ACTA
STOMATOLOGICA
CROATICA
www.ascro.net

Acta Stomatol Croat. 2008;42(2):147-154.

IZVORNI ZNANSTVENI RAD
ORIGINAL SCIENTIFIC PAPER

Şeyda Hergüner Siso, Feridun Hürmüzlü

Fizikalna svojstva triju različitih vrsta svjetlosno polimerizirajućih materijala od kompozitne smole

Physical Properties of Three Different Types of LC Composite Resins

Zavod za restorativnu stomatologiju Stomatološkog fakulteta Sveučilišta Cumhuriyet, Sivas, Turska
Department of Restorative Dentistry, School of Dentistry, Cumhuriyet University, Sivas, Turkey

Sažetak
Svrha: Zadatak ovoga istraživanja bio je odrediti fizikalna svojstva triju različitih vrsta kompozitnih smola: Point 4 (mikrohibrid), Solitaire 2 (stlačiv) i Definite (ormocer). ***Materijal i metode:*** U fizikalnom dijelu istraživanja preparirano je po 10 uzoraka prema standardnim protokolima iz svakoga od triju restorativnih materijala za sljedeće testove: na tlačnu čvrstoću (ADA 27), na vlačnu čvrstoću prema promjeru presjeka (ADA 27), na čvrstoću savijanja (ISO 4049) i na dubinu postignute polimerizacije (ISO 4049). Podaci su nakon toga bili podvrgnuti statističkoj analizi uz pomoć Kruskal-Wallisova testa i Mann-Whitneyeva-*U* testa. ***Rezultati:*** Vrijednosti dobivene testovima na tlačnu čvrstoću, vlačnu čvrstoću prema promjeru presjeka te na dubinu postignute polimerizacije bili su sljedeći: Point 4 (202,49, 47,12, 93,09, 4,74); Solitaire 2 (248,92, 59,74, 92,97, 4,12); i Definite (174,73, 50,82, 10,3.15, 5,25). Kod vrijednosti dobivenih za tlačnu čvrstoću, vlačnu čvrstoću prema promjeru presjeka i dubinu polimerizacije bilo je statistički znatnih razlika ($p<0,05$), ali ih nije bilo kod testa na čvrstoću savijanja ($p>0,05$). ***Zaključak.*** Prema rezultatima testova na tlačnu čvrstoću i vlačnu čvrstoću prema promjeru presjeka, materijal Solitaire 2 postigao je najvišu vrijednosti a Definite je bio najbolji kad je riječ o testu dubine polimerizacije.

Zaprimljen: 16. studeni 2007.
Prihvaćen: 21. svibnja 2008.

Adresa za dopisivanje
Dr. Şeyda Hergüner Siso,
Cumhuriyet University
School of Dentistry
Department of Restorative Dentistry
Sivas, Turska
Tel: + 90 346 2191010/2701
Fax: + 90 346 2191237
seydaher@hotmail.com

Ključne riječi
ormocer; kondenzibilan; hibridni kompozitni materijal; fizikalna svojstva; kompozitne smole; čvrstoća savijanja

Uvod

Dobar izbor restorativnog materijala jedan je od najvažnijih čimbenika koji određuju uspjeh u restorativnoj stomatologiji. Zbog toga su posljednjih godina obavljena mnogobrojna istraživanja u adhezivnoj stomatologiji (1,2). To je dalo pozitivne rezultate te pomaže stomatolozima u odabiru pravih materijala i metoda. Unatoč tom razvoju, ni jedan se materijal ne može smatrati idealnim s obzirom na dentalnu restoraciju. Kako bi smanjili negativne učinke materijala, stomatolozi moraju dobro poznavati njihova fizikalna, kemijska, biološka i klinička

