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The Influence of Adhesive Luting Systems on Bond Strength and Failure Mode of an Indirect Micro Ceramic Resin-based Composite Veneer

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Abstract

Aim: This study evaluated the bond strength and failure mode of enamel/resin-based composite veneers bonded with three different dual cured resin adhesive systems.

Methods and Materials: Standard preparations for laminate veneer restorations were made on 30 human central incisors using depth cutting burs (0.5 mm depth at the incisal area and 0.3 mm at the gingival area). Thirty indirect laminates were prepared using a highly filled polymeric material (GC Gradia) according to the manufacturer's instructions. After sandblasting the fitting surfaces, the specimens were randomly divided into three groups (ten per group) based on the type of resin cement luting systems; Excite/Variolink II, Single Bond/Rely X Veneer Cement, and Clearfil New Bond/Panavia F. The specimens were stored in water at 37ºC for 48 hours. Fracture testing was performed using a universal testing machine where the load was applied from the incisal direction at 135º to the long axis of the tooth (0.5 mm/min). The one-way analysis of variance (ANOVA) and Chi-Square tests were used for statistical analysis at a significance level of $p>0.05$.

Results: The ANOVA showed no significant difference was found among the groups ($P>0.05$). Indirect veneers showed mean enamel bond strength of 114.4 ± 48N, 159.7 ± 83.4 N, and 126.1 ± 51.7 N with Variolink II, Rely X veneer cement, and Panavia F, respectively. The Chi-Square tests showed no significant difference regarding the failure mode frequencies in different types of failure in the three groups ($p>0.05$). The failure mode analysis showed mainly adhesive failure in the resin cement/laminate interface in all groups.

Conclusion: There was no significant difference in bond strength of veneers with the three different resin cements tested. In addition, there was no significant difference in the frequency of the failure mode in each type of failure among the three test groups. The failure analysis revealed mainly an adhesive failure at the resin cement/veneer interface.

Clinical Significance: The results of this study suggest the use of Excite/Variolink, Single Bond/RelyX, or Clearfil New Bond/Panavia F are all appropriate choices for luting of indirect micro ceramic resin-based composite veneers in terms of bond strength and failure mode.

Keywords: Adhesive resin, luting resin cement, bond strength, indirect resin composite veneer

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Introduction

Patients with sound but discolored teeth often request restorations designed to improve their appearance. Such restorations might include veneer restorations using a tooth shaded material to cover the labial surfaces of unattractive teeth. The procedure can be performed using either direct or indirect methods. A systematic review by Wakiaga et al.[1] reported no reliable evidence of either a direct or indirect type of veneer restoration being superior in terms of longevity of the restoration. The porcelain laminate veneer is a common esthetic treatment used for unattractive anterior teeth. Substantially less tooth reduction is required for these restorations compared to a conventional esthetic crown preparation which is consistent with the practice philosophy of minimally invasive dentistry. The long-term clinical success of porcelain veneers is dependent on careful case selection, an accurate diagnosis, appropriate and precise tooth preparation, and an adhesive bonding procedure.[2]

Recent development of indirect resin-based composite resins has offered the dental profession the possibility of fabricating adhesive esthetic veneers for anterior teeth. Indirect composite resin veneers have seen minimal use for several reasons.[3]

- Dentists are able to place direct resin based composites themselves
- The difficulty associated with bonding laboratory-made fully cured composite resin restorations
- Unpredictability of strength
- The difficulty of making color corrections
- The difficulty of seating the restoration

Surface conditioning with acid or sandblasting of veneers made from hybrid composite filled with barium glass and colloidal silica offers a significant improvement in bond strength.[4] Hummel et al.[5] showed indirect hybrid composite resins had a higher bond strength with etching than microfilled resin composites, but mechanical roughening produced the greatest bond strength with microfilled resin composites. In a recent study by Gresnigt and Özcan[6] the cementation surfaces of the highly filled polymeric laminate veneers (Estenia, Kuraray Europe GmbH, Frankfort, Germany) were silica coated. Microetching with silanized silica or aluminum oxide followed by wetting with an unfilled resin proved to be an effective surface pretreatment for dual cure resin cementation of the laboratory processed indirect resin restorations.[7]

D'Arcangalo and Vanini[8] and Swift et al.[4] claimed the bond strength of an indirect resin restoration to dentin was significantly affected by surface treatment with the best conditioning method being sandblasting or sandblasting with silanization to create maximum bond strength.

