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Influence of Ceramic Thickness and Luting Agent on the Survival of Bonded Ceramic Veneers. An in-Vitro Study

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Abstract The purpose of thislaboratory study was to examine the compressive strength of ceramic veneers of different thicknesses bonded with two different resin cements.A total of 40 ceramic specimens (5x10mm) in dimensions were fabricated according to manufacturer's instructions. Specimens were randomly divided according to their thicknesses (1 & 2 mm) into two groups (G1, G2), with 20 samples each. Each group was further subdivided two subgroups(RelyX, G-CemLinkAce) according to luting agent applied. All specimens went through thermocycling (1500 cycles between 5-55°C) and compressive test. According to the Kruskal-Wallis test ($P<0.05$), the highest mean compressive strength value was observed in the GC 2mm group (30.670 ± 2.992 MPa), whereas the lowest mean compressive strength value was observed in RelyX 1mm group 10.380 ± 3.278 MPa). The visual analysis data suggest that GC 2mm group was the only group that showed 100% failures as mixed.The ideal thickness of the veneer should be up to 1.0 mm for high translucency of the veneer andproper polymerization of the luting cement.

Keywords: *bonding, dental ceramics, luting agent, polymerization, compressive strength*

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1. Introduction

With the development and improvement of dental ceramics, the use of metal-free restorations has been increasing in the past decades. The use of ceramic materials has increased significantly and been more frequent [1,2,3,4]. These materials present many features, such as translucence, fluorescence, thermal-linear expansion coefficient that is close to dental structure, biological compatibility, chemical stability, compression and abrasion resistance. These properties enable them for being used as a substitute of the natural teeth [1,2,3].

The survival rate of restorations ranges between (82%-96%) in 10-20 years. The main reasons of ceramic failures are fracture of ceramics, which ranges (5.6%-11%) and marginal defects (12%-20%) [4,5].

The clinical success of ceramic restorations is related to the intimate bond between the restoration and tooth structure through the luting agent [6]. The most common adhesive agents are resin cements, which have been reported to provide a bond to ceramics that can be beneficial for the underlying prepared tooth structure. This type of bonding is considered as one important factor for the longevity of restorations, since successful luting increases retention, improves tooth fracture resistance and restoration and reduces the incidence of micro-leakage incidence [7,8,9].

Adhesive bonded restorations offer the advantage of sealing the margins of the restorations while avoiding the solubility of cements. Furthermore, adhesive luting of bonded restorations not only provides minimally invasive restorations but also strengthens the glassy matrix ceramics [10].

With these advances in adhesive technology and good properties of ceramics available on the market, the use of minimal invasive treatments using ceramic veneers have been offered as a treatment option for cases that require minor color, shape and position changes [10,11]. The strength of any restoration material is of clinical interest because the material properties affect the preparation design. General ceramic preparation guidelines require an axial and occlusal tooth reduction of about 1.5 - 2.0 mm to ensure the stability of a restoration [12]. However, the excessive removal of tooth structure may cause potential damage to the dental pulp or reduce the stability of the remaining tooth structure. Thus, using minimal invasive techniques together with a minimal thickness of the restoration can help in the preservation of prepared teeth [12].

Here, it is important to mention that the thickness of the ceramic restorations has an impact on the polymerization of the resin cement, especially when light-cured cements are used. Inadequate polymerization may lead to color instability, decrease in bond strength between prepared tooth structure and restoration, post-operative sensitivity and toxicity from the residual monomer leading to increased risk of microleakage and caries [13,14,15,16].

To our knowledge, literature investigating the influence of the ceramic thickness and luting agent on the survival of ceramic veneers are scarce. In one study, the influence of ceramic veneer thickness on the polymerization of two different resin cements was investigated [17]. Here, it was concluded that with a ceramic thickness of up to 1.2mm, clinically adequate polymerization could be achieved. However, an increase in curing time and/or light intensity was required for veneers thicker than 0.9mm [17]. Nevertheless, different results may be seen due to the thermocycling regimes encountered in the oral environment.

Therefore, the aim of the current study was to investigate the compressive strength of ceramic veneers of different thicknesses luted with two different resin cements. The null hypothesis of this study was that neither ceramic thickness nor luring agent had an influence on the survival of ceramic veneers.

