IDR International Dental Research

Original Article

Effects of accelerated aging cycles on resin cement-glass ceramic bond strength

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Abstract

Aim: A successful restoration is the result of the proper adhesion between dental tissue, cement and restoration material. The long-term durability of this bond is mandatory for clinical success. The aim of the present study is to investigate the influences of three different thermal cycle applications on resin cement-glass ceramic shear bond strength.

Methodology: In the present study, a single CAD/CAM glass ceramic block and five different resin cements (Panavia V5, RelyX U200, G-CEM LinkForce, RelyX Veneer,and Variolink Esthetic) were used. A total of 240 sections 2 mm in thickness were obtained under water cooling in a precision cutting machine with the aid of a diamond saw. Cementation of glass ceramic samples was conducted in accordance with the instructions of the manufacturer, and the cemented samples were incubated at 37 °C for 24 hours. Afterwards, samples were randomly divided into four groups according to thermal cycle: control group, 1750, 3500 and 7000 cycles (n = 12). Following aging procedures, the samples were tested for shear bond. Statistical analyses were done by using the IBM SPSS 20.0 program. While the ANOVA test was used for intra-group statistical analyses, LSD multi-comparison analysis was used for detection of the inter-group differences. Statistical significance was set at $p < 0.05$.

Results: Although an overall reduction was seen in shear bond of all cement groups following thermal cycle applications, this reduction was found to be statistically significant for Panavia V5, RelyX Veneer and Variolink Esthetic ($p<0.05$). Following 1750 cycles of thermal cycle application, Panavia V5 and G-Cem LinkForce with dual-cure property showed higher shear bond strength than RelyX Veneer and Variolink Esthetic with light-cure structure ($p<0.05$).

Conclusion: The reduction in bond strength following the thermal cycle procedure is associated with water absorption in the resin cement-glass ceramic interface. So resin cement preferred for cementation of restorations is among the key parameters for clinical success.

Keywords: cementation, ceramics, resin cements

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Received: 1 May 2021
Accepted: 28 July 2021

Access Online

DOI: 10.5577/intdentres.2021.vol11.no2.10

How to cite this article: Eskitaşçıoğlu M, Bozbay R, Ünalan Değirmenci B. Effects of accelerated aging cycles on resin cement-glass ceramic bond strength. Int Dent Res 2021;11(2):121-8. https://doi.org/10.5577/intdentres.2021.vol11.no2.10

Introduction

Glass ceramics, which were discovered incidentally in 1953, are still among the most preferred dental materials today due to their aesthetic properties and durability (1, 2). The aesthetic properties of glass ceramics are characterized by two basic optical parameters defined as color and translucency. While it becomes possible to imitate the natural tooth structure with the increase in translucency in many patients, masking ability can be demonstrated with the balance of color and opacity (3). With this solution-oriented approach offered by monolithic glass ceramics, it becomes very easy to ensure patient satisfaction and increase clinical success (4). Dental biomaterials are expected to stay stable in the oral cavity for many years (2), and glass ceramics are quite resistant to the acidic/alkaline corrosive intra-oral environment of 37 °C (5). However, glass ceramic restorations with expanded clinical indications should be resistant to chemical solubility according to ISO 6872:2015/AMD 1:2018 standards (6).

Indirect glass-ceramic restorations are a complex of dental tissue, resin cement used in cementation, and restorative material. And long-term clinical success depends on the success of all elements of the complex. However, resin cements used in the cementation of restorations and expected to provide durable retention and a good marginal seal constitute the clear point of this clinical continuity (4). Adhesive cementation is not just a difficult protocol that takes time, it is also a process in which humidity control is of clinical importance (7). Moisture trapped in the adhesive layer during polymerization causes sub-optimal polymerization of adhesive monomers at the tooth-adhesive-restoration interface (8), increased permeability in the hybrid layer (9), and adhesive phase separation phenomenon due to low conversion of hydrophilic monomers (10). However, it should not be overlooked that the polymerization reaction also contributes to the proper development of polymers involved in adhesion (11). This means that the polymerization mechanism of the clinically preferred resin cement, the type of adhesive, and the number of steps required for cementation gain more importance (12).

