Immediate dentin sealing improves bond strength of indirect restorations

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Statement of problem. Delayed dentin sealing is traditionally performed with indirect restorations. With this technique, dentin is sealed after the provisional phase at the cementation appointment. It was demonstrated that this chronology does not provide optimal conditions for bonding procedures. Immediate dentin sealing (IDS) is a new approach in which dentin is sealed immediately following tooth preparation, before making the impression.

Purpose. The purpose of this study was to determine whether there were differences in microtensile bond strength to human dentin using IDS technique compared to delayed dentin sealing (DDS).

Material and methods. Fifteen freshly extracted human molars were obtained and divided into 3 groups of 5 teeth. A 3-step etch-and-rinse dentin bonding agent (DBA) (OptiBond FL) was used for all groups. The control (C) specimens were prepared using a direct immediate bonding technique. The DDS specimens were prepared using an indirect approach with DDS. Preparation of the IDS specimens also used an indirect approach with IDS immediately following preparation. All teeth were prepared for a nontrimming microtensile bond strength test. Specimens were stored in water for 24 hours. Eleven beams ($0.9 \times 0.9 \times 11$ mm) from each tooth were selected for testing. Bond strength data (MPa) were analyzed with a Kruskal-Wallis test, and post hoc comparison was done using the Mann-Whitney U test (α=.05). Specimens were also evaluated for mode of fracture using scanning electron microscope (SEM) analysis.

Results. The mean microtensile bond strengths of C and IDS groups were not statistically different from one another at 55.06 and 58.25 MPa, respectively. The bond strength for DDS specimens, at 11.58 MPa, was statistically different (P=.0081) from the other 2 groups. Microscopic evaluation of failure modes indicated that most failures in the DDS group were interfacial, whereas failures in the C and IDS groups were both cohesive and interfacial. SEM analysis indicated that for C and IDS specimens, failure was mixed within the adhesive and cohesively failed dentin. For DDS specimens, failure was generally at the top of the hybrid layer in the adhesive. SEM analysis of intact slabs demonstrated a well-organized hybrid layer 3 to 5 μm thick for the C and IDS groups. For DDS specimens the hybrid layer presented a marked disruption with the overlying resin.

Conclusions. When preparing teeth for indirect bonded restorations, IDS with a 3-step etch-and-rinse filled DBA, prior to impression making, results in improved microtensile bond strength compared to DDS. This technique also eliminates any concerns regarding the film thickness of the dentin sealant. (J Prosthet Dent 2005;94:511-9.)

CLINICAL IMPLICATIONS

Tooth preparation for indirect bonded restorations such as composite/ceramic inlays, onlays, and veneers can generate significant dentin exposure. The results of this study indicate that freshly cut dentin surfaces may be sealed with a dentin bonding agent immediately following tooth preparation, prior to impression making. A 3-step etch-and-rinse dentin bonding agent with a filled adhesive resin is recommended for this purpose.

If a considerable area of dentin has been exposed during tooth preparation for indirect bonded restorations, it is suggested that a dentin adhesive be applied strictly according to the manufacturer's instructions. Successful dentin bonding is of particular clinical importance for inlays, onlays, veneers, and dentin-bonded porcelain crowns because the final strength of the tooth-restoration complex is highly dependent on adhesive procedures. Long-term clinical trials by Dumfahrt and Schaffer[1] and Friedman[2] showed that porcelain veneers partially bonded to dentin have an increased risk of failure. Advances in dentin bonding agent (DBA) application techniques[3-15] suggest that these failures can likely be prevented by changing the application procedure of the DBA. In fact, there are principles that should

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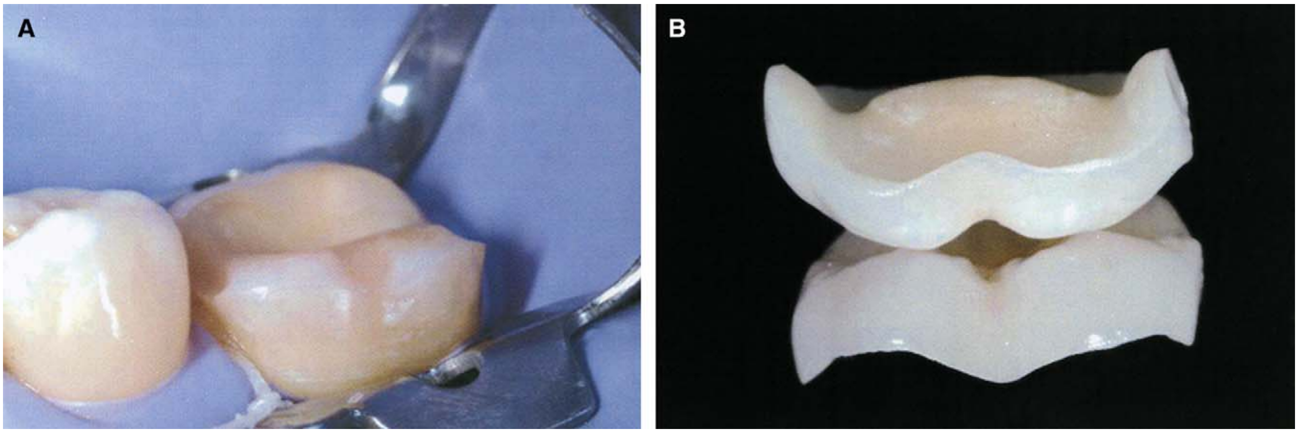

