

Biyoaktif Rezin Modifiye Cam İyonomer Simanın Mekanik Özelliklerinin Karşılaştırmalı Değerlendirilmesi

Comparative Evaluation Of Mechanical Properties Of A Bioactive Resin Modified Glass Ionomer Cement

Emre Korkut¹, Onur Gezgin¹, Fatih Tulumbacı², Hazal Özer¹, Yağmur Şener¹

¹Necmettin Erbakan Üniversitesi Diş Hekimliği Fakültesi, Çocuk Diş Hekimliği ABD, Konya

²Ankara Yıldırım Beyazıt Üniversitesi Diş Hekimliği Fakültesi, Çocuk Diş Hekimliği ABD, Ankara

ÖZET

AMAÇ: Dental restoratif materyalin fonksiyonel kuvvetlere direnme kabiliyeti, uzun süreli klinik performansı için önemli bir gerekliliktir. Basınç ve bükülme mukavemeti ile yüzey mikro sertliği, dental restoratif malzemelerin önemli fiziksel özellikleridir. Bu çalışmanın amacı dört farklı rezin modifiye cam iyonomer siman (RMGIC)'in mekanik özelliklerini karşılaştırmaktır.

YÖNTEM: Çalışmada kullanılan materyaller; Photac Fil Quick Aplicap (3M ESPE, Minnesota, ABD), GC Fuji II GP (GC Corporation, Tokyo, Japonya), Riva Light Cure (SDI, Illionis, ABD) ve ACTIVA Bioactive (Pulpdent Corporation, Watertown, ABD). Basınç dayanımı, eğilme mukavemeti ve yüzey mikro sertliğini test etmek için ISO standardına göre numuneler hazırlandı (n = 10). Veriler, SPSS yazılımı (sürüm 18, SPSS Inc., Chicago, IL, ABD) kullanılarak analiz edildi. Tek yönlü ANOVA ve Tukey HSD post hoc testi materyallerin arasındaki farkları saptamak için yapıldı (p < 0.05).

BULGULAR: En yüksek basınç ve eğilme mukavemet değerleri ACTIVA Bioactive'den elde edildi. Photac Fil Quick Aplicap'ın yüzey mikro sertlik değerleri ile ACTIVA Bioactive arasında anlamlı fark gözlenmedi. Riva Light Cure, eğilme mukavemeti ve yüzey mikro sertliğinde en düşük değerleri sergiledi.

SONUÇ: Bu çalışmanın sınırlılıkları içinde, ACTIVA Biyoaktif Restoratif materyal, geleneksel RMGIC'lere göre daha iyi mekanik ve fiziksel özellikler göstermiştir. Bununla birlikte, bu dental restoratif materyalin klinik performansını doğrulamak için kontrollü klinik çalışmalar tavsiye edilmektedir.

Anahtar Kelimeler: Biyoaktif, Basınç mukavemeti, Cam-İyonomer Siman, Yüzey mikro sertliği

ABSTRACT

INTRODUCTION: The ability of dental restorative material to resist the functional forces is an important requirement for their long-term clinical performance. Compressive strength, flexural strength and surface microhardness are significant physical properties of dental restorative materials. The purpose of this study is to compare the mechanical properties of four different resin modified glass ionomer cements (RMGICs).

METHODS: Materials used in the study; Photac Fil Quick Aplicap (3M ESPE, Minnesota, ABD), GC Fuji II GP (GC Corporation, Tokyo, Japan), Riva Light Cure (SDI, Illionis, ABD) and ACTIVA Bioactive (Pulpdent Corporation, Watertown, USA). Specimens were prepared (n=10) according to the ISO standard for testing compressive strength, flexural strength and surface microhardness. The data were analyzed using SPSS software (version 18, SPSS Inc., Chicago, IL, USA). One-way ANOVA and Tukey HSD post hoc-test was performed to identify differences between the materials (p<0.05).

RESULTS: The highest compressive and flexural strength values were obtained from ACTIVA Bioactive. There was no significant difference between surface microhardness values of Photac Fil Quick Aplicap and ACTIVA Bioactive. Riva Light Cure exhibited the lowest values for flexural strength and surface microhardness.

CONCLUSION: Within the limitations of this study, ACTIVA Bioactive Restorative material showed better mechanical and physical properties than conventional RMGICs.

Keywords: Bioactive, Compressive strength, Glass-Ionomer Cement, Surface microhardness

INTRODUCTION

Glass Ionomer Cements (GICs) were introduced by Wilson and Kent in 1970's. They have numerous advantages such as being compatible with the color of the tooth, a chemically adhesive material, in addition to

their anticariogenicity and fluoride release.¹ Resin modified glass-ionomer cements (RMGICs) were first produced in 1992 with the development of glass ionomer cement.

