Original Article

Compressive strength of lithium disilicate inlay cementation on three different composite resins

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Abstract *Background/purpose:* Ceramic restorations have been increasingly applied over recent years. But the performance of cement is still unknown after cementation. This study was aimed to compare the compressive strength and the performances of three different types of composite resin after lithium disilicate inlay cementation.

Materials and methods: Twenty-four human maxillary premolars were embedded in resin blocks, finished a MOD inlay preparation and scanned with an extraoral scanner. Lithium disilicate ceramic inlays (IPS e.max, Ivoclar Vivadent, Liechtenstein) were fabricated according to the scanner's model. All the specimens were then etched, bonded, and cemented with three different composite resins. Right after 5000 thermal cyclings, the specimens were accepted compressive tests to evaluate the compressive strength and failure types. Moreover, the fracture fragments of the specimens were examined using scanning electron microscopy (SEM) to verify the fracture type.

Results: Dual-cured resin cement (Rely X Ultimate) showed the highest compressive strength (1002 ± 508 N), followed by the light-cured flowable resin (Z350 XT) (971 ± 209 N) and light-cured bulkfill (Filtek Bulkfill) resin (581 ± 191 N). Type IV (root fracture) failures in the dual-cured resin cement group was 25%, and light-cured flowable resin was 37.5%. But none of type IV fracture was found in the light-cured bulkfill flowable group.

Conclusion: Dual-cured resin cement demonstrates the highest compressive strength after ceramic inlay cementation. Light-cured bulkfill resin shows the lowest compressive strength, but catastrophic failure is absent in this group.

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Introduction

Dental ceramic indicates some advantages in esthetic, function and strength.[1] Minimal invasive treatments, including laminate veneer, ceramic inlay, onlay, and over-lay,[2] are become more popular in recent years. The materials of choice in modern dental ceramic are feldspathic porcelain, leucite based material, lithium disilicate, and zirconia. Compared to conventional crown preparations, inlay preparation reduces almost 40% tooth structure and the amount of tooth preparation can be limited dramatically.[3] Many studies agree that larger amounts of tooth preparation will certainly increase the risk of tooth fracture.[4] With greater preservation of tooth structure, the prevention of pulp damage and root canal treatment will be avoided, and the long-term survival rate of tooth will be anticipated. In the situation of certain amount of enamel is preserved, post-free indirect restoration is an up-to-date option over the conventional crown restoration treatment.[5]

Aside from the conventional crown and bridge restoration, a wide variety of materials are available to be used in bonded restoration. The most popular material in the recent years is lithium disilicate, which is demonstrated to have moderate tensile strength and etchable property.[6]

Bonded restoration is usually a complicated procedure, in which one of the critical factors is the selection of bonding cement. A wide range of composite resin have been reported to used, such as light-cured, self-cured and dual cured composite resin.[7,8] Some classifications of composite resin are based on the filler particles, like microhybrid, or nanohybrid. For example, the bulkfill composite resin is widely used recently due to its convenience and clinical manipulation. Furthermore, the desirable curing depth up to 4.0 mm is suitable for inlay cementation particularly in the case of deeper inlay margin.[9]

No evidence and study has been focused on investigation the compressive strength of different types of composite resin. It is, therefore, the present study was aimed to compare the compressive strength associated with three different resin-based cements using in ceramic inlay cementation. The failure modes and images under scanning electron microscope (SEM) were also observed and evaluated.

Materials and methods

Tooth selection and storage

A total of twenty-four human maxillary premolars was selected. Those samples were examined and verify of root canal treatment, fracture or caries were excluded. The mesial-distal dimension of the tooth was measured at a range from 6.0 to 9.0 mm, and buccal-lingual dimension was ranged from 7.0 to 11 mm. Average square measurement was 56 mm². These specimens were cleansed and stored in thymol solution before study.

