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A Comparison of the Flexural Strength and Elastic Modulus of Condensable and Hybrid Composite Resins

Kondanse Edilebilen ve Hibrit Kompozit Rezinlerin Esneme Dayanıklılığı ve Elastisite Modülünün Karşılaştırılması

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ABSTRACT

Objective: Condensable composites have been used widely for posterior applications since their introduction. The aim of this study was to compare the flexural strength and elastic modulus of four condensable composite resins (Filtek P-60, Pyramid Dentin, Solitaire 2, SureFil) and three hybrid composite resins (Charisma, InTen-S, Tetric Ceram).

Materials and Methods: The resins were placed in a mold measuring 25mm length, 2 mm width and 2 mm thickness (n =10). The samples were prepared and tested according to ISO specifications 4049. Flexural strength and modulus of elasticity were determined at 24 hours and nine months later. The center of the bar was subjected to a compressive load at a rate of 1 mm/min. Statistical analyses were performed using analysis of variance (ANOVA) and the Duncan's Multiple Range tests ($p<0.05$).

Results: The results indicated statistically significant differences ($p<0.05$) among the tested composite resins. Filtek P-60 at 24 hours provided the highest flexural strength and the highest rigidity ($p<0.05$). The results at the end of nine months also demonstrated that Tetric Ceram, Filtek P-60 and SureFil had significantly higher flexural strengths than InTen-S, Pyramid Dentin, Solitaire 2 and Charisma ($p<0.05$). For most materials flexural strength and modulus of elasticity did not change after storage in water for nine months. Only the flexural strength and modulus of elasticity of Filtek P-60 decreased ($p<0.05$) and the modulus of elasticity of Pyramid Dentin increased significantly ($p<0.05$).

Conclusion: According to the results of this study some condensable materials are similar to the hybrid composites in their flexural strength and elastic modulus. Condensable composites may be easier for clinicians

ÖZET

Amaç: Kondanse edilebilen kompozitler ilk tanıtımlarından bu yana posterior uygulamalarda yaygın olarak kullanılmaktadır. Bu çalışmanın amacı 4 kondanse edilebilen kompozit (Filtek P-60, Pyramid Dentin, Solitaire 2, SureFil) ve 3 hibrit kompozitin (Charisma, IntenS, TetricCeram) esneme dayanıklılığı ve elastisite modülünü karşılaştırmaktır.

Materyal ve Metod: Rezin materyaller 25 mm uzunluğunda, 2 mm genişliğinde ve 2 mm kalınlığındaki kalıplara yerleştirildi (n=10). Örneklerin hazırlanması ve test ISO 4049 standartlarına uygun olarak gerçekleştirildi. Esneme dayanıklılığı ve elastisite modülleri 24 saat ve 9 ay sonunda belirlendi. Örneklere 1 mm/dakika sabit hızda yükleme kuvveti uygulandı. Veriler istatistiksel olarak Varyans analizi (ANOVA) ve Duncan's multiple range testleri ile analiz edildi ($p<0.05$).

Bulgular: Sonuçlar, incelenenen kompozit rezinler arasında istatistiksel olarak anlamlı farkların bulunduğunu gösterdi ($p<0.05$). Filtek P-60 24 saat sonuçları en yüksek esneme dayanıklılığı ve en rijit materyal olarak belirlendi ($p<0.05$). 9 ay sonunda Tetric Ceram , Filtek P-60 ve SureFil 'in IntenS, Pyramid Dentin, Solitaire 2 and Charisma'ya göre daha yüksek esneme dayanıklılığına sahip olduğu belirlendi ($p<0.05$). Çalışmada kullanılan birçok materyalde 9 ay suda bekletmenin esneme dayanıklılığı ve elastisite modülünü değiştirmediği görüldü. Ancak Filtek P-60'ın esneme dayanıklılığı ve elastisite modülününazaldığı, Pyramid Dentin'in elastisite modülünün arttığı belirlendi.

