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The Effect of Three Variables on Shear Bond Strength When Luting A Resin Inlay to Dentin

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Clinical Relevance

In order to maximize the bond strength of a resin inlay to dentin, the exposed dentin surface should be sealed with DBA before taking an impression. In addition, the bonding agent should be gently air dried and light cured before applying the luting material.

SUMMARY

The current study evaluated the effects of three variables on the shear bond strength of indirect composite restorations to human dentin. The three variables examined included immediate dentin sealing (IDS), the thinning of dentin adhesives by air-blowing before cementation and light-curing the dentin adhesive before cementation.

One-hundred and eighty cylinder composite inlays, 2 mm in diameter and 3 mm in length, were made using a Tescera ATL system (BISCO Inc). Tooth disks 2-mm thick were obtained from 90 freshly-extracted human premolars. Two indirect composite cylinders were assigned to a single tooth disk. The discs were randomly divided into six groups according to the luting methods. AdheSE (Ivoclar Vivadent) was used as the dentin-bonding agent (DBA) for all groups. In Groups 1, 2 and 3, the dentin was sealed with AdheSE before taking the impression. After priming, the adhesive was lightly air-blown, then light-cured. On the other hand, the dentin was not sealed before taking the impression in Groups 4, 5 and 6. Regarding the application of DBA before cementation, it was gently air-blown and light-cured before cementation in Groups 1 and 4; whereas, it was heavily air-blown and light-cured in Groups 2 and 5 and gently air-blown but not light-cured in Groups 3 and 6. Z-250 and Duo-Link were used as luting materials. After 24-hours of storage, the bonded inlays were subjected to a shear bond test.

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For each luting material, one-way ANOVA and Duncan's Multiple Range Test were used to compare the shear bond strength. Paired *t*-tests were also performed to compare the shear strength between the two luting materials. All the statistical tests were carried out at the 95% confidence level.

In Z-250, the results of the shear bond strength were as follows: Group 1(14.90MPa) > Group 2(12.22MPa), Group 4(12.16MPa) > Group 5(9.61MPa), Group 3(9.60MPa) > Group 6(3.54MPa)($p<0.05$). In Duo-Link, the following shear bond strengths were obtained: Group 1(14.65MPa) > Group 2(13.04MPa), Group 4(12.66MPa) > Group 5(10.10MPa) > Group 3(8.40MPa) > Group 6(2.88MPa) ($p<0.05$). The mean shear bond strength of Z-250 and Duo-Link were not statistically different with the exception of Group 5.

In conclusion, the shear bond strength of the indirect composite restoration to dentin can be improved by dentin sealing with DBA before taking an impression, gently air drying and light curing the DBA before the luting procedure.

INTRODUCTION

Since the acid-etching technique was introduced in dentistry,[1] various adhesive methods have been developed to bond composites to tooth structure. Although considerable advances have been made, polymerization contraction and its associated problems, such as microleakage, secondary caries and cuspal deflection, are still major problems.[2] An indirect composite restoration, where most of the contraction occurs extra-orally, is recommended to reduce such problems.[3-4]

A higher bond strength was observed in the direct method, where the dentin adhesive is light-cured before applying the resin composite, compared with when the dentin adhesive and resin composite had been polymerized together.[3-4] However, in the indirect method, the thickness of the polymerized adhesive may hinder placement of the restoration. The thickness of the polymerized adhesive can reach up to 200~300 μm in areas such as the inner line angles of the cavity and the Chamfer margin.[5] Therefore, some manufacturers recommend the adhesive not be polymerized beforehand but be polymerized with the resin cement for clinical convenience. Some practitioners prefer to over-dry the adhesive instead of using the general method of gently-drying, that is, they wish to obtain minimal dentin adhesive thickness for clinical applications. Obtaining adequate bond strength using a suitable adhesive method is essential for a successful indirect restoration. Therefore, the adhesive methods mentioned above need to be verified scientifically.

The immediate dentin sealing (IDS) technique, which seals the exposed dentin surface using dentin adhesives before taking an impression, was attempted in order to reduce hypersensitivity during the provisional phase of an indirect tooth-colored restoration.[6] A scanning electron microscopy study of the porcelain laminate veneer showed that the traditional application of dentin adhesive resulted in bonding failure between the hybrid layer and the overlying resin; whereas, unbroken and continuous interfaces were obtained when the IDS technique was applied.[7] Magne and others[8] reported that this method resulted in higher bond strength than the conventional method. These authors also suggested that this technique eliminates any concern regarding film thickness of the dentin sealant.

