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INVESTIGATION OF BOND STRENGTH BETWEEN REINFORCED GLASS CERAMICS AND ADHESIVE SYSTEMS WITH DIFFERENT SHELF LIFE

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Aim: To investigate the bonding capability of resin cement with different shelf-lives and also, to examine the microshear bond strength between various reinforced-glass ceramics and composite resin cement.
Materials and methods: Three different glass ceramic blocks were used in this study; Leucite-reinforced glass ceramic (LRC), lithium silicate glass ceramic reinforced with zirconia (ZLC) and lithium-disilicate glass ceramic (LDC). The blocks were cut with a saw with the thickness of 1 mm. and placed in acrylic molds. The composite rods prepared in 1mm. diameter and they were bonded to ceramic surfaces with resin cement (Multilink N, Ivoclar AG) with three different shelf lives (Group 1: Not-past shelf-life, group 2: shelf-life past 6 months, group 3: Shelf-life past 12 months). Microshear bond strength test was applied to the samples.
Results: According to the statistical analysis, a significant difference was found between leucite-reinforced glass ceramic (LRC) and lithium-disilicate glass ceramic (LDC) in the group 3 (p=0.047). In all three ceramic samples, significant difference was found between group 1 and group 2 (p=0.007). There was no statistically difference between LDC, LRC, ZLC samples in the group 1.
Conclusion: Resin cement with shelf-life past 12 months decreased the bond strength, while resin cement with shelf-life past 6 months did not affect the bond strength.
Key words: Reinforced glass ceramics, Bond strength, Shelf-life

1. INTRODUCTION

The materials used in prosthetic restorations, along with the development of technology and the increase in aesthetic expectations, have led researchers to constantly developing material production. In particular, studies are continuing to ensure that the materials used in all-ceramic restorations have both aesthetics and high durability. Leucite-reinforced glass ceramic (LRC) and lithium-disilicate glass ceramic (LDC) are preferred in prosthetic treatments due to their superior aesthetic properties. However, due to its fragility, studies are continuing to develop the mechanical and physical features. One of the substance used to increase the mechanical properties of all ceramics is zirconia. With the development of zirconia-reinforced lithium silicate (ZLC) material, due to the zirconia in its content, crack propagation in the matrix has been stopped and its durability has increased (1,2,3). Thus, it is possible to produce aesthetic restorations with higher fracture strength.

Long-term clinical success of all ceramic restorations is not only dependent on new materials, but also closely related to the bond strength between materials and dental tissues (4,5). Therefore, adhesive cementation should be applied in the cementation of all ceramics. The long-term success for tooth-cement-ceramic material complex, it is necessary to perform the bonding stages of each surface precisely. It is proved that the system provides the longest and most reliable bonding between the tooth and the resin cement is the “total-etch system” (6). Various studies have been carried out to roughening the ceramic surface with mechanical and chemical processes in order to provide micromechanical bonding between the ceramic surface and the resin cement (7,8). The most accepted method for roughening the ceramic surface is the applying hydrofluoric acid and silane (9-12). In glass ceramics reinforced with zirconia, micromechanical retention is achieved by dissolving the glass matrix with applying the hydroflouric acid (HF) to the surface. However, it is thought that the distribution of zirconia particles in the ZLC ceramic blocks etched with HF acid may affect the bond strength (13). Therefore, in this study, the bond strength between ZLC, LDC and LRC ceramics was also compared as a secondary objective.

Chemical bonding between ceramic surface and resin cement is provided by covalent and hydrogen bonds formed by the application of silane to the roughened ceramic surface. The wettability of the ceramic surface is increased. Silane is a substance that is very sensitive to moisture contamination, has rapid solvent evaporation and a very short shelf-life. Generally, attention is paid to the storage conditions of the material in the clinics, but in some cases, materials that have passed their shelf life for a short time are used. Various studies have been conducted on how a material affects its mechanical and chemical properties related to shelf life, but there is not enough data on how shelf life affects bond strength. Silane and composite resin cement are evaluated as a whole, so in this study, in the same conditions expired silane and composite resin cement were used together.

The first purpose of this study was to investigate the microshear bond strength of reinforced glass ceramics and resin cements with different shelf-lives. Secondary, comparison of bond strength between three different glass ceramics and resin cement. The first null hypothesis was that adhesive systems with different shelf-lives would not affect the bonding capability of ZLC, LRC, LDC glass ceramics. The second null hypothesis was there is no difference on the bond strength between ZLC, LRC, LDC ceramics and resin cement.