Sonuç: Bu çalışmanın sonucuna göre bazı kondanse edilebilen materyaller esneme dayanıklılığı ve elastisite modülü bakımından hibrit kompozitlere benzerdir. Kondanse edilebilen kompozitler geleneksel rezin kompozitlere göre klinisyenler tarafından daha kolay uygulana-

to handle than conventional resin-based composites, however selecting these materials must be made carefully as it seems that not all of them were qualify for stress-loaded posterior restorations. The clinical applications and performance of condensable composites require further study.

bilir ancak stres altında olan posterior restorasyonlarda bu materyallerin hepsi uygun değildir, bu bakımdan bu materyallerin seçiminde dikkatli olunmalıdır. Kondanse edilebilen kompozitlerin kliniksel uygulamaları ve performansları bakımından yeni çalışmalara ihtiyaç vardır.

KEYWORDS
Comparative study, Composite resins, Flexural strength, Elastic modulus

ANAHTAR KELİMELER
Karşılaştırmalı çalışma, Kompozit rezinler, Esneme dayanıklılığı, Elastisite modülü

INTRODUCTION

Resin composites have become a popular alternative material to the amalgam restoration in stress-bearing posterior teeth[1,2,3]. Besides being free of mercury, more esthetic, and less costly than ceramic inlays and cast gold inlays, resin composites offer an additional advantage of bonding to tooth structures following acid etching and placement of a bonding agent[3].

Early problems included excessive wear rate, postoperative sensitivity, loss of anatomic form and secondary caries have been encountered, and initially resulted, in a diminished acceptance of these materials as alternatives to dental amalgam for the restoration of molar and premolar teeth[2,4]. Considerable research toward solving these problems has been conducted, and today's materials are superior to their predecessors in several respects. The progression of composites from macrofills to microfills, of from hybrid to microhybrids has lead to the development and introduction of new formulations flowable and condensable product in to the dental market[3,5-9]. Each category offer certain advantages and limitations compared to the universal hybrid composites[8-11]. Hybrid composites were developed in an attempt to combine the favorable properties of the macrofilled and the microfilled materials. Advanced hybrid composites present good material properties and clinical performance[10,11].

The physical and mechanical properties of composite resins vary according to their compositions. The filler content, filler particle size and distribution of the filler particles all highly influence the physical and mechanical properties of the composite resins[2,3,12-14].

Condensable composites have been introduced into the dental market with high expectations as an alternative to dental amalgam. When compressed mechanically the larger filler particles mechanically interlock with the smaller fillers to provide the characteristics ''packable'' property[2]. On the basis of the perceived high-filler load, these materials were expected to exhibited superior physical and mechanical properties in addition to improved handling characteristics. Condensable composites are indicated primarily for use to restore load-bearing surfaces of permanent posterior teeth[2,3,15-17]. Since they are non-sticky, they can be used with conventional amalgam instruments in addition to with metal matrix bands and wooden wedges[16].

Several new products have been marketed as high-density or condensable resin composite restorative materials. Unfortunately not much information exists on the different mechanical properties of current condensable composite resin products. More data are needed to characterize each condensable composite and to help dentists in material selection.

The purpose of this study was to compare the mechanical properties of four condensable (Filtek

P-60, Pyramid Dentin, Solitaire 2, SureFil) and three hybrid composite (Charisma, InTen-S, Tetric Ceram) materials currently available. The flexural strength and elastic modulus of these products were evaluated both at 24 hours and after aging in water for nine months.

METHODS and MATERIALS

The materials used in the study are listed in Table I.

Flexural Strength

Flexural strength was conducted according to ISO Standard-404918. (International Standards Organization, 2000), using a three-point bending method. The samples were prepared and one researcher conducted the testing to maximize standardization. Twenty rectangular bar samples of each material, measuring 25 mm in length, 2 mm in thickness and 2 mm in width, were prepared by compacting the test materials into a teflon mold between two glass microscopic slides. Each specimen was light activated with a visible light source (Hilux Curing Light, Benlioğlu Dental Inc, Turkey) in 4 overlapping positions of 40 seconds each, across the length of the mold. Output of the curing light was verified to ensure it was above 500mW/cm2. Following polymerization, ten samples of each material were stored in distilled water at 37°C for 24 hours. The remaining ten specimens were stored under the same conditions for nine months. Every group of 10 samples was tested for flexural strength and elastic of modulus. After storage and prior to the loading, the thickness and width of the samples were measured using a digital micrometer (Digimatic, Mitutoyo Corp, Tokyo, Japan) with an accuracy of 0.01 mm at three locations along the rectangular bar samples. The mean value of the three measurements was used in the subsequent flexural strength and modulus of elasticity calculations.