Introduction

In restorative dentistry, choosing the correct restorative material is one of the primary variables that determine its success. Particularly in recent years, a lot of research has been done on adhesive dentistry (1,2). This has resulted in a number of positive developments and has provided dentists with assistance in selecting the correct materials and methods. In spite of these developments, however, it is impossible to refer to an ideal material in regard to dental restoration. In order to lessen a material's negative effects, dentists must know its svojstva. To je zbog razlike u preparaciji restoracije i žvačne snage zuba te činjenice da je uspješnost dentalnih restorativnih materijala vezana za njihova fizikalna i kemijska svojstva (3). Glavni čimbenici koji pridonose fizikalnim svojstvima pojedinih punila su veličina čestica i njihova disperzija. Ipak, zna se da sastav smolne matrice materijala utječe i na fizikalna svojstva (4-7). Fizikalna je snaga glavni čimbenik koji određuje uspjeh restorativnog materijala. Kakvoća izvedbe materijala pod žvačnim silama utječe na vlačnu, tlačnu i posmičnu čvrstoću te čvrstoću savijanja(3). Kao što je slučaj s mnogim proizvodima, poželjno je zamijeniti ranije razvijene kompozitne smole za koje se utvrdilo da im karakteristike nisu sjajne jer nemaju dovoljan otpor na trošenje i kratkotrajne su, te tržištu predstaviti proizvode visoke kakvoće za kliničku primjenu. S tom su namjerom posljednjih godina razvijeni hibridni, kondenzibilni i ormocerski kompoziti, kao zamjena amalgamskim materijalima. Solitaire (Heraeus Kulzer, Njemačka) bio je prva kondenzibilna kompozitna smola na tržištu – proizveden je bio godine 1997. Poslije je poboljšan i nazvan Solitaire 2 (Heraeus Kulzer, Njemačka). Tehnika primjene slična je onoj koja se koristila za amalgamske ispune. Uporaba metalnih trakica sa stezačem i kolčića omogućila je jednostavnije interproksimalne kontakte (5, 8, 9). Godine 1998. predstavljen je Definite (Degussa, Hanau, Njemačka) kao prvi dentalni restorativni materijal na temelju "ormocerske" (organski preinačena keramika) tehnologije. Razvijeni su i multifunkcionalni uretan i tioeter-metakrilatski alkoksilani kao sol-gel prekursori za sintezu inorgansko-organskih kopolimernih kompozitnih materijala za dentalnu primjenu. Reakcijama hidrolize i polikondenzacije u alkoksisilnim skupinama silana potiče se nastanak inorganske mreže Si-O-Si, dok su metakrilatne skupine još dostupne za svjetlom aktiviranu organsku polimerizaciju. Novost u inorgansko-organskom kopolimernom sastavu Definitea bio je navodno revolucionarni pomak s obzirom na mehanička svojstva i načine postupka. Point 4 (Kerr Sybron, Orange, Kanada) razvijen je kombinacijom karakteristika postojanog hibridnog kompozita i estetske mikropunjene kompozitne smole. To je bio materijal koji se jednostavno polirao, a sadržavao je ultra male čestice s lijepim estetskim svojstvom i niskom disperzijom čestica punila.

Svrha je ovog istraživanja odrediti fizikalna svojstva triju vrsta kompozitnih smola: Pointa 4 (mikrohibrida), Solitaira 2 (kondenzibilan) i Definitea (ormocera).

physical, chemical, biological and clinical properties well. This is due to the differences in restoration and the mastication strength of teeth and the fact that the success of dental restorative materials is related to their physical and chemical properties (3). The main factors affecting physical properties are filler type, size and dispersion. It is common knowledge, however, that the make up of a material's resin matrix also has an effect on its physical properties (4-7). Physical strength is the main factor which determines the clinical success of a restorative material. The restorative material's performance under mastication force affects the tensile, compression, shear and flexural strengths (3). As with most products, it is desirable to replace earlier developed composite resins found to have inadequate characteristics, such as wear resistance and durability, and introduce higher quality products into the market for clinical use. It was with this purpose in mind that hybrid, packable and ormocer composite resins have been developed as alternative amalgam materials over the past few years. Solitaire (Heraeus Kulzer, Germany), the first packable composite resin to be introduced, came on the market in 1997. Later, after improving its physical properties, Solitaire 2 (Heraeus Kulzer, Germany) was released. An application technique similar to that used with amalgam can be used for the placement. The use of metal matrix bands and wedges allow for easier establishing of interproximal contacts (5, 8, 9). In 1998, the material Definite (Degussa, Hanau, Germany) was marketed as the first dental restorative material based on "ormocer", organically modified ceramic technology. Multifunctional urethane athioether methacrvlate alkoxysilanes have been developed as sol-gel precursors for synthesis of inorganic-organic copolymer composite materials for dental applications. By hydrolysis and polycondensation reactions the alkoxysilyl groups of the silane promote the formation of an inorganic Si-O-Si network, while the methacrylate groups are still available or light-activated organic polymerisation. The novel inorganic-organic copolymer composition of Definite was claimed to represent a revolutionary breakthrough with respect to mechanical properties and handling characteristics. Point 4 (Kerr,Sybron, Orange, Canada) was developed by combining the characteristic of a durable hybrid composite and an aesthetic microfil composite resin. Point 4 was an easily polished material consisting of ultra small particles with a nice aesthetic quality. The dispersion of filler particles is quite low.

The purpose of this research is to determine physical properties of three types of composite resin: Point 4 (microhybrid), Solitaire 2 (packable) and Definite (ormocer).

Materijali i metode

Određeni su bili tlačna i vlačna čvrstoća, dubina polimerizacije i čvrstoća savijanja hibridnog kompozita (Pointa 4), ormocera (Definitea) i kondenzibilnog kompozita (Solitaira 2). Kompozitni materijali rabljeni u ispitivanju navedeni su u Tablici 1. Pripremili smo deset uzoraka od svakoga spomenutog restorativnog materijala za svako testirano fizikalno svojstvo, s konačnim zbrojem od 120 uzoraka.