Fig. 1. Example of complete-coverage tooth preparation design enabled by optimized adhesive procedures (**A**) and corresponding porcelain "occlusal veneer" or overlay (**B**). Tooth structure removal can be up to 50% of that required for traditional complete-coverage crown.

be respected during the clinical procedure of dentin-resin hybridization, the most important of which are related to the problems of (1) dentin contamination[6-7] and (2) susceptibility of the hybrid layer to collapse until it is polymerized.[11] These essential factors, when considered in relation to the use of indirect bonded restorations, especially bonded porcelain restorations, lead to the conclusion that dentin should be sealed immediately after tooth preparation, prior to impression making—the so-called *immediate dentin sealing (IDS) technique*.[16,17]

When used on complete-crown coverage preparations and combined with glass-ionomer or modified-resin cements, IDS can result in significantly increased retention.[18] IDS can therefore be useful for improving retention for short clinical crowns and excessively tapered preparations. Provided that optimal adhesion is also achieved at the intaglio surface of the restorations—including with the use of techniques such as porcelain etching and silanization for inlays, onlays, and veneers—traditional principles of tooth preparation can be omitted, allowing more conservative tooth preparations (Fig. 1),[19-21] resulting in removal of up to 50% less tooth structure. The aim of this study was to evaluate the influence of IDS on dentin bond strength using the nontrimming microtensile bond test.[22,23] A conventional 3-step etch-and-rinse adhesive was chosen because of its proven reliability and improved adaptation to dentin.[24,25]

MATERIAL AND METHODS

Tooth preparation

Freshly extracted, sound human molars stored in solution saturated with thymol were used once approval was obtained from the University of Southern California Institutional Review Board. Flat midcoronal dentin surfaces were created after removal of the occlusal half of the crown using a model trimmer. The surfaces were evaluated for the presence of any remaining enamel, which was removed by additional trimming when observed, followed by finishing with 600-grit SiC paper (GatorGrit; Ali Industries, Fairborn, Ohio) under water to create a relatively smooth dentin surface.

Experimental design

The experimental design was based on a recent study by Tay et al.[23] A 3-step etch-rinse adhesive system (OptiBond FL; Kerr, Orange, Calif) was used according to the manufacturer's instructions: 15 seconds of dentin etching with 37.5% phosphoric acid, abundant rinsing, air drying for 5 seconds, application of primer (bottle 1) with a light brushing motion for 30 seconds, air drying for 5 seconds, application of adhesive resin with a light brushing motion for 15 seconds, and air thinning for 3 seconds. Experimental groups varied according to the sequence and mode of application of the dentin adhesive (Table I).

The control (C) group consisted of 5 teeth immediately bonded (etch-prime-adhesive, adhesive polymerized) and restored. Direct restorations consisted of 1.5-mm-thick increments of composite resin (Z100; 3M ESPE, St. Paul, Minn); each layer was light polymerized (Demetron LC; Kerr) for 20 seconds at 600 mW/cm^2.

The indirect restoration, delayed dentin sealing (DDS) group, consisted of 5 teeth first restored with a provisional restoration material (Tempfil Inlay; Kerr) left in place for 2 weeks, immersed in saline solution. Following that delay, the provisional restoration was removed and dentin was cleaned by airborne-particle abrasion (RONDOflex; KaVo, Lake Zurich, Ill and CoJet; 3M ESPE), followed by the application of the dentin bonding agent (etch-prime-bond). The adhesive resin

Table I. Experimental groups and sequence

Control group	DDS group	IDS group
Tooth preparation + Dentin bonding (etch/prime/adhesive), adhesive polymerized + Direct restoration	1. Tooth preparation	1. Tooth preparation + IDS = Dentin bonding (etch/prime/adhesive), adhesive polymerized
	2. Provisional restoration (+ 2-week delay)	2. Provisional restoration (+ 2-week delay)
	3. Provisional removed microairborne-particle abrasion of dentin + Dentin bonding (etch/prime/adhesive), adhesive not polymerized + Restoration	3. Provisional removed, microairborne-particle abrasion of adhesive + Adhesive not polymerized + Restoration

was left unpolymerized until the application of the restorative material (Z100; 3M ESPE).

The indirect restoration, immediate dentin sealing (IDS) group, consisted of 5 teeth immediately bonded (etch-prime-bond-polymerize). Polymerization of the adhesive was followed by the application of an air-blocking barrier (glycerin jelly) and 10 seconds of additional light exposure with the same light unit to polymerize the oxygen-inhibition layer. The bonded surfaces were then isolated with petroleum gel. Teeth were restored with a provisional restoration material (Tempfil Inlay; Kerr), left in place for 2 weeks, and immersed in saline solution. Following that delay, the provisional restoration was removed and the sealed dentin was cleaned by airborne-particle abrasion (RONDOflex and CoJet). One coat of adhesive resin was then applied and left unpolymerized until the application of the restorative material (Z100; 3M ESPE).

