bisphenol A-glycidyl dimethacrylate.
UDMA, urethane dimethacrylate
TEGDMA, triethyleneglycol dimethacrylate
PEGDMA, polyethylene glycol dimethacrylate
Bis-EMA, ethoxylated bisphenol a dimethacrylate
PMMA, poly methyl methacrylate
UHMWPE, ultra high molecular weight polyethylene

Table 1: Materials used in the research

Test specimens for each group were prepared in the following way:

Group ECME: E-glass fiber was placed at the bottom of the mold (tension side), and polymerized, by the directions of producer company. The rest of the mold was filled with nanohybrid composite, and polymerized on one side of the mold at each 1/3 of specimen's length, by the directions of producer company.

Group EFU: E-glass fiber and nanofill composite resin were used in this group. Test specimens were prepared similarly as the ones in ECME group.

Group RCME: Polyethylene fiber was wetted with Single Bond (3M/ESPE, St. Paul, MN, USA). Then, polyethylene fiber was placed at the bottom of the mold (tension side), and a layer of nanohybrid composite was placed on top of it. At each 1/3 of specimen's length, fiber and composite resin were polymerized for 20 second duration. The rest of the mold was filled with nanohybrid composite and polymerized similarly.

Group RFU: Polyethylene fiber and nanofill composite resin were used in this group. Test specimens were prepared as the ones in RCME group.

Group CME: Nanohybrid composite resin was placed in a mold by the incremental techniques. Polymerization of both increments was realized on one side of the mold at each one-thirds of the side by the directions of producer company.

Group FU: Nanofill composite resin specimens were prepared as the ones in CME group.

All of the specimens were polymerized by using Henry Schein 1500 light curing unit (Henry Schein Inc., Melville, USA).

The color of composite resins used in the present study was A2. Just after specimens were prepared, half of the specimens in each group were placed in distilled water, and the other halves were placed in mouthwash (Kloroben, Drogsan, Turkey), and then kept at 37°C for 7 days. Half of the specimens in the solution were tested for 3-point bending test at the end of the 1st day while the other half were tested at the end of 7th day in the same manner to be able to derive conclusions whether the bending strength was changing with waiting duration.

Before the 3-point bending test was applied, specimens' dimensions were measured by a digital compass of 0.01 sensitivity. Measurements were performed at 3 points for the width and height, and their average values were used in the calculation of bending strength. The 3-point bend test was performed immediately after removing the specimens from the distilled water and without drying the specimens and was performed according to the ISO 4049 specifications in such a way that the diameter for both supports and the loading piston was 2 mm and the span in between supports was 20 mm (Figure 1). This test was performed by using Instron Universal testing instrument (Model 2519-106, Instron Corp, Norwood, Mass, USA), and cross head speed was adjusted as 0.1 mm/min. Maximum load was recorded before the fracture. Flexural strength was computed from: $S = 3FL/2bd^2$,where S is the flexural strength (in MPa), F is the maximum load applied to the specimen (Newton), L is the span in between the supports (20 mm), and b and h are respectively the width and height of the specimen in mm.

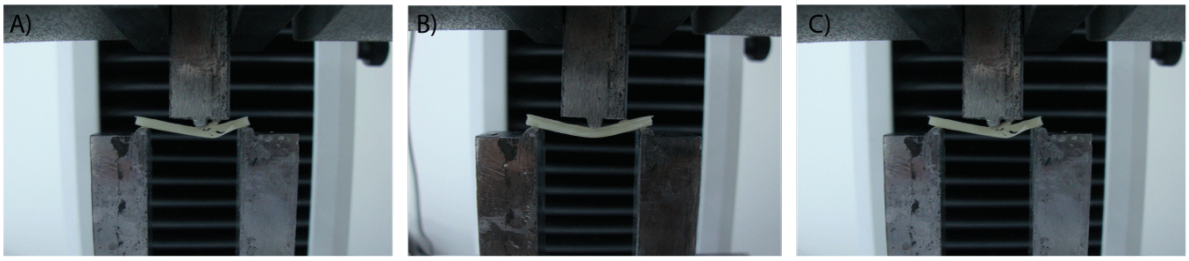

Figure 1: Fiber reinforced test specimen in 3-point bending test: (A) glass fiber reinforced composite resin; (B) glass fiber reinforced composite resin under flexure test; (C) cracked polyethylene fiber reinforced composite resin after flexure test.

