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Effect of newly Developed Resin Cements and Thermocycling on the Strength of Porcelain Laminate Veneers

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ABSTRACT

Aim: The aim of this study was to determine the effect of different luting cements and accelerated artificial aging (AAA) in the fracture resistance of porcelain laminate veneers (PLVs).

Materials and methods: A total of 80 disc-shaped specimens were prepared using computer-aided design/computer-aided milling technology from lithium disilicate glass-ceramic blocks. Specimens (0.5 mm thick, 10 mm diameter) were divided into eight groups of 10 specimens per group. The control groups consisted of specimens without cement and not subjected to AAA (CN group) and specimens prepared without cement but subjected to AAA (CW group). The experimental groups were subjected to AAA and cemented with Variolink Veneer, Variolink Esthetic LC, Variolink Esthetic DC, RelyX Unicem, RelyX Veneer, or RelyX Ultimate. Specimens were individually tested for biaxial flexure on a universal testing machine. One-way analysis of variance and the Tukey's *post hoc* test were used to compare the groups' significance statistically ($\alpha = 0.05$).

Results: The loads to fracture (LTF) values in the CN group were higher than those in the CW and experimental groups. The lowest LTF value was in the CW group (31.5 ± 9.5 N) and the highest LTF value in the CN group (56.7 ± 10.6 N). Tukey's *post hoc* test demonstrated a statistically significant ($p < 0.01$) difference between the CN group and the other groups.

Conclusion: Artificial aging had a significant effect on the LTF value of the tested specimens compared with the resin cements used. Cohesive failure within the PLVs was the most common mode of failure.

Clinical significance: Fatigue strength of dental ceramics and moisture was shown to affect the mechanical properties of all-ceramic restorations. All-ceramic material is extremely sensitive to humidity and thermocycling.

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INTRODUCTION

Porcelain laminate veneers (PLVs) are widely used due to its optical properties, durability, esthetic appeal, and maximum preservation of tooth structure.[1] The success of this restoration is greatly determined by the strength and durability of the bond formed among three different components of bonded veneer complex, which include enamel surface, luting resin, and the porcelain veneer.[2] Improvements in the chemical and physical properties of the resin-based cements and bonding agents also helped in achieving long-term success of PLV.[3] High esthetic and less invasive tooth preparation has increased the popularity of laminate veneers.[2,4] Despite the high clinical performance of these laminates, a drop in their survival rate has been reported as a consequence of ceramic fracture.[1,5]

Adhesive technologies have improved significantly in the last few years, and both dual- and light-cure adhesive resins have been used as luting agents with PLVs.[3,6-8] The new-generation resin cements are capable of forming better bond between the interfaces.[9] Light-curing materials used as luting agents are easily handled and are characterized by controllable hardening times with no time restriction; they are easier to precisely seat the veneer and to accurately remove the excess cement.[10] The dual-curing materials are advantaged by their self-curing component, which favors conversion even in the presence of scarce radiant energy. However, the fluid nature and mixing of two components have given rise to the formation of porosities or voids and incorporation of bubbles; moreover, their handling times are limited.[10]

Material strength is one of the most important mechanical properties that should be determined for a new clinical material or design to assure long-term clinical success. However, there is no standard procedure for testing the strength of a ceramic material. Different *in vitro* tests have been proposed to evaluate the mechanical properties of all-ceramic materials. Uniaxial bending tests, including 3-point and 4-point bending tests, and biaxial bending tests are traditional fracture strength tests but they have been criticized because they lack correlation to clinical performance or the mode of failure.[11-13] The loads to fracture (LTF) test has been widely used since the test environment is close to the service environment.[14,15] A significant difference in the failure load of PLVs has been reported, ranging from 118.9 to 713.3 N based on the testing environment.[13,16] Thermocycling is an *in vitro* method through which the adhesive resin and the tooth are subjected to temperature extremes compatible with the oral cavity.[17] Accelerated artificial aging has been shown to be an efficient method for evaluating the longevity of different dental materials. This technique simulates the clinical parameters by altering the temperature and humidity.[18]

Resin cements have been reported to provide a bond to ceramics that can be advantageous to the prepared tooth structure. The polymerized composite resin provides a support layer of uniform thickness and rigidity to the PLVs that equalizes the differences in properties between dentin and enamel and provides continuous support.[19] Adhesive cement used as a luting agent has been reported as one of the most important factors that will determine the long-term success of PLVs.[5] The cementation of such restorations is crucial for this long-term success of the retention of the laminate restorations.[20,21] Only limited studies are available that investigated the mechanical properties of PLV cemented using newly introduced resin cements. Hence, this study is conducted to evaluate the effect of different newly developed luting cements and artificial aging on the fracture resistance of PLVs. The null hypothesis is that there would be no difference in the fracture resistance of PLVs with different resin cements after being subjected to artificial aging.