The clinical success of indirect resin-based composite veneers is attributed to the intimate bond achieved between the restoration and tooth structure through the resin cement. A chemical bond is formed between the bonding agent and resin cement and, to a lesser extent, between the bonding agent and the veneer. One recent study[6] showed no significant difference in fracture strength between direct and indirect resin-based composite veneers to enamel. The study also showed the failure mode was mostly cohesive failures in the body of veneer and adhesive failures at the resin cement/veneer interface.

Kalender et al.[9] in evaluation of the shear bond strength of enamel/porcelain specimens bonded with three different dual cure cements found the shear bond strength of Variolink II was significantly higher than Rely X ARC and Panavia F.

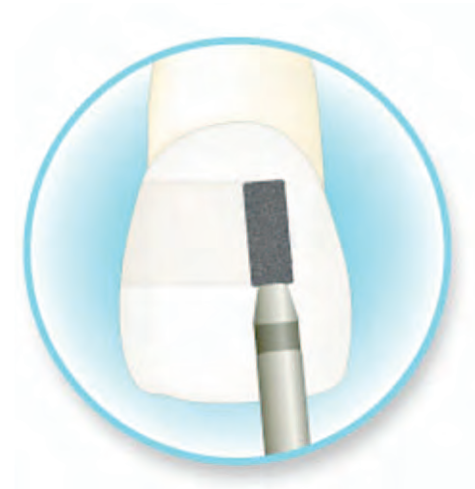
One study[10] showed the bond strength of Scotchbond Mp and Rely X to dentin were significantly higher than that of Panavia F, while another study[11] demonstrated the microtensile bond strength of Panavia F used for luting IPS Empress disks to dentin was significantly higher than Relay X and Multi-link.

The aim of this study was to test the null hypothesis that three dual cured adhesive luting materials had the same retention strength when used to lute a light-cured indirect resin-based composite.

Methods and Materials

Tooth Selection and Preparation

Thirty extracted human maxillary central incisors with anatomic crowns 10 mm in length and 8 mm in mesiodistal width were selected for the study. Each tooth was free of dental caries and restorations. The teeth were cleaned and restored in saline solution at room temperature immediately after extraction.



The facial surfaces of the teeth were prepared to accommodate veneers of equal thickness. Facial reduction was 0.3 mm at the cervical third and 0.5 mm at the middle and incisal thirds.[12] Tooth preparation was extended to include the interproximal contact areas using rotary instruments (Brasseler USA, Savannah, GA, USA) and a water coolant. Brassler self-limiting depth-cutting disks #834-3-016 (0.3 mm) and #843-31-021 (0.5 mm) were used to define the depth cuts. Then Brassler KSI #3500-5-31-52-012 diamond burs (1.2 mm chamfer) were used to refine the preparations. All tooth preparations were completed entirely in enamel without sharp line angles. Cervical finish lines were developed at the cementoenamel junction (CEJ) so the final composite veneers were 10 mm in length, to reproduce dimensions of the anatomic crown of the tooth.

Die Preparation

Impressions for the 30 prepared teeth were made with a condensation silicon; Speedex (Coltène/Whaledent Inc., Cuyahoga Falls, OH, USA). Impressions were cast in vacuum-mixed die stone (Die Keen, Heraeus Kulzer USA, Irvine, CA, USA) according to the manufacturer's instructions. After setting the stone, dies were removed from the impressions and painted with two coats of die spacer (Bell De St. Claire, Kerr, Romulus, MI, USA) to 0.5 mm short of the finish line of the preparations. Two coats of Die Lube® die lubricant (Degussa, South Plainfield, NJ, USA) were then applied to each die.