Tooth embedding and preparation

Teeth were embedded in light-cured resin (Vertex light curing trayplates; Vertex dental, Singapore) and cured in the light-cured box (Preci shuttle IV; Yeti Dental, Engen, Germany) for 3 min. Teeth were prepared with silicon guides and chamfer burs (Drendel + Zweiling, Kalletal, Germany). MOD tooth preparation was performed according to inlay guidelines. The Central fossa depth was measured 1.5 mm, the buccal and palatal cusp width was >2 mm. The cavity margin was smoothened with marginal trimmers (NM1, NM2; Deppler, Rolle, Switzerland). All procedures were done under binocular loupes (Eyemag ProS 4.3X, Zeiss, Oberkochen, Germany). Areas of dentin exposure were sealed with a bonding agent (Single bond universal; 3M ESPE, MN,USA), and light-cured (Demi plus;Kerr, CA, USA) for 10 s (Fig. 1a—d).

Wax pattern and press ceramic

Inlay cavity prepared teeth were scanned and imaged with a desk scanner (Wieland; Ivoclar Vivadent, Liechtenstein). Wax patterns were designed (Dental CAD; ExoCAD, Darmstadt, Germany) and milled accordingly (Ceramill Motion 2; Amann Girrbach AG, Koblach, Austia). Wax patterns were embedded and the glass ceramic inlays were fabricated (IPS e.max Press/LTA2; Ivoclar Vivadent, Liechtenstein) (Fig. 2a—c). Inlay fitness was examined under binocular loupes. If any defects were found, inlays were remade under the same procedure.

Inlay cementation

Ceramic inlays were etched with 5% hydraulic acid (Ivoclar Vivadent, Liechtenstein) for 30 s and rinsed in running water. Bonding agent (3M ESPE) was applied onto the ceramic surfaces. Enamel of prepared teeth was etched in 37% phosphoric acid (Super etch; SDI, Bayswater, Australia) for 30 s. A bonding adhesive (3M ESPE) was applied onto the teeth surfaces and dried in 10 s and light-cured. One of the three types of composite resins: duel-cured composite resin (Rely X Ultimate A3;3M ESPE, MN,USA), light-cured flowable composite resin (Filtek Z350XT;3M ESPE, MN,USA), and light-cured bulkfill flowable (Filtek Bulkfill;3M ESPE, MN,USA) were used as the cement and three experimental groups (10 teeth of each) was divided (Table 1). During inlay cementation, an ultrasonic vibration tip (Varios 970; NSK, Kanuma, Japan) was applied to avoid air capsulation and
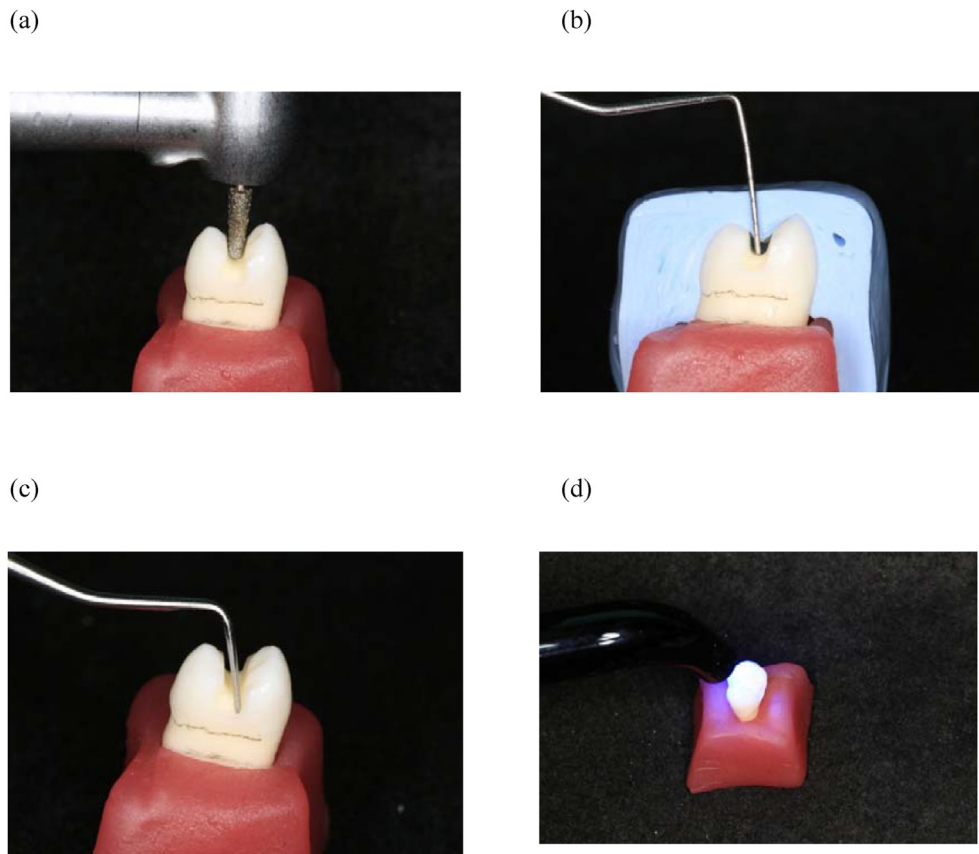
(a) (b)

