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Evaluation of the Effect of Different Bonding Systems and Restorative Materials on Shear Bond Strength in the Repair of High-Viscosity Glass Ionomer Cement

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ABSTRACT

Aim: High viscosity glass ionomer cements have been produced to increase the mechanical properties of glass ionomer cements. The aim of this study is to determine the appropriate adhesive system and restorative material that can be used in fracture repair of high viscosity glass ionomer cements.
Material and Methods: A total of 140 standard size acrylic blocks were used in the study. 14 groups were formed from randomly selected acrylic blocks, with 10 samples in each group. High viscosity glass iomomer cement was placed in the first 13 groups, and resin-modified glass ionomer cement was placed in the last group. After the thermal cycle aging process was applied to all samples, repair restorations were performed with 4 different adhesive systems, 2 different composite resins and 2 different restorative types of glass ionomer cement. After the repair restorations, thermal cycle aging was applied again and the shear bond strengths were evaluated. One-way analysis of variance and Duncan multiple comparison test were used for statistical analysis.
Results: The highest shear bond strength values were obtained by the total etch adhesive system (p<0.001). The lowest shear bond strength values were obtained when high-viscosity glass-iomomer cement without adhesive system was restored with high-viscosity glass iomomer cement (p<0.001).
Conclusion: For higher shear bond strength values in the repair of high-viscosity glass ionomer cements should use to total etch adhesive systems and composite resin.

Yüksek Viskoziteli Cam İyonomer Siman Tamirinde Farklı Bonding Sistemlerinin ve Restoratif Materyallerin Makaslama Bağlantı Dayanımı Üzerine Etkisinin Değerlendirilmesi

Makale Bilgisi

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ÖZET

Amaç: Cam iyonomer simanların mekanik özelliklerini arttırmak amacıyla yüksek viskoziteli cam iyonomer simanlar üretilmiştir. Bu çalışmanın amacı yüksek viskoziteli cam iyonomer simanların kırık tamirinde kullanılabilecek uygun adeziv sistem ve restoratif materyali belirlemektir.
Gereç ve Yöntemler: Çalışmada standart boyutta toplam 140 akrilik blok kullanıldı. Rastgele seçilen akrilik bloklardan her grupta 10'ar örnek olacak şekilde 14 grup oluşturuldu. İlk 13 gruba yüksek viskoziteli cam iyomomer siman, son gruba ise rezin-modifiye cam iyonomer siman yerleştirildi. Tüm örneklere termal siklus ile yaşlandırma işlemi uygulandıktan sonra 4 farklı adeziv sistem, 2 farklı kompozit rezin ve 2 farklı restoratif tipte cam iyonomer siman ile tamir restorayonları yapıldı. Tamir restorasyonlarının ardından tekrar termal siklus ile yaşlandırma işlemi uygulandı ve bağlantı yüzeylerindeki makaslama bağlantı dayanım kuvvetleri değerlendirildi. İstatistiksel analizler için Tek yönlü varyans analizi ve Duncan çoklu karşılaştırma testi kullanıldı.
Bulgular: En yüksek makaslama bağlanma dayanımı değerleri total etch adeziv sistem ile elde edildi (p<0,001). En düşük makaslama bağlanma dayanımı değerleri adeziv sistem kullanılmayan yüksek viskoziteli cam iyomomer simanın yüksek viskoziteli cam iyomomer siman ile restore edildiğinde elde edildi(p<0,001).
Sonuç: Yüksek viskoziteli cam iyonomerler simanların tamirinde, yüksek makaslama bağlanma dayanımı değerleri için, total etch sistemler ile kompozit rezin restorasyonların kullanımı önerilir.
Anahtar kelimeler: Cam iyonomer, kompozit rezin, adeziv sistem, makaslama bağlanma dayanımı, termal siklus

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INTRODUCTION

In today's dentistry practices, with the advances in adhesive techniques, protective and preventive treatments have begun to be preferred and the principle of protecting healthy dental tissues has become more important. Instead of multi-session restorations, the use of single-session direct restoration techniques has been developed.[1]

