Direct Dentin Bonding Technique Sensitivity When Using Air/Suction Drying Steps

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ABSTRACT

Statement of Problem: Moisture control before and after application of the primer/adhesive components of etch-and-rinse dentin bonding agents is usually achieved using a stream of air delivered by an air syringe. Suction drying with a suction tip is a common alternative for moisture control, but data about the use of suction drying instead of the air syringe is scarce or nonexistent.

Purpose: The purpose of this study was to compare the dentin microtensile bond strength (MTBS) using either the air syringe or the suction tip to control the amount of moisture.

Materials and Methods: Fifteen freshly extracted human molars were divided randomly into three groups of five. A three-step etch-and-rinse dentin bonding agent (OptiBond FL) was used. Group 1 was the control group and utilized air drying alone (with an air syringe) during the placement of the dentin adhesive on the ground-flat occlusal dentin surface. Group 2 also used air drying alone, but teeth were prepared with a standardized MOD cavity. Group 3 utilized suction drying alone in the standardized MOD cavity. All teeth were restored with 1.5-mm-thick horizontal increments of composite resin (Filtek Z100). Specimens were stored in water for 24 hours, then prepared for a nontrimming MTBS test. Bond strength data were analyzed with a Kruskal–Wallis test at $p < 0.05$. Specimens were also evaluated for mode of fracture and interface characterization using scanning electron microscope (SEM) analysis.

Results: The mean MTBSs were not statistically different from one another ($p = 0.54$) at 54.0 MPa (air-drying, flat dentin), 53.4 MPa (air-drying, MOD), and 49.2 MPa (suction drying, MOD). Microscopic evaluation of failure modes indicated that most failures were interfacial. Failed interfaces, when analyzed under SEM, appeared typically mixed with areas of failed adhesive resin and areas of cohesively failed dentin.

Conclusions: There are no differences in MTBS to human dentin using either the air syringe or the suction tip to control the amount of moisture. The conventional three-step dentin bonding agent used in the present study not only proved insensitive to the moisture-control method but also to the effect of increased polymerization shrinkage stress (ground-flat versus MOD preparation).

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CLINICAL SIGNIFICANCE

Although the effect of common errors on the performance of total-etch adhesives has been investigated, data about the use of suction drying instead of an air syringe is scarce or nonexistent. The present study demonstrated that both the air syringe and the suction tip can be used to control moisture when using etch-and-rinse dentin bonding agents. The conventional three-step dentin bonding agent tested, OptiBond FL, demonstrated low technique sensitivity.

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INTRODUCTION

Although there is a tendency to simplify dentin bonding procedures, data repeatedly confirm that conventional three-step etch-and-rinse adhesives still perform most favorably, are most reliable in the long term, and must still be regarded as the "gold standard" in dentin bonding.[1–3] Especially in the case of posterior bonded restorations, a filled etch-and-rinse adhesive such as OptiBond FL (Kerr, Orange, CA, USA) allows both dentin hybridization and formation of a low-elastic-modulus liner (stress absorber) with significantly improved adaptation to dentin.[2] This same product appears to be insensitive to polymerization shrinkage stress and water degradation compared with more recent self-etching products.[4]

Etch-and-rinse dentin bonding agents require moisture control before and after application of the primer/adhesive components, the dilemma being the removal of excess water or solvent from the dentin while keeping it moist.[5,6] It is well established that excessive air drying can cause collapse of the collagen matrix and interfere with resin infiltration, whereas inadequate solvent evaporation and/or residual water during dentin bonding can result in dilution or incomplete polymerization of the resin.[7–9] In most aforementioned studies,[1–4,7–9] moisture control is achieved using a stream of air delivered by an air syringe from the dental unit. Another option for moisture control would be to deliver negative pressure to the surface of the tooth using the so-called "suction drying" with a suction tip. In our knowledge, such approaches for moisture control have not been compared yet.