(c) (d)

Figure 1   MOD tooth preparation procedures. (a) Tooth preparation with heavy chamfer bur; (b) Depth check with silicon guide; (c) Marginal trimmer smoothening; (d) Immediate dentin sealing.

void formation until completely setting of cement. Positioning of ceramic inlay was maintained using the composite resin condenser (Comporoller; Kerr, CA. USA), and additional light-cured for 40 s each from the buccal, lingual, and occlusal sides. Excess cement was completely removed with a scaler (Montana Jack®; PDT Inc, MT, USA).

Thermocycling

After 24 hours storage, all the specimens were placed in a water bath for thermocycling for 5000 cycles.

Compressive strength test

Specimens were finally tested for compressive strength at a device which held the specimen, using a crosshead at speed of 1 mm/min. A round-shape adaptor, 4 mm in diameter, was applied, and a piece of aluminum foil was placed between the adaptor and specimens to distribute force equally. The test was monitored and considered complete at the sign of non-linear changes in the output graphs.

Compressive strength analysis

Fracture modes were identified and examined under the optical microscope according to the Guess classification,[10] 4 types of fracture modes were listed as following:

type I: crack line refined to ceramic;
type II: cohesive fracture;
type III: adhesive fracture
type IV: vertical root fracture.

Scanning electron microscope analysis

One of the specimens of each group was selected for SEM analysis under 200X and 1000X. The micrographs were analyzed.

Statistical analysis

The records and data were statistically analyzed using descriptive statistics and nonparametric statistics, and Dunn Method for joint rank as the post-hoc analysis was also indicated. The null hypothesis could be stated as "the compressive strengths of three different composite resin within ceramic inlay restorations are not different."
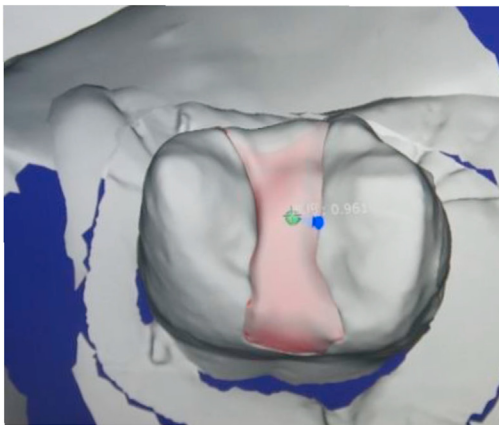
Results

Compressive strength

The compressive strengths in the present study was varied across three different composite resins on cementation of

(a)

(b)

(c)

Figure 2 Lithium disilicate inlay fabrication procedures, (a) Tooth scanning; (b) Wax pattern design; (c) Lithium disilicate inlay.

lithium disilicate inlay. Dual-cured composite resin represented the compressive strength as 1002 ± 508 N; light-cured flowable composite resin 971 ± 209 N and light-cured bulkfill flowable composite resin 581 ± 191 N respectively (Table 2, Fig. 3). The compressive strength of three different groups showed significant differences ($p < 0.05$, Kruskal—Wallis test). Notably, the compressive strength of bulkfill flowable composite resin was expressed the lowest of the three groups.