Preparation for microtensile bond strength testing

All restored specimens were stored in distilled water at room temperature for 24 hours before testing. Each specimen was individually secured with wax (GEO-Cervical; Renfert, St. Charles, Ill) to a transparent plastic sectioning block. Using the nontrimming technique developed by Shono et al[22] (Fig. 2), multiple beams were prepared, with composite resin comprising half of the beam and dentin comprising the other half. To prepare the beams, specimens were first vertically sectioned into 0.9-mm-thick slabs using a low-speed diamond saw (Isomet; Buehler Ltd, Lake Bluff, Ill) under water lubrication. The slabs were sectioned again into beams with approximately 0.81-mm^2 cross-sectional areas. The specimens were attached to a table-top material tester (Micro Tensile Tester; Bisco, Schaumburg, Ill) using cyanoacrylate (Zapit; DVA, Corona, Calif) and subjected to microtensile testing at a crosshead speed of 5.4- kg force per minute. Eleven beams were prepared from each tooth. After testing, the failure mode of each beam was determined under stereoscopic microscope (×30). Failure was classified as an *interfacial failure* if the fracture site was located entirely between the adhesive and dentin or if the fracture site continued from the adhesive into either the composite resin or dentin, and as a *substrate failure* if the fracture occurred exclusively within the resin composite or dentin.

Bond strength data obtained from the 3 experimental groups were analyzed with a Kruskal-Wallis test, with each tooth (mean microtensile bond strength testing [MTBS] from the 11 beams) used as a single measurement, yielding 5 measurements per group. Statistical significance was set in advance at the .05 level. Post hoc comparison was done using the Mann-Whitney U test.

Scanning electron microscopy

The dentin and resin sides of 4 fractured beams (interfacial failure) from each group were air dried, sputter coated with gold/palladium, and examined using a scanning electron microscope (SEM). Unused slabs (2 from each group) were also prepared for the SEM analysis of the intact dentin-resin interface. The sectioned surface of each slab was etched for 30 seconds with 35% phosphoric acid and replicated with a vinyl polysiloxane material (Aquasil ULV; Dentsply Caulk, Milford, Del) for the fabrication of gold-coated resin specimens.

Fig. 2. Schematic representation of preparation of composite resin-dentin beams in "nontrimming" version of microtensile bond test.

Table II. Mean microtensile bond strength values (MPa) and SDs of OptiBond FL

Control group			DDS group			IDS group		
	Mean	SD		Mean	SD		Mean	SD
Tooth 1	59.34	9.67	Tooth 1	26.52	10.10	Tooth 1	56.54	6.35
Tooth 2	53.48	9.10	Tooth 2	1.00	2.22	Tooth 2	61.96	9.71
Tooth 3	44.73	11.33	Tooth 3	17.81	2.82	Tooth 3	53.61	4.10
Tooth 4	55.52	5.48	Tooth 4	0.36	0.82	Tooth 4	60.43	7.65
Tooth 5	62.24	18.2	Tooth 5	12.20	7.40	Tooth 5	58.69	4.15
Group	55.06^a	6.69	Group	11.58^b	11.19	Group	58.25^a	3.28

Values for each tooth obtained from 11 measurements (11 beams). Groups identified with different superscripts are significantly different ($P<.05$).

RESULTS

Microtensile bond strength

Table II lists the MTBS values of OptiBond FL to dentin in the control (C) and experimental (DDS and IDS) groups. The mean MTBS varied from 12 to 58 MPa. The Kruskal-Wallis test indicated a significant difference among the 3 groups (P=.0081). The Mann-Whitney U test applied to the C and IDS groups did not show a difference. The mean bond strength of the DDS group, 11.58 MPa, was significantly lower (P=.008) than that of the 2 other groups (55.06 and 58.25 MPa for the C and IDS groups, respectively). The large variation within the DDS group (group with the smallest mean and the largest standard deviation) is explained by the numerous failures at "near-0" load due the very low bond strength. Such failures did not occur in the other groups. Results of the failure modes determined by optical microscopic evaluation are shown in Table III. Failures were either interfacial or cohesive in dentin for the C and IDS groups, whereas most of the failures in the DDS group were interfacial. Obvious cohesive failure in the restorative composite occurred only in 3 beams.

SEM observations

The fractured beams for both the C and IDS groups demonstrated interfacial failure that was typically mixed, with both areas of failed adhesive resin and areas of cohesively failed dentin ("islands") showing numerous hybridized smear plugs and "torn" (irregular) intertubular dentin (Figs. 3 and 4). For DDS specimens, it was more difficult to determine the exact nature of interfacial failure because of the similar nature of the filled adhesive and hybrid layer: Figure 5 suggests failure at the top of the hybrid layer and in the adhesive, as there were no exposed dentin tubules. The intact slabs for all groups generated a well-organized hybrid layer of 3- to 5-μm thickness and resin tags. For the C and IDS groups, this "interdiffusion zone" was usually in continuity with the dentin underneath (Fig. 6, *A* and *B*). For DDS specimens, gaps were frequently observed between the hybrid layers and systematically presented a marked disruption with the overlying composite resin (Fig. 6, *C* and *E*). In contrast, C and IDS specimens showed rare discontinuities either in the dentin-resin interface or between the prepolymerized adhesive and the luting composite.