The purpose of this study was to determine if there are differences in microtensile bond strength (MTBS) to human dentin using either the air syringe or the suction tip to control the amount of moisture when using a filled etch-and-rinse dentin bonding agent in MOD preparations.

MATERIALS AND METHODS

Freshly extracted, sound human molars stored in solution saturated with thymol were used (approval obtained from the University of Southern California Institutional Review Board). For group 1, the control group, flat midcoronal dentin surfaces were created after removal of the occlusal half of the crown using a model trimmer followed by finishing with 600-grit SiC paper (Gatorgrit, Ali Industries, Fairborn, OH, USA) under water. For experimental groups 2 and 3, a standard MOD preparation (5-mm buccolingual width, 4-mm occlusal depth; Figure 2) was obtained using a high-speed handpiece and a large cylindrical coarse diamond bur (835-012, Brasseler, Savannah, GA, USA) mounted on a dental surveyor. The dentin surfaces were evaluated for the presence of any remaining enamel islands, which were removed by additional trimming when observed.

The experimental design was based on a recent publication by Tay and colleagues.[1] A three-step etch-rinse

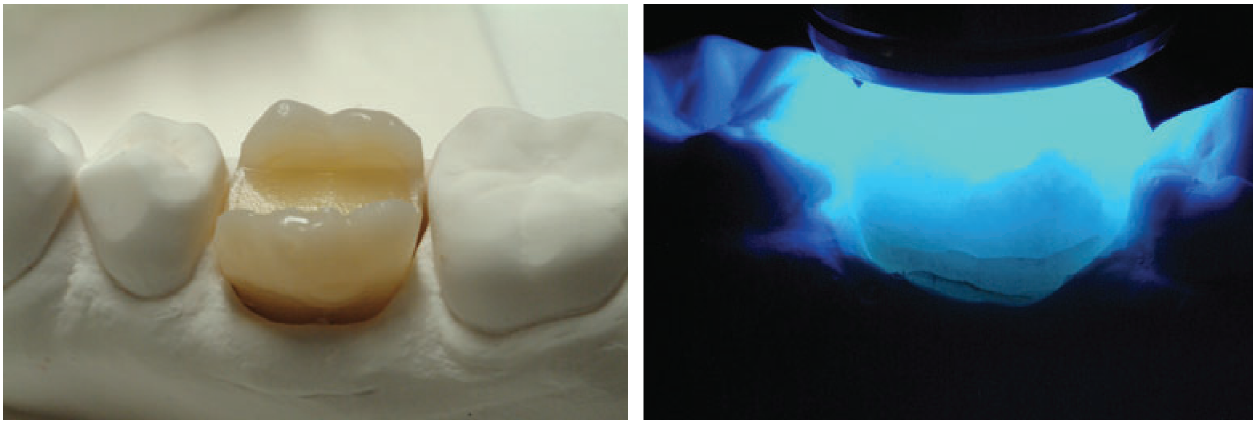

Figure 1. Experimental setup during adhesive steps. Teeth were fitted in a stone model in order to simulate neighboring teeth and their relative influence on the air flow during adhesive procedures (left). Final application and curing of the restorative material (right). Note the development of horizontal cracks at the lingual cusp base.

adhesive system (OptiBond FL) was used according to the manufacturer's instructions: 15-second dentin etching with 37.5% phosphoric acid; abundant rinsing followed by drying for 5 seconds using air syringe (groups 1 and 2) or suction drying (group 3); application of primer (bottle 1) with a light brushing motion for 30 seconds; drying for 5 seconds using air syringe (groups 1 and 2) or suction drying (group 3); application of adhesive resin with a light brushing motion for 15 seconds; and air thinning for 3 seconds. The primary goal of the study design was to evaluate the drying method in intracoronal preparations (MOD) where internal line angles make moisture control more difficult. Group 1 was created as a control for which moisture control would be due to simple geometry (flat ground dentin, no internal line angles). Because only one control group was needed, a flat restoration/suction drying group was not included.