2. Materials and Methods

A total number of 40 ceramic specimens (5x 10mm) were fabricated according to manufacturers instructions from a pressable ceramic material (IPS e.max Press, IvoclarVivadent AG, Schaan, Liechtenstein) from a Low Translucency (LT) ingot (A 3.5). Specimens were divided according to their thicknesses (1 & 2 mm) into two groups (G1, G2), with 20 samples each. Each group was further subdivided according to the luting agent into two subgroups (Rely X, G-Cem Link Ace). A detailed description of different groups is shown in Figure 1.

2.1. Samples Preparation

Forty ceramic specimens were fabricated from pressable ceramic material(IPS e.max Press), then fired and glazed from one side (veneered surface) according to manufacturers recommendations. The specimens were then finished to a smooth surface using 220-, 400-, and 600- sandpaper under water-cooling, followed by polishing using silicone points to ensure an even and smooth surface. Specimens of the different groups (G1, G2) were divided into two subgroups (10 each) and were placed on dark background resin discs (diameter: 30mm, shade: C4) to simulate the color of a dark underlying dental structure. The first two subgroups were luted with two different resin cements namely (RelyX and G-Cem Link Ace). The cements were applied onto the inner surface of the specimens (non-glazed), cement residues were removed and the specimens were pressed for 10 minutes to ensure complete setting of the cement. All specimens were then stored in a dry place at room temperature for 24 hours.

2.2. Thermocycling

To simulate thermal stresses and aging, all samples were thermocycled (SD Mechatronik Thermocycler, SD Mechatronik GmbH, Feldkirchen-Westerham, Germany) for 1500 cycles (5-55°C) with a dwell time of 20 seconds and a transfer time of 10 seconds.

2.3. Measurement of Compressive Strength

The compressive strength of all specimens was measured in a universal testing machine (Model no. 3369, Instron, Canton, USA) with a cross-head speed of 1mm/min. Specimens were loaded till fracture and the maximum load (N) and compressive strength (MPa) were calculated.

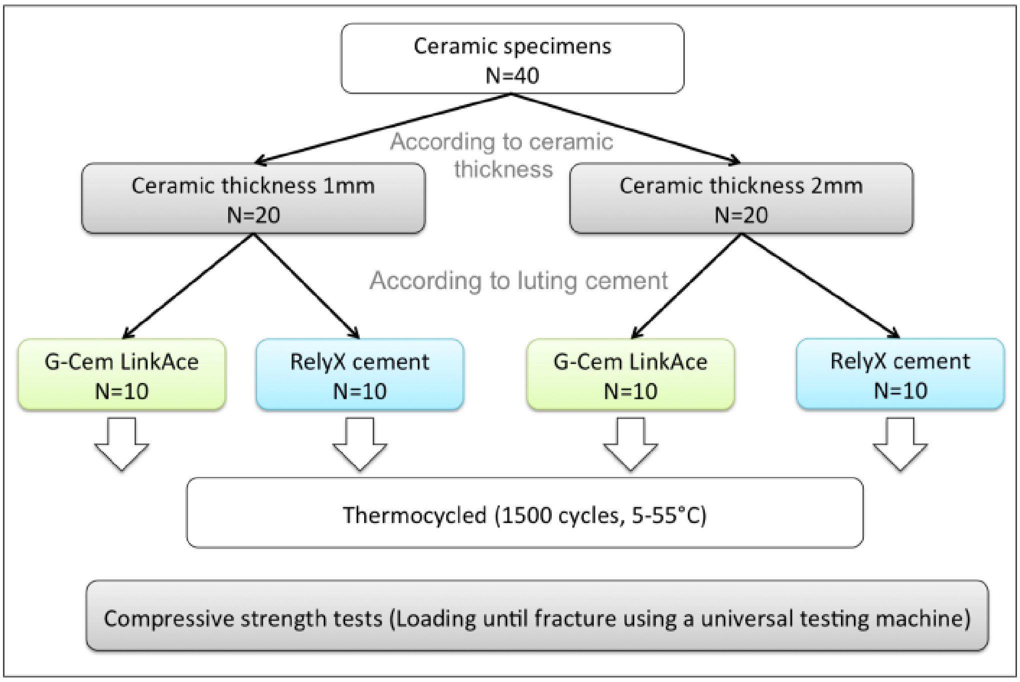

Figure 1. A schematic image showing the different test groups and a brief workflow of the study.

2.4. Microscopic Observation

Following the compressive strength tests, fractured surfaces of selected samples were observed using a light stereomicroscope (Nikon SM2-10, Tokyo, Japan) at a magnification of 20x. This observation was performed to investigate the different types of failure modes within the study groups.