A three-point bending test was carried out using a universal testing machine (Lloyd Ins. Ltd., LR 30K, UK) to evaluate the flexural strength and elastic modulus. The crosshead speed was set at 1mm/minute. The apparatus consisted of two rods, mounted parallel with the distance of 20 mm between

TABLE I

Restorative materials used in the study

Type	Commercial name	Manufacturer	Batch number	Filler weight	Particle size Mean (µm)
Hybrid composite	Charisma	Heraeus Kulzer D-41538 Dormagen, Germany	010053	78%	0.04-0.7 below 2 µm
Hybrid composite	InTen-S	Ivoclar Vivadent AG, Schaan, Liechtenstein	E34723	74%	0.2-7.0 µm
Hybrid composite	Tetric Ceram	Ivoclar Vivadent AG, Schaan, Liechtenstein	557671	79%	1.0 µm
Condensable composite	Filtek P–60	3M ESPE Dental Products, St Paul, MN, USA	20020318	80%	0.6 µm (0.01-3.5)
Condensable composite	Pyramid Dentin	Bisco Inc. 110 W Irving Park Rd. Schaumburg, IL 60193	010705	80%	below 1 µm
Condensable composite	Solitaire 2	Heraeus Kulzer D-41538Dormagen, Germany	040232	75%	0.7-8 µm (2-25 µm max)
Condensable composite	SureFil	DentsplyDeTrey, GmbH D 78467 Konstanz, Germany	331113	82%	0.8 µm

their centers. The maximum load supported by the sample prior to failure was recorded electronically by the testing machine's central processing unit. A chart plotter recorded the load- deformation profile. Flexural strength (σ), in megapascals (MPa), was calculated using the following formula:

σ = 3 Pl/ 2bd2

Where P is the maximum load at the point of fracture (Newton), l is the distance between the supports (20mm), b is the width of sample measured prior to testing (mm), and d is the thickness of the sample between the tension and compression surfaces measured prior to testing (mm).

Modulus of Elasticity

Modulus of elasticity was determined according to ISO Standard-4049 18. The modulus of elasticity, E, in gigapascals (GPa), was determined from the slope of the stress strain curve generated from the three-point bending test results by using the following equation:

E= (ΔF / ΔY) X (l3 / 4bd3)

Where ΔF / ΔY is the change in force (ΔF) per unit change in deflection of the center of the sample (ΔY), l is the distance between the supports on the tension surface (20 mm), b is the width of the sample, and d is the mean thickness of the sample between the tension and compression surfaces.

The 24-hour and nine-month data were subjected to statistical analyses using analysis of variance (ANOVA) and Duncan's Multiple Range test to compare the differences among groups of materials (p<0.05).

RESULTS

Flexural Strength Testing

The results of the 24-hour and nine-month flexural strength tests are presented in Figure 1, Tables 2a and 2b. Comparison by ANOVA showed highly significant differences in flexural strength among the groups at both 24 hours (p<0.001) and nine-month (p<0.001). The condensable composite Filtek P-60 had the highest flexural strength at 24 hours (136.27 MPa). Charisma (79.09 MPa) and Solitaire 2 (88.63 MPa) were represented the lowest values at 24 hours. The ranking of the flexure strengths from lowest to highest was as follows: Charisma < Solitaire 2 < Pyramid Dentin < InTen-S < SureFil < Tetric Ceram < Filtek P-60.