A univariate analysis of variance (ANOVA) test was performed to determine the differences among the 6 groups and 2 solutions, followed by a post hoc Schefee test significant difference test with a confidence level of 0.05 to determine the mean differences. Differences between the storage times were analyzed with a paired sample t test. The statistical analysis was performed with statistical software (SPSS v16.0; SPSS, Inc, Chicago, Ill).

Results

The minimum, maximum, mean and standard deviation values of 1st and 7th days are presented in Tables 2 and 3. The highest flexural strength values were observed in the EFU group in distilled water for 24 hours (577.00 ± 42.39 MPa) (Figure 2) and the lowest were observed in the CME group in mouthwash for 7 days (93.25 ± 12.19 MPa) (Figure 3).

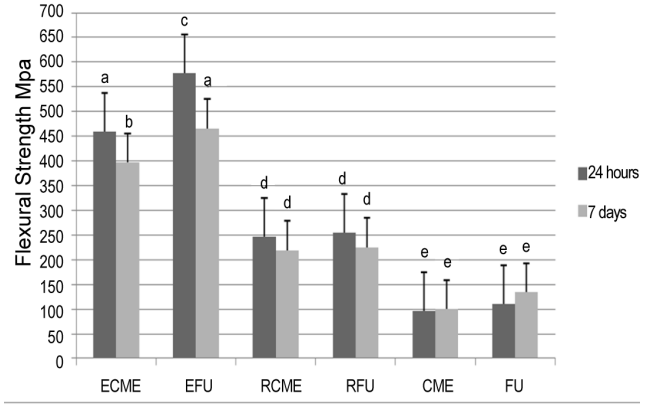

Figure 2: The mean flexural strength values of groups in stored distilled water for 24 hours and 7 days.

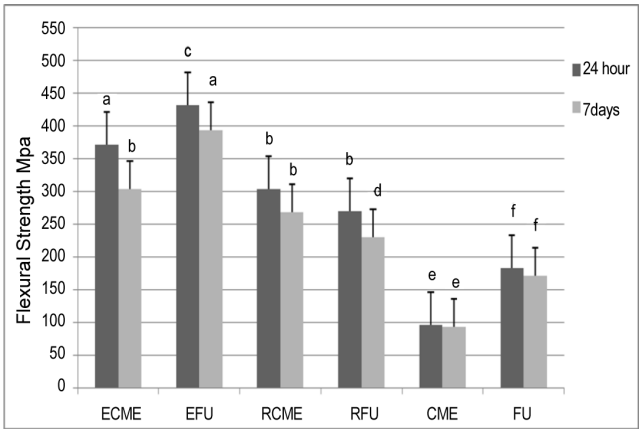

Figure 3: The mean flexural strength values of groups in stored mouthwash for 24 hours and 7 days.

Groups	Minimum	Maximum	Means	Sd
ECME	227,25	539,25	415,06	118,80
EFU	384,38	608,25	504,31	95,29
RCME	210,38	310,50	275,13	46,77

RFU	171,00	370,13	262,00	68,74
CME	89,63	100,50	95,25	4,51
FU	97,13	189,75	146,94	41,12

Table 2: The minimum, maximum, means and standard deviation (Sd) values of specimens at first day (MPa)

Groups	Minimum	Maximum	Means	Sd
ECME	237,38	530,63	350,06	109,26
EFU	348,75	544,13	429,81	81,47
RCME	113,25	293,25	243,19	66,50
RFU	169,13	295,88	226,88	46,51
CME	81,00	109,88	96,44	10,68
FU	100,25	175,50	152,25	27,32

Table 3: The minimum, maximum, means and standard deviation (Sd) values of specimens at seventh day (MPa)

The mean flexural strength of the EFU and the ECME groups had significantly higher than that of the RFU and the RCME groups ($p<0.05$). However, no significant differences were found between the EFU and the ECME groups, and the RFU and the RCME groups ($p>0.05$). The RFU and the RCME groups had higher flexural strength values than the FU and the CME groups. A significant difference was noted between the CME group and the RFU, and the RCME groups ($p<0.05$); while no significant difference were found among the FU, the RFU, and the RCME groups ($p>0.05$). In addition, flexural strength of the CME and FU was not statistically different ($p>0.05$).