The current study evaluated the effects of immediate dentin sealing, the thinning of dentin adhesives by gentle or heavy air blowing and light curing or the effects without light curing of a dentin adhesive before cementation on the shear bond strength of a composite cylinder to human dentin.

METHODS AND MATERIALS

AdheSE (Ivoclar Vivadent, Schaan, Liechtenstein) was used as the dentin adhesive in this study. Dual cured resin cement Duo-Link (BISCO, Schaumburg, IL, USA) and the restorative composite Z250 (3M ESPE, St Paul, MN, USA) were used as luting materials.

A. Specimen Preparation & Immediate Dentin Sealing

Ninety human premolars recently extracted for orthodontic purposes from patients between 10 and 25 years of age, who had no cavities, cracks or other defects, were used and stored in a saline solution. A tooth slice 2-mm thick was prepared parallel to the occlusal surface under water irrigation using a low-speed diamond wheel (Minitom, Struers, Copenhagen, Denmark). After confirming that there was no enamel remnant remaining at the section, the dentin surface was polished under moist conditions using 600-grit SiC paper. One slice per a tooth was prepared. The specimens were randomly divided into six groups. For Groups 1, 2 and 3, the IDS groups, the tooth surface was covered with transparent tape in which two 2.5-mm diameter holes had been punched. The tooth surfaces exposed through the two holes were primed and bonded using the dentin adhesive (AdheSE) according to the manufacturer's recommendation and light-cured for 20 seconds using Bluephase (Ivoclar Vivadent) at a power density of 1000mW/cm^2. For Groups 4, 5 and 6, the non-IDS groups, the dentin adhesives were not applied. The surfaces of all the groups had been rinsed, cleaned with wet cotton and dried. The impression materials were then applied (Extrude, Kerr, Orange, CA, USA) for five minutes to mimic a clinical situation. After removing the impression materials, the tooth surface was rinsed and dried. The surface was then covered with Fermit (Ivoclar Vivadent), light-cured and kept under 100% humidity for four days.

B. Indirect Composite Cylinder Making

Tescera Dentin A2 Shade composites (BISCO) were placed into a Teflon mold with an inner diameter of 2 mm and a height of 3 mm and placed in the Light box of a Tescera ATL system and light-cured under pressure. The light-cured composites were removed from the mold and placed in the Black box of a Tescera ATL system and heat-cured. The light- and heat-curing process were carried out according to the manufacturer's recommendations. Thus, 180 Tescera composite cylinders were made.

C. Luting Procedure

The 180 Tescera composite cylinders were assigned to a 90-tooth slice specimen. Two composite cylinders were assigned per specimen. The cylinder surfaces were sand blasted with 50 µm aluminum oxide powder, then coated with silane (Monobond S, Ivoclar Vivadent) for 60 seconds. After the coated surfaces were dried, the adhesive of an AdheSE system was applied and stored in a light-proof box. In Groups 1, 2 and 3, the adhesive of an AdheSE system was applied to the two previously sealed IDS surfaces of each tooth slice with two 2.5 mm diameter holes after being covered with the previously used transparent tape. In Group 1, air was blown onto the adhesive at a pressure of 0.5kgf/m^2, and the sample was light-cured for 20 seconds using Bluephase (Ivoclar Vivadent). In Group 2, air was blown onto the adhesive at a pressure of 3.0kgf/m^2, followed by light-curing for 20 seconds using Bluephase. In Group 3, air was blown onto the adhesive at a pressure of 0.5kgf/m^2, but this group was not light-cured. In Groups 4, 5 and 6, the tooth surface was covered with transparent tape in which two 2.5-mm in diameter holes had been punched. The two tooth surfaces exposed through the holes were primed and bonded with dentin adhesive (AdheSE, Ivoclar Vivadent) according to the manufacturer's recommendation. In Group 4, air was blown onto the adhesive at a pressure of 0.5kgf/m^2, followed by light-curing for 20 seconds using Bluephase (Ivoclar Vivadent). In Group 5, air was blown onto the adhesive at a pressure of 3.0kgf/m^2 followed by light-curing for 20 seconds using Bluephase. In Group 6, air was blown onto the adhesive at a pressure of 0.5kgf/m^2, but it was not light-cured. In all groups, the composite cylinders were cemented to the surface of each tooth slice using DuoLink (BISCO) or FiltekZ-250 (3M ESPE) under a constant pressure of 5kgf, then light-cured for 60 seconds using Bluephase. The specimens were stored at 37°C under 100% humidity conditions for one day.