DISCUSSION

The results of the present study strongly favor immediate dentin sealing using OptiBond FL. Although early bond strength of the adhesive was measured and no inference with respect to the durability of the bond can be made, there are several rational motives and other practical and technical reasons confirming the validity of sealing dentin immediately, before making impressions.[17]

Table III. Distribution of failure modes as observed by optical microscopy

Failure mode	Control group	DDS group	IDS group
Interfacial (%)	62	98	49
Dentin substrate (%)	34	2	49
Composite substrate (%)	4	0	2

First, freshly cut dentin is the ideal substrate for dentin bonding.[3,6,8] Significant reductions in bond strength can occur when simulating dentin contamination with various provisional cements compared to freshly cut dentin. In practice, freshly cut dentin is present only at the time of tooth preparation, prior to impression making.

Secondly, prepolymerization of the DBA results in improved bond strength. In studies evaluating DBA bond strength, the infiltrating resin and adhesive layer are usually polymerized first (prepolymerization), prior to placing composite increments, which appears to generate improved bond strength when compared to specimens in which DBA and the overlying composite are polymerized together.[4,9] These results can be explained by the collapse of the unpolymerized dentin-resin hybrid layer caused by pressure during composite resin or restoration placement,[9,11] which correlate well with the impaired bond strength and SEM observations for the DDS group in the present study. Prepolymerizing the DBA is compatible with the direct application of composite restorations; however, prepolymerizing the adhesive resin raises several issues when applied during the luting of indirect bonded restorations. Polymerized DBA thicknesses can vary significantly according to surface geometry—on average, 60 to 80 μm on a smooth convex surface and up to 200 to 300 μm on concave surfaces such as marginal chamfers.[3,11] As a result, applying and polymerizing the DBA immediately before the insertion of an indirect composite resin or porcelain restoration could interfere with the complete seating of the restoration. Practically speaking, it is therefore recommended that the adhesive resin be kept unpolymerized before the restoration is fully seated, which was

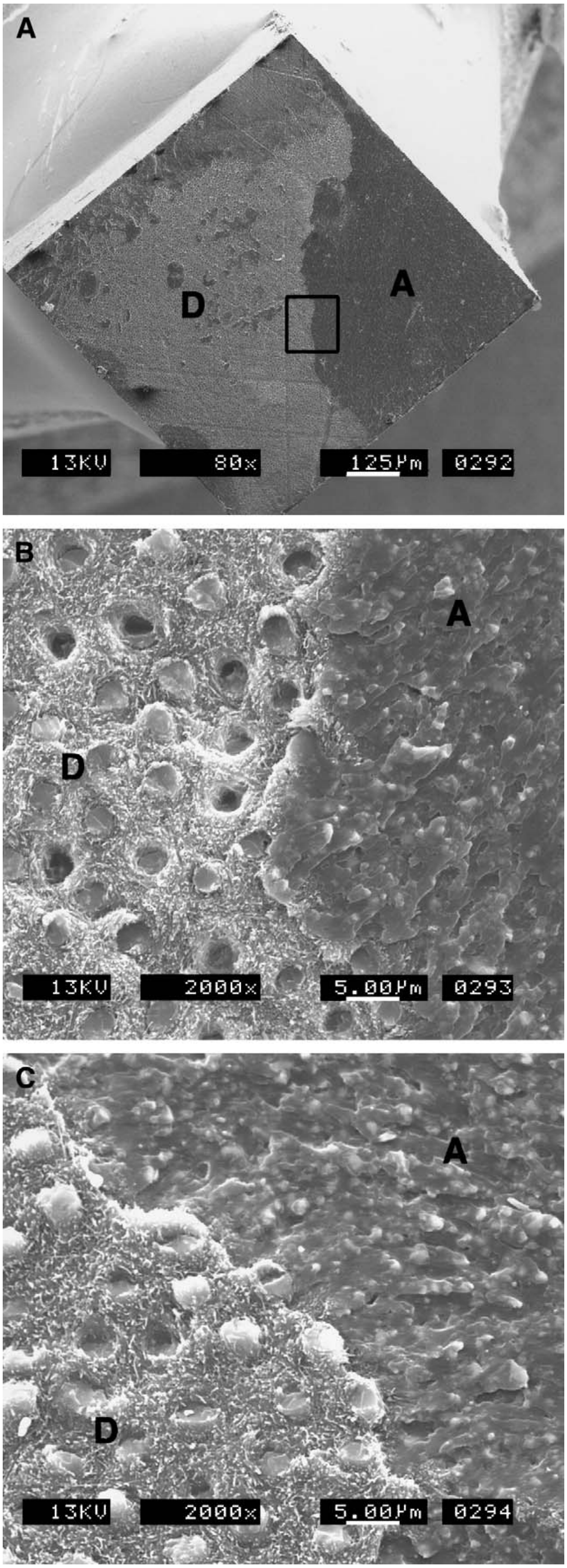

Fig. 3. A, Typical SEM micrograph of composite side of fractured beam from control group, which failed at 47.1 MPa. Note mixed interfacial failure, mainly in dentin *(D)* and, in part, in filled adhesive *(A)*. Original magnification ×80. **B,** Higher magnification of dentin-adhesive transition area on composite side. Original magnification ×2000. **C,** Corresponding view from tooth side suggests cohesive fracture in dentin beneath hybrid layer (note blocked hybridized resin plugs and ragged collagen fibrils between). There is very tight relationship between filled adhesive *(A)* and dentin *(D)*. Original magnification ×2000.