Materials and methods

Compressive strength, diametral tensile strength, depth of cure and flexural strength of a hybrid composite (Point 4), ormocer (Definite) and packable composite (Solitaire 2) were determined. The composite materials used in this study are listed in Table 1. We made 10 specimens of each restorative material for each physical property tested, resulting in a total of 120 specimens.

Tablica 1. Tehnički profili procijenjenih restorativnih materijala
Table 1 Technical profiles of the restorative materials evaluated

Materijal • Material	Definite	Solitaire 2	Point 4
Matrica • Matrix	Ormocer matrica • Ormocer matrix	UDMA, BISGA, TEGDMA, Tetra funkcionalni monomer • Tetra functional monomer	BISGMA, TEGDM, EBADM
Punila • Fillers	barijevo staklo, silikat • Barium glass, silicate	Ba_2SiO_4, SiO_2, modificirani apatit • modified apatit	BaG, Pigmenti • Pigments
Veličine punila • Filler size	1-1.5	0.7-5-8	0.4
% udjela punila prema težini • Filler content % by weight	77%	75%	76%
% udjela punila prema volumenu • Filler content % by volume	61%	66%	57.2%
Proizvođač • Manufacturer	Degussa, Hanau, Njemačka • Germany	Heraeus Kulzer, Njemačka • Germany	Kerr, Sybron, Orange, Kanada • Canada
Nijansa • Shade	A2	A2	A2
Broj serije • Lot number	30001791	R185218	205585

Test na vlačnu čvrstoću prema promjeru presjeka

Vlačna čvrstoća prema promjeru presjeka procijenjena je prema specifikacijama ADA 27. Smole su bile stavljene u kružni kalup promjera 6 mm i visine 3 mm, te postavljene u slojeve od otprilike 2 mm debljine, a svaki je 40 sekundi polimeriziran svjetlom (ovisno o preporukama proizvođača, svjetlo mora biti što je moguće bliže površini kompozita).

Svjetlosna polimerizacija obavljena je bila pomoću Hiluxa (Benlioğlu, Ankara, Turska) jakosti 450 mW/cm². Zatim su uzorci bili pohranjeni 24 sata u destiliranoj vodi na temperaturi od 37±1°C te je najviša vrijednost primijenjene sile, kad je riječ o neuspjehu kod materijala, određena univerzalnim strojem za ispitivanje (LF Plus, LLOYD Instruments, Ametek Inc, Velika Britanija) kod brzine od 0,5 mm/min. Vlačna čvrstoća u odnosu prema promjeru presjeka bila je određena prema sljedećoj jednadžbi:

Vlačna čvrstoća prema promjeru presjeka (MPa) = 2 x neuspješno opterećenje (N)/ π x promjer x duljina

Diametral Tensile Strength Test

Diametral tensile strength was evaluated according to ADA 27 specifications. The resins were placed in a circular mold 6 mm in diameter and 3 mm height. The resins were placed in increments of approximately 2 mm, each one being light-cured for 40 s (depending of the manufacturer's recommendations, lamp must be as close as possible to the surface of the composite). Light curing was performed using an Hilux (Benlioğlu, Ankara, Turkey) with an intensity of 450 mW/cm². The cured specimens were stored in distilled water at 37±1°C for 24 hours and the peak force-to-failure was determined with a universal testing machine (LF Plus, LLOYD Instruments, Ametek Inc, England) operating at a crosshead speed of 0.5 mm/min. Diametral tensile strength was determined according to the following equation:

Diametral Tensile Strength (MPa) = = 2x Failure load (N)/ π x Diameter x Length

Test na tlačnu čvrstoću

Tlačna je čvrstoća bila procijenjena prema specifikacijama ADA 27. Smole su bile stavljene u kružne kalupe promjera 3 mm i visine 6 mm, a zatim postavljene u slojevima od otprilike 2 mm debljine, a svaki je polimeriziran 40 sekundi (ovisno o preporukama proizvođača). Nakon toga su uzorci bili pohranjeni 24 sata u destiliranoj vodi na temperaturi od 37±1˚C te je najviša vrijednost primijenjene sile, kad je riječ o neuspjehu materijala, određena univerzalnim strojem za ispitivanje (LF Plus, LLOYD Instruments, Ametek Inc, Velika Britanija) kod brzine od 0,5 mm/min. Tlačna je čvrstoća određena prema sljedećoj jednadžbi:

Tlačna čvrstoća (MPa) =
= neuspješno opterećenje (N)/A^2

Test na čvrstoću savijanja

Čvrstoća savijanja procijenjena je prema specifikacijama ISO 4049. Smole su bile postavljene u kalup od nehrđajućeg čelika, dug 25 mm, visok 2 mm i širok 2 mm, a zatim su polimerizirane svjetlom u tri iradijacije - svaka u trajanju 40 sekundi (prema preporukama proizvođača). Nakon toga su uzorci bili pohranjeni 24 sata u destiliranoj vodi na temperaturi od 37±1˚C. Zatim su odloženi u uređaj za savijanje u tri točke na paralelnim osloncima i opterećeni sve dok se nije pojavila fraktura kod brzine od 0,5 mm/min u univerzalnom stroju za testiranje.