As permanent direct restorative materials, amalgam, composite resins and glass ionomer cements (GICs) are generally used in routine applications.[2] Amalgam contains 42-45% mercury by weight. The use of amalgam has decreased due to the fact that mercury vapor negatively affects human health, rarely causes allergic reactions, amalgam waste can cause environmental pollution and is not aesthetic.[3] Although composite restorations are highly aesthetic and color compatible, they require technical precision during application. In addition, composite resins may cause problems such as polymerization shrinkage, as a result of the stress occurring within the material, it can lead to microleakage, post-operative sensitivity, discoloration and secondary caries.[4] For this reason, the studies for a durable restorative material that can be used safely in the field of dentistry continues. Glass ionomer cements are among the filling materials routinely used today; It has advantages such as chemical bonding to the tooth, ability to release fluoride, biocompatibility, and a thermal expansion coefficient similar to dental hard tissues.[5,6] In order to improve the mechanical properties of GICs, high viscosity GICs were produced by reducing the filler particle sizes. Moreover, powder-liquid ratio, particle sizes and distributions in high viscosity GICs have been changed.[7,8]

A high viscosity restorative system that can be condensed similar to amalgam (EQUIA; GC Europe, Tokyo, Japan), designed for use in the permanent restoration of Class I, II and V cavities, was introduced to the market in 2007.[9,10] The hardening mechanisms of these newly developed high viscosity cements are the same as traditional GICs, but according to traditional GICs; wear resistance, surface hardness, bending and compression resistance are increased. Studies have reported that, unlike other GICs, early exposure to water does not adversely affect the physical properties of these materials, as the hardening reaction in high viscosity GICs is completed faster.[11,12]

Adhesion is the coming together of two different surfaces by physical or chemical. In restorative applications, adhesion occurs between mineralized tooth structures and filling materials.[13] Many dental adhesive systems have been developed to achieve sufficient bonding strength in enamel and dentin.[14] Today, routinely used systems can be classified depending on the way they are used as three-stage etch and rinse, two-stage etch and rinse, two-stage self-etch and single-stage self-etch adhesive. In etch and rinse systems, the smear layer is removed with orthophosphoric acid and the collagens on the dentin surface are revealed. On the other hand, self-etch adhesives, do not require acid application or washing, and they modify the smear layer by demineralizing the dentin with the acid.[15] Researchers have focused on inventing the ideal adhesive system and adhesive technique for perfect adaptation in dental restorative materials.[16]

In permanent restorations, it is possible for fractures to occur over time for various reasons. In such a case, the necessity of repairing the fracture or completely removing the restoration and making a new restoration is controversial. In this study, it was aimed to determine the appropriate adhesive system and restorative material that can be used in the repair of fractures of high viscosity GICs, which are stated to be used in permanent restorations.

MATERIAL AND METHOD

Preparation of Acrylic Blocks

A total of 140 acrylic blocks of standard size were used in the study. Cylinder-shaped blocks were prepared from cold acrylic (SC Cold Acrylic, Imicryl Kimya, Konya, Turkey) by using silicone molds, 2 cm diameter and 2 cm height. There was a standard slot with a diameter of 6 mm and a depth of 2.5 mm in the middle of each acrylic block (Figure 1). After the acrylic blocks were removed from the molds, the surfaces of them were sanded with 100 and 320 grit silicon carbide sandpaper for standardization.

Figure 1: Preparation of acrylic blocks

Creating Groups

14 groups were created from randomly selected acrylic blocks, with 10 samples in each group (Figure 2). The groups are shown in Table 2. High viscosity GIC (Equia forte fil capsule, GC, Japan) was placed in 13 groups according to the manufacturer's instructions. Resin-modified GIC (Fuji II LC capsule, GC, Japan) was placed in the last group. Glass ionomers in capsule form were mixed in an amalgamator (SYG-200, China). According to the manufacturer's instructions, Equia Coat was applied on Equia forte fil glass ionomers, which may be affected by moisture in the early period, and polymerized for 20 seconds with an LED light device (Woodpecker G, China). The samples were kept in an oven at 37°C for 24 hours in a 100% humidity environment. All GIC surfaces were polished with 100 and 320 grit silicon carbide sandpaper to obtain standard surfaces.