Microceramic Composite Veneer Fabrication

All 30 veneers were fabricated with the A2 shade GC Gradia indirect microceramic composite system (GC America Inc., Alsip, IL, USA). A layering technique was used to create the composite veneers. After application of each layer, it was initially cured with the GC StepLight SL®-I (GC America Inc.) for 10 seconds; after placement of all layers, final curing was performed using a GC Labolight LV-III® (GC America Inc) for 3 minutes. The composite veneers were then finished with Brasseler #863-11-016 diamond burs (Brasseler, USA) to standardized dimensions using an electronic Mitutoyo Boley gauge caliper to measure the height and a Mitutoyo dial caliper to measure the thickness (Mitutoyo Crop, Kawasaki, Japan). Final dimensions for all veneers were 0.3 mm and 0.5 mm thickness at the cervical third and incisal two thirds, respectively, and 10 mm in length. The fitting surfaces of all veneers were air abraded with 50 µm aluminum oxide (Micro-etcher, Model ERC, Danville Engineering, San Ramon, CA, USA) used with a pressure of 50Kg/Cm at a distance of 5 mm. The prepared teeth were acid etched for 20 seconds with 35% phosphoric acid gel (Ultra Etch®, Ultradent Products, South Jordan, UT, USA) then thoroughly rinsed with water for 30 seconds and blot dried.

Veneer Cementation

Micro ceramic composite veneers were randomly assigned to the following three groups (n=10) based on the type of luting resin systems:

- **Group EV.** The Virolink II (Ivoclar Vivadent, AG, Schaan, Lichtenstein) dual-curing resin composite luting system was used in this group of teeth. At first, a thin layer of Excite® one-bottle total etch adhesive resin (Ivoclar Vivadent, Schaan, Lichtenstein) was applied according to manufacturer's instruction. The base and catalyst of Virolink II were mixed carefully in a 1:1 ratio on a mixing pad for 10 seconds and then applied to both the prepared tooth and the composite veneer. The veneer was seated on the prepared teeth with light finger pressure and excess cement was removed with an explorer. It was light cured for 40 seconds per marginal surface using a Demetron® light curing unit (Kerr- Orange, CA, USA) at 500 mw/Cm^2.
- **Group SR.** The Rely X® dual-curing luting composite system, (3M ESPE Dental Products, St. Paul, MN, USA) was used to cement the veneers in this group. Adper

Single Bond total etch one-bottle adhesive resin (3M ESPE Dental Products, St. Paul, MN, USA) was applied in one layer prior to cementation. The appropriate amount of cement was then dispensed onto a mixing pad and was mixed for 10 seconds. A thin layer of cement was applied and evenly distributed to the bonding surface of the veneer. The cement was applied directly on to the tooth surface. The veneer was slowly seated and the excess cement was removed immediately after seating and light cured.
- **Group CP.** Panavia F (Kuraray Co, LTD Umeda, KiTa-Ku, Osaka- Japan) dual curing resin based cement system was used for cementation of the veneers in this group. According to manufacturer's instruction, ED primer was applied to the entire tooth surface and air-dried. The fitting surface of veneers silanated using Clearfil New Bond® (Kuraray, Osaka, Japan) according to the manufacturer's instructions. Panavia F paste was mixed for 30 seconds then applied to the conditioned composite veneer substrate. Oxygaurd (Kuraray, LTD Umeda, KiTa- Ku, Osaka, Japan) was used in all margins and light cured.

The margins of all veneers were then finished with Brasseler #379F-31-0 23 and #132F-31-008 finishing diamond burs.

Specimen Preparation and Testing

The 30 maxillary incisors were mounted individually in 1×1 phenolic rings using epoxy resin (Buehler Ltd, Lake Bluff, IL, USA) with the long axis parallel to center line of the ring. Each tooth was suspended in the middle of the ring by means of a No.1 paper clip (Acco USA Inc.,

Table 1. Mean and standard deviation fracture load (N).