Başvuru Tarihi: 22.08.2017

Kabul Tarihi: 15.12.2017

Stronger and less fragile hybrid materials have been produced later by addition of water-soluble and GICs formulation and become compatible materials with resin

composites. RMGICs are composed of fluoroaluminosilicate glasses, polyacrylic acid, resin

composites, photo or chemical initiators and methacrylate monomers.^{1,2}

The physical and mechanical properties of the RMGICs are better compared to conventional GICs. They have a prolonged working time, rapid hardening by visible light, improved aesthetic appearance and translucency and higher early strength.^{3,4} RMGICs contain acid-based and polymerizable components and thus are set by at least two mechanisms. They micromechanically interlock to dentine through infiltration of the collagen network previously exposed by using a polyacrylic acid pretreatment and they chemically bond through ionic interaction of the carboxyl groups from the acid and the calcium ions of the hydroxyapatite crystals within the partially demineralized dentin and enamel. RMGICs are considered as an useful alternative to amalgam in restorative and pediatric dentistry.^{3,5}

ACTIVA BioACTIVE restorative material, an enhanced RMGIC, was introduced by Pulpdent Corporation in 2013. The new products possess the properties of a RMGIC plus a modified resin matrix with improved resilience and physical properties. In addition to the light-polymerization and chemical cure ability, it contains polyacid components and glass particles, which undergo

an acid/base neutralization hardening reaction. Thus, it contains three hardening mechanisms. Also, ACTIVA BioACTIVE restorative contains no bisphenol-A or derivatives and bisphenyl-A-glycidyl methacrylate. Therefore, its increased physical and mechanical properties may provide improved clinical performance and durability. The manufacturer reports that bioactive fillers mimic the physical and chemical properties of natural teeth.^{6,7} However, in the literature review, no data was found on the physical properties of ACTIVA Bioactive restorative material. The ability of the dental restorative material to resist the functional forces is an important requirement for their long-term clinical performance. Compressive strength, flexural strength and surface microhardness are significant physical properties of dental restorative materials.^{7,8} The purpose of this study is to compare the physical properties (compressive strength, flexural strength and Hardness) of RMGICs, namely Photac Fil Quick Aplicap, Riva light Cure, ACTIVA BioACTIVE restorative material and Fuji II.

Material	Manufacturer	Chemical composition
Photac Fil Quick Aplicap	3M, ESPE, Minnesota, ABD	Natrium-calcium-aluminium-lanthanum-fluorosilicate glass, 2-hydroxyethylmethacrylate, difunctional monomers, activator (amine), copolymer of acrylic acid and maleic acids, camphoroquinone stabilisers (radical captors, chelating agents)
Fuji II LC	GC Corporation, Tokyo, Japan	Alumino-fluorosilicate glass, polyacrylic acid, 2-hydroxyethylmethacrylate, 2,2,4-trimethyl hexamethylene dicarbonate, triethylene glycol dimethacrylate
Riva Light Cure	SDI, Bayswater, Australia	Fluoro-aluminosilicate glass, polyacrylic acid, tartaric acid
ACTIVA Bioactive-Restorative	Pulpdent Corporation, Watertown, MA USA	Blend of diurethane and other methacrylates with modified polyacrylic acid (44.6%) Amorphous silica (6.7%) Sodium fluoride (0.75%)

Table 1. Resin based glass ionomer restorative materials evaluated in the study.

MATERIALS AND METHODS

Specimen preparation

Four different RMGIC materials (Table 1) were used for the study. Specimens for the mechanical tests (compressive strength, flexural strength and surface microhardness) were prepared according to the ISO 9917-2:2010 standard.

Compressive strength testing

Cylindrically shaped specimens (8 mm height and 4 mm) were prepared from each material (n=10) using a teflon mold. The material prepared in the form of a capsule was condensed in the mold and excess material was removed by applying a standard force (0.50 kg) between the two glasses. The samples were polymerized on both surfaces by the light-emitting diode curing unit (Elipar Freelight II, 3M ESPE, St. Paul MN, USA) for

40 seconds. The lower and upper surfaces of the obtained specimens were polished with 1200 grits of silicon carbide abrasive. All samples were measured and standardized using a caliper. The specimens were stored in distilled water at 37°C for 24 hours to complete their polymerization. Compressive strength of each specimen

was measured by a universal testing machine (Instron Model No: 4202, Instron Corp., Canton, MA, USA) at a crosshead speed of 1 mm/min and values were recorded. Compressive strength was determined in megapascals (MPa) by dividing the failure load (N) with the specimen cross-section area (mm²).