In the current literature, many studies are available comparing resin cements with conventional water-based cements, and these studies focus mainly on shear bond strength, tensile bond strength, fracture resistance and marginal gap (13, 14). However, as previously emphasized by Blatz et al., the adhesion between dental tissue and resin cement alone is not the only factor for restoration; the continuity of bond strength between ceramic and resin cement is also a factor (14). Although in vitro studies and systematic reviews have reached a consensus about the combination of micro-mechanic and chemical surface procedures for long-term durable resin bonds between ceramic and resin cement (15, 16), scientific evidence is quite insufficient that evaluates the change of this bond in time and reveals it comparatively (17). The aim of this in vitro study is to evaluate the effects of different thermal cycles on CAD/CAM glass-ceramic and resin cement bond. The null hypothesis of the research is that the applied cycle time and the preferred resin cement will have no effect on the shear bond strength.

Materials and Methods

For the present study, 240 samples (n = 10) 14 mm in length, 12 mm in width and 2 mm in thickness were obtained from a CAD/CAM glass-ceramic block (Cerec Blocs, Dentsply Sirona Corp., Germany) under water cooling with the help of a low-speed diamond saw (IsoMet 1000, Buehler Ltd., Lake Bluff, IL) (Figure 1). Samples were abraded by a single operator with 800-, 1000-, and 1200-grit silicon carbide papers, respectively, for standardization and simulating real CAD/CAM restoration surfaces. All sections were embedded in PVC cylinders with a height of 20 mm and a diameter of 25 mm with the aid of an autopolymerizing acrylic resin (SC cold acrylic, Imicryl, Turkey) with the surface to be cemented exposed. They were then randomly divided into 20 subgroups (n = 12) according to the resin cement to be used and the thermal cycle to be applied (Table 1).

Table 1. Study groups of the research

Study Groups	Resin Cement	Thermocycling Cycle
1	Panavia V5	No Thermocycling (Control)
2	*Panavia V5*	*1750 cycle*
3	Panavia V5	3500 cycle
4	*Panavia V5*	*7000 cycle*
5	RelyX U200	No Thermocycling (Control)
6	*RelyX U200*	*1750 cycle*
7	RelyX U200	3500 cycle
8	*RelyX U200*	*7000 cycle*
9	G-CEM LinkForce	No Thermocycling (Control)
10	*G-CEM LinkForce*	*1750 cycle*
11	G-CEM LinkForce	3500 cycle
12	*G-CEM LinkForce*	*7000 cycle*
13	Variolink Esthetic	No Thermocycling (Control)

14	*Variolink Esthetic*	*1750 cycle*
15	Variolink Esthetic	3500 cycle
16	*Variolink Esthetic*	*7000 cycle*
17	RelyX Veneer	No Thermocycling (Control)
18	*RelyX Veneer*	*1750 cycle*
19	RelyX Veneer	3500 cycle
20	*RelyX Veneer*	*7000 cycle*

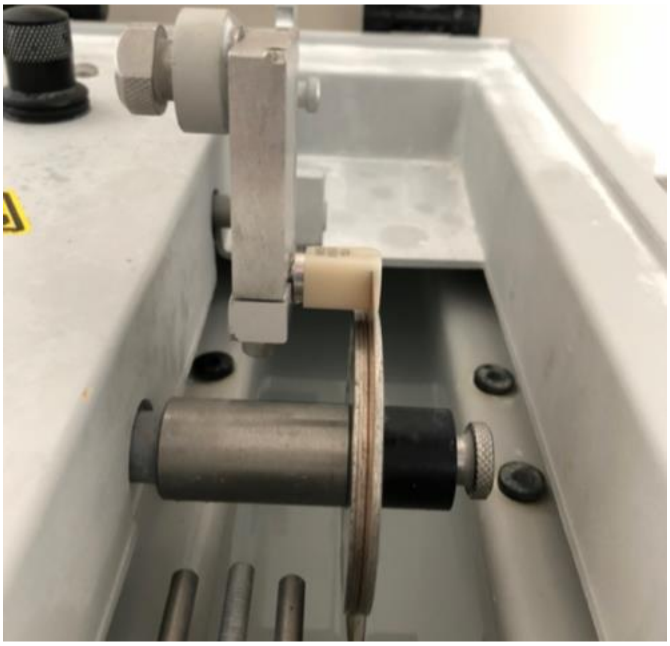

Figure 1. Samples were obtained from CAD / CAM glass ceramic block under water cooling with the help of low-speed diamond saw