Teeth were fitted in a stone model in order to simulate neighboring teeth and their relative influence on air flow during adhesive procedures (Figure 1). The adhesive system was always used on a freshly cut dentin surface. Air drying following etching and primer application (groups 1 and 2) was achieved by a full steady stream of air delivered by the air syringe from the dental unit at a constant distance of 2.5 cm. Suction drying (group 3) was obtained through the application of a high-speed suction tip (Evacuation Tip—Vented, Starryshine, Anaheim, CA, USA) within 0.5 cm from the dentin surface (without contact). Each group consisted of five teeth immediately bonded (etch-prime-adhesive, adhesive-cured) and restored. Restorations consisted of three to four 1.5-mm-thick increments of Filtek Z100 composite (3M ESPE, St. Paul, MN, USA), with each layer light-cured for 20 seconds (Demetron LC, Kerr).

All restored specimens were stored in distilled water at room temperature for 24 hours before testing. Each specimen was individually secured with sticky wax to a Plexiglas sectioning block. Using the nontrimming technique developed by Shono and colleagues[10] (Figure 2), multiple beams were prepared, with resin composite comprising the top half of the beam and dentin comprising the other half. To do so, specimens were vertically sectioned into 0.9-mm-thick slabs using a

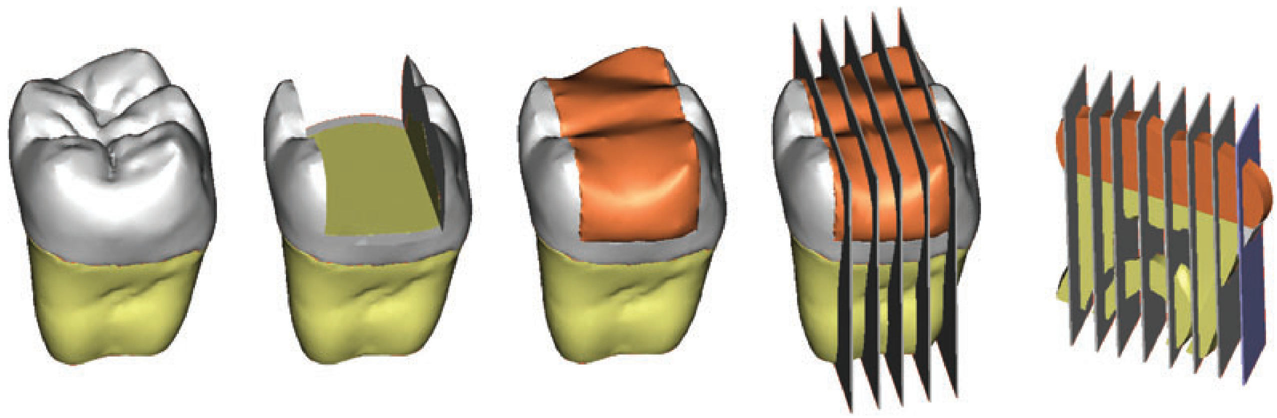

Figure 2. Schematic representation of preparation of composite resin-dentin beams in the "nontrimming" version of the microtensile bond test.

low-speed diamond saw (Isomet, Buehler Ltd., Lake Bluff, IL, USA) 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 tabletop material tester (The Micro Tensile Tester, Bisco, Schaumburg, IL, USA) using cyanoacrylate (Zapit, DVA, Corona, CA, USA) and subjected to microtensile testing at a rate of 5.4-kg force per minute. Ten to eighteen beams were used from each tooth. Beams were considered acceptable for testing when enough substrate was available for gluing in the testing jig (ca. 8-mm length with 4 mm of dentin or composite on each side of the interface). After testing, the failure mode of each beam was determined under a stereoscopic microscope (×30). Failures were classified as "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 resin composite or dentin, and as "substrate failure" if the fracture occurred exclusively within the resin composite or dentin.