After nine months Tetric Ceram (119.13 MPa), Filtek P-60 (112.66 MPa), and SureFil (105.71 MPa)

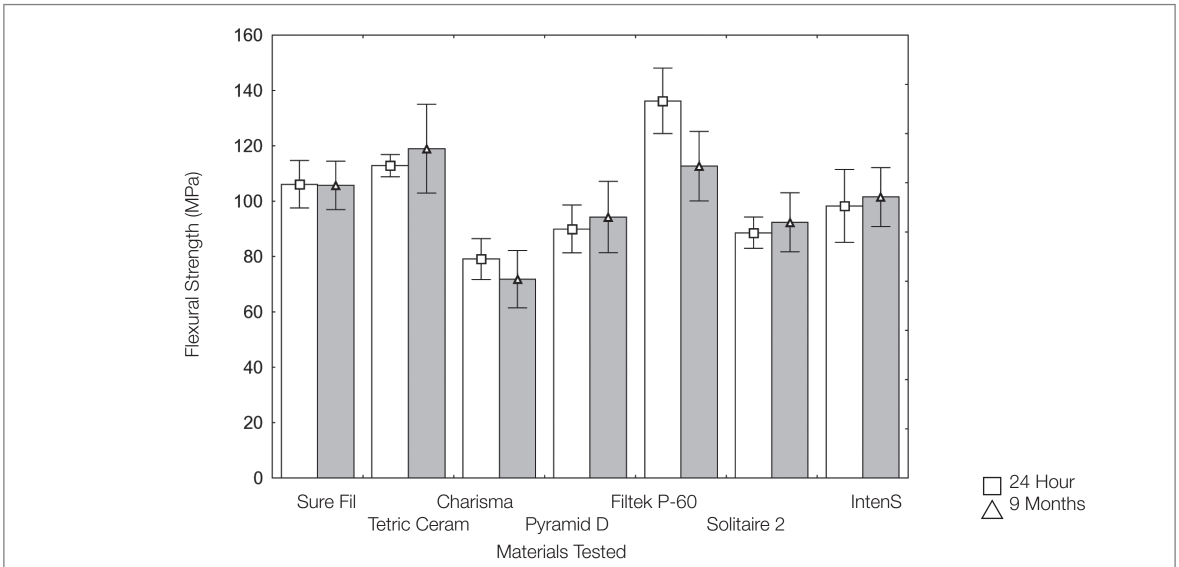

FIGURE 1

Flexural Strength Results

TABLE IIa

*Mean flexural strength values of the materials at 24 hours (MPa) **

Test material	Mean flexural strength ± SD
Charisma	79.09 ±7.39 a
Solitaire 2	88.63 ± 5.67 ab
Pyramid Dentin	89.99 ± 8.63 b
InTen-S	98.31 ± 13.16 bc
SureFil	106.16 ± 8.58 cd
Tetric Ceram	112.86 ± 3.99 d
Filtek P- 60	136.27 ± 11.84 e

SD: Standard deviation
** (Groups with the same superscript letters are statistically similar p> 0.05)*

TABLE IIb

*Mean flexural strength values of the materials at nine-months (MPa)**

Test material	Mean flexural strength ± SD
Charisma	71.85 ±10.35 [a]
Solitaire 2	92.39 ± 10.65 [b]
Pyramid Dentin	94.29 ± 12.88 [b]
InTen-S	101.51± 10.67 [bc]
SureFil	105.71 ± 8.75 [bcd]
Filtek P-60	112.66 ± 12.58 [cd]
Tetric Ceram	119.13 ± 16.03 [d]

SD: Standard deviation
** (Groups with the same superscript letters are statistically similar p> 0.05)*

showed higher flexural strength values than the other materials (p<0.05).

The flexural strength of Filtek P-60 decreased significantly from 24-hour to nine-month (p<0.05). Ranking of the flexural strength values was similar with the exception of the change in ranking between Filtek P-60 and Tetric Ceram (Filtek P-60 < Tetric Ceram).

Modulus of Elasticity

The results of the 24-hour and nine-month modulus of elasticity tests are shown in Figure 3, Table 3a and 3b. Comparison by ANOVA revealed highly significant differences in the modulus of elasticity between the groups at both 24 hours (p<0.001) and nine-month (p<0.001). Filtek P-60 at 24 hours provided the highest rigidity (12.44 GPa); SureFil had the second highest modulus (9.53 GPa). Solitaire 2 at 24 hours had the lowest elastic modulus values (5.68 GPa). Pyramid Dentin (7.08 GPa), Tetric Ceram (7.46 GPa), InTen-S (7.54 GPa), and Charisma (7.79 GPa) demonstrated statistically similar results at 24 hours.