Before cementation procedures, glass-ceramic specimens were cleaned in an ultrasonic bath containing 99.5% isopropyl alcohol (1440 D, Odontrobras, Brazil) for 5 minutes, hydrofluoric acid (Ultradent Products, Inc., USA) was applied for 60 seconds, and the specimens were washed with air water spray and dried. For cementation, Panavia V5 (Kuraray Noritake Dental, Japan), G-CEM LinkForce (GC Europe Corp., Belgium) and RelyX U200 (3M ESPE, USA) with dual-cure properties and Variolink Esthetic (Ivoclar Vivadent, Lichtenstein) and RelyX Veneer (3M ESPE, USA) resin cements with light-cure properties were used. The ceramic primer of each resin cement group was applied to the etched porcelain surfaces with the aid of a microbrush for 20 seconds, in accordance with the manufacturer's instructions, and dried gently with air. Clearfil ™ Ceramic Primer Plus was used for Panavia V5, G-Multi Primer was used for G-CEM LinkForce, Monobond S was used for Variolink Esthetic, and RelyX Ceramic Primer was used for RelyX Veneer and RelyX U200. A special plastic apparatus (UltraTester™, Ultradent Products Inc., USA) developed in accordance with ISO 29022:2013 standards was placed on the CAD/CAM glass-ceramic surfaces, whose surface treatments were completed, and resin cement was injected into the cavity on the apparatus (Figure 2). Afterwards, without moving the apparatus, the LED light device (EliparTM FreeLight 2, 3M ESPE, St. Paul, MN, USA) was applied for 40 seconds and resin cements were polymerized, and resin cement cylinders with a diameter of 2.35 mm and a height of 3.0 mm were formed on the glass ceramic surfaces. Glass ceramic-resin cement complexes were randomly divided into four groups according to the thermal cycle to be applied: control group, 1750, 3500 and 7000 cycles (n = 12). During thermal cycle procedures, the device (CORIO CD-B27, Julabo Inc., Germany) was adjusted so that the transfer time of the samples was to be 7 seconds, and the waiting time was 30 seconds in baths with the temperatures of 5 oC and 55 oC (±20 °C). The samples in the control group were kept indirectly in a circulation water bath (Nüve BM 402, Nüve, Ankara, Turkey) at a constant temperature of 37 °C. Specimens subjected to accelerated aging were placed in the metal mold in the universal tester (Shimadzu AGS-X, Shimadzu Corporation, Japan) and fixed with the help of screws. The tip used for the shear test was placed on the glass-ceramic sections at an angle of 90°, and the tip was moved at a speed of 1 mm/min (Figure 3). Shear bond strength forces were recorded in newtons (N). Newton values recorded for measuring the amount of force applied per unit area were converted to megapascals (MPa).