Čvrstoća savijanja (MPa)= $3FL/2BH^2$
F: neuspješno opterećenje (N)
L: razmak među osloncima (20 mm)
B: Širina (mm)
H: Visina (mm)

Test na dubinu polimerizacije

Dubina polimerizacije bila je procijenjena prema specifikacijama ISO 4049. Kompozitne su smole bile stavljene u kružni kalup promjera 4 mm i visine 8 mm te su u njima uzorci polimerizirani. Smole su polimerizirane svjetlom 40 sekundi (prema preporukama proizvođača), zatim su uzorci izvađeni iz kružnog kalupa, a nedovoljno polimeriziran mekan restorativni materijal s dna uzorka bio je uklonjen plastičnom spatulom. Visina valjka polimeriziranog materijala bila je izmjerena mikrometrom s točnošću od ± 0,1 mm, a dobivena je vrijednost podijeljena s dva. Tu vrijednost bilježimo pod nazivom dubina polimerizracije prema specifikaciji ISO 4049.

Podaci su nakon toga bili podvrgnuti statističkoj analizi pomoću Kruskal-Wallisova testa i Mann-Whitneyeva *U* testa.

Compressive Strength Test

Compressive Strength was evaluated according to ADA 27 specifications. The resins were placed in a circular mold 3 mm in diameter and 6 mm height. The resins were placed in increments of approximately 2 mm, each one being light-cured for 40 s (depending on the manufacturer's recommendations). The cured specimens were stored in distilled water at 37±1˚C for 24 hours and the peak force-to-failure was determined with a Universal Testing Machine operating at a crosshead speed of 0.5 mm/min. Compressive Strength was determined according to the following equation:

Compressive Strength (MPa) =
= Failure load (N)/A^2

Flexural Strength Test

Flexural Strength was evaluated according to ISO 4049 specifications. The resins were placed in a stainless steel mold 25 mm long, 2 mm high and 2 mm wide. The resins were light cured in three overlapping irradiations of 40 s each (depending on the manufacturer's recommendations) Cured specimens were stored in distilled water at 37±1˚C for 24 hours. The specimens were positioned in a three-point bending apparatus on parallel supports and the loaded until fracture occurred at a cross-head speed of 0.5 mm/min in universal testing machine.

Flexural Strength (MPa)= $3FL/2BH^2$
F: Failure load (N)
L: Between the supports (20 mm)
B Width (mm)
H: Height (mm)

Depth of Cure Test

Depth of cure was evaluated according to ISO 4049 specification. The resins were placed in a circular mold 4 mm in diameter and 8 mm high. We cured specimens in the depth of cure molds. The resins were light-cured for 40s (depending on the manufacturer's recommendations). The specimens were removed from the circular mold, and the inadequately cured soft restorative material was removed from the bottom of the specimen with a plastic spatula. The height of the cylinder of cured material was measured with a micrometer to an accuracy of ± 0.1 mm, and the obtained value was divided by two. This value was recorded as the depth of cure according to ISO 4049.

The data were analyzed using Kruskal Wallis and Mann Whitney-*U* tests.

Rezultati

Prosječni rezultati i standardne devijacije kod testa za vlačnu čvrstoću prema promjeru presjeka prikazane su u Tablici 2. Prema postignutim rezultatima, bilo je znatnih razlika između materijala Definite, Solitaire 2 i Point 4. Tijekom usporedbe rezultata testa za čvrstoću presjeka prema skupinama od dva uzorka, razlike između Solitaire 2 i Definitea, te razlike između Solitaira 2 i Pointa 4 bile su velike, a one između Definitea i Pointa 4 nisu bile znatne. Prosječni rezultati i standardne devijacije za test na tlačnu čvrstoću prikazani su u Tablici 3. Prema rezultatima ispitivanja pronađene su znatne razlike između materijala Definite, Solitaire 2 i Point 4. Tijekom usporedbe u skupinama od dva, razlike između Solitaira 2 i Definitea, te razlike između Solitaira 2 i Pointa 4 pokazale su statističku znatnost. Razlike između Definitea i Pointa 4 nisu bile statistički velike. Prosječni rezultati i standardne devijacije za test čvrstoće savijanja prikazani su u Tablici 4. Prema rezultatima ispitivanja, razlike između Definitea, Solitaira 2 i Pointa 4 nisu bile statistički znatne. Prosječni rezultati i standardne devijacije za test dubine polimerizacije prikazani su u Tablici 5. Prema rezultatima ispitivanja, razlike između Definitea, Solitaira 2 i Pointa 4 statistički su bile znatne. Tijekom usporedbe rezultata dubine polimerizacije prema skupinama od dva, utvrđeno je da su razlike između Definitea i Pointa 4, Definitea i Solitaira 2, te Solitaira 2 i Pointa 4 statistički velike.