Figure 2: Creation of the samples

Table 2. Formation of the groups

Groups	Repaired surface	Bonding system	Feature of bonding system	Restorative material
Group 1	Equia forte fil	Adper single bond 2	Total etch	Gradia direct posterior
Group 2	Equia forte fil	Clearfil S3 bond	One-stage self etch	Gradia direct posterior
Group 3	Equia forte fil	Futura bond NR	Two-stage self etch	Gradia direct posterior
Group 4	Equia forte fil	All-bond universal	Universal bond	Gradia direct posterior
Group 5	Equia forte fil	Adper single bond 2	Total etch	Filtek P60 posterior
Group 6	Equia forte fil	Clearfil S3 bond	One-stage self etch	Filtek P60 posterior
Group 7	Equia forte fil	Futura bond NR	Two-stage self etch	Filtek P60 posterior
Group 8	Equia forte fil	All-bond universal	Universal bond	Filtek P60 posterior
Group 9	Equia forte fil	Adper single bond 2	Total etch	Fuji II LC
Group 10	Equia forte fil	Clearfil S3 bond	One-stage self etch	Fuji II LC
Group 11	Equia forte fil	Futura bond NR	Two-stage self etch	Fuji II LC
Group 12	Equia forte fil	All-bond universal	Universal bond	Fuji II LC
Group 13	Equia forte fil	-	-	Equia forte fil
Group 14	Fuji II LC	-	-	Fuji II LC

Preparation of Repair Restorations

In this study, 4 different adhesive systems, 2 different composite resins and 2 different restorative types of GIC were used. The materials used are shown in Table 1. As repair material, Gradia direct Posterior (GC, Japan) was used in 4 groups of samples, Filtek P60 posterior (3M ESPE, USA) was used in 4 groups, and resin–modified GIC was used in 4 groups. Four adhesives system was a total etch adhesive system (Adper single bond 2, 3M ESPE, USA), a single-stage self-etch adhesive system (Clearfil S3 bond, Kuraray, Japan), a two-stage self-etch adhesive system (Futura bond NR, Voco, Germany). and a universal adhesive system (All-bond universal, Bisco, USA). They were applied according to the manufacturer's instructions. The same LED light device was used for polymerizations. In another group, high viscosity GIC was placed directly (without applying adhesive agent). Resin-modified GIC was placed on the last group where resin-modified GIC base was used (without applying adhesive agent). All repair materials placed were prepared to be 2.5 mm high and 2.5 mm diameter. The samples were kept in an oven at 37˚C for 24 hours in a 100% humidity environment.