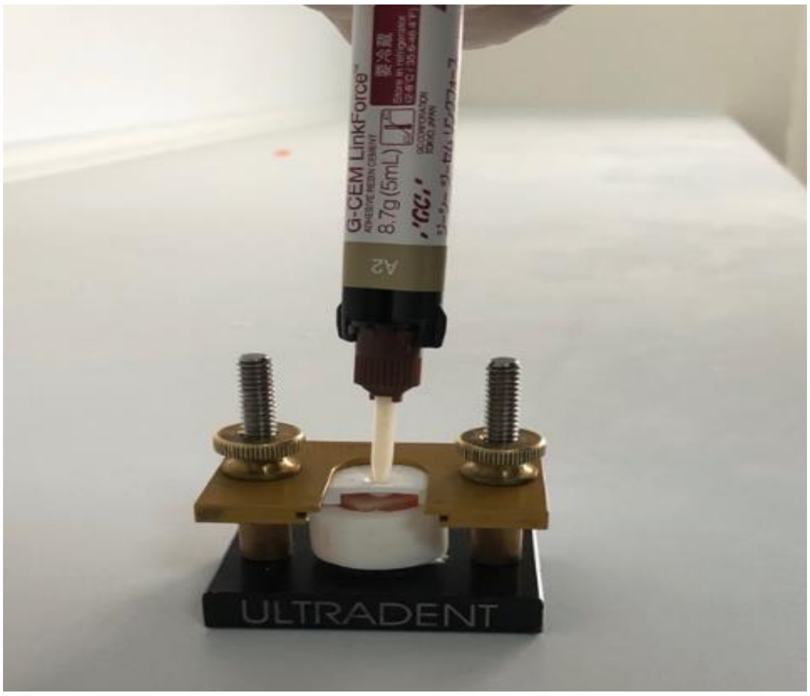

Figure 2. Resin cement was injected into the cavity on the apparatus

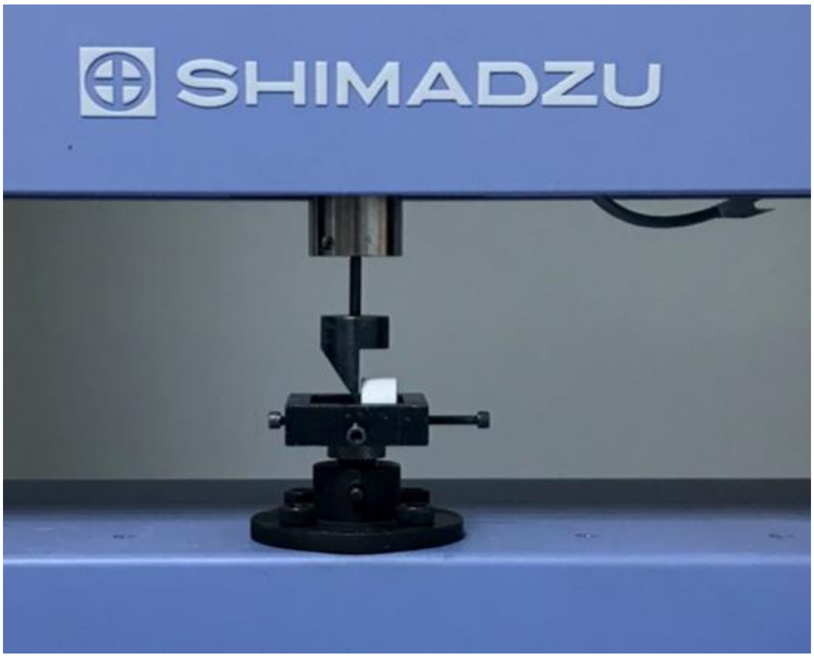

Figure 3. The tip used for the shear test was placed on the glass ceramic sections at an angle of 90°.

Statistical analysis

Statistical analysis of the data was done by using the IBM SPSS Version 22 (IBM SPSS Inc., Armonk, NY, USA). Homogeneity of the test groups was tested with the Levene's test. While an ANOVA test was used for assessment of the homogenously distributed data, an LSD multi-comparison analysis was preferred for detection of the source of inter-group differences. Significance level was set at $p<0.05$.

Results

Descriptive statistical values of shear bond strength according to the resin cement used and the applied thermal cycle are shown in Table 2. ANOVA test results revealed that both the resin cement and the applied thermal cycle had a significant effect on the glass ceramic-resin cement shear bond strength ($p < 0.05$). A decreasing trend was observed in shear bond strength values after thermal cycle application in all cement groups. However, this reduction is statistically significant for only Panavia V5, Variolink Esthetic and RelyX Veneer ($p < 0.05$). The maximum shear bond strength was detected in the Panavia V5 group (5.06 MPa) in which a thermal cycle was not applied. In the control group, Panavia V5 was followed by RelyX U200, G-CEM LinkForce, RelyX Veneer and Variolink Esthetic cement, respectively. However, the difference between bond strength values is not statistically significant ($p > 0.05$) (Table 3). While a statistical difference was found between the shear bond strength values of the cements after 1350 and 3000 cycles of thermal cycle application ($p < 0.05$), this difference was not found to be statistically significant after 7000 cycles of thermal cycle ($p > 0.05$). The minimum bond strength value was found in Variolink Esthetic cement, to which was applied 2.26 MPa and 7000 thermal cycles.