MATERIALS AND METHODS

The sample size calculation was done based on a similar study published earlier.[17] Ten specimens per group achieved 90% power to detect differences among the means with a 0.05 (α) significance level (effect size of 0.77). A disk made of a pattern resin (GC America, Oklahoma, OK) with 0.5 mm thickness and 10 mm diameter was fabricated and scanned using computer-aided design (CAD)/computer-aided milling technology (Amann Girrbach, Charlotte, NC). Sixty disk-shaped specimens of A1 shade were milled from lithium disilicate glass-ceramic blocks (IPS e. max CAD; Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's directions. A fine-grit diamond rotary instrument (ZR-Diamonds^{TM}; Komet, San Francisco, CA) was used for disk finishing. Digital calipers (Electronic Digital Caliper, Shan, China) were used to measure the thickness. Specimens were coated on one side with a layer of neutral-shade glaze and fired at 765°C. All specimens were ultrasonically cleaned for 1 minute before cementation.[22]

The specimens were randomly divided into eight groups of 10 specimens per group. Two control groups were used: One without thermocycling (CN group) and another with thermocycling (CW group), and both groups without cement. Six experimental groups were subjected to artificial aging and cemented with Variolink Veneer (VV), Variolink Esthetic LC (VL), Variolink Esthetic DC (VD), RelyX Unicem (RX), RelyX Veneer (RV), or RelyX Ultimate (RU) (Table 1). Before cementation, the porcelain surfaces were treated with hydrofluoric acid for 60 seconds and air-dried. The cementation protocol for each brand was followed based on the manufacturer's recommendations. Each specimen was subjected to a 1-kg weight for 20 seconds. The top surfaces of all specimens were light cured (Elipar Freelight 2; 3M ESPE, St. Paul, MN) for 40 seconds. The specimens were subjected to artificial aging using an Atlas ultraviolet 2000 test machine (Material Testing Technology LLC, Chicago, IL) and were embedded in a vinyl polysiloxane (ExaMix NDS, GC America, Tulsa, OK) impression material that exposed only the glazed surface of each disk specimen.[20] The trays were transferred between two water baths maintained at 65 ± 1°C and 4 ± 1°C, with a 5 seconds submergence in each water bath and a transfer time of 70 seconds for 3,500 cycles.[23,24] A closed-loop servo hydraulic universal testing machine (Material Test System Corporation, ADMET, Norwood, MA) system was used to apply the LTF of the 80 specimens. The load applicator contacted the center of each specimen. The machine was programmed in displacement control to apply an increasing load by moving the actuator 1 mm/minute until the specimen failed. The peak load was recorded on the controller and the maximum LTF (in Newtons) for all specimens were recorded.

RESULTS

The LTF values in the CV group were higher than those in the CW and experimental groups. The lowest LTF value

Table 1: Product names, types, manufacturers, and composition of the resin cement materials used in this study

Product name	*Group*	*Type*	*Manufacturer*	*Composition*
Variolink Veneer	VV	Light cure	Ivoclar Vivadent, Schaan, Liechtenstein	Dimethacrylates Inorganic fillers Ytterbium trifluoride Catalysts and stabilizers Pigments
Variolink Esthetic LC	VL	Light cure	Ivoclar Vivadent, Schaan, Liechtenstein	Urethane dimethacrylate Methacrylate monomers Inorganic fillers Initiators and stabilizers Pigments
Variolink Esthetic DC	VD	Dual cure	Ivoclar Vivadent, Schaan, Liechtenstein	Urethane dimethacrylate Methacrylate monomers Inorganic fillers Initiators and stabilizers Pigments
RelyX Unicem	RX	Dual cure	3M ESPE, St. Paul, Minneapolis, MN	Bifunctional (meth)acrylate Inorganic fillers Initiators and stabilizers Pigments
RelyX Veneer	RV	Light cure	3M ESPE, St. Paul, Minneapolis, MN	BisGMA TEGDMA Zirconia/silica and fumed silica Pigments Photoinitiator
RelyX Ultimate	RU	Dual cure	3M ESPE, St. Paul, Minneapolis, MN	Methacrylate monomers Radiopaque alkaline (basic) fillers Initiator components Stabilizers Rheological additives Fluorescence dye