	Compressive strength (Mpa±SD)	Flexural strength (Mpa±SD)	Surface microhardness (VHN±SD)
Group I-Photac Fil Quick Aplicap (Photac)	167,52±10,68 ^a	84,87±3,36 ^a	71,54±6,76 ^a
Group II-Fuji II LC (Fuji)	164,52±10,97 ^a	81,75±6,67 ^{a,b}	43,27±6,24 ^b
Group III-Riva Light Cure (Riva)	153,65±14,61 ^a	64,36±4,29 ^b	42,34±3,67 ^b
Group IV-ACTIVA Bioactive Restorative (ACTIVA)	182,27±12,36 ^a	96,49±12,56 ^a	65,4±5,66 ^a

Table 2. The mean values and standard deviations of compressive strength, flexural strength and surface microhardness for each group.

Flexural strength testing

The specimens were prepared using a rectangle stainless steel mold with dimensions of 2 x 2 x 25 mm for each group (n=10). Each specimen was subjected to three-point bending test by a universal testing machine (Zwick DmbH & Co.KG, Ulm, Germany) with a crosshead speed of 0.50 mm/min. The distance between the supports was set to 20 mm. The maximum load at specimen failure was recorded and the flexural strength was calculated using the following formula;

$$\alpha = (3FL/2bh^2)$$

where α is the flexural strength, F is the load at fracture (N), L is the specimen length (mm), b is the specimen width (mm), and h is the specimen height (mm).

Surface microhardness testing

Ten disc shaped specimens from each group were prepared using teflon molds with a height of 2 mm and a diameter of 8 mm (n=10). Each sample was subjected to a force of 100 gr for 15 seconds on the sample surface with a Vicker's hardness tester (Matsuzawa Seiki Co. Ltd., MHTZ, Tokyo, Japan) and five measurements were made for each surface. The mean values were recorded as Vicker's Hardness number (VHN).

Statistical Analysis

The data were statistically analyzed using SPSS software (Version 18.0, SPSS Inc., Chicago, IL, USA). One-way ANOVA and Tukey HSD post-hoc test was performed to determine differences between the groups ($p<0.05$).

RESULTS

The mean values and standard deviations of compressive strength, flexural strength and surface microhardness for each material are shown in Table 2. There was no statistically significant difference between the compressive strength of the materials ($p>0.05$). ACTIVA BioACTIVE restorative materials exhibited the highest compressive strength values (182.27±12.36). Also, the highest flexural strength values were exhibited by ACTIVA BioACTIVE (96.49±12.56MPa±Sd) and there was no significant difference between Photac Fil Quick Aplicap, ACTIVA BioACTIVE and Fuji II LC ($p>0.05$), while the lowest flexural strength value was obtained from Riva Light Cure (64.36±4.29MPa±Sd). There was no significant difference for the surface microhardness between Photac Fil Quick Aplicap and ACTIVA BioACTIVE. Riva Light Cure and Fuji II LC had statistically lower surface microhardness than Photac Fil Quick Aplicap and ACTIVA BioACTIVE ($p<0.05$).

DISCUSSION

Various *in vitro* test methods have been performed to predict the clinical performance of the dental restorative materials. The most commonly used mechanical properties to characterize dental materials are compressive strength and flexural strength.⁹ Compressive strength is the ultimate compression stress that the material can withstand. For hard brittle materials, it demonstrates their mechanical behavior under static stretching as reflected in the toughness of the material. Flexural strength is a measure of the tensile

strength. It identifies the amount of stress and force a structure can withstand. Many factors can affect these mechanical properties of RMGICs, such as the chemical composition, microstructure, mixing method, degree of conversion and the interaction of various factors.¹⁰

In this study, the mean compressive strength values for each material were determined to predict the clinical performance and durability of the materials. In previous studies, the compression strength of RMGICs were found to be between 67.61 and 218.46 MPa.¹⁰⁻¹³ According to ISO (International Standards Organization) standards, the materials are considered to be reliable if they have a compressive strength above 130 MPa.¹⁴ The four different RMGIC used in the present study have shown higher compressive strength than the 130 MPa limit set by the ISO standards.

The present study also examined the flexural strengths of the materials. In the literature, the flexural strength values of RMGICs are reported to be between 18.203 and 83.1 MPa.^{10,13,15} The minimum flexural strength requirement for of occlusal restorations was stated as 80 MPa by the ISO standards.¹⁴ The flexural strength values of the materials tested except Riva Ligth Cure in present study was almost compatible with the ISO standards.