Table 2. Descriptive statistics of shear bond strength according to the resin cement and thermocycling

Resin Cement	Thermocycling Cycle	n	Mean (MPa)	Standard Deviation
Panavia V5	Control	12	5.06	1.73
	1750	*12*	*4.30*	*1.82*
	3500	12	3.32	1.55
	7000	*12*	*2.94*	*1.26*
RelyX U200	Control	12	4.61	1.35
	1750	*12*	*3.16*	*1.52*
	3500	12	3.44	0.87
	7000	*12*	*3.86*	*1.75*
G-CEM LinkForce	Control	12	4.24	1.73
	1750	*12*	*4.41*	*1.82*
	3500	12	4.02	1.55
	7000	*12*	*3.27*	*1.26*
Variolink Esthetic	Control	12	3.78	0.63
	1750	*12*	*3.04*	*1.16*
	3500	12	2.32	0.91
	7000	*12*	*2.26*	*1.62*
RelyX Veneer	Control	12	3.90	0.89
	1750	*12*	*3.09*	*1.11*
	3500	12	2.39	0.78
	7000	*12*	*2.46*	*0.78*

Table 3. Variance analysis results according to the thermocycling cycles

Thermocycling Groups		Sum of Squares	df	Mean Square	F	Sig.
Control	*Between Groups*	*13.376*	*4*	*3.344*	*2.224*	*0.078*
	Within Groups	*82.702*	*55*	*1.504*		
1750 cycle	*Between Groups*	*22.879*	*4*	*5.720*	*2.767*	*0.036*
	Within Groups	*113.681*	*55*	*2.067*		
3500 cycle	*Between Groups*	*25.559*	*4*	*6.390*	*4.854*	*0.002*
	Within Groups	*72.399*	*55*	*1.316*		
7000 cycle	*Between Groups*	*19.733*	*4*	*4.933*	*2.270*	*0.073*
	Within Groups	*119.540*	*55*	*2.173*		

Discussion

Maintaining the clinical success of adhesively cemented restorations for a long time is very challenging in dentistry. Successful survival can be achieved with the continuity of a reliable bond between ceramic, cement and dental tissue (18). The results of the present study originating from the same focal point showed that resin cement selection and thermal cycle had a statistically significant effect on glass ceramic-resin cement shear bond strength ($p < 0.05$). Therefore, the null hypothesis of the research was rejected.

In the cementation of all-ceramic restorations, the use of resin cements is recommended because of less microleakage than conventional cements, low solubility in oral fluids, superior aesthetic properties and high bond strength (19). The result of the study by Fleming et al., which revealed that glass ceramics cemented with resin cement were strengthened structurally, paved the way for the widespread use of resin cements (20). Also, cementation of glass ceramics as adhesive has become a routine clinical protocol based on the report that it reduced the enlargement of the breakages in glass ceramics (21). In light of these data, given the clinical importance of adhesive cementation, five resin cements with different polymerization mechanisms were included in this study, and only the glass ceramic-resin cement bond was analyzed in order to avoid the differences that might be caused by the natural tooth tissue at micro-level.