Results

The average results and standard deviations for the diametral tensile strength test are shown in Table 2. According to the test results, there were significant differences between Definite, Solitaire 2 and Point 4 materials. When diametral strength test results were compared in groups of two, the differences between Solitaire 2 and Definite and those between Solitaire 2 and Point 4 were significant differences, whereas the differences between Definite and Point 4 were not significant. The average results and standard deviations for the compressive strength test are shown in Table 3. According to the test results, there were significant differences between Definite, Solitaire 2 and Point 4 materials. When compressive strength test results were compared in groups of two, the differences between Solitaire 2 and Definite and those between Solitaire 2 and Point 4 were found to be statistically significant. The differences between Definite and Point 4 were not statistically significant. The average results and standard deviations for the flexural strength test are shown in Table 4. According to the test results, the differences between Definite, Solitaire 2 and Point 4 materials were not found to be statistically significant. The average results and standard deviations for the depth of cure test are shown in Table 5. According to the test results, the differences between Definite, Solitaire 2 and Point 4 materials were found to be statistically significant. When depth of cure test results were compared in groups of two, the differences between Definite and Point 4, Definite and Solitaire 2, and Solitaire 2 and Point 4 were all found to be statistically significant.

Tablica 2. Rezultati testova na vlačnu čvrstoću prema promjeru presjeka
Table 2 Diametral tensile strength test results

Materijal • Material	N	Prosjek • Average	Standardna Devijacija • Standard Deviation
Definite	10	50.82	2.46
Solitaire 2	10	59.74	1.19
Point 4	10	47.12	1.39
Kw=12.54 p=0.002 p<0.05			

Tablica 3. Rezultati testova na tlačnu čvrstoću
Table 3 Compressive strength test results

Materijal • Material	N	Prosjek • Average	Standardna Devijacija • Standard Deviation
Definite	10	174.73	9.58
Solitaire 2	10	248.92	10.33
Point 4	10	202.49	10.11
Kw=13.75 p=0.001 p<0.05			

Tablica 4. Rezultati testova na čvrstoću savijanja
Table 4 Flexural strength test results

Materijal • Material	N	Prosjek • Average	Standardna Devijacija • Standard Deviation
Definite	10	103.15	2.79
Solitaire 2	10	92.97	3.42
Point 4	10	93.09	4.50
Kw=4.25 p=0.119 p>0.05			

Tablica 5. Rezultati testova na dubinu polimerizacije
Table 5 Depth of cure test results

Materijal • Material	N	Prosjek • Average	Standardna Devijacija • Standard Deviation
Definite	10	5.25	0.11
Solitaire 2	10	4.12	0.08
Point 4	10	4.74	0.06
Kw=23.75 p=0.000 p<0.05			

Rasprava

Udjel punila, veličina njihovih čestica i raspodjela, čimbenici su koji itekako utječu na fizikalna svojstva kompozitne smole (6, 10, 11). Visoko punjeni kompozitni materijali mogu postići dobra svojstva i dobri su za kliničku izvedbu (12,13). Frakture u sklopu tijela restoracije i na rubovima navedene su kao velik problem u slučaju neuspjeha u radu s posteriornim kompozitima. Materijalna svojstva koja se odnose na frakture, poput otpornosti, elasticiteta i marginalnog raspada materijala pod opterećenjem, obično se procjenjuju određivanjem čvrstoće savijanja i načina savitljivosti. Dokazano je da volumen punila i razina težine punila kompozita korelira s čvrstoćom materijala i elastičnosti (14, 15). Materijali s većom čvrstoćom savijanja manje su skloni obimnim frakturama restoracije, ali i onima marginalnima (16,17). Naviješteno je i da sastav smolne matrice utječe na mehanička te fizikalna svojstva materijala od kompozitnih smola (18,19).

Prema podacima proizvođača, smolastu fazu konačnog kompozita čini ormocer koji ima sposobnost dvostruke konverzije monomera, što poboljšava fizikalna svojstva materijala. Prema podacima objavljenima u literaturi, čvrstoća savijanja i elastičnost ormocera statistički su iste ili niže od vrijednosti istih parametara kod hibridnih kompozita (6,20,21). Sugerira se da punilo, razina njegova opterećenja te interakcije punila i matrice vjerojatno imaju veći utjecaj na parametre frakture dentalnih kompozita, negoli sama struktura organske matrice (6,22,23).

Između skupina nije bilo statistički znatnih razlika. U našem su istraživanju restorativni materijali Point 4, Definite i Solitaire 2 pokazali velike sličnosti. Dok nisu postojale statistički velike razlike između materijala prema čvrstoći savijanja, težine punila mogle bi se pokazati djelotvornima.