The resin component of RMGICs is usually hydroxyethyl methacrylate (HEMA). Photac Fil Quick Aplicap, Fuji II LC and Riva Light Cure that were used in the present study have HEMA as a resin matrix. Authors reported that the RMGICs were manufactured by adding resin monomers (HEMA or Bis-GMA) to the conventional GICs.¹⁰ Previous studies have shown that, compared to conventional GICs, RMGICs exhibit higher mechanical strength, stronger adhesion and lower solubility.^{16, 17}

ACTIVA BioACTIVE restorative material has structural differences from other RMGICs. It is the first bioactive dental material with reactive ionomer glass fillers and a shock-absorbing resin component.¹⁸ These differences may explain the better mechanical and physical properties they have compared to the other RMGICs except Photac Fil Quick Aplicap. In this study, the compressive and flexural strength values for ACTIVA BioACTIVE restorative material are higher than the values required by ISO standards for occlusal restorations. In a study conducted by *Pameijer et al.* (2015), the flexural strength of the ACTIVA BioACTIVE restorative material was compared to other commercial GICs and flexural fatigue of the ACTIVA BioACTIVE restorative was found to be significantly greater than other materials as compatible with the present study.⁷ Our results are consistent with previous studies.^{6, 7, 18}

Surface microhardness is one of the most important physical characteristics of dental restorative materials. Examining microhardness provides an understanding of the setting characteristics and depth of cure of the resin based restorative materials. Also, it has been used as an indicator of degree of conversion in resin based restorative materials. In this study hardness evaluation was carried out 24 hours after polymerization. Previous studies report that 24 hours is sufficient time to reach the maximum hardness.¹⁹⁻²¹

The surface hardness of resin based restorative materials are influenced by the size and amount of filler particles and the distribution of the fillers in the free spaces.²² The smaller glass particle sizes are correlated with higher surface hardness. As the particle size decreases in the light-curing RMGICs, the polymerization depth increases and the surface hardness increases accordingly.²³ Valanezhad et al., investigated the mechanical and physical properties of the new material by adding different amounts of nanoparticle bioactive glass (NBG) to RMGIC. When added at low concentrations the NBG fills the gaps in the matrix. Under stress, the cracks formed were smaller and fewer in number. Also, higher surface hardness values were obtained. With the NBG filling the gaps in the resin matrix, more adhesion surface for polyacrylic acid was obtained and thus, the flexural strength values were increased. When the concentration of NBG is increased, the bonding between the resin matrix and NBG weakens, which negatively affects all mechanical and physical properties.²⁴

In the present study, surface microhardness of the materials was tested using a Vicker's hardness tester. There was no significant difference between Photac Fil Quick Aplicap (group I) and ACTIVA BioACTIVE (group IV). Group I have a smaller particle size (5.56µm) than the other RMGICs (>5.90 µm), while Group IV have bioactive nanoparticles. In the literature review, no data was found about the surface microhardness of ACTIVA BioACTIVE restorative material. However, the results of surface microhardness test obtained from materials except ACTIVA BioACTIVE restorative material were parallel with similar studies.^{15, 25, 26}

Based on these findings, RMGICs can be an alternative compomer or composite resin materials for permanent or especially primary dental restorations. In particular, ACTIVA BioACTIVE restorative, which contains a proprietary and flexible resin matrix with energy absorbing elastomeric components (a mixture of

modified polyacrylic acid and polybutadiene modified diuretene dimethacrylate with a diurea-on and methacrylate) as stated by the manufacturer, can be used in high stress areas where glass ionomer cements are contraindicated.⁷

CONCLUSION

Within the limitations of this study, ACTIVA BioACTIVE restorative material showed highest values mechanical and physical properties compared to conventional RMGICs tested (but not statistically significant). Activa BioACTIVE restorative material met the requirements of minimum standards set by the ISO 4049 as flexural strength of 80 MPa and compressive strength of 130 MPa for occlusal restorations. Controlled clinical studies are recommended to confirm the clinical performance of this dental restorative material.

Financial Support

The authors declare that they have no conflicts of interests and there is no funding source for this study.

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Yazışma Adresi:

Yrd. Doç. Dr. Fatih TULUMBACI
Ankara Yıldırım Beyazıt Üniversitesi
Diş Hekimliği Fakültesi
Çocuk Diş Hekimliği AD
fatihtulumbaci@hotmail.com