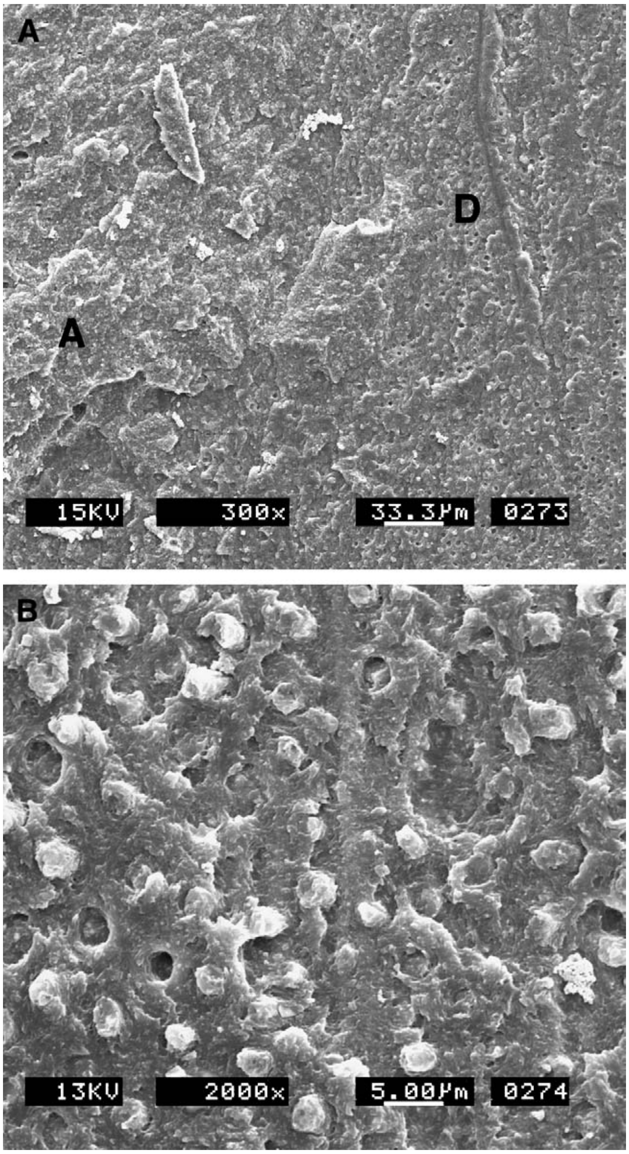

Fig. 4. **A,** Typical SEM micrograph of fractured beam from IDS group, which failed at 57.4 MPa. Note mixed interfacial failure, mainly in dentin *(D)* and, in part, in filled adhesive *(A)*. **B,** Higher magnification of dentin area on tooth side also suggests cohesive fracture in dentin beneath hybrid layer with blocked hybridized resin plugs. Original magnification ×2000.