Vlačna čvrstoća prema promjeru presjeka (DTS) i tlačna čvrstoća prihvatljivi su i uobičajeni testovi za ispitivanje dentalnih kompozita (24). U našem su ispitivanju DTS-vrijednosti kompozita bile u rasponu od 40 do 60 MPa, a to je prihvatljivo za takve materijale.

Velika tlačna čvrstoća materijala upućuje na količinu vlačne čvrstoće koju može izdržati. Važnost svojstava kompozitnih smola postala je jasna posljednjih nekoliko godina (25).

Povećanje tlačne čvrstoće omogućuje rascjepe, frakture i pukotine unutar restoracije. A veći udjel punila u matrici poboljšava mehanička svojstva dentalnih kompozita, kao što su tlačna i vlačna čvrstoća prema promjeru presjeka (24,26-28).

Discussion

Filler content, filler size and the distribution of the filler particles were determined to highly influence the physical properties of the composite resin (6, 10, 11). The high fillers loaded composites which are able to achieve good material properties and a good clinical performance (12,13). Fractures within the body of restorations and at the margins have been cited as major problem regarding the failure of posterior composites. The fracture related to material properties, such as fracture resistance, elasticity and the marginal degradation of materials under stress have usually been evaluated by the determination of the material parameters, flexural strength and flexural modulus. It has been shown that the filler volume and filler weight level of the composites correlate with the material strength and elastic modulus (14, 15). Higher flexural strength materials are less prone to bulk fracture of the filling as well as fracture of the margins (16,17). It was suggested that the composition of the resin matrix also influenced the mechanical and physical characteristics of composite resins (18,19).

According to the manufacturer, the resinous phase of the definite composite is composed of ormocer, which has the capacity to double the conversion of monomers, improving the physical properties of the material. Flexural strength and modulus of elasticity of ormocers statistically equal to or lower than those of hybrid composites were reported in literature. (6,20,21). That suggest that filler themselves, filler load level, and the filler-matrix interactions probably have a greater influence on the fracture parameters of dental composites than the structure of the organic matrix (6,22,23). There were no statistically significant differences among all groups. Point 4, Definite and Solitaire 2 restorative materials were also very close in our study. While there was no statistically significant difference between the flexural strengths of the materials, the filler weights could be efficacious.

Diametral tensile strength (DTS) and compressive strength are acceptable and common tests for dental composites (24). In the present study, the composite DTS values were in the 40 to 60 MPa range, which are acceptable values for composites.

A material's high compressive strength indicates the amount of tensile strength that it can withstand. The importance of the characteristics of composite resins has become clear in recent years (25). With the increase of tensile strength, gaps, fractures and cracks can form inside the restoration. An in-

Razlika između rezultata testova vlačne čvrstoće prema promjeru presjeka i tlačne čvrstoće strukturalno različitih materijala Point 4, Solitaire 2 i Definite, pokazala se statistički znatnom. Solitaire 2, zbog većeg udjela punila, postigao je najbolje rezultate.

Test na dubinu polimerizacije vezan je za sljedeće čimbenike: veličinu čestica punila, sastav, nijansu, translucentnost, intenzitet izvora svjetla i duljinu trajanja iradijacije (29-32). Budući da su nijansa, izvor svjetla i duljina trajanja izloženosti iradijaciji svjetlom uređeni prema standardima za sve materijale u našem ispitivanju, ti čimbenici uopće nisu utjecali na dubinu polimerizacije. Ona je također vezana za veličinu čestica punila. Manhart i suradnici došli su do spoznaje da kompoziti s većim česticama punila postižu veću dubinu polimerizacije (5). Prema rezultatima našeg pokusa, velika dubina polimerizacije materijala za definitivni kompozitni ispun mogla bi biti vezana za veličinu čestica punila. Veličina čestice punila uglavnom pojačava penetraciju svjetlosti (33). To je možda još jedan razlog da se poveća dubina polimerizacije. Dok su rezultati našeg istraživanja upućivali na razlike među materijalima s obzirom na tlačnu čvrstoću, vlačnu čvrstoću prema promjeru presjeka i vrijednosti dubine polimerizacije, nije uočena razlika među materijalima s obzirom na čvrstoću savijanja.

Istraživanja koja se bave fizikalnim svojstvima predstavljaju prihvatljiv način procjene materijala od kompozitne smole. Ipak, potrebne su kontrolne kliničke studije kako bi se odredila njihova dugoročna izvedba u fiziološkim uvjetima. Izbor restorativnog materijala oslanja se na očekivana svojstva i zahtjeve svake preparacije ili restoracije.