2.5. Statistical Analyses

The results of all groups were recorded in Newton (N) for the maximum load and in MegaPascal(MPa)for the compressive strength. Since the data was not normally distributed the statistical analysis for all groups was performed using non-parametric tests. The Kruskal-Wallis test was used for the statistical analysis of dependency of ceramic thickness and luting agent on the compressive strength of the specimens. The level of significance was set at $p<0.05$. Calculations were made using the statistical software SPSS, version 23.0.0.0 (SPSS Inc., Chicago, IL, USA).

3. Results

Table 1 represents the compressive strength within the different study groups; where the highest mean compressive strength value was observed in the GC 2mm group (30.670 ± 2.992 MPa), whereas the lowest mean compressive strength value was observed in RelyX 1mm group 10.380 ± 3.278 MPa). Statistical significant differences were observed between all study groups ($p<0.05$).

In Table 2, the descriptive statistics of maximum load (N) within the study groups is presented. The highest mean maximum load value was observed in GC 2mm group (2409.858 ± 235.144 N). On the other hand, the lowest mean maximum load value was observed in RelyX-1mm group (815.516 ± 257.385 N). Here, statistically significant differences were seen among all groups ($p<0.05$).

Table 1. Compressive strength values of the different study groups (n=10) in MPa

Study group	Mean value ± SD	Median	Minimum	Maximum
GC 1mm	17.83 ± 5.78	20.07	6.21	22.85
GC 2mm	30.67 ± 2.99	29.74	26.85	34.22
RelyX 1mm	10.38 ± 3.28	11.76	4.57	12.57
RelyX 2mm	15.38 ± 3.04	15.39	11.86	19.87

Table 2. Maximum load values of the different study groups (n=10) in N

Study group	Mean value ± SD	Median	Minimum	Maximum
GC 1mm	1401.06 ± 454.36	1577.97	487.98	1794.47
GC 2mm	2409.86 ± 235.14	2336.48	2109.17	2688.01
RelyX 1mm	815.52 ± 257.38	924.17	359.32	987.13
RelyX 2mm	1207.29 ± 238.23	1208.93	931.55	1560.31

As the sample size within each study group was small, nonparametric tests were used to study whether statistical significant differences existed between the study groups in terms of both compressive strength (MPa) and maximum load (N). Here, the Kruskal-Wallis test showed significant statistical differences at a significance level of 0.05 ($p <0.05$). Both ceramic thickness (P value < 0.05) and luting cements (material) ($P< 0.05$) factors had statistical significant effect on the maximum load. Furthermore, statistical data suggested that both ceramic thickness ($P=0.000$) and luting cements ($P=0.000$) had a significant effect on the compressive strength of the study groups. However, their interactive effect was not found to be significant ($P=0.07$).

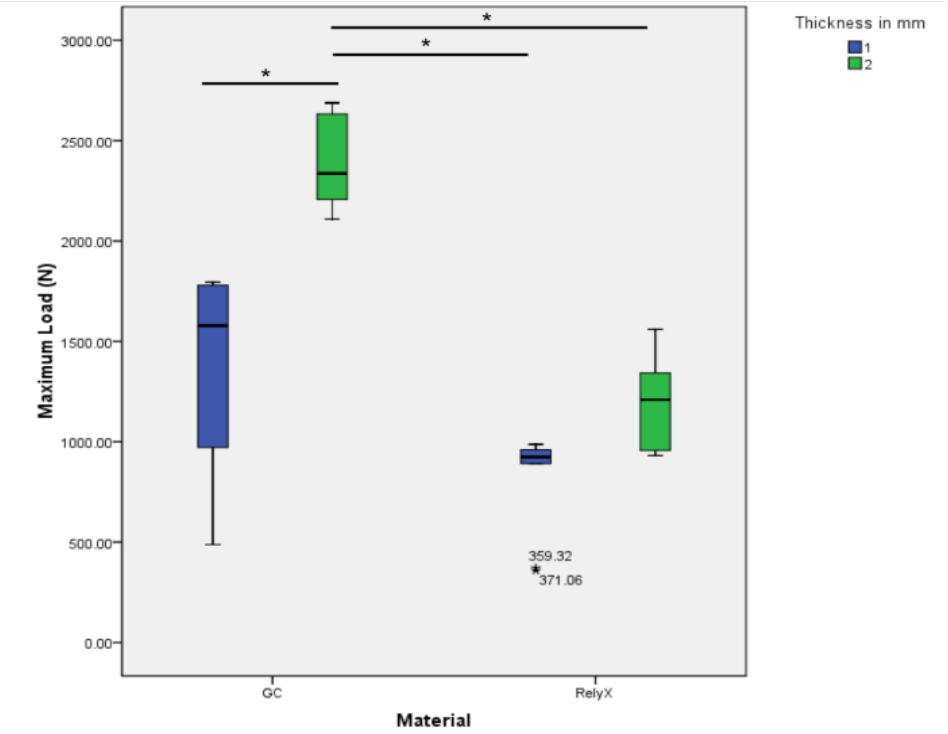

Figure 2. The mean maximum load to fracture values represented in boxplots. The lines (*) represent statistical significant differences between the studied groups.

