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Fracture resistance of lithium disilicate ceramic cemented on dentin with different curing strategies

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Objectives: To determine the effect of lithium disilicate ceramic thickness and curing mode of resin cement on the compressive fracture resistance of ceramic restored on dentin.

Materials & Methods: The ceramic disk-shaped specimens with a diameter of 7 -mm with different thickness of 0.8-mm and 1.5-mm were produced equally from CAD/CAM lithium disilicate ceramic block (e.max CAD). The specimen disk was cemented on flattened dentin using universal adhesive (Single Bond Universal; SBU) with resin cement (RelyX Ultimate; ULT) in two different curing modes (n=8); 1) light-curing of adhesive and resin cement (LL) and 2) co-curing of adhesive through light-curing of resin cement (AL). The compressive fracture load was indented perpendicular to the restorative surface using a universal testing machine until the restoration was fractured. The fracture loading (N) was statistically analyzed using two-way ANOVA and Tukey's Post-Hoc test (α=0.05).

Results: The ceramic thickness and curing mode of resin cement were statistically significant at $p<0.05$. The thicker restorative material could withstand higher fracture resistance. The cementation with adhesive and resin cement in light-curing mode SBU/ULT(LL) performed better fracture resistance than co-curing mode SBU/ULT(AL) at the same thickness.

Conclusion: The adequate thickness of lithium disilicate ceramic improved fracture resistance. The separately light-curing on adhesive and cement has been recommended for adhesive cementation to increase the fracture resistance of restoration.

Keywords: auto-curing mode, CAD/CAM, curing mode, fracture resistance, light-curing mode

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Introduction

Nowadays, dentistry of dental restorative, esthetic outcomes are significantly demanded. The development of digital dentistry combined for a better solution in restoration, especially for CAD/CAM technologically advanced. Lithium disilicate glass-ceramic is an all-ceramic system currently developed to increase mechanical property and enhance translucency [1, 2]. It is widely used in single and multi-unit dental restorations, regularly for dental crowns, bridges, and veneers. According to clinical studies, lithium disilicate crown has a satisfaction survival rate of 98.4% after eight years of functioning [3]. However, the fracture is the main factor of restoration failure [4]. The way to increase the fracture resistance of the ceramic restoration is to cement with tooth structure [5]. Thus, it is crucial to select the proper type of ceramic materials, thickness, and cementing agents to achieve a durable bond.

Several kinds of resin-based luting agents are recommended for cementation of restoration. However, it is essential to achieve adequate polymerization of luting resin under restoration. Because the degree of monomer conversion of the resin is related to the final mechanical properties

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of the material [6]. Furthermore, curing modes of dual-cured adhesive systems were reported to affect the bond strength of indirect composite restorations to dentin as auto-curing modes could lower the bond strength than when the resin cement is light-cured [7]. However, only a few studies evaluated the fracture resistance of ceramic restoration bonded tooth with different adhesively-cementation. The purpose of this study was to determine the compressive fracture resistance of lithium disilicate ceramic in different thicknesses restored with various curing modes of resin cement.

Materials & methods

Teeth preparation

Thirty-two extracted non-carious human third molars from aged 18-40 were collected under a protocol reviewed and approved by the Ethical Reinforcement for Human Research of Mahidol University (COE MU-DT/PY-IRB 2020/021.1906). The teeth were stored in a 0.1% thymol solution at 4°C until used. Each tooth was embedded in the center of a 3-cm diameter of polyvinyl chloride (PVC) mold with self-cured embedding resin (Specifix-40 curing agent; Struers, Ballerup, Denmark). The occlusal third of the crown was cut off parallel to the occlusal surface with a high-speed cutting machine (Accutom-50; Struers, Ballerup, Denmark). Standardized dentin surface smear layer was produced with wet-sanded 320-grit SiC paper (Carbimet; Buehler, IL, USA) using a polishing machine (RotoPol-21; Struers, Copenhagen, Denmark) [8], as shown in Figure 1A. The flattened dentin surfaces were carefully examined for remaining enamel and pulp tissue under the stereomicroscope (SMZ-2T; Nikon, Tokyo, Japan).

Material preparation

The lithium disilicate ceramic blocks (e.max CAD; Ivoclar Vivadent, Schaan, Liechtenstein) were milled to a cylinder-shaped with a 7 mm diameter using CAD/CAM milling system (inLab CAD software version 18.0 and inLab MC XL milling unit; Dentsply Sirona, Bensheim, Germany). Each cylinder-shaped material was sliced with a high-speed precision cutting machine (Accutom-50; Struers) to obtain 16 disks of 0.8-mm and 1.5-mm thickness, as presented in Figure 1B. The inner surface of the ceramic disk was polished with 240-grit SiC paper. The outer surface of the disk was applied with IPS e.max CAD Crystall/Glaze Paste (Ivoclar Vivadent, Schaan, Liechtenstein). After glazing, all specimens were fired in a compatible ceramic furnace (Programat® P500, Ivoclar Vivadent, Schaan, Liechtenstein) following the manufacturer's instruction. Finally, all disks were measured with a digital vernier caliper (CD-6' SX, Mitutoyo, Kanagawa, Japan) to verify the thickness.