The temperature changes that occur during the thermal cycle application trigger the changing expansion and contraction in different materials, causing the formation of mechanical stress. For this reason, a thermal cycle is frequently used to simulate mechanical fatigue in a moist oral environment at interfaces that tend to degrade, such as the resin-ceramic interface (22). Sathish et al. also reported that both the resin cement type and the thermal cycle application had a significant effect on the strength value in their study evaluating the bond strength at the ceramic-resin cement interface. The researchers also emphasized that there was a statistically significant decrease in bond strength values in the RelyX group, which is an MDP-free cement, after thermal cycle application (23). Marocho et al. similarly reported that resin cement and aging have a significant effect on the microtensile bond strength to the ceramic surface; however, they emphasized that aging did not cause a significant decrease in the connection with the tooth surface (24). All these data are in parallel with the current results. However, in the study of Vanderlei et al. investigating strength values between three different resin cements with different polymerization and thermal cycle applications, they reported that resin cement type had a significant effect on bond strength. However, a significant bond reduction occurred in no-resin cements following aging done both in dry and humid environments (25). These different findings may have resulted from the researchers' experimentally using adhesive resins with different pH values before using resin cement. In the present study, only the primer surfaces recommended to use in the set in accordance with the instructions of the manufacturers were used.

Today, it is known that dual-cure resin cements used for all-ceramic restorations exhibit full polymerization capacity, and thereby they are more resistant to occlusal loading (26). Acquaviva et al. have emphasized that dual-cure resin cements are advantageous with chemically firming compounds that support conversion even in the presence of radiant energy (27). Also in the current study, light-cure resin cements exhibited lower bond values as compared to dual-cure resin cements. This result is consistent with the literature and may be associated with the fact that the polymerization in dual-cure resin cements is activated with a low energy and has the chance to continue chemically. In a study evaluating the hydrolytic stability of zirconia ceramics cemented with different dual-cured resin cements, it was found that the bonding strength of Clearfil Esthetic cement containing MDP in its primer decreased significantly after being kept in water for 6 months (28). In the current study, Clearfil ceramic primer was used in Panavia V5 and Clearfil Esthetic cements, and this primer contains MDP. Consistent with the literature, a statistically significant decrease was observed in the control group, to which a thermal cycle was not applied, when compared to the groups that underwent 3500 and 7000 cycles. This finding may be due to the water absorption of the bond, in which the bond strength is largely provided by the MDP monomer. However, despite the presence of MDP monomer in the primer of G-Cem LinkForce, another resin cement evaluated in the present study, no significant decrease was found in the bond values after the thermal cycle. This difference may have resulted from the differences between resin cements with regard to monomer compound, initiator and solvent. The current study on the bond strength of the accelerated aging process with glass-ceramics cemented with different resin cements has several limitations, as with any in vivo research design. The most important of these is that the dental tissue is not used, and the glass ceramic-resin cement interface is directly exposed to aging, and the contraction and expansion forces that can be created by the dental tissue are ignored. In addition, only one type of ceramic was used for different resin cements, and the effect of different ceramic materials on bond strength was not investigated. However, glass-ceramic surfaces were only etched before cementation, and the effect of different surface treatment procedures on bond strength was not evaluated. So further in vitro and in vivo studies are required.

Conclusions

The following inferences can be made within the limitations of the study:

1. Before thermal cycle applications, dual-cured Panavia V5, G-CEM LinkForce and RelyX U200 cements exhibited higher bond strength values compared to light-cured resin cements.
2. The decrease observed in the shear bond strength of G-Cem LinkForce and RelyX U200 cements after thermal cycle applications is not statistically significant, unlike other resin cements.
3. After the application of 3500 and 7000 cycles of thermal cycles simulating long-term clinical use, a significant decrease in shear bond strength was detected in Panavia V5, Variolink Esthetic, and RelyX Veneer cements.

Acknowledgements: The authors declare no competing interests.

Peer-review: Externally peer-reviewed.

Author Contributions: Conception – M.E.; Design – R.B., B.Ü.D.; Supervision – M.E.; Materials – B.Ü.D., R.B.; Data Collection and/or Processing – B.Ü.D., M.E.; Analysis and/or Interpretation – R.B.; Literature Review – M.E., B.Ü.D.; Writer – R.B.; B.Ü.D.; Critical Review –M.E.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: This research was financially supported by Van Yüzüncü Yıl University, Scientific Research Project Division (TDH-2018-7021

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