There was no statistically significant difference between the flexural strength of specimens in stored mouthwash and distilled water ($p>0.05$) and between the immersion times ($p>0.05$).

Discussions

Fisher et al. [24] observed a statistically significant difference in flexural strength among the composite resins in their research. They found that the flexural strength of nanofill composite resins were higher as compared to that of nanohybrid composite resins. Sideridou et al. [25] compared physical properties of 3 different nanohybrid and 2 nanofill composite resins in their study. After being kept in water for 1 day, specimens from nanofill composites (Filtek Supreme Body; FSB) had the highest flexural strength while the ones from nanohybrid composites (Tetric EvoCeram; TEC) had the lowest flexural strength. Statistically no significant difference was observed among the other composite resins (nanohybrid, Grandio, GR; nanohybrid, Protofill-nao, nanofill, PR and Filtek Supreme Translucent, FST). After the specimens were kept in water for 30 days, the flexural strength of TEC stayed constant while the flexural strength of other composite resins decreased, and GR had highest flexural strength while TEC had the lowest flexural strength.

Rodrigues Junior et al. [26] investigated elasticity modulus and flexural strength of different kinds of composite resins. They found that microhybrid composite resins (Filtek Z-250, Esthet-X, respectively) had the highest flexural strength. Nanofill (Filtek Supreme) and microhybrid (Charisma) composite resins had similar flexural strength, and these presented higher flexural strengths than microfine (Helio Fill) composite resins.

In another study, researchers observed no statistically significant differences between the flexural strengths of microhybrid and nanofill composite resins [27]. In the present study, flexural strength of the FU group was higher than that of the CME group but the results were not statistically significant ($p>0.05$). The variation among the results were thought of as originated from the difference in filler size, filler amount, polymer matrix, and coupling between filler and matrix in the composition of composite resins [2,22,28,29].

Fibers are used to improve the flexural strength of composite resins [4,9,30]. The orientation of fiber layer affects flexural strength of composite resins. When the fiber is placed at the bottom (tension side), the material has the highest flexural strength [6,31]. Therefore, in the present study, fiber layer was placed in the tension side. In composite resins reinforced with fibers, while cracks were observed in all composite resins after 3-point bending test, cracks were not observed in fiber materials but some bending existed. In an investigation performed previously, fracture was not observed in glass fiber materials [6]. Spyrides and Bastian [18] reported that while no delamination between the composite and fiber was observed in composites reinforced with glass fiber, delamination between the layers and cracks in the interface were observed in composite resins reinforced with polyethylene fibers. The same behavior was observed in the present study with the composite resins reinforced with polyethylene fiber (Figure 4).