Cementation process

All ceramic disks were pretreated with 5% hydrofluoric acid etching (HF; IPS Ceramic Etching Gel, Ivoclar Vivadent, NY, USA) for 20 s. The ceramic disks were cleaned with running tap water for 60 s, then the surface was air-dried. The surface was treated with silane primer (Monobond N, Ivoclar Vivadent, Schaan, Liechtenstein) and left for 60 s, then gently air-dried. The pretreated ceramic disk was cemented randomly onto the prepared dentin surface following two different curing modes (Table 1). The first curing mode (LL), the adhesive (Scotchbond Universal; 3M ESPE, Seefeld, Germany; 'SBU') was applied to the dentin surface with rubbing for 20 s and gently air-dried for 5 s. The adhesive was cured for 10 s using a polywave LED light-curing unit (Bluephase N; Ivoclar Vivadent, Schaan, Liechtenstein) at high mode at the light intensity around 1,000 mW/cm^2.

The ceramic disks were cemented with dual-cure resin cement (RelyX Ultimate; 3M ESPE, Seefeld, Germany; 'ULT') under a constant seating force of 1-kg for 1 min, then an excessive cement was removed with a microbrush. The restoration was polymerized using a polywave LED light-curing unit, for 20 s of each surface at four proximal surfaces and top surface, with a total light-curing time of 100 s. The second curing mode (AL), the adhesive and cementation were similar to the first curing mode except for the adhesive was not separately polymerized with a light curing unit. After cementation, all specimens were kept at 100% humidity at 37°C for 24h, then transferred to pre-warmed artificial saliva at 37°C and stored for an additional 6 d.

Compressive fracture resistance testing

The cemented restoration was aligned to the center of the universal testing machine (Instron 5566, Instron Ltd., Buckinghamshire, England). A round 2-mm-diameter steel indenter was loaded in compressive force with a crosshead speed of 0.5 mm/min until the restoration failed. The failure load specimen was recorded in Newtons (N), as present in Figure 1C.

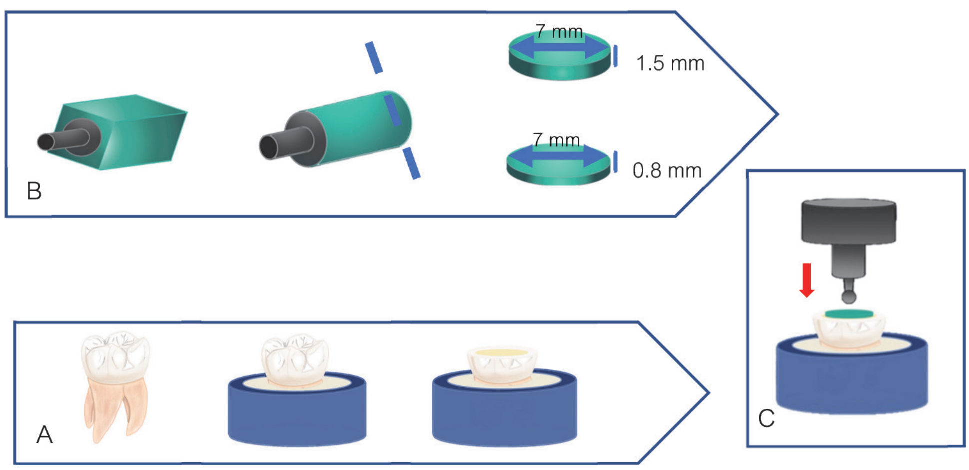

Figure 1 Specimen preparation and compressive fracture resistance testing. A tooth was embedded with self-cured acrylic in PVC mold, and the occlusal enamel was cut off, exposing the flat dentin surface (A). The CAD/CAM resin-matrix-ceramic block was milled and sliced to form 7 mm-diameter of restoration with 0.8-mm and 1.5-mm thickness (B). After cementation, the specimen was loaded with axial force using a 2-mm diameter stainless steel round indenter until fracture (C).

Table 1 Adhesive and resin cement strategies in this study

Resin cement	Mode of polymerization	Procedures
Single Bond Universal and RelyX Ultimate **(SBU/ULT)**	Light-curing for adhesive and cement **(LL)**	**Adhesive**: Apply SBU following the self-etch mode; Dry the dentin with gentle air, apply the adhesive to the dentin, rub it for 20s, gentle air dry for 5s, then light-cure for 10s. **Cement**: Mix the ULT base and catalyst paste on the mixing pad, apply to the inner surface of the material disk, and place on the prepared dentin, remove excessive cement, then light-cure for 20s/surface (total of 100s).
	Auto-curing for adhesive and Light-curing for cement **(AL)**	**Adhesive**: Apply SBU following the self-etch mode; Dry the dentin with gentle air, apply the adhesive to the dentin, rub it for 20s, gentle air dry for 5s, and leave it in place. **Cement**: Mix the ULT base and catalyst paste on the mixing pad, apply to the inner surface of the material disk, and place on the prepared dentin, remove excessive cement, then light-cure for 20s/surface (total of 100s).