Filtek P-60 (10.96 GPa) and SureFil (10.01 GPa) at nine-month provided the highest rigidity. Solitaire 2 (6.62 GPa) and Charisma (6.85 GPa) at nine months had the lowest elastic modulus values. Filtek P-60 was found to demonstrate a decrease in elastic modulus from 24-hour to nine months, but Pyramid Dentin increased in modulus after nine months ($p<0.05$). Among the other materials tested, there were no significant differences in modulus between the two time periods.

DISCUSSION

There is an increasing demand by patients for tooth-colored materials for the restoration of posterior teeth. The high filler loaded composite resins were developed with the hope of providing better clinical performance when used as posterior restorative materials[3,17].The condensable composites have been developed with claims by manufacturers to offer better handling characteristic during placement as well as improved physical and mechanical properties than traditional hybrid composite resins. However, not consistently better results were reported from in vitro studies regarding the superiority of these materials when compared to hybrid composites[2,15].

This study specifically compared the flexural strength and modulus of elasticity of four condensable resin-based composites with those of three hybrid composites. Mechanical tests utilized ISO test methods for resin based restorative materials and provided basic comparative information. The ISO has set 80 MPa as the minimum flexural strength for polymer-based filling and restorative materials claimed suitable for restorations involving occlusal surfaces. All of the composite materials tested exceeded this requirement with the single exception of Charisma composite resin.

Many researchers have shown a reduction in the mechanical-physical properties of the flexural strength, elastic modulus and fracture toughness of composites after storage in water for extended periods of one or more months[2,3,15,19,20]. Aging of the material in water for six months and up to two years caused a significant decrease in fracture toughness for most of the composites tested. Hardness and flexural strength were reduced upon soaking for six months, however these changes appeared to stabilize and return to almost the original levels after the six-month time period unless the material were poorly cured[21].

In this present study the flexural strength at nine-month was not significantly lower than at 24-hour time period measurements of the majority of the materials. Only the flexural strength and modulus of elasticity of Filtek P-60 decreased and the modulus of elasticity of Pyramid Dentin increased significantly ($p<0.05$).

The use of water alone as means of mimicking oral conditions emerges as in adequate. In the oral cavity, the additive effects of saliva, including salivary enzymes and dietary solvents, may present a more detrimental effect than water on the mechanical properties of composite resins[20,22]. However testing mechanical properties of the aged condensable composites will provide some insight into the susceptibility of the materials to undergo degradation in vivo.

It has been established that the properties of composite resins are dependent upon the material composition. In general, the monomer constituents affect degree of conversion, viscosity, surface tension and contact angle[15,23]. The filler characteristics affect the mechanical properties of the resin composites, and it has been shown that a correlation exist between filler content and mechanical properties[24]. Besides the filler system, monomer structures of the resin matrix also influence the flexural strength of composite resins[25].

In this study, Filtek P-60 at 24 hours provided the highest flexural strength values. Charisma and Solitaire 2 were represented the lowest values at 24 hours (Figure 2, Table 2a). After nine months Tetric Ceram, Filtek P-60 and SureFil showed higher flexural strength values than the other materials. Charisma had the lowest flexural strength values at nine-month (71.85 MPa) (Figure 1, Table 2b). The modulus of elasticity being representative of the rigidity of the material is supportive of the fact that the material will not deform under occlusal loading[2]. Failure of posterior composite restorations often is associated with fractures within the body and at the margins of the restorations[3]. Fracture related material properties, such as fracture resistance and elasticity, have been evaluated by the determination of the material parameters of fracture toughness, flexural strength and modulus of elasticity[3,26]. A correlation exists between filler content and mechanical properties, particularly for Young's modulus[24]. The higher the filler content, the higher the modulus and the higher the resistance to deformation. The best compromise would appear to be a fine hybrid resin composite with a flexural modulus of approximately 10 GPa for most restorations[27]. In this study, Filtek P-60 at 24 hours provided the highest rigidity (12.44 GPa). Solitaire 2 at 24 hour provided lowest rigidity (5.68 GPa) (Figure 2, Table 3a). Filtek P-60 (10.96 GPa), SureFil (10.01 GPa) demonstrated the highest modulus of elasticity values at nine months where Solitaire 2 (6.62 GPa) and Charisma (6.85 GPa) showed the lowest values (Figure 2, Table 3b). The relatively high mean elastic modulus of Filtek P-60 and SureFil, which approximates that of currently used posterior resin materials, are favorable for these two products in this regard. The low mean value reported for Solitaire 2 is a concern.