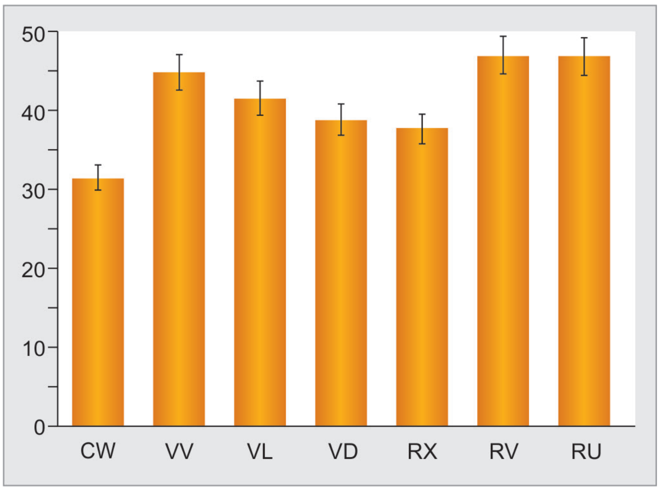
BisGMA: Bisphenol A-glycidyl methacrylate; TEGDMA: Triethylene glycol dimethacrylate

Table 2: Descriptive analysis of load to fracture value (N) of all groups

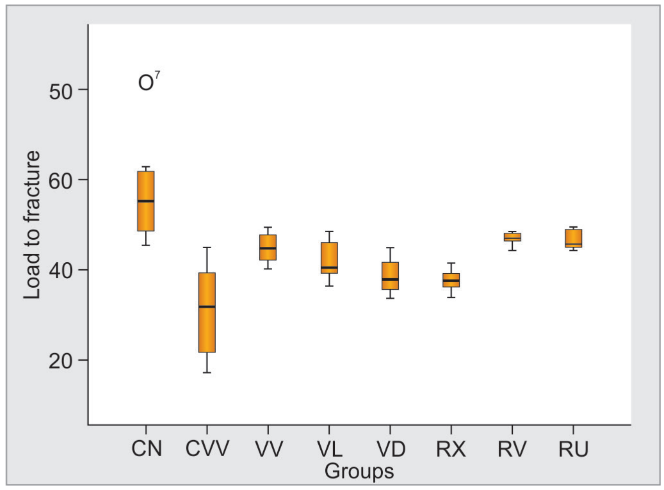
Group	*Sample number*	*Mean (n)*	*Standard deviation*	*Standard error*	*95% confidence interval for mean*		*Minimum*	*Maximum*
					Lower bound	Upper bound		
CN	10	56.78	10.65	3.37	49.16	64.39	45.45	81.78
CW	10	31.51	9.55	3.02	24.68	38.35	17.35	45.09
VV	10	44.88	3.55	1.12	42.34	47.42	40.16	49.63
VL	10	41.56	3.98	1.26	38.72	44.41	36.51	48.47
VD	10	38.84	3.96	1.25	36.01	41.68	33.79	45.01
RX	10	37.72	2.21	0.70	36.14	39.31	33.99	41.58
RV	10	47.04	1.27	0.40	46.13	47.95	44.4	48.47
RU	10	46.81	2.19	0.69	45.24	48.38	44.32	49.57

VV: Variolink Veneer; VL: Variolink Esthetic LC; VD: Variolink Esthetic DC; RX: RelyX Unicem; RV: RelyX Veneer; RU: RelyX Ultimate

was in the CW group (31.5 ± 9.5 N), and the highest mean LTF value was in the CN group (56.7 ± 10.6 N) (Table 2). The LTF values for each group were compared using one-way analysis of variance, as graphically displayed in Graph 1. A statistically significant difference was found among the specimen groups ($p < 0.001$). Tukey's *post hoc* test demonstrated a statistically significant ($p < 0.01$) difference between the CN group and the other groups (CW, VV, VL, VD, RX, RV, and RU) and no statistically significant difference between the experimental groups VV, VL, VD, RX, RV, and RU ($p > 0.05$). The box plots show the spread of the overall LTF value for all of the specimen groups through five statistics: Minimum, first quartile, median, third quartile, and maximum (Graph 2). Scanning electron microscope (SEM) analysis revealed crack propagation through the surface of the ceramic discs; this was the most common cause of failure (Figs 1A and B). Seven specimens broke into pieces.