Statistical analysis

The compressive fracture load data was analysed with the Shapiro-Wilk test and Levene's test to affirm the normal distribution and the homogeneity of variances. The two-way analysis of variance (ANOVA) was used to analyze the ceramic thickness and curing mode factors and followed by Tukey's post hoc test with R statistics (R Foundation for Statistical Computing, Vienna, Austria, version 3.6.0). All tests were employed at a significant level of 5% ($p<0.05$).

Results

The fracture load of all groups is presented in Figure 2. The two-way ANOVA revealed that ceramic thickness and curing mode statistically significantly influenced fracture resistance ($p<0.01$). The highest fracture resistance was for e-max at 1.5-mm with SBU/ULT(LL). The lowest fracture load was for e-max at 0.8-mm with SBU/ULT(AL). Regarding curing mode, the 'LL' group has a higher fracture load for both 0.8-mm and 1.5-mm ceramic thickness than the 'AL' group.

Discussion

This study aimed to evaluate the influence of ceramic thickness and curing mode to the fracture resistance of ceramics under compressive fracture load. The result showed that the thicker ceramic significantly increased fracture resistance of ceramics restoration and the LL group was significantly higher fracture resistance than the AL group at the same ceramic thickness. Therefore, the null hypothesis of this study had to be rejected.

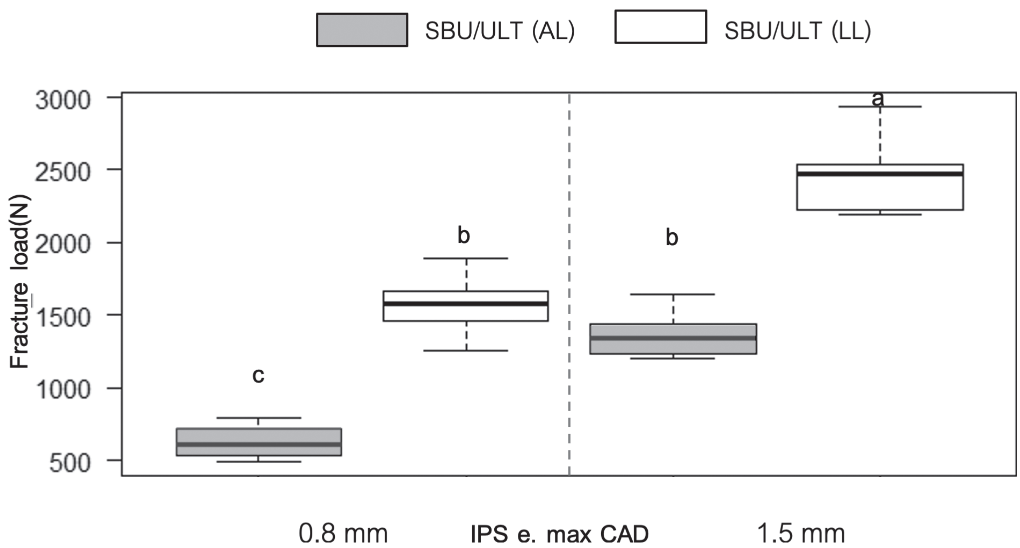

Figure 2 Boxplots representing the fracture loading on the IPS e. max CAD with the thickness of 0.8-mm and 1.5-mm restored on flattened dentin. The boxes extend from the first quartile (Q1) to the third quartile (Q3), the thick horizontal line in the box represents the median fracture loading, and the black dot in the box represents the mean value. The whiskers extend to the minimum and maximum values.

The fracture resistance of cemented restoration on dentin was higher for the 1.5-mm ceramic thickness than the 0.8-mm ceramic thickness. The result corroborated the previous studies [9-11], in which the thicker glass ceramic and composite crown restoration showed the higher fracture strength. Moreover, the thicker restorative material generally resulted in higher fracture resistance [10-13].

Regarding the curing mode of adhesive on fracture resistance, the 'LL' group revealed a significantly higher fracture resistance than the 'AL' group. The use of this adhesive with RelyX Ultimate following the recommendation from the company was either with or without light-curing. However, it was known that the degree of conversion (DC) of auto/self-cured adhesive was lower than light-curing [14]. A low degree of conversion reduces the bond strength [15] and increases the adhesive layer permeability [16]. Moreover, a previous study reported that the delayed light-curing adhesive could give time for water absorption from dentin [17]. Nevertheless, a literature reported that light-curing of both adhesive and composite cement ('LL' group) contribute to the higher bond strength than the AL group [7, 18].

Conclusion

This study concluded that the thickness of ceramic and curing mode of adhesive significantly influenced the fracture resistance of ceramic bonded to dentin. The thicker ceramic restoration presents superior fracture resistance than thinner ceramic restoration. Therefore, a separately light-curing on the adhesive followed by the light-curing on the resin cement resulted in the highest fracture resistance.

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