2. MATERİALS AND METHODS

Three computer-aided design and computer-aided manufacturing (CAD-CAM) dental ceramic blocks including, leucite-reinforced glass ceramic (LRC), lithium silicate glass ceramic reinforced with zirconia (ZLC) and lithium-disilicate glass ceramic (LDC) were used. The ceramic blocks were cut with a diamond saw (Isomet diamond saw 1000, Buehler, USA) with the thickness of 1 mm. and then crystallized in a ceramic furnace. The ceramic samples placed in the acrylic mold were cleaned in an ultrasonic bath for 2 minutes. Three different ceramic groups were prepared with 6 samples in each group (Group ZLC, Group LDC, Group LRC). Each group was divided into three subgroups.

In the all ceramic groups, 10% hydrofluoric acid (Ultradent, Germany) was applied to the ceramic surfaces for 20 seconds. surfaces were thoroughly washed with air/water spray and then dried. Silane (Monobond N, Ivoclar Vivadent) was applied to ceramic surfaces for 60 seconds.. The composite rods with 1mm. diameter and 5 mm. height were prepared. The composite rods and ceramic samples were bonded with resin cement (Multilink N, Ivoclar AG)

with three different shelf lives (Group 1: Not-past shelf-life, Group 2: Shelf-life past 6 months, Group 3: Shelf-life past 12 months).
The samples were placed in the universal testing device for microshear bond strength test (Shimadzu AG-XD 50kN, Shimadzu Corporation, Japan). A thin wire with 0.2 mm thickness was placed around the composite rod. Before applying force, for each samples it was ensured that the wire is adjacent to the joint surface and aligned with the center of load. Shear force was applied at 0.5 mm/min until debonding occurs. A total of 144 samples were tested. The force required for debonding was recorded in Newton (N) and these results were converted to megapascals (MPa). Statistical analysis was performed using SPSS for Windows 24.0 program and $p<0.05$ was considered statistically significant. First, the data were analyzed for homogeneity (Levene's test) and normality (Kolmogorov-Smirnov test). Due to non-parametric distribution of the data, Mann Whitney U test was used to compare the microshear bond strength.

3. RESULTS

Table 1 shows the standart deviation and average degree of shear bond strength results for the zirconia-reinforced lithium silicate (ZLC), lithium disilicate (LDC), and leucite reinforced ceramic (LRC) specimens between the resin cement. Mann Whitney U test was performed to compare the bonding ability of resin cements with different shelf lives.

Table 1.

	Group 1		Group 2		Group 3	
	Mean Mpa	Standart Deviation	Mean Mpa	Standart Deviation	Mean Mpa	Standart Deviation
LRC	20.0588	6.7484	17.4282	7.6651	15.1651	6.4032
LDC	17.7570	5.4185	19.9273	9.8071	12.6272	5.4609
ZLC	20.4534	6.6879	14.7317	5.4474	14.6525	6.8505

LRC: Leucite Reinforced Ceramic, LDC: Lithium-Disilicate Ceramic, ZLC: Zirconia-Reinforced Lithium Silicate Ceramic.

The p values of the bond strength of resin cements with different shelf lives, and different materials are given in table 2. According to the statistical analysis, while a significant difference was found between LRC and LDC groups with the resin cement which shelf-life past 12 months ($p=0.047$), there was no significant difference was found between LRC and ZLC groups ($p=0.515$), LDC and ZLC groups ($p=0.210$) with the resin cement which shelf-life past 12 months. Also, a significant difference was found between resin cement which are not past shelf-life, and which shelf-life past 12 months in LDC, LRC, ZLC groups ($p=0.007$). In terms of bond strength, there was no statistical difference between LDC, LRC, ZLC ceramics in group 1.

When the shear bond strength values of the resin cement in group 2 were examined, there was no statistical difference between the LRC group and LDC group ($p=0.539$), between the LRC group and ZLC group ($p=0.445$), and between the LDC group and ZLC group ($p=0.184$).

Table 2.

P Value*										
		LRC			LDC			ZLC		
Table 2	Shelf Lives	Group.1	Group.2	Group.3	Group.1	Group.2	Group.3	Group .1	Group.2	Group.3
LRC	Group.1	-	0.270	0.007*	0.305	-	-	0.985	-	-
	Group.2	0.270	-	-	-	0.539	-	-	0.445	-
	Group.3	0.007*	-	-	-	-	0.047*	-	-	0.515
LDC	Group.1	0.305	-	-	-	0.669	0.007*	0.196	-	-
	Group.2	-	0.539	-	0.669	-	-	-	0.184	-
	Group.3	-	-	0.047*	0.007*	-	-	-	-	0.210
ZLC	Group.1	0.985	-	-	0.196	-	-	-	0.290	0.007*
	Group.2	-	0.445	-	-	0.184	-	0.290	-	-
	Group.3	-	-	0.515	-	-	0.210	0.007*	-	-