Table 1 Composite resin cements used.

Composite resin cement	Manufacture	Composition	Shade
RelyX™ Ultimate	3M ESPE	Methacrylate monomers, radiopaque, silanated fillers, Initiator components, dark cure activator for scotchbond universal, fluorescence dye, rheological additives	A3
Filtek™ Z350XT	3M ESPE	bis-GMA, UDMA, TEGDMA, bis-EMA,PEGDMA	A3
Filtek™ Bulk Fill	3M ESPE	bisGMA, UDMA, bisEMA, procrylat resins	A3

Fracture modes

Type I fracture was not observed in our present study. The frequencies and occurrence of the remaining fracture types were disclosed as following:

(a) dual-cured resin cement group: type II 37.5% = type III 37.5% > type IV 25%;

(b) light-cured flowable composite resin group: type II 25% < type III 37.5% = type IV 37.5%,

(c) light-cured bulkfill flowable composite resin group: type II 50% = type III 50% > type IV 0% (Table 3).

Scanning electron microscope analysis

One of the specimens of each experimental group was selected for SEM analysis (200X, 1000X; Fig. 4 and Fig. 5). Micrographs revealed composite resin residues retaining on the tooth surface in duel-cured composite resin group and light-cured flowable composite resin group. Mixed fractures, like adhesive and cohesive fractures were commonly observed in our study and light-cured bulkfill flowable composite resin group found the relatively smooth surfaces instead.

Table 2 Mean (SD) for compressive strength of 3 groups of composite resin.

	Mean $\pm$ SD(N)
Rely X Ultimate	1002 ± 508
Filtek Z350 flowable A3	971 ± 209
Filtek Bulkfill A3	581 ± 191*

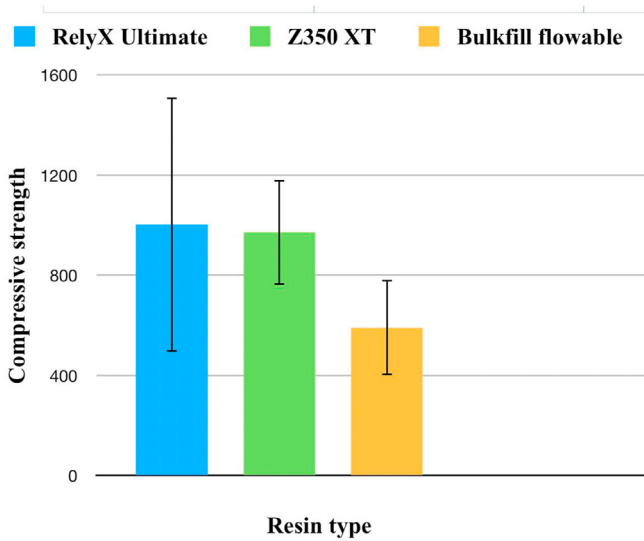* Statistically significant difference among groups ($p < 0.05$), Kruskal—Wallis test.

Figure 3   Compressive strength of three different resins after cementation on lithium disilicate inlay.

Table 3   Type of fractures (%).

|	I	II	III	IV	Total %
RelyX Ultimate	0%	37.5%	37.5%	25%	100%
Filtek Z350 XT flowable	0%	25%	37.5%	37.5%	100%
Filtek Bulkfill	0%	50%	50 %	0%	100%

Discussion

The null hypothesis that "the compressive strength of three different composite resins within ceramic inlay restorations are not different" is therefore rejected by our present findings. Cementation group in Rely X Ultimate is obviously showed the superior compressive strength over the other groups.

Regarding bonded porcelain restoration, dual-cured and light-cured cements are frequently mentioned in some comparative studies. Little knowledge is available on the bulkfill resin. Previous studies reported greater bond strength of both dual-cured and light-cured composite resin after light-cured processing.[11] In our present study, all three experimental groups are initiated by light-cured and the curing time is set at least 40 s. The multiple aspects of light cured resin are assured to have better mechanic properties.