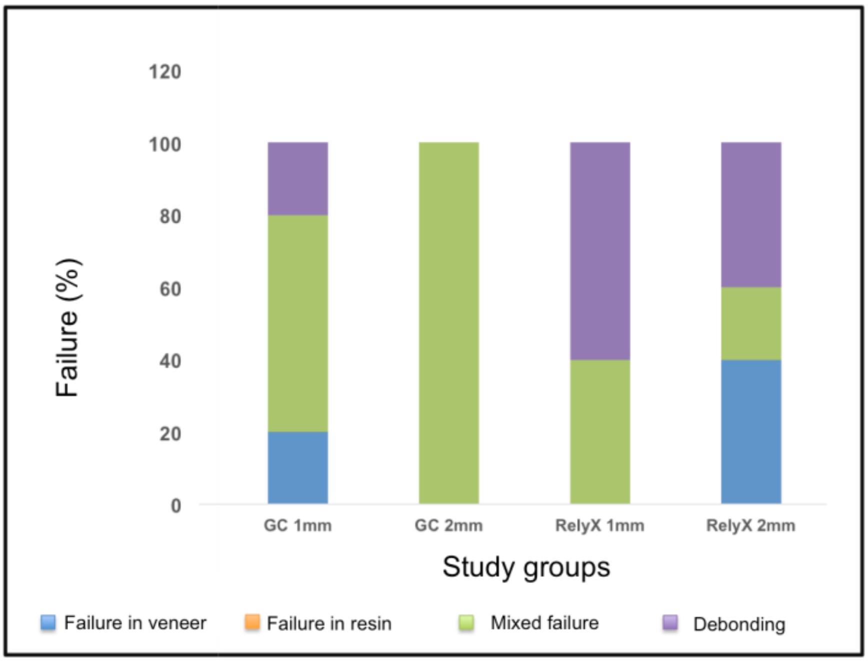

Figure 3. Graphical representation of the different types of failure modes and their percentage failure within the study groups. It can be clearly noticed that no failures in resin were observed among all groups.

Figure 2 represents the maximum load of all groups. The highest maximum load required to break the material in compression was observed in the GC 2mm group with a median of 2336.48 N and a maximum value of 2688.01 N. Whereas, the lowest maximum load to break a material was observed in RelyX-1mm group with a median value of 924.17 N and maximum value of 987.13 N. Moreover, Figure 2 showed that two values of maximum load observed in group RelyX-1mm could be considered as outliers compared to other observed values (359.32 N and 371.06 N)

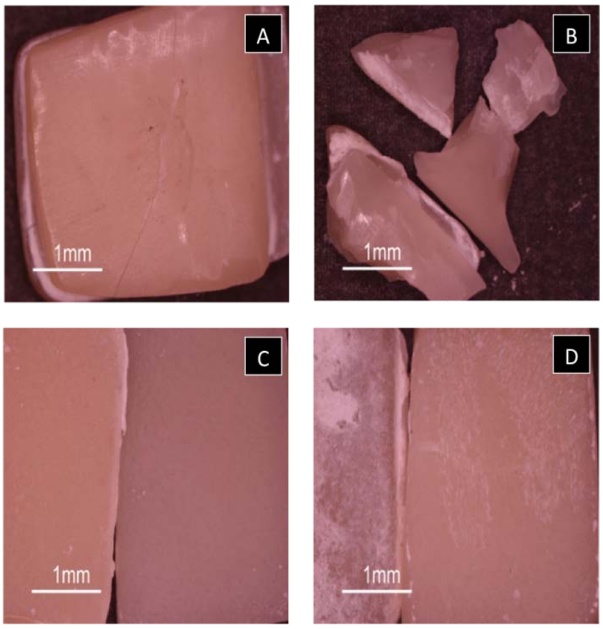

Figure 4. Representative stereomicroscope photomicrographs (magnification x20). A: Depicting failure of GC 1mm sample in veneer itself. B: Depicting mixed failure of GC 2mm sample. C: Depicting adhesive failure of RelyX 1mm sample at the interface of veneer and resin composite, and D: Depicting adhesive failure of Rely X 2mm sample at the interface of veneer and resin composite.