Group	Mean	SD
Excite/Variolink (EV)	114.4	48.9
Single Bond/RelyX (SR)	159.7	83.4
Clearfil New Bond/PanaviaF (CP)	126.1	51.7

Table 2. Frequency of veneer's failure mode (n= 10 per group).

Group	Cohesive(C) Veneer	Adhesive(A1) Veneer/Cement	Adhesive(A2) Tooth/Cement	Mixed (M)
Excite/Variolink (EV)	2(20%)	4(40%)	2(20%)	2(20%)
SingleBond/RelyX (SR)	3(30%)	5(50%)	0(0%)	2(20%)
Clearfil NewBond/PanaviaF (CP)	1(10%)	7(70%)	1(10%)	1(10%)

Wheeling, IL, USA) that engaged the tooth at the CEJ and rested on the edges of the ring. When the axis of the tooth was positioned correctly, as judged by two investigators, epoxy resin was poured in the ring. All specimens were embedded up to 2 mm below the CEJ.

The fracture loads (N) were determined using a Model 8500 Instron universal testing machine (Instron Engineering, Norwood, MA, USA) with crosshead speed of 0.5 mm/min. The load was applied at a 135° angle to the incisal edge of each test tooth. This orientation was standardized by securing the phenolic rings in a mounting jig. Modes of failure were microscopically assessed with a SZTP stereo microscope (Olympus, Tokyo, Japan) at the original magnification of X20.

The One-Sample Kolmogorov Smirnov non-parametric analysis accepted the normality hypothesis of the data ($P>0.05$). As a result, a one-way analysis of variance (ANOVA) was then conducted. The failure mode frequencies were analyzed using the Chi-Square test. A level of significance of $\alpha=0.05$ was satisfied during the entire statistical analyses.

Results

Table 1 presents the fracture load means and standard deviations for three groups.

The one-way ANOVA revealed no significant difference among mean fracture loads ($P>0.05$). Table 2 presents the failure modality frequency for veneers. The Chi-Square test showed no significant difference with respect to the frequencies of the modes of failure among the test groups ($P>0.05$).

An analysis of the fractured veneer laminates showed primarily four types of failures:

- Cohesive fractured of the veneer (C)
- Adhesive failure between the cementation interface and the laminate (A1)
- Adhesive failure between the cementation and tooth (A2)
- Mixed failure (M)

The observed failure types per group are demonstrated in Table 2. The most frequently experienced failure types were adhesive in nature at the bonded veneer/cement interface (16/30), while only six restorations out of 30 showed cohesive failure.

Discussion

The results obtained support the null hypothesis of expected similar adhesive forces using different resin cement materials.

Tooth preparations for bonded restorations, including composite veneers, should be restricted to enamel because extensive exposure of dentin can reduce bond strengths.[13] Ferrrari et al.[14] reported the enamel of 114 sectioned anterior teeth was 0.3 to 0.5 mm thick at the gingival third, 0.6 to 1.0 mm at the middle third, 1.0 to 2.1 mm at the incisal third surfaces, and suggested the enamel at the gingival third might need to be totally removed to prevent an over-contoured ceramic veneer restoration. In the present *in vitro* study 30 tooth preparations accommodated veneers with a 0.3 mm gingival third thickness and a 0.5 mm middle third thickness. All veneers in this study were bonded to etched enamel.