Graph 1: The load to fracture value (mean ± standard deviation) of all groups



Graph 2: Box plots of LTF value among the groups

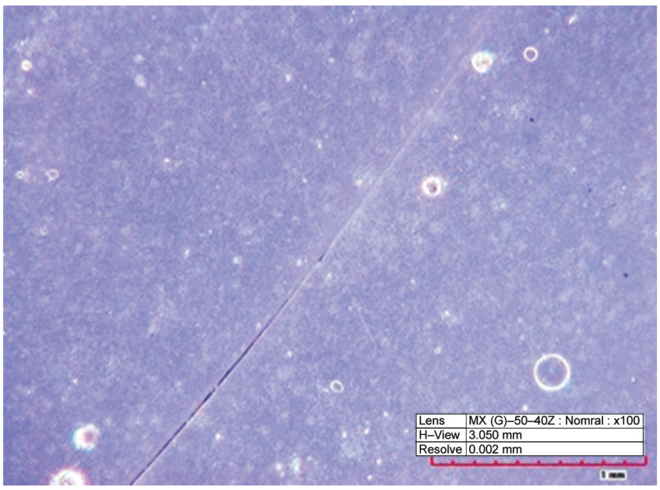


Fig. 1: Common mode of failure of a tested specimen under SEM

DISCUSSION

The success of porcelain veneers is greatly determined by the strength and durability bond between tooth surface, the luting agent, and the porcelain veneer.[25] The resin luting cements are vulnerable to water sorption, polymerization shrinkage, wear, and microleakage. Thus large marginal discrepancies can result in undue exposure of luting material to oral fluids.[26] The luting agent's sealing ability and resistance to the varying stresses are also important factors that influence the extent of leakage.[27] The cement layer thickness should be uniform and thin to avoid any stress in the cement at the bonding interface.[28] The failure of PLV restorations was mainly due to the development of flaws on the glazed surface of the restorations. The cracking and failure of the porcelain laminate restorations can occur as a consequence of thermal variations encountered in the oral environment.[29] The observations from the study proved that artificial aging has a significant negative effect on the strength and survival rate of PLVs.

Fatigue strength of dental ceramics and moisture was shown to affect the mechanical properties of all-ceramic restorations. All-ceramic material is reported to be extremely sensitive to humidity.[30] Thermocycling of all-ceramic material has been shown to have a significant effect on their mechanical properties.[29] Self-glazing was the most appropriate procedure to be carried out to control surface flaws in porcelain restorations. Porosity affects crack propagation behavior of ceramics.[31]

A total of 3,500 cycles were used to approximate 1 year of clinical service of a PLV restoration, assuming that a maximum of ten extreme thermocycles would occur a day with a short dwell time of 5 seconds.[29] Inherited surface voids or cracks on the ceramic discs during thermocycling increased the chances of failure. The distribution of stress generated at the enamel, cement, and ceramic interfaces by shearing forces has a major impact on the failure modes. Hence, the bond quality should be evaluated by numerical bond strength values as well as the failure modes.[32]

The SEM analysis of failed specimens showed surface crack propagation that could explain the low value of fracture resistance of thermocycled specimens. Addison et al[29] evaluated the fracture strength of PLVs subjected to three different temperature regimes and found that thermocycling, regardless of the temperature used, is the most influential factor that affects the LTF value. Comparable results could be explained using the same material and test environment.

The observations of the study revealed that the resin cements did not significantly affect the fracture resistance value. The results found in this study differ from previously published studies, and this may be attributed to the use of different parameters and materials.[33] Further studies are needed to determine the effect of aging and cement used on the tensile and shear bond strength of PLVs.

CONCLUSION

The following conclusions were made based on the observations:

- Thermocycling had a statistically significant negative effect on the LTF value of the PLVs, while the different resin cements used had no effect.
- The SEM revealed that surface flow and cohesive failure of tested specimens were the most common mode for failure.
- Further studies are required to evaluate the color change of the dental ceramic/resin cement set when subjected to other aging methods, with variations in technique for obtaining restorations and other physical characteristics of the involved materials.

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