D. Shear Bond Strength Test

The specimens were bonded to a metal plate using cyanoacrylate adhesive (Zapit, Dental Ventures of America, Corona, CA, USA). The metal plate was fixed to the Instron specimen (EZ test, Shimadzu, Kyoto, Japan). The specimen was looped by a wire onto its undersurface. A force was applied to the specimen at a crosshead speed of 0.5 mm/minute until the composite cylinder had broken out of the tooth slice (Figure 1). The load data was measured concomitantly during these procedures, and the data was stored on a computer using the WinAGSLite program (Shimadzu, Kyoto, Japan). Table 1 shows the flow data obtained.

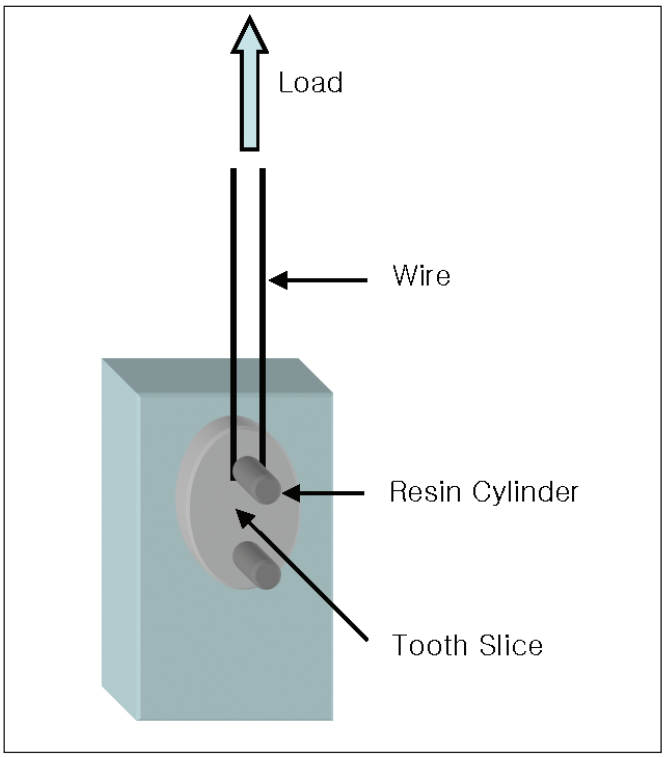

Figure 1: *Schematic diagram of the shear bond test apparatus.*

E. Statistical Analysis

For each luting material, Z250 and Duo-link, one-way ANOVA and the Duncan's multiple range test were used to compare the shear bond strength of the groups. In each group, a paired *t*-test was used to compare the shear bond between Z-250 and Duo-link. All statistical tests were carried out at the 95% confidence level.

RESULTS

Table 2 and Figure 2 show the results of the shear test. When Z250 was used as the luting material, the following order of shear bond strength was obtained: Group 1 > 2, 4 > 3, 5 > 6 ($p<0.05$).

When Duo-link was used as a luting material, the order of shear bond strength was as follows: Group 1 > 2, 4 > 3, 5 > 6 ($p<0.05$).

There was no significant difference in shear bond strength between Z250 and Duo-Link in each group, with the exception of Group 5.

DISCUSSION

In the current study, the shear bond strength of the IDS groups was higher than the corresponding non-IDS Groups: Group 1 > Group 4, Group 2 > Group 5, Group 3 > Group 6. These results are consistent with previous studies[6-9] and can be explained by use of the dentin adhesive before taking the impression generating a hybrid layer, which prevents contamination and denaturing of the dentin until the indirect restoration is cemented.