The fracture mode in our present study is classified based on Guess's classification reporting in 2013.[10] According with the different type of fracture, Type I, II and III are usually restorable, while type IV is non-restorable. The results of our study demonstrate Type IV fracture is absent only in the bulkfill group. No previous studies have mentioned and reported on the fracture mode of bulkfill resin as a cement in inlay adhesion because most of the studies recognize the weakest point of junction is located between dentin and cement layer.[12–14] It is highly specu-lated that the bonded layer is already damaged when
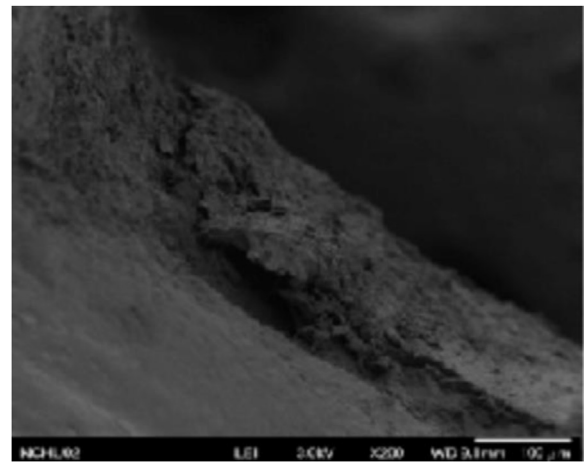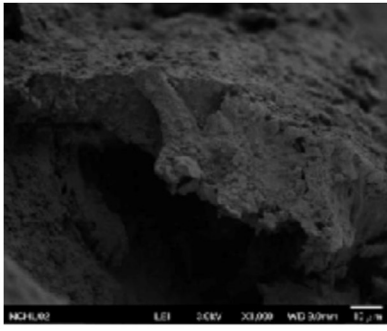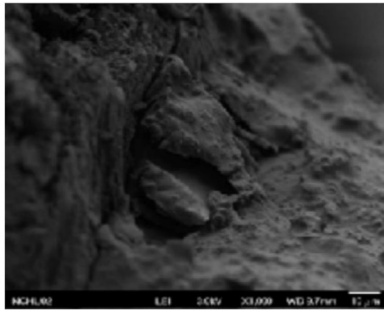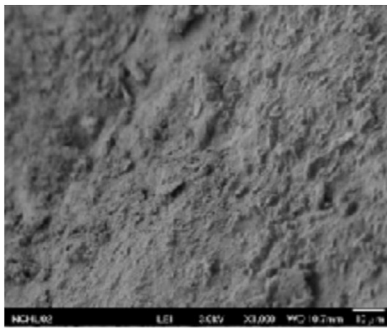

(a)
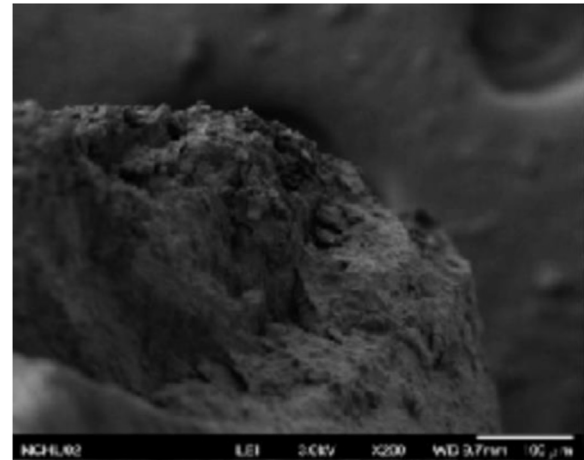
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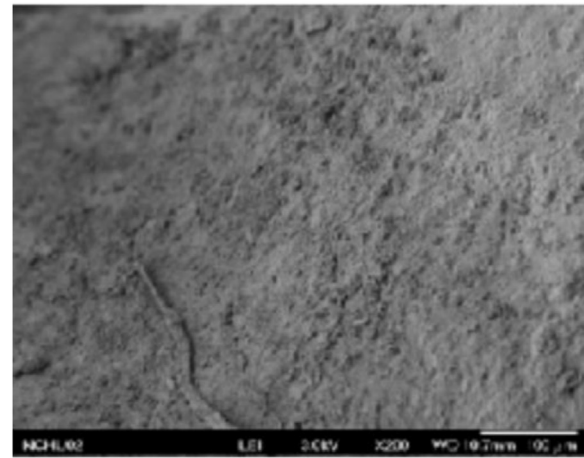
(c)