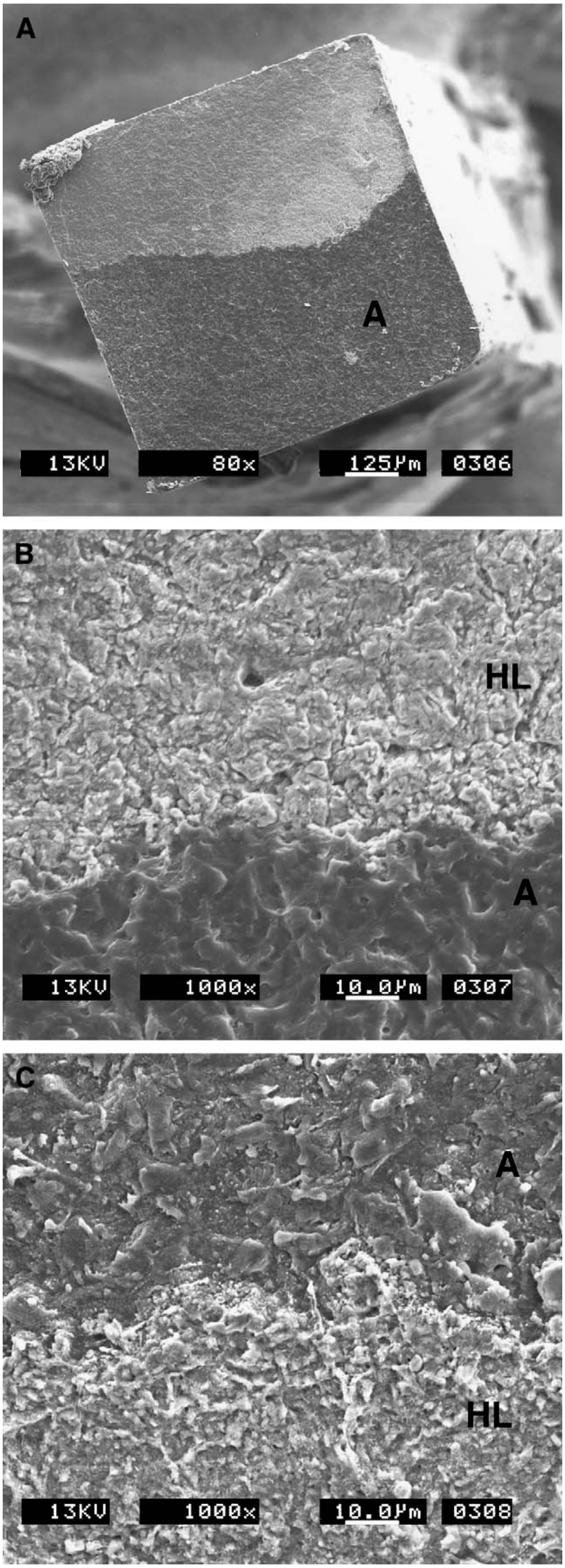

Fig. 5. **A,** Typical SEM micrograph of composite side of fractured beam from DDS group, which failed at 12.7 MPa. Note adhesive failure with 2 distinct areas. Original magnification ×80. **B,** Higher magnification on composite side reveals failure both in adhesive *(A)* and at top of hybrid layer *(HL)*. Note absence of exposed dentin tubules. Original magnification ×2000. **C,** Corresponding view from tooth side suggests same conclusions. Original magnification ×2000.

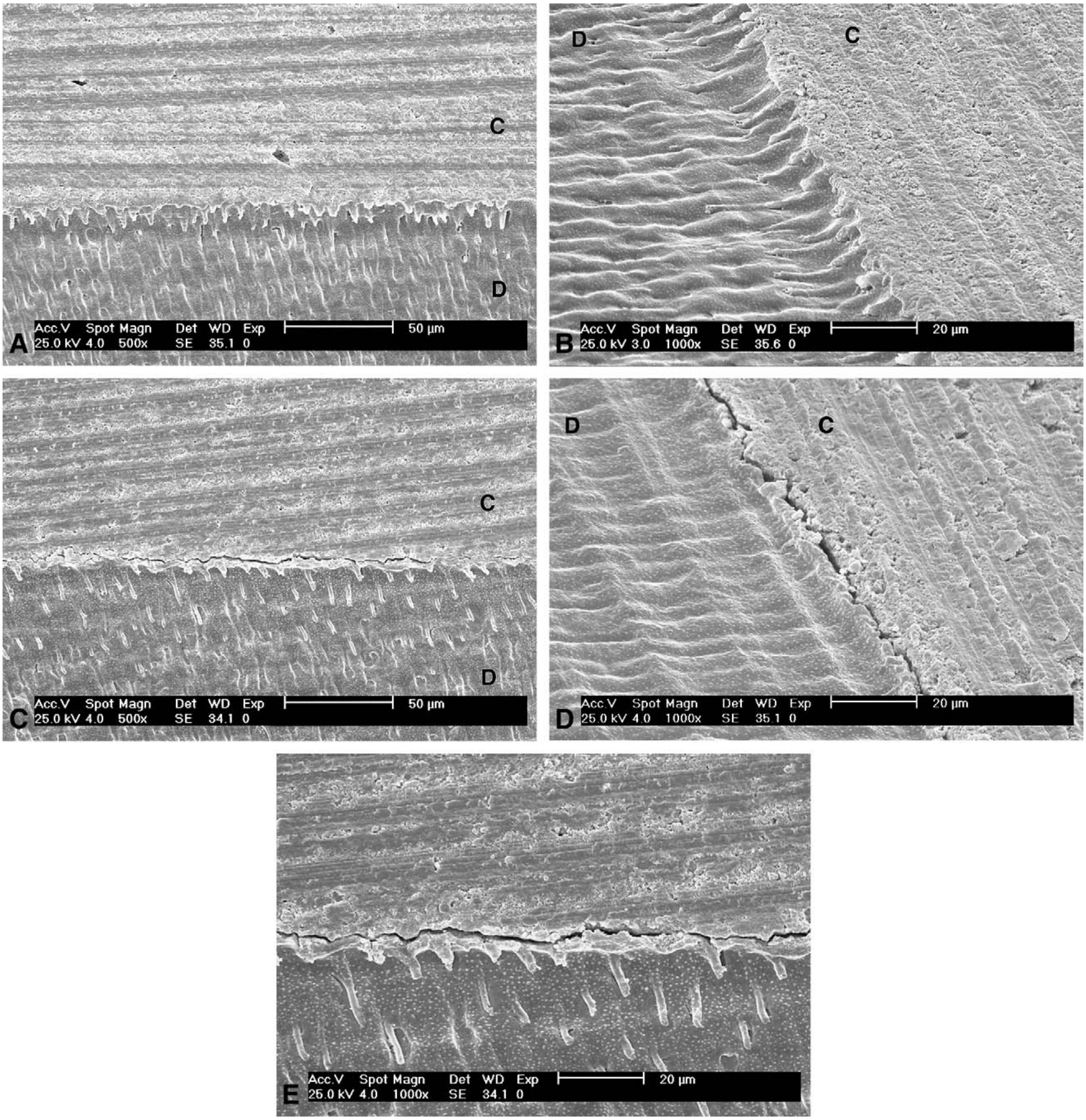

Fig. 6. Typical SEM micrographs (**A,** original magnification ×500 and **B,** original magnification ×1000) of demineralized specimens section replica (intact untested slab) for IDS group. Junction between the composite *(C)* and the prepolymerized adhesive is invisible, and no gap can be detected between the adhesive and the dentin *(D)*. **C, D,** Similar SEM views for typical DDS group. Gap is clearly detectable between the composite *(C)* and dentin *(D)*. **E,** A closer examination shows the continuity between the hybrid layer and dentin and the gap at the top of hybrid layer as result of delayed dentin bonding. Original magnification ×1000.