Table 1. Materials used in the study

Materials	Materials Description	Content	Colour	Producer	Lot number
Equia Forte Fil	Bulk Fil glass hybrid restorative system	Powder:Floro-alumino-silicate glass, Polyacrylic acid, oxidised ferric Liquid: polybazic carboxylic acid, distiled water	A2	GC Dental, Tokyo, Japan	1610251
Fuji II LC	Resin-reinforced glass ionomer restorative cement in capsule form	Powder: Floro-alumino-silikat glass Liquid: poliakrilik acid, HEMA, 2,2,4, trimetil heksametilen dikarbonat, TEGDMA	A2	GC Dental, Tokyo, Japan	1611246
Adper single bond 2	Total etch adhesive system	BIS-GMA, HEMA, dimethacrylate, amines, methacrylic copolymer of polyacrylic and polyitaconic, acids, ethanol, water, photoinitiator	-	3M ESPE	N961805
Clearfil S3 bond	One-stage self etch adhesive system	10-MDP, Bisfenol A diglisidmetakrilat, HEMA, etanol, hidrofilik alifatik metakrilat, koloidal silika, kamforokinon, silan, akselatör, iniatör, water	-	Kuraray, Japan	700028
Futura bond NR	Two-stage self etch adhesive system	Bis-GMA, hyroyethyl-methacrylate, BHT, ethanol, organic asit, fluorides	-	Voco, Germany	1719524
All-bond universal	Universal adhesive system	MDP, bis-GMA, ethanol		Bisco, USA	1700001591
Gradia direct posterior	Microfil hybrid composite	Urethane dimethacrylate co-monomer matrix, silica, prepolymerised fillers, fluoroalumino-silicate glass (vol %65)	A2	GC Dental, Tokyo, Japan	1701272
Filtek P60 posterior	Microhybrid	Bisglycidyl ether dimethacrylate (bis-GMA) Urethane dimethacrylate (UDMA), 2,2-bis(4-(2-Methacryl-oxyethoxy)phenyl)propane (BIS-EMA), zirconia/silica filler % 61	A3	3M ESPE, USA	NA13766
EQUIA Forte Coat	Low viscosity nanofilament surface capping resin	50% Metil metakrilat, 0.09% kamforokinon	-	GC Dental, Tokyo, Japan	1608051
K-Etchant syringe	35% phosphoric acid	35% phosphoric acid, kollaida silica	-	Kuraray, Japan	3S0102

Bis-GMA, bisphenol diglycidyl methacrylate; MDP, 10-methacryloyloxydecyl dihydrogen phosphate;

Thermal Cycle Application

Thermal cycling process was carried out using 2 separate water baths at temperatures between 5 °C and 55 °C, in the form of 5000 cycles each (Figure 3). Thermal cycle aging process was applied both before the repair restoration application and after the repair restoration was completed. Dwell time was set as 30s and transfer time was set as 5s in each water bath. After the thermal cycle aging process, the shear bond strengths of the samples were evaluated.

Figure 3: Thermal cycling

Measuring Shear Bond Strength

For shear bond strength testing, each acrylic block was placed in a universal testing machine (LRX 5K Universal Testing Machine, LLOYD Instruments, LRX) (Figure 4). A mechanism with a screw clamping system was used to place the samples. Shear bond strength was measured by subjecting the samples to shear force with a knife-edge tip at a transverse speed of 1.0 mm/min. Force was applied until fracture occurred. These values, where the fracture occurred, determined in Newton, were converted to Megapascals by dividing by the connection surface area.

Figure 4: Shear connection strength test

Fracture Types Analysis

Post-fracture surfaces were classified as adhesive, cohesive and mixed fracture types under a stereomicroscope (Olympus SZ61, Munster, Germany) at x30 magnification.

Statistical Analysis

SPSS program (SPSS 17 for Windows, SPSS Inc., Chicago, IL, USA) was used to analyze the data. The normality assumption of the data was examined with the Shapiro Wilk test and it was determined that the data showed normal distribution ($P>0.05$). With the Levene test, it was determined that the variances of the data were homogeneous ($P>0.05$). For this reason, one-way analysis of variance was used for group comparisons. Duncan multiple comparison test was used for multiple comparisons within groups. Chi-square test for independence was used to examine fracture types.

RESULTS

The shear bond strength values obtained from each group of 4 were compared with the 13th and 14th groups without adhesive system and significant statistical differences were determined ($p<0.001$). In the 10th group, statistical evaluations were performed on 9 specimens in this group due to the failure of one specimen after the thermal cycle. The mean shear bond strength values and standard error obtained from the groups were given in Tables 3-5. In addition, adhesive systems were statistically evaluated within themselves and significant statistical differences were found between different groups with the same adhesive system ($p<0.001$) (Tables 6-9). When the results were evaluated as a whole, the highest shear bond strength value was found in group 5 and the lowest value was found in group 13. Significant statistical differences were found in terms of fracture types. The most common fracture type was cohesive fracture ($p<0.001$) (Graph 1).