Figure 4   Specimens examined under SEM at 200X, (a) RelyX Ultimate group; (b) Z350XT group; (c) Bulkfill group.

(a) adhesive and cohesive failure on the bonded surface

(b) adhesive and cohesive failure on the bonded surface

(c) adhesive failure on the bonded surface

Figure 5   Specimens examined under SEM at1000X, (a) RelyX Ultimate group; (b) Z350XT group; (c) Bulkfill group.

compressive force loading before tooth fracture. In other words, it is believed that the frequency of repairable mode will be high in this type. Further research may be encouraged along this direction to confirm the occurrence.

The compressive strength of Rely X Ultimate and Z350XT are measured 1000 N approximately that is similar and comparable with some previous studies.[10,15] Margin of the lithium disilicate inlay in our study is located at the enamel and the exposed dentin are treated with immediate dentin sealing. Highly filled (Optibond FL, CA, Kerr) dentin bonding agent are usually used for immediate dentin sealing, with a shear bond strength of 16.3—19 MPa, which the strength is higher than that of the delay dentin sealing (0.3—14.9 MPa).[16—19] Universal adhesive are used for immediate dentin sealing in our study to prevent collapse of collagen layer. The unknown long-term outcomes are also needed further studies to clarify.

Water absorption can reduce bond strength, causing hydrolysis of the hybrid layer.[20] The experimental specimens, even after 5000 cycles of thermal cycling, are never found to have delaminated. Findings are consistent with good maintenance of bond strength under moist environments. Increasing thermal cycles may further mimic the long-term outcomes of the bonding strength.

Bulkfill resin can be applied in 4 mm increments in one time, and its conversion is higher than the conventional resin.[21] However, the bulkfill resin is higher in translucency. Therefore, its effects on the color of ceramic need further studies to clarify. The compressive strength of bulkfill in our study is measured at 581 ± 191 N and the occlusal force of human is calculated between 20 and 1000 N,[22,23] typically and generally lower than <270N during daily chewings. Chong et al. (2016) have reported that the maximum biting force varied with age, with 541.4 ± 296.3 N for young people, and 420.5 ± 242.0 N for the elderly.[24] Our study shows that the compressive strength of inlay cementation, either the dual-cured resin (Rely X Ultimate) or the light-cured resin (Z350 XT) can meet the standard, and the bulkfill resin is indicated on the border line.

In conclusion, within the limits of this *in vitro* study, the compressive strength of adhesive lithium disilicate inlay within the maxillary premolars are higher at light-cured flowable resin and dual-cured resin cement. Those of the bulkfill resin (Filtek Bulkfill Flowable) are the lowest of the three different composite resin material. Regarding failure types, all the failure types of bulk-fill group are restorable. Root fracture or the non-restorable fracture are not found within the bulkfill resin group.

Authorship statement

Conception and design of study: *J.H Weng, C.H Cheng*.
Acquisition of data: *J.H Weng, H.L Chen*.
Analysis and/or interpretation of data: *J.H Weng*.
Drafting the manuscript: *J.H Weng*.
Revising the manuscript critically for important intellectual content: *J.F Liu, G Chen*.
Approval of the version of the manuscript to be published (the names of all authors must be listed): *J.H Weng, H.L Chen, G Chen, C.H Cheng, J.F Liu*.

Declaration of competing interest

The authors have no conflicts of interests relevant to this article.

Acknowledgments

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