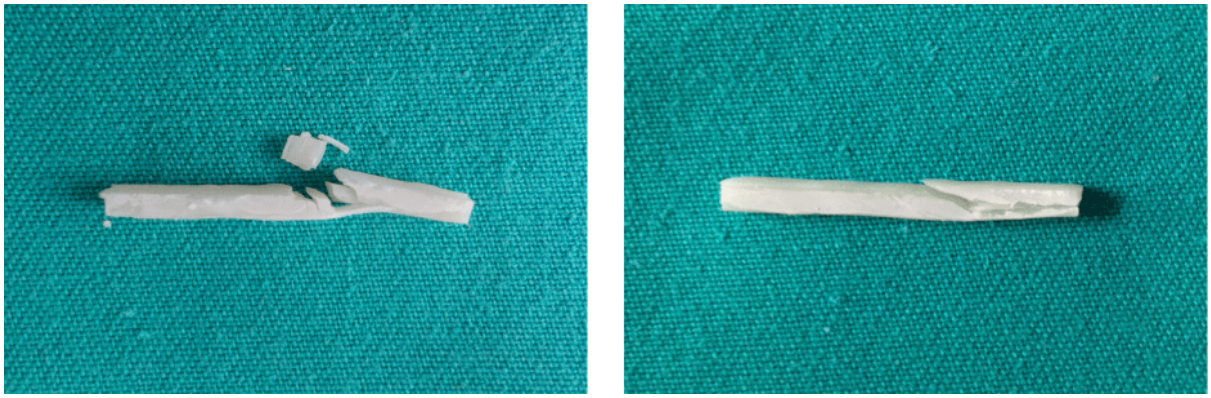

Figure 4: Cracked specimens after the 3-point bending test: (A) test specimen reinforced with glass fiber; (B) test specimen reinforced with polyethylene fiber.

Some studies were found similar results to the present study, and showed that the glass fibers had higher flexural strength than the polyethylene fibers [32-35]. Gaspar Junior et al. [36] compared the flexural strength and elasticity modulus of glass pre-impregnated fiber system and polyethylene non-impregnated fiber system. They stated that the flexural strength of non-impregnated polyethylene fiber was higher as compared to that of the pre-impregnated glass fiber, which is not the case in the present study. Spyrides and Bastian [18] stated that flexural strengths of polyethylene and glass fiber were statistically equivalent. In the present study, flexural strength of the EFU and the ECME groups was found to be higher as compared to the RCME and the RFU groups. Moreover, flexural strength of these four groups were higher than those of the FU and the CME.

The 3-point bending test is widely used for determining physical properties of composite resin materials [1,2,28,30]. Stress distribution in the 3-point bending test is similar to the stress distribution in fixed bridges. For this reason, the 3-point bending test was utilized to evaluate flexural properties of materials [30].

Fischer et al. [24] reported a significant increase in flexural strength of nanohybrid composite materials after being kept in water while there was a slight decrease in flexural strength of nanofill composite resins. Sideridou et al. [25] stated that no significant difference between the 1st and 30th days was observed in stored distilled water and artificial saliva. Rodrigues Filho et al. [37] stated that there was no significant decrease in the flexural strength of two different type of composite resins when they were kept in water. Gohring et al. [6] reported that flexural strength of glass fiber was affected by neither keeping in water nor thermocycling. Ellakwa et al. [17] observed a significant decrease in flexural strength of pre-impregnated-glass and UHMWPE fibers after storing in water for 6 months. Chai et al. [38] evaluated the effect of water sorption on flexural strength and flexural modulus of fiber reinforced composite resins. They reported that storing Stick and FibreKor specimens in distilled water for 1 day or 180 days had no significant difference on their flexural strengths. In the Vectris specimens they observed a significant decrease in flexural strength in the 180th day as compared to the 1st. There is little information about the effect of mouthwash on the flexural strength of fiber reinforced composite resins. Lahdenperä et al. [39] investigated flexural properties of glass fibre reinforced provisional fixed partial denture polymer and release of chlorhexidine digluconate, and stated no reduction in flexural strength of test specimens when the chlorhexidine digluconate-laced fibers were compared to those of conventional fiber reinforcements. In the present study, storing different solutions were no statistically significant on the flexural strength of fiber reinforced and unreinforced composite resins ($p>0.05$). Moreover, flexural strength of the specimens slightly decreased in the 7th day as compared to the 1st, but these results were not statistically significant ($p>0.05$).

The limitations of the present study include the absence of artificial aging, thermal cycling and the use of rectangular specimens instead of more complex fixed partial denture shapes. In vitro studies are limited in their ability to predict the success of a material or technique in a clinical situation. Within the limitations of the present study, it can be concluded that; flexural strength of composite resins improved with fibers and fiber type influenced the flexural strength. However, storage times and solutions had no significant effect on the flexural strength of test specimens.

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