simulated by the DDS group in the present study. In this situation, the pressure of the luting composite resin during the placement of the restoration can create a collapse of demineralized dentin (collagen fibrils) and subsequently affect the adhesive interface cohesiveness.[9,11] The corresponding micromorphological results are shown in Figure 6, *E*. A significant gap at the top of the hybrid layer is visible. Thinning of the adhesive layer to less than 40 μm would theoretically allow for prepolymerization, before insertion of the restoration; however, because methacrylate resins show an inhibition layer of up to 40 μm thick,[26] excessive thinning can prevent the polymerization of light-activated DBAs. All of the aforementioned issues can be resolved if exposed dentin surfaces are sealed immediately; the DBA being applied and polymerized directly after the completion of tooth preparations, before making the definitive impression, was confirmed to generate superior bond strength[13,14] and fewer gap formations.[11,15] The resulting interphase, simulated in the IDS group of the present study, could potentially better withstand long-term exposure to thermal and functional loads compared to the same adhesive being applied and polymerized together with the restoration.

Thirdly, IDS allows stress-free dentin bond development. Dentin bond strength develops progressively over time. In directly placed adhesive restorations, the weaker early dentin bond is immediately challenged by the overlying composite resin shrinkage and subsequent occlusal forces. However, when using IDS and indirect bonded restorations, because of the delayed placement of the restoration (intrinsic to indirect techniques) and postponed occlusal loading, the dentin bond can increase over time and residual stresses can dissipate,[27] resulting in significantly improved restoration adaptation as demonstrated by Dietschi et al.[12]

Finally, IDS protects dentin against bacterial leakage and sensitivity during the provisional phase of treatment. Based on the fact that provisional restorations may permit microleakage of bacteria and, subsequently, dentin sensitivity, Pashley et al[3] proposed sealing dentin during crown preparation. This idea proves even more useful when using bonded porcelain restorations, given the specific difficulty of obtaining sealed and stable provisional restorations. An in vivo study confirmed the ability of different primers to prevent sensitivity and bacterial penetration when preparing for porcelain veneers.[6]

The potential exposure of the polymerized adhesive to the oral fluids, permitting water sorption,[28] could compromise the bond between the existing adhesive and the new restoration. Considering the results of the present study (group IDS versus group C), placement of a provisional restoration for a period up to 2 weeks did not seem to affect this bond, which may be explained by remaining free radicals, van der Waals interactions (intermolecular forces), and micromechanical interlocking. As a matter of fact, just prior to restoration placement in the IDS group, the existing adhesive layer was meticulously cleansed by microairborne-particle abrasion. Using pumice or roughening with a coarse diamond rotary cutting instrument at low speed can also promote the bond to the sealed dentin.[11,16,17] Clinically, the entire tooth preparation surface could then be considered and conditioned as it would be in the absence of dentin exposure: H_3PO_4 etch (30 seconds), rinse, then dry and coat with adhesive resin. At this time, no prepolymerization of the adhesive is indicated because it would prevent the complete seating of the restoration. As demonstrated by the bond strength results and SEM analysis of the IDS group in the present study, bonding to the existing adhesive was sufficient to generate cohesive failures in dentin, and no gaps were observed between the prepolymerized adhesive and the new restoration (Figs. 6, *A* and *B*). The success of this procedure might also be attributed to the dentin bonding system, especially the filled adhesive. OptiBond FL (Kerr) is particularly indicated for IDS because of its ability to form a consistent and uniform layer, as well as its cohesiveness with the final luting composite resin.[11] Although there is a tendency to simplify bonding procedures, recent data confirm that conventional 3-step etch-and-rinse adhesives still perform most favorably and are most reliable in the long term.[24,25] Especially for posterior bonded restorations, OptiBond FL allows both dentin hybridization and the formation of a low elastic modulus liner (stress absorber) with significantly improved adaptation to dentin.[12] There are no data, however, suggesting that IDS cannot be applied successfully in conjunction with other adhesive systems.

Several practical and clinical facts support the use of IDS. Patients experience improved comfort during the provisional restoration stage, limited need for anesthesia during definitive insertion of the restorations, and reduced postoperative sensitivity.[3,6] When applying IDS, owing to the direct and immediate polymerization mode, light-activated DBAs can be used. Without IDS, the use of dual-polymerizing DBAs to ensure complete polymerization through the restoration may be required. As IDS is performed primarily on exposed dentin surfaces, the clinician can focus on the "wet bonding" to dentin (for total etching situations), whereas enamel conditioning can be performed separately at the stage of definitive restoration placement.

Caution must be applied during the provisional restoration stage because sealed dentin surfaces have the potential to bond to resin-based provisional materials and cements. As a result, retrieval and removal of direct provisional restorations can be difficult. Tooth preparations must be rigorously isolated with a separating medium, such as a thick layer of petroleum jelly, during fabrication of the provisional restoration. Therefore, it is suggested the clinician consider fabricating provisional restorations indirectly, avoiding resin-based provisional cements and providing mechanical retention and stabilization instead, such as locking the restoration on the tooth through addition of liquid resin in palatal embrasures. Splinting multiple restorations can also significantly enhance the primary stability of the provisional restoration. The results of the present study indicated that clinical trials using immediate dentin sealing should be initiated.