GC Gradia is a highly filled, light cured indirect resin composite restorative material that was used for fabrication of the veneers in this study. It contains micro-fine ceramic/prepolymer filler along with a urethane dimethacrylate matrix to produce a superior ceramic composite resin. According to the manufacturer's instructions sandblasting with 50-µm alumina was performed for treatment of the fitting surface. A previous study showed sandblasting increases the force required for bond failure of laboratory made composite resin veneers.[15] Acid etching alone is not sufficient to produce effective bond strengths and hydrofluoric acid treatments are detrimental to the resin composite.[5]

Three different dual curing resin cements were selected for bonding of the veneers. The results of this study showed no significant difference in the bond strength of veneers bonded to enamel using resin cements. This result is in contrast with a previous study[11] reporting the enamel bond strength of porcelain veneer with Rely X was significantly lower than Panavia F. Another study[10] evaluated the bond strength of Clearfil APX indirect composite resin to dentin using Rely X demonstrated significantly higher values than Panavia F.

One recent study[16] compared the shear bond strength of Gradia indirect resin composite to dentin with and without the use of a priming agent. Statistical analysis showed adhesion values without a priming agent always appeared higher than or not significantly different from values when a priming agent was used. Moreover, two resin cements, Super-Bond C&B and Rely X, showed the highest bond strengths.

Three specific adhesive resins were used as primers in the present study. Excite and Single Bond were applied to the enamel surface and left uncured because light polymerization decreases as a result of increasing the veneer thickness. Moreover, polymerization of the adhesive layer before cementation may result in resin pooling and incomplete seating of the veneer.[17] Clearfil New Bond is a dual cure adhesive resin and is recommended for priming of enamel or dentin before luting veneers. Coelho Santos et al.[18] showed the effect of pre-curing of the adhesive was material specific. A recent study by Arrias et al.[19] suggested dual cure adhesive systems were as strong or even stronger when they were left in the uncured state prior to indirect resin composite restoration. Therefore, in this study the total curing of the adhesive resin and the resin luting cement was performed.

Normal incisal bite force averages range between 130 and 230 N.[20] Bonding with adhesively cemented indirect composite resin veneers in this study had adequate mean load values: 114.4N, 126.1N, and 159.7N, respectively, for Variolink II, PanaviaF, and Rely X indicating composite laminate veneers could be considered strong enough to withstand normal masticatory forces.

No significant differences were observed in failure mode frequencies among the test groups. This is in agreement with results of a recent study by Gresnigt and Özcan.[6] Although in the present study most of the failures were adhesive in nature at the cement/veneer interface (16/30), only six out of 30 specimens showed cohesive failure in the laminate body.

Gresnigt and Özcan[6] found cohesive failure in 20 out of 50 specimens, adhesive failures were present in 19 out of 50. The differences in failure mode frequencies in their study and the present study are probably related to conditioning of the fitting surface of veneers which were silica coated using a chairside air abrasion device. In addition, they applied woven bidirectional E-glass fiber at the cementation interface at different locations in that study.

The adhesive finding (40-70%) compared to cohesive finding (10-30%) may also be influenced by the method of conditioning of the fitting surface of the veneers. A recent study by D'Arcangelo and Vanini[8] showed sandblasting or both sandblasting and silanization provided significant additional resistance to tensile load in indirect resin composite restorations. Bouschlicher et al.[7] concluded microetching with silica or alumina followed by wetting with an unfilled adhesive was an effective surface treatment for the dual-cure resin cementation of laboratory-processed indirect composite restorations.

The adhesive failure shows the weak link between the resin cement and veneer[5] which is probably due to the high degree of resin conversion as a result of using heat and light applied for processing laboratory-type resin composites. This improves the mechanical strength and hardness, but on the other hand it makes the attachment of the polymerized composite difficult.[21]

The least frequency of failures related to adhesive failure at the tooth/cement interface (n=3) is due to the presence of a suitable bond between the resin adhesive and etched enamel.

Future clinical trials are needed to determine if the efficacy of the bond observed in this study is maintained in the clinical setting.

Conclusion

1. There was no significant difference in the bond strength of veneers with the three different resin cements tested.
2. There was no significant difference in frequency of failure mode in each type of failure among three groups tested. Failure analysis showed mainly adhesive failure at the resin cement/veneer interface.

Clinical Significance

The results of this study suggest the use of Excite/Variolink, Single Bond/RelyX, or Clearfil New Bond/Panavia F are all appropriate choices for luting of indirect micro ceramic resin-based composite veneers in terms of bond strength and failure mode.