Figure 3 presents the failure modes of the fractured specimens. Predominantly, mixed failure mode was observed in most of the groups. However, in the Rely X 1 mm group, most failures occurred due to debonding, i.e., 60%. Similarly, the RelyX 2mm group showed more or less the same trend of debonding, i.e., 40%. The GC 2mm group was the only group that showed 100% failures as mixed. The typical failure modes can be optically seen in Figure 4.

4. Discussion

This study evaluated the survival of ceramic veneers of different thicknesses and luted with two different resin cements. The hypothesis of this study was rejected, since both thickness and luting agent showed a direct influence on the compressive strength of the tested ceramic veneers.

Clinical success of ceramic resins is dependent upon different factors. One of the most important factors which determines the strength of veneer adherence to the tooth structure is the type of cement used for bonding it [18,19].

Failure of veneers can be due to the flaw development on the cemented surface of the restoration [20,21]. The fracture resistance of all ceramic materials can be increased by luting agents through the penetration into these flaws and irregularities of the restoration's internal surface. Therefore, they inhibit the crack propagation [1,19,21].

Some studies showed that the survival of ceramic veneers don't only depend on tested variables, but also rely on patient-related factors, materials and operator-related factors [20].

In addition, clinical investigations are costly and it is disputable from an ethical point of view to test materials in patients without preclinical tests. In this manner, laboratory aging and in vitro testing methods are applied in a way to simulate the intra-oral circumstance as nearly as could be expected under the circumstances [20].

In a recent study, it was recommended that expansive imperfections on the surface of the ceramic veneers may become extended because of the thermocycling regimes usually experienced in the oral environment [20]. It was proposed by the authors that at lower strength levels an asymmetry created in the survival likelihood distributions, demonstrative of bigger surface flaws being imposed by adverse tensile stresses on the specimen surface by the thermocycling regimes [20].

The material exhibiting highest tension values - G Cem - is a dual-curing cement. The mechanical properties of the bond to enamel as well as to dentin give it the most advantageous characteristics [22].

The polymerization of resin cement is initiated chemically or by the emission of a certain light [18]. Like that of resin composites, resin cement polymerization is not complete even in ideal clinical environments and this significantly affects the mechanical properties of resin cements [23]. Blackman et al. (1990) evaluated DC of dual-cure resin cements applied in ceramic inlay. They showed that the polymerization ratio of dual cure resin cements in ceramic inlay thicknesses up to 3 mm is acceptable [24]. Incomplete polymerization is one of the most important causes of resin cement failure in clinical settings, so the optimization of DC is necessary to improve the physical properties of resin cements [22,25].

Peumans et al. showed that light emission through ceramic veneers is linked to a 40 to 50% reduction in light intensity. They also concluded that ceramic thickness is more important than color and opacity of the ceramic in reducing the light intensity passed through the veneer. [23,26] In addition, Linden et al. (1991) demonstrated that the opacity of the ceramic veneer affects light intensity in thicknesses exceeding 0.7 mm [27]. Both studies recommended the use of dual cure resin cement in ceramic veneers with thicknesses of over 1 mm. The results of the current study confirm their findings and it is suggested that light cure resin cements in ceramic veneers of less than 1 mm be used.

The incomplete polymerization of the resin cement results in both a low degree of conversion and the presence of a greater quantity of residual monomers, which can affect the physical properties of the restoration [17]. A hydrolytic degradation of resin cement is one of the consequences of water sorption over time. This degradation occurs because the resin cement chemical bonds are broken or the material is softened by the water action [28]. It should be borne in mind that the thickness of the veneer up to 1,0 mm and its high translucency guarantee the correct polymerization of the laurel cement, allowing the use of light-curing material. In the case of higher restoration thickness or increased color saturation, consideration should be given to the chances of good polymerization and the use of dual-curing material [28].

Further more, according to Cho et al. their study results showed that thickness of 0.9 mm can be considered to be the critical thickness for DC resin cement [17].

5. Conclusions

In conclusion, it should be borne in mind that the thickness of the veneer up to 1.0 mm and its high translucency guarantee the correct polymerization of the luting cement, which allows the use of light-cured material. In the case of a higher restoration thickness or increased color saturation, the chances of good polymerization should be considered and the use of dual-curing material should be taken into account.

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