CONCLUSIONS

According to the results of this study, some condensable materials were similar to the hybrid composites in their flexural strength and elastic modulus. Condensable composites may be easier for clinicians to handle than conventional resin-based composites, however selecting these materials must be made carefully as it seems that not all of them full fill the requirements for stress-loaded posterior restorations. The diversity among the tested materials indicated that the clinician should consider the anticipated clinical use and select the material with the most appropriate properties. The clinical applications and performance of condensable composites require further study.

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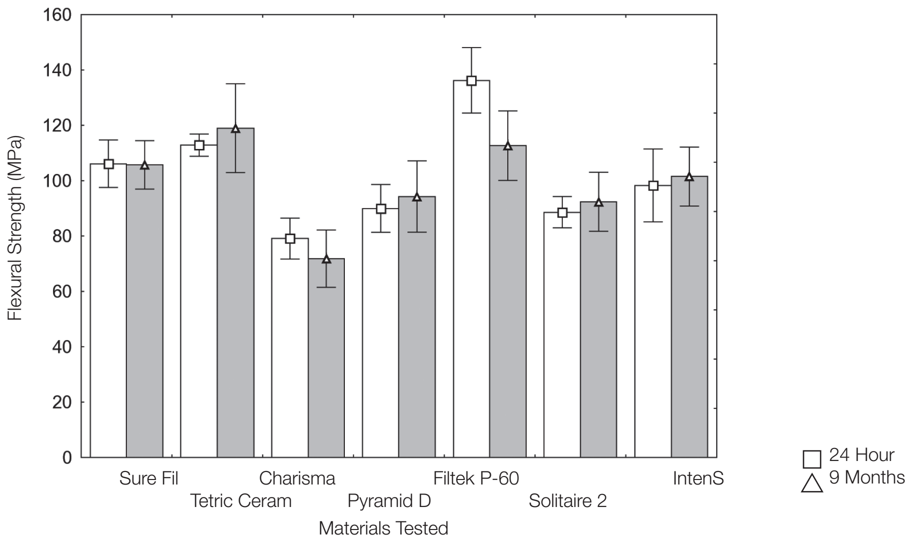

FIGURE 2

Modulus of elasticity results

TABLE IIIa

Modulus of Elasticity of the materials after 24 hours (GPa)

Test material	Mean modulus of elasticity ±SD
Solitaire 2	5.68 ± 0.65 [a]
Pyramid Dentin	7.08 ± 0.96 [b]
Tetric Ceram	7.46 ± 0.47 [b]
InTen-S	7.54 ± 0.63 [b]
Charisma	7.79 ± 0.75 [b]
SureFil	9.53 ± 0.72 [c]
Filtek P-60	12.44 ± 0.64 [d]

SD: Standard deviation
** (Groups with the same superscript letters are statistically similar p> 0.05)*

TABLE IIIb

Modulus of Elasticity of the materials after nine-months (GPa)

Test material	Mean modulus of elasticity ±SD
Solitaire 2	6.62 ±1.23 a
Charisma	6.85 ± 1.04 a
InTen-S	8.04± 0.52 b
Tetric Ceram	8.35 ± 1.11 b
Pyramid Dentin	9.24 ± 0.79 b c
SureFil	10.01± 0.90 cd
Filtek P-60	10.96 ± 0.68 d

SD: Standard deviation
** (Groups with the same superscript letters are statistically similar p> 0.05)*

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