$p < 0.05$, LRC: Leucite-Reinforced Ceramic, LDC: Lithium-Disilicate Ceramic, ZLC: Lithium silicate reinforced with zirconia

The failures in the samples were examined under the light microscope after the shear bond strength test. When the surfaces were examined, the fractures in which the composite resin was completely separated from the ceramic surface with the cement, no cement residue was observed on the surfaces and the ceramic surface was smooth, were considered as “adhesive failure”, and this type of failure was most common in the "ZLC ceramic group bonded with cement with shelf-life past 12 months". The bonding surface is completely covered with cement; Failures of the bonds within the composite resin were considered as “cohesive failures”. This type of failure was most common in the “LDC ceramic group bonded with not past shelf-life cement”. While cement residues were observed on the ceramic surface, fractures with exposed ceramic surfaces in places were considered as “mixed failure”. The most mixed failures were seen in the “LDC and LRC groups bonded with not past shelf-life cement”.

4. DISCUSSION

Adhesive cementation is applied in the cementation of all-ceramic systems. Before cementation, mechanical and chemical procedures must be applied on the inner surface of the restoration (14,15). In the present study, only chemical bonding processes (HF acid and silane) were applied to the ceramic surface. As a result of roughening glass ceramics with hydrofluoric acid; surface roughness increases and micro-mechanical connection is provided. In glass ceramics reinforced with zirconia, surface roughness can be provided due to the glass matrix it contains. The other chemical bonding method is silane application. The chemical bonding between resin cement and glass ceramics is provided by silane bonding agents. Silanes are bifunctional agents containing organic and inorganic groups. Inorganic groups are attached to the ceramic surface by condensation reaction, and organic groups containing methacrylate are attached to the resin cement (16). Silanes also increase the wettability of the surface, contributing to its micromechanical retention (17). However, the situation is different in the adhesive cementation of zirconia. It has been shown in many studies that the use of silane and resin cement containing phosphate monomer (MDP) positively affects the bond strength of zirconia (18-21). Therefore, in this study, it was aimed to compare the bond strength of glass ceramics reinforced with zirconia and glass ceramics without zirconia. According to the results obtained, the bond strength of zirconia-reinforced glass ceramics with the application of hydrofluoric acid, silane and cement without MDP did not differ from other glass ceramic groups. This result is thought to be due to the glass matrix content of the ZLC material. Similar to the results of present study, Peumans et al. (22) showed that HF acid and silane application were effective in zirconia reinforced lithium disilicate blocks.

One of the factors affecting the clinical success of adhesive systems is storage conditions and shelf life. There are many studies examining the changes in the chemical structure of expired composite resins (23-25). In these studies, mechanical and chemical properties such as microhardness, water sorption, nanoleakage were investigated. There is not enough data on how the use of expired composite resin affects the bond strength. In this study, resin cement which shelf-life past 6 months did not affect the bond strength, while the bond strength decreased in resin cements which shelf-life past 12 months. In a study with application of universal adhesive, it was reported that the adhesive with a 3 month expiration date adversely affected the bond strength (26). The difference with the data obtained from the study may be different due to the material used in the study. Dimethacrylates, which are included in the structure of dentin adhesives, are an important factor in terms of bond strength. Dimethacrylates are not water resistant, over time they hydrolyze into methacrylic acid and cross-diols in the bottle. Studies have determined that this disintegration reduces the bond strength by disrupting the structure of the adhesive over time (27). Therefore, dentin adhesives should be consumed quickly. The situation is different for resin-based materials. Shelf life is extended when stored in appropriate conditions.

Generally, resin-based materials have a shelf life of 18-24 months when stored in a cool place, but it has been reported that the shelf life of materials stored at room temperature is shortened (28). In the present study, the use of resin cements with an expiration date of 12 months, the bond strength decreased, which may be related to the storage of the composite resin at room temperature.

In the present research, only bonding performance of expired shelf-life composite resins was deter- mined, biological and cytotoxic properties of these materials were not tested. Cytotoxicity of these materials is more important than bond strength or chemical properties. Therefore, more in vitro and in vivo studies on this subject are needed.

CONCLUSION

Within the limitations of this research, the following can be concluded:

Shelf-life past 12 months negatively affect the bond strength of composite resin cement and ceramic materials.

Shelf-life past 6 months did not affect the bond strength of composite resin cement and ceramic materials.

The bond strength of zirconia reinforced glass ceramic blocks showed similar bond strength with LDC and LRC ceramics as a result of the application of HF acid, silane and not past shelf-life composite resin cement.

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