Table 1: *Flow Chart of Materials Application Methods on Dentin Surface*

Group	1	2	3	4	5	6
Tooth slicing						
Immediate dentin sealing using AdheSe	O	O	O	X	X	X
Impression						
Temporary filling with Fermit						
Tescera Inlay making						
Storage (4 days)						
AdeheSE application						
Air blow pressure	0.5kg/m^2	3.0kg/m^2	0.5kg/m^2	0.5kg/m^2	3.0kg/m^2	0.5kg/m^2
Light curing	Yes	Yes	No	Yes	Yes	No
Tescera Inlay setting with DuoBond or Z250						
Storage (1 day)						
Shear bond strength test						

Table 2: *Results of Shear Bond Strength Test (MPa)*

	1	2	3	4	5	6
Z-250	14.90±2.50	12.22±1.61	9.60±3.54	12.16±2.29	9.61±3.21	3.54±0.97
Duo-Link	14.65±2.01	13.04±1.39	8.39±1.94	12.67±2.13	10.10±1.82	2.88±0.64

The shear bond strength of Group 1 was the highest in the current study. This suggests that, in order to achieve the maximum retention in an indirect composite restoration, the cavity should be sealed before taking an impression and the bonding agent should be slightly air-blown and light-cured before cementation. Clinicians may hesitate to accept this technique, because a lightly blown, light-cured adhesive can hinder placement of an indirect composite restoration. In the current study, the shear bond strength of Group 2 was the second highest of all the groups examined. Therefore, as an alternative method, clinicians may heavily blow the adhesive, thus thinning the layer under the same conditions where the cavity had been previously sealed with adhesive before taking the impression. Considering the results from Groups 3 and 6, clinicians who do not wish to light-cure the adhesive before cementation for fear of incomplete seating of the indirect restoration, should at least seal the cavity with an adhesive before taking the impression.

In the current study, the shear bond strength of Group 6 was the lowest. The shear bond strength of Group 3 was higher than Group 6 but lower than Groups 1, 2 and 4. This indicates the importance of light-curing the adhesive before cementation in an indirect resin restoration. When dentin adhesives are not light-cured before cementation, particularly if the exposed dentin has not been protected using dentin adhesives before taking the impression, the exposed, decalcified collagen can collapse during the cementing procedure as a consequence of the pressure applied in the process. This can lead to a faulty hybrid layer and failure of an indirect restoration.[10] This result is inconsistent with those reported by Magne and others.[8] In the Magne and others study, the results showed similar microtensile bond strengths in a control group in which the prepared teeth were immediately bonded, light cured, then restored with composites and an immediate dentin sealing group in which the dentin surface had been sealed immediately after preparation, stored in saline for two weeks with provisional restoration, followed by application of a dentin bonding agent and polymerization, together with the resin composite. Magne and others used a thick restora-

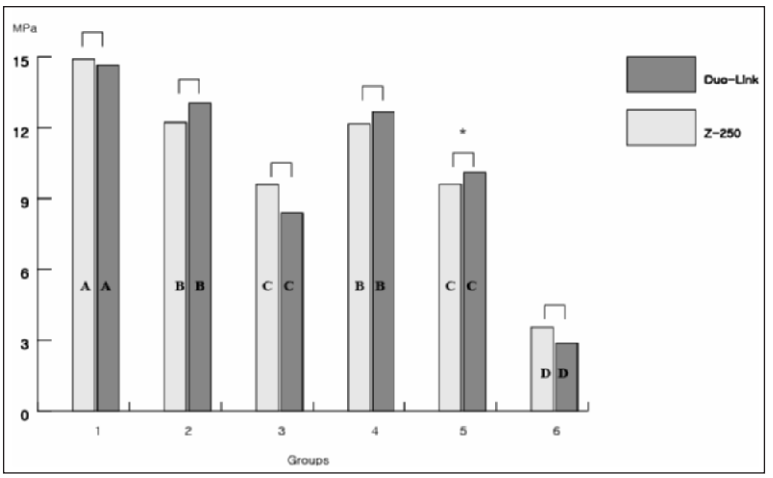

Figure 2. *Shear bond strength. The same capital letters in the bar represent the same shear bond strength in each material at the* p=*0.05 level. *represents a significant difference in shear bond strength between Duo link and Z250 at the* p=*0.05 level.*

tive composite as a core that was placed on the flat dentin surface that was previously coated with adhesives, which resulted in a low c-factor condition. However, the c-factor of an indirect tooth-colored restoration is usually much higher than that of a direct restoration. As bond strength is affected by the c-factor,[11-12] its results may be different from clinical situations. However, it is difficult to make a direct comparison, because Magne and others used a different bonding system, a three-step total etching system.