References

1. Wakiaga J, Brunton P, Silikas N, Glenny IS. Direct versus indirect veneer restorations for intrinsic dental stain. Evid Based Dent 2004; 5:43.
2. Chichoyan F, Vanheusden A. Bonded porcelain veneer. Rev Belqe Med Dent 2006; 61:47-64.
3. Chirstensen GJ. What is veneer? J Am Dent Assoc 2005; 61:9-12.
4. Swift EJ, Brodeur C, Cviko E, Pires JA. Treatment of composite surface for indirect bonding. Dent Mater 1992; 8:193-196.
5. Hummel SK, Marker U, Goldfogle M. Surface treatment of indirect resin composite surface before cementation. J Prosthet Dent 1997; 77:568-572.
6. Gersniqt MM, Ozcan M. Fracture strength of direct versus indirect laminates with and without fiber application at the cementation interface. Dent Mater 2006; 6[Epub ahead of print].
7. Bouschlicher MR, Cobb DS, Vargas MA. Effect of two abrasive systems on resin bonding to laboratory processed indirect resin composite restorations. J Esthet Dent.1999; 11(4):185-96.
8. D'Arcangelo C, Vanini L. Effect of three surface treatments on the adhesive properties of indirect composite restorations. J Adhes Dent 2007; 9:319-326.
9. Kalender A, Onal B, Turkan M, Dalger H, Kaytam B. Shear bond strength of three different resin luting cements to bovine teeth. Gen Dent 2005; 53:38-42.
10. de Menzes Mj, Arrais CA, Giannini M. Influence of light – activated and auto - and dual polymerizing adhesive systems on bond strength of indirect composite resin to dentin. J Prosthet Dent 2006; 96:115-121.
11. Escribano N, de la Macorra JC. Microtensile Bond strength of adhesive luting cements to ceramic. J Adhes Dent. 2006; 8:337-341.
12. Castelnuovo J, Tjan AHL, Philips K, Nicholls JI, Kois JC. Fracture Load and mode of failure of ceramic veneers with different preparations. J Prosthet Dent 2000; 83:171-180.
13. Sheets CG, Toniguchi T. Advantages and limitations in the use of porcelain and castable ceramic laminate veneers. J Prosthet Dent 1990; 64:406-411.
14. Ferrari M, Patroni S, Balleri P, Measurement of enamel thickness for etched laminate veneers. Int J Preriodontics Restorative Dent 1992; 12:407-413.
15. Tam LE, McComb D. Shear bond strength of resin lusting cement to laboratory made composite resin veneers. J Prosthet Dent 1991; 66; 314-321.
16. Nahiae D, Vermeersch C, Verven J. Effect of a priming age of bond strength of indirect composite to dentin using cement systems. European cells and materials 2007; 13:46.
17. Rouse JS. Anterior ceramic crowns In: Summitt JB, Robbins JW, Hilton TJ, Schwartz RS, dos Santos J, eds. Fundamentals of Operative Dentistry, Chicago: Quintessence, 2006: 509.
18. Coelho Santos MJ, Mavaro MF, Tam L, McComb D. The effect of dentin adhesive and cure mode on film thickness and micro tensile bond strength to dentin in indirect restorations. Oper Dent 2005; 30:50-57.
19. Arrais CA, Giannini M, Rueggeberg FA, Pashley DH. Effect of curing mode on microtesile bond strength to dentin of two dual adhesive systems in combination with resin luting cements for indirect restoration. Oper Dent 2007; 32:37-44.
20. Hagberg C. Assessment of bite force. A review. J Croniomandibular Disord 1987; 1:162-169.
21. Ozcan M, Alander P, Vallittu PK, Huysmans Mc, Kalk W. Effect of three surface conditioning method to improve bond strength particulate fiber resin composite. J Mater Sci Mater Med 16(2005), PP.21-27.

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