Graph 1: Groups in terms of fracture types

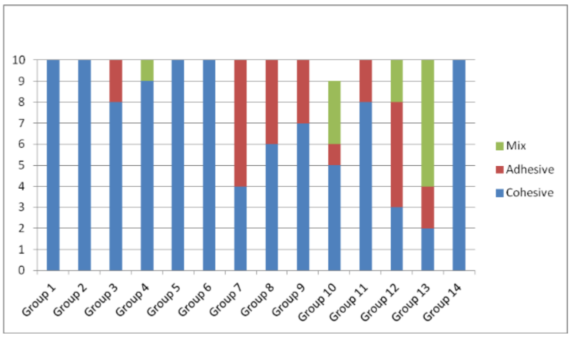

Table 3. Shear connection strength values of the Gradia direct posterior composite applied groups

Groups	n	Mean ± SD
Group 1	10	16,31 ± 1,07a
Group 2	10	13,73 ± 0,74b
Group 3	10	14,89 ± 0,69ab
Group 4	10	11,64 ± 0,42c
Group 13	10	7,17 ± 0,37d
Group 14	10	12,91 ± 0,6bc
P value		<0,001

Table 4. Shear connection strength values of the group applied with Filtek P60 posterior composite

Groups	n	Mean ± SD
Group 5	10	20,64 ± 1,28a
Group 6	10	18,5 ± 1,04a
Group 7	10	15,6 ± 0,75b
Group 8	10	11,71 ± 0,54c
Group 13	10	7,17 ± 0,37d
Group 14	10	12,91 ± 0,6c
P value		<0,001

Table 5. Shear bond strength values of the resin-modified glass ionomer cemented group

Groups	n	Mean ± SD
Group 9	10	12,07 ± 0,41ab
Group 10	9	10,66 ± 0,72b
Group 11	10	11,98 ± 0,72ab
Group 12	10	7,52 ± 0,81c
Group 13	10	7,17 ± 0,37c
Group 14	10	12,91 ± 0,6a
P value		<0,001

Table 6. Shear bond strength values of the group using total etch adhesive system

Groups	n	Mean ± SD
Group 1	10	16,31 ± 1,07b
Group 5	10	20,64 ± 1,28a
Group 9	10	12,07 ± 0,41c
P value		<0,001

Table 7. Shear bond strength values of the group using one-stage self etch adhesive system

Groups	n	Mean ± SD
Group 2	10	13,73 ± 0,74b
Group 6	10	18,50 ± 1,04a
Group 10	9	10,66 ± 0,72c
P value		<0,001

Table 8. Shear bond strength values of the group using two-stage self etch adhesive system

Groups	n	Mean ± SD
Group 3	10	14,89 ± 0,69a
Group 9	10	15,60 ± 0,75a
Group 11	10	11,98 ± 0,72b
P value		<0,001

Table 9. Shear connection strength values of groupsın using universal adhesive system

Groups	n	Mean ± SD
Group 4	10	11,64 ± 0,42a
Group 10	10	11,71 ± 0,54a
Group 12	10	7,52 ± 0,81b
P value		<0,001

DISCUSSION

High viscosity glass ionomers have been developed in order to strengthen the mechanical properties of conventional glass ionomers and increase their wear resistance. High viscosity glass ionomers have the same curing mechanism as conventional glass ionomers, and their solubility is reduced and their surface hardness, abrasion resistance and flexural compression strength are increased. Conventional glass ionomers, high viscosity glass ionomers, resin-modified glass ionomers, composite resins can be used in fracture repair of high viscosity glass ionomers.[17] In our study, different bonding systems and restorative materials that can be used in the repair of fractures and as a permanent restoration option, were investigated.[18]