Due to its inferior physical properties and high water absorption, it is desirable to minimize the amount of unfilled resin used in a composite restoration. The air-thinning of dentin adhesives prior to polymerization is a common practice recommended by most manufacturers. However, overly aggressive thinning has been implicated as a cause of the decreased cure of adhesives. The results of the current study also support this. In the current study, the bond strength of Groups 2 and 5 was lower than that of Groups 1 and 4, respectively.

Park and others[13] reported the possibility of using a restorative composite as a luting material when the high power density curing lamp, curing time and thickness of the resin overlay had been optimized. In the current study, the dual polymerization resin cement Duo-link, and the light curing resin composite Z-250, were used for comparison. However, both showed similar shear bond strength with the exception of Group 5. Further studies, such as an analysis of the breakage surface, will be needed to determine why there was no difference in bond strength despite there being a difference in viscosity. Dual-cured composite cements were reported to show greater wear due to their lower filler content and relatively inferior physical properties.[14-15] Considering the high wear resistance of contemporary restorative composite materials, the use of restorative composites as luting cements may contribute to the reduced wear of cementing materials. This possibility will require further research.

CONCLUSIONS

The shear bond strength of a resin inlay to dentin was improved by IDS before taking an impression, gently air drying and light curing of the DBA before applying the resin cements. There was no significant difference related to which of the two luting agents that was studied was used.

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References

1. Buonocore MG (1955) A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces *Journal of Dental Research* **34(6)** 849-853.
2. Garberoglio R, Coli P & Brannstrom M (1995) Contraction gaps in Class II restorations with self-cured and light-cured resin composites *American Journal of Dentistry* **8(6)** 303-307.
3. Frankenberger R, Sindel J, Kramer N & Petschelt A (1999) Dentin bond strength and marginal adaptation: Direct composite resins vs ceramic inlays *Operative Dentistry* **24(3)** 147-155.
4. McCabe JF & Rusby S (1994) Dentine bonding—the effect of pre-curing the bonding resin *British Dental Journal* **176(9)** 333-336.
5. Pashley EL, Comer RW, Simpson MD, Horner JA, Pashley DH & Caughman WF (1992) Dentin permeability: Sealing the dentin in crown preparations *Operative Dentistry* **17(1)** 13-20.
6. Paul SJ & Scharer P (1997) The dual bonding technique: A modified method to improve adhesive luting procedures *The International Journal of Periodontics & Restorative Dentistry* **17(6)** 536-545.
7. Magne P & Douglas WH (1999) Porcelain veneers: Dentin bonding optimization and biomimetic recovery of the crown *The International Journal of Prosthodontics* **12(2)** 111-121.
8. Magne P, Kim TH, Cascione D & Donovan TE (2005) Immediate dentin sealing improves bond strength of indirect restorations *The Journal of Prosthetic Dentistry* **94(6)** 511-519.
9. Ozturk N & Aykent F (2003) Dentin bond strengths of two ceramic inlay systems after cementation with three different techniques and one bonding system *The Journal of Prosthetic Dentistry* **89(3)** 275-281.
10. Dietschi D & Herzfeld D (1998) *In vitro* evaluation of marginal and internal adaptation of Class II resin composite restorations after thermal and occlusal stressing *European Journal of Oral Science* **106(6)** 1033-1042.
11. Nikolaenko SA, Lohbauer U, Roggendorf M, Petschelt A, Dasch W & Frankenberger R (2004) Influence of c-factor and layering technique on microtensile bond strength to dentin *Dental Materials* **20(6)** 579-585.
12. Nikaido T, Kunzelmann KH, Chen H, Ogata M, Harada N, Yamaguchi S, Cox CF, Hickel R & Tagami J (2002) Evaluation of thermal cycling and mechanical loading on bond strength of a self-etching primer system to dentin *Dental Materials* **18(3)** 269-275.
13. Park SH, Kim SS, Cho YS, Lee CK & Noh BD (2004) Curing units' ability to cure restorative composites and dual-cured composite cements under composite overlay *Operative Dentistry* **29(6)** 627-635.
14. Noack MJ & Roulet JF (1991) Tooth-colored inlays *Current Opinion in Dentistry* **1(2)** 172-178.
15. Van Meerbeek B, Inokoshi S, Willems G, Noack MJ, Braem M, Lambrechts P, Roulet JF & Vanherle G (1992) Marginal adaptation of four tooth-coloured inlay systems *in vivo* *Journal of Dentistry* **20(1)** 18-26.