Zaključci

1. Rezultati testa na vlačnu čvrstoću za materijale Definite, Solitaire 2 i Point 4 upućivali su na slične razine izdržljivosti;
2. Rezultati testa na vlačnu čvrstoću prema promjeru presjeka otkrili su statistički znatne razlike između materijala Definite, Solitaire 2 i Point 4. Solitaire 2 je postigao najbolji rezultat.
3. Rezultati testa na tlačnu čvrstoću pokazali su statistički znatne razlike između materijala Definite, Solitaire 2 i Point 4. Solitaire 2 postigao je najbolje rezultate.
4. Rezultati testa na dubinu polimerizacije otkrili su statistički velike razlike između materijala Definite, Solitaire 2 i Point 4. Definite je postigao najveću vrijednost.

crease in filler content in the matrix improves the mechanical properties of dental composites, such as compressive and diametral tensile strength (24,26-28). The difference between the diametral tensile strength and compressive strength results of the structurally different Point 4, Solitaire 2 and Definite materials was found to be statistically significant. Solitaire 2, which has a higher filler volume, scored the highest.

The depth of cure is related to the following factors: filler size, composition, shade, translucency, intensity of light source, and length of irradiation exposure (29-32). Because the shade, light source and length of irradiation exposure to light were regulated according to standards for all of the materials in our study, these factors had no effect on the depth of cure. Depth of cure is also related to the size of the fillers. Manhart et al. findings that larger particle composites had the greatest depth of cure (5). According to the results of our experiment, definite material's high depth of cure could be related to its filler particle size. A composite resin's particle size increasingly augments the light penetration (33). This is another explanation for the increase in depth of cure. While the results of our study indicated differences between the materials we used concerning compressive strength, diametral tensile strength and depth of cure values, no difference was observed between the values in regard to flexural strength.

Physical property studies are accepted methods to evaluate resin materials. However clinical follow ups are necessary to determine their long-term performance under physiological conditions. The choice of restorative material rests upon the expected properties that each cavity or restoration area demands.

Conclusions

1. The results of the flexural strength test for Definite, Solitaire 2 and Point 4 restorative materials indicated similar durability levels.
2. The results of the diametral tensile strength test revealed statistically significant differences between Definite, Solitaire 2 and Point 4 materials. Solitaire 2 achieved the highest score.
3. The results of the compressive strength test revealed statistically significant differences between Definite, Solitaire 2 and Point 4 materials. Solitaire 2 received the highest score.
4. The results of the depth of cure test revealed statistically significant differences between Definite, Solitaire 2 and Point 4 materials. Definite achieved the highest value.

Abstract
Objectives: The aim of this study was to determine physical properties of three different types of composite resins: Point 4 (microhybrid), Solitaire 2 (packable) and Definite (ormocer). **Materials and Methods:** In the physical section of this study, 10 samples for each of the following tests were prepared from each of the three restorative materials according to standard protocols: compressive strength test (ADA 27), diametral tensile strength test (ADA 27), flexural strength test (ISO 4049) and depth of cure test (ISO 4049). The data were analyzed using Kruskal Wallis and Mann Whitney-*U* tests. **Results:** The compressive, diametral tensile strength, flexural strength, depth of cure test values respectively of the materials were: Point 4 (202.49, 47.12, 93.09, 4.74); Solitaire 2 (248.92, 59.74, 92.97, 4.12); and Definite (174.73, 50.82, 103.15, 5.25). While significant statistical differences were observed in the values of the compressive strength, diametral tensile strength and depth of cure tests ($p<0.05$), no significant variance was found in the results of the flexural strength test ($p>0.05$). **Conclusion:** According to the results of the compressive strength and diametral tensile strength tests, Solitaire 2 received the highest value, whereas Definite scored highest on the depth of cure test.

Received: November 11, 2007
Accepted: May 21, 2008

Address for correspondence
Dr. Şeyda Hergüner Siso
Cumhuriyet University, Sivas
School of Dentistry
Department of Restorative Dentistry,
Turkey
Tel: +90 346 2191010/2701
Fax: +90 346 2191237
seydaher@hotmail.com

Key words
Ormocer; Packable; Hybrid Composite; Physical Properties; Composite Resins; Tensile Strength