CONCLUSIONS

Tooth preparation for indirect bonded restorations such as composite/ceramic inlays, onlays, and veneers can generate significant dentin exposure. The results of this study indicate that to improve dentin bond strength, these freshly cut dentin surfaces should be sealed with a DBA immediately following tooth preparation, before making impressions. A 3-step etch-and-rinse DBA with a filled adhesive resin is suggested for this specific purpose.

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REFERENCES

1. Dumfahrt H, Schaffer H. Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: part II—clinical results. Int J Prosthodont 2000;13:9-18.
2. Friedman MJ. A 15-year review of porcelain veneer failure—a clinician's observations. Compend Contin Educ Dent 1998;19:625-8, 630, 632.
3. Pashley EL, Comer RW, Simpson MD, Horner JA, Pashley DH, Caughman WF. Dentin permeability: sealing the dentin in crown preparations. Oper Dent 1992;17:13-20.
4. McCabe JF, Rusby S. Dentine bonding—the effect of pre-curing the bonding resin. Br Dent J 1994;176:333-6.
5. Bertschinger C, Paul SJ, Luthy H, Scharer P. Dual application of dentin bonding agents: effect on bond strength. Am J Dent 1996;9:115-9.
6. Cagidiaco MC, Ferrari M, Garberoglio R, Davidson CL. Dentin contamination protection after mechanical preparation for veneering. Am J Dent 1996;9:57-60.
7. Paul SJ, Scharer P. Effect of provisional cements on the bond strength of various adhesive bonding systems on dentine. J Oral Rehabil 1997;24:8-14.
8. Paul SJ, Scharer P. The dual bonding technique: a modified method to improve adhesive luting procedures. Int J Periodontics Restorative Dent 1997;17:536-45.
9. Dietschi D, Herzfeld D. In vitro evaluation of marginal and internal adaptation of class II resin composite restorations after thermal and occlusal stressing. Eur J Oral Sci 1998;106:1033-42.
10. Frankenberger R, Sindel J, Kramer N, Petschelt A. Dentin bond strength and marginal adaptation: direct composite resins vs ceramic inlays. Oper Dent 1999;24:147-55.
11. Magne P, Douglas WH. Porcelain veneers: dentin bonding optimization and biomimetic recovery of the crown. Int J Prosthodont 1999;12:111-21.
12. Dietschi D, Monasevic M, Krejci I, Davidson C. Marginal and internal adaptation of class II restorations after immediate or delayed composite placement. J Dent 2002;30:259-69.
13. Ozturk N, Aykent F. Dentin bond strengths of two ceramic inlay systems after cementation with three different techniques and one bonding system. J Prosthet Dent 2003;89:275-81.
14. Jayasooriya PR, Pereira PN, Nikaido T, Tagami J. Efficacy of a resin coating on bond strengths of resin cement to dentin. J Esthet Restor Dent 2003;15:105-13.
15. Jayasooriya PR, Pereira PN, Nikaido T, Burrow MF, Tagami J. The effect of a "resin coating" on the interfacial adaptation of composite inlays. Oper Dent 2003;28:28-35.
16. Magne P, Belser U. Immediate dentin bonding. In: Magne P, Belser U, editors. Bonded porcelain restorations in the anterior dentition: a biomimetic approach. Chicago: Quintessence; 2002. p. 270-3, 358-63.
17. Magne P. Immediate dentin sealing: a fundamental procedure for indirect bonded restorations. J Esthet Restor Dent 2005;17:144-55.
18. Johnson GH, Hazelton LR, Bales DJ, Lepe X. The effect of a resin-based sealer on crown retention for three types of cement. J Prosthet Dent 2004;91:428-35.
19. Magne P, Perroud R, Hodges JS, Belser UC. Clinical performance of novel-design porcelain veneers for the recovery of coronal volume and length. Int J Periodontics Restorative Dent 2000;20:440-57.
20. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for anterior teeth. J Prosthet Dent 2002;87:503-9.
21. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for posterior teeth. Int J Periodontics Restorative Dent 2002;22:241-9.
22. Shono Y, Ogawa T, Terashita M, Carvalho RM, Pashley EL, Pashley DH. Regional measurement of resin-dentin bonding as an array. J Dent Res 1999;78:699-705.
23. Tay FR, Carvalho R, Sano H, Pashley DH. Effect of smear layers on the bonding of a self-etching primer to dentin. J Adhes Dent 2000;2:99-116.
24. Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, et al. Buonocore memorial lecture. Adhesion to enamel and dentin: current status and future challenges. Oper Dent 2003;28:215-35.
25. De Munck J, Van Meerbeek B, Satoshi I, Vargas M, Yoshida Y, Armstrong S, et al. Microtensile bond strengths of one- and two-step self-etch adhesives to bur-cut enamel and dentin. Am J Dent 2003;16:414-20.
26. Rueggeberg FA, Margeson DH. The effect of oxygen inhibition on an unfilled/filled composite system. J Dent Res 1990;69:1652-8.
27. Park JW, Ferracane JL. Measuring the residual stress in dental composites using a ring slitting method. Dent Mater 2005;21:882-9.
28. Ito S, Hashimoto M, Wadgaonkar B, Svizero N, Carvalho RM, Yiu C, et al. Effects of resin hydrophilicity on water sorption and changes in modulus of elasticity. Biomaterials 2005;26:6449-59.

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