Adhesive systems play an important role in the bond strength of restorations. Adhesive systems can be classified as etch & rinse adhesives and self-etch adhesives. Etch & rinse adhesive systems remove the smear layer and demineralise the dentin tissue to a depth of several micrometres, exposing the collagen-rich hydroxyapatite structure. Thus, hydrophilic monomers infiltrate collagen fibres.[19] However, it has been reported that the acid roughening step may cause postoperative sensitivity. This step was removed and self-etch adhesives were developed to ensure ease of application and to reduce the possibility of recontamination with blood and saliva during washing and drying of the cavity.[20] Perdigao et al.[21] compared different adhesive systems and found that there was no difference between the systems in terms of shear strength, but marginal leakage was observed more in self-etch systems than in total etch systems. In our study, similar to the results of the study by Barutçugil et al.[22] , it was observed that the bond strength was higher when total etch systems were used. In our study, in the comparison of the use of one-stage self etch adhesive system and two-stage self etch adhesive system in the repair of high viscosity glass ionomer, statistically similar results were found in the groups using Gradia direct posterior and Resin-modified glass ionomer. In the groups using Filtek P60 posterior composite, the shear bond strength values of one-stage self-etch adhesive system and total etch adhesive system were statistically similar. This may be due to the differences in the content of the adhesive systems. Dental restorative materials are affected by temperature and pH changes in the oral environment.[23] Therefore, In our study, aging was done by thermal cycle in order to comply with in-vivo studies. This method mimics the effect of hot and cold substances on teeth.[24] In this study, materials and bonding systems that can be used in the repair of high-viscosity glass ionomer aged by thermal cycling were investigated. A review of the literature revealed no studies in which different materials were used with different adhesive systems for the repair of high-viscosity glass ionomers. Previous studies were generally performed between tooth and restorative materials.[25,26,27]

Shear bond strength tests are one of the frequently preferred methods for the evaluation of dental materials and techniques under in vitro conditions.[27] In this study, shear bond strength test was preferred because it is a practical and common method. Fractures observed in restorative materials cause failure in dental treatment. Fracture types were analysed and classified as adhesive, cohesive or mixed fracture in our study.[28] While adhesive fractures occur between the tooth surface and the restoration, cohesive fractures occur in the restoration. Poitevin et al.[29] suggested that adhesive type fracture may reflect the bond strength values more accurately, but cohesive fractures were more common in the samples in study.

In our study, high viscosity glass ionomer, resin-modified glass ionomer and two different brands of composite resins with microfillers (Gradia direct Posterior, Filtek P60 posterior restorative) were used to repair high viscosity glass ionomer. Shear bond strength was found to be higher in composite resins in all different adhesive techniques. When composite resins were compared, "Filtek P60 posterior" was found to be more durable than Gradia direct posterior in all groups. The reason for this may be the content differences between the brands. In addition, the presence of "zirconia" in the content of Filtek P60 posterior and its absence in Gradia direct posterior may also lead to this difference. When resin-modified glass ionomer was used in the repair of high viscosity glass ionomer, it was observed that the bond strength was lower than composite resins. Summers et al.[30] compared resin-modified glass ionomer and composite resins in the bonding of orthodontic brackets and found that the bond strength of composite resins was higher. Similarly, in our study, values of the shear bond strengths of composite resins (groups 1-8) were quite high.

In all groups, the lowest connection strength was observed in group 13, that is, when high-viscosity glass ionomer was used without any adhesive system in the repair of high-viscosity glass ionomer. When resin-modified glass ionomer was used without any adhesive system in resin-modified glass ionomer repair, the shear bond strength was statistically significantly higher than in group 13.

CONCLUSION

Based on these findings, it can be concluded that an adhesive system should be used in the repair of high viscosity glass ionomers and it would be beneficial to use a total etch system and the type of composite used is also important. It was concluded that resin modified glass ionomers used with an adhesive system were not as successful as composite resins in the repair of high viscosity glass ionomers.

Ethical Approval

Ethics committee approval was not required in this study.

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Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

Design: BÖ, Data collection and processing: AE, Analysis and interpretation: BÖ, AE, Literature Review: BM, Writing: BM, BÖ.

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