Literatura

1. Cobb DS, MacGregor KM, Vargas MA, Denehy GE. The physical properties of packable and conventional posterior resin-based composites: a comparison. J Am Dent Assoc. 2000 Nov;131(11):1610-5.
2. Nash RW, Lowe RA, Leinfelder K. Using packable composites for direct posterior placement. J Am Dent Assoc. 2001 Aug;132(8):1099-104.
3. Wang L, Perlatti P, Lopes IG, Pereira JC. Mechanical properties of dental restorative materials: relative contribution of labaratory test. J Appl Oral Sci. 2003;11(3):162-7.
4. Kawaguchi M, Fukushima T, Horibe T. Effect of monomer structure on the mechanical properties of light-cured composite resins. Dent Mater. 1989;8(1):40-5.
5. Manhart J, Chen HY, Hickel R. The suitability of packable resin composites for posterior restorations. J Am Dent Assoc. 2001;132(5):639-45.
6. Manhart J, Kunzelmann, Chen HY, Hickel R. Mechanical properties and wear behavior of light-cured packable composite resin. Dent Mater. 2000;16(1):33-40.
7. Peutzfeld A. Resin composites in dentistry: the monomer system. Eur J Oral Sci. 1997;105(2):97-116.
8. Jackson RD, Morgan M. The new posterior resins and a simplified placement technique. J Am Dent Assoc. 2000;131(3):375-83.
9. Nash RW, Lowe RA, Leinfelder K. Using packable composites for direct posterior placement. J Am Dent Assoc. 2001;132(8):1099-104.
10. Manhart J, Kunzelmann, Chen HY, Hickel R. Mechanical properties new composite restorative materials. J Biomed Mater Res. 2000;53(4):353-61.
11. Xu X, Burgess JO. Compressive strength, fluoride release and recharge of fluoride- releasing materials. Biomater. 2003;24(14):2451-61.
12. Ruddell DE, Maloney MM, Thompson JY. Effect of novel filler particles on the mechanical and wear properties of dental composites. Dent Mater. 2002; 18(1):72-80.
13. Lohbauer U, Von Der Horst T, Frankenberger R, Kramer N, Petschelt A. Flexural fatique behavior of resin composite dental restoratives. Dent Mater. 2003; 19(5): 435-40.
14. Germain H, Swartz ML, Philips RW, Moore BK. Properties of microfilled composite resins as influenced by filler content. J Dent Res. 1985;64(2):155-60.
15. Gladys S, Van MB, Braem M, Lambrechts P, Vanherle G. Comparative physico-mechanical characterization of new hybrid restorative materials with conventional glass-ionomer and resin composite restorative materiala J Dent Res. 1997;76(4):883-94.
16. Rouley JF, Degronge M. Adhesion. The silent revolution in dentistry Quintessence Pub, Leibzig, Germany, 2000
17. Yap AUJ, Teoh SH. Comparion of flexural properties of composite restoratives using the ISO and miniflexural tests. J Oral Reh. 2003;30:171-7.
18. Atai M, Nekoomanesh M, Hashemi SA, Amani S. Physical and mechanical properties of an experimental dental composite based on a new monomer. Dent Mater. 2004; 20(7):663-8.
19. Lu H, Stansbury JW, Nie J, Berchtold KA, Bowman CN.Development of highly reactive mono-(meth)acrylates as reactive diluents for dimethacrylate-based dental resin systems. Biomaterials. 2005; 26(12):1329-36.
20. Munksgaard EC. Changes in expansion and mechanical strength during water storage of a traditional and three modified resin composites. Acta Odontol Scand. 2002; 60(4):203-7.
21. Asmussen E, Peutzfeld A. Light-emitting diode curing: Influence on selected properties of resin composites. Quintessence Int. 2003; 34(1): 71-5.
22. Ikejima I, Nomoto R, McCabe JF. Shear punch strength and flexural strength of model composites with varying filler volume fraction, particle size and silanation. Dent Mater. 2003;19(3): 206-11.
23. Ruddell DE, Maloney MM, Thompson JY. Effect of novel filler particles on the mechanical and wear properties of dental composites. Dent Mater. 2002; 18(1):72-80.
24. Zandinejad AA, Atai M, Pahlevan A. The effect of ceramic and porous fillers on the mechanical properties of experimental dental composites. Dent Mater. 2006;22(4):382-7.
25. Leinfelder KF. Evaluation of criteria used for assessing the clinical performance of composite resin in posterior teeth. Quintessence Int. 1987;18(8):531-6.
26. Chung KH. The relationship between composition and properties of posterior resin compoites. J Dent Res. 1990;69(3):852-6.
27. Chung KH, Greener H. Correlation between degree of conversion filler concentration and mechanical properties of posterior composite resins. J Oral Reh. 1990;17(5):487-94.
28. Went SL Jr. The effect of heat used as secondary cure upon the physical propertis of three composite resins. I.Diametral tensile strenght, compressive strenght, and marginal dimensional stability. Quintessence Int 1987:18(4):265-71.
29. Baharaw E, Abraham D, Cardosh HS, Helf M. Effect of exposure time on the depth of polymerization of a visible light-cured composites resin. J Oral Reh. 1988:15(2);167-72.
30. Ferracane JL, Greener EH. Fourier transforms infrared analysis of degree of polymerization in unfilled resins: methods comparison. J Dent Res. 1984;63(8):1093-5.
31. Khairy M, Simonsen RJ. Factors viable to effect depth of cure of posterior composite resin. J Dent Res. 1989;68:342.
32. Li Y, Swartz ML, Philips RW, Moore BK, Robert RA. Effect of filler content and size on properties of composites. J Dent Res. 1985;64(12):1396-401.
33. Jain P ,Pershing A. Depth of cure and microleakage with high- intensity and ramped resin-based composite curing lights J Am Dent Assoc. 2003;134(9):1215-23.