Bond strength data obtained from the three experimental groups were analyzed with a Kruskal–Wallis test, with each tooth (mean MTBS from the 10–18 beams) used as a single measurement,[11] yielding five measurements per group. Statistical significance was set in advance at the 0.05 level.

The dentin and resin side of four fractured beams (interfacial failure) from each group were air-dried, sputter-coated with gold/palladium (RMS-76-M, Ernest Fullam, Schenectady, NY, USA), and examined using a scanning electron microscope (SEM) (Cambridge 360, Carl Zeiss, Thornwood, NY, USA). Untested slabs (two 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, rinsed, air-dried, and sputter-coated with gold/palladium.

RESULTS

Table 1 lists the MTBSs of OptiBond FL to dentin in the control and experimental groups (groups 2 and 3). The MTBS varied from 49 to 54 MPa. The Kruskal–Wallis test failed to indicate any significant difference among the three groups ($p = 0.54$). Results of the failure modes determined by optical microscopic evaluation are shown in Table 2. Most failures (56–92% of the beams) were interfacial for all three groups. Substrate failures occurred mainly in

TABLE 1. MTBS AND SDs OF OPTIBOND FL.

	Control Group 1: Flat Restoration, Air Drying		Group 2: MOD Restoration, Air Drying		Group 3: MOD Restoration, Suction Drying	
	Mean MTBS	SD	Mean MTBS	SD	Mean MTBS	SD
Tooth 1	44.43	7.37	48.03	13.95	43.79	7.94
Tooth 2	47.68	8.64	48.27	15.10	49.38	18.11
Tooth 3	63.20	14.14	60.67	18.29	50.17	10.72
Tooth 4	65.29	8.49	60.59	11.79	44.13	16.56
Tooth 5	49.70	7.07	49.63	12.37	58.47	15.09
Group	54.06[a]	9.52	53.44[a]	6.59	49.19[a]	5.96

MTBS = microtensile bond strength.
Groups identified with the different superscripts are significantly different ($p < 0.05$).
Mean MTBS for each tooth was obtained from 10 to 17 beams.

TABLE 2. DISTRIBUTION OF FAILURE MODES AS OBSERVED BY OPTICAL MICROSCOPY.

	Interfacial (%)	Dentin Substrate (%)	Composite Substrate (%)
Control group 1: Flat restoration, air drying	92	4	4
Group 2: MOD restoration, air drying	56	33	11
Group 3: MOD restoration, suction drying	69	25	6

dentin (up to 34% of the beams). Obvious cohesive failure in the restorative composite occurred rarely (up to 11% of the beams). No beams failed prematurely during preparation for bond strength testing.

Fractured beams for all groups demonstrated interfacial failures that were typically mixed with areas of failed adhesive resin and areas (or islands) of cohesively failed dentin with hybridized smear plugs and "torn" (irregular) intertubular dentin (Figures 3 and 4). Intact slabs for all groups generated a well-organized hybrid layer of 3 to 5-µm thickness and resin tags. This "interdiffusion zone" was usually in continuity with the dentin underneath (Figure 5). Even when cohesive failures caused by sample preparation and dehydration were found within the composite and dentinoenamel junction, the adhesive interface resisted this intense stress.

DISCUSSION

Although early 24-hour dentin bond strength of the adhesive was quantified and no inference to the durability of the bond can be made, the results of the present study suggest that a potential method for moisture control during bonding procedure is suction drying. Although the effect of common errors on the performance of total-etch adhesives has been investigated,[7,8] data about the use of suction drying instead of an air syringe is very scarce or nonexistent.

The goal of moisture control is to prevent the accumulation of residual water or other solvents in order to decrease the permeability of the hybridized dentin.[12] Increased permeability caused by incomplete solvent removal is certainly the most serious bonding error as it creates channels for water movement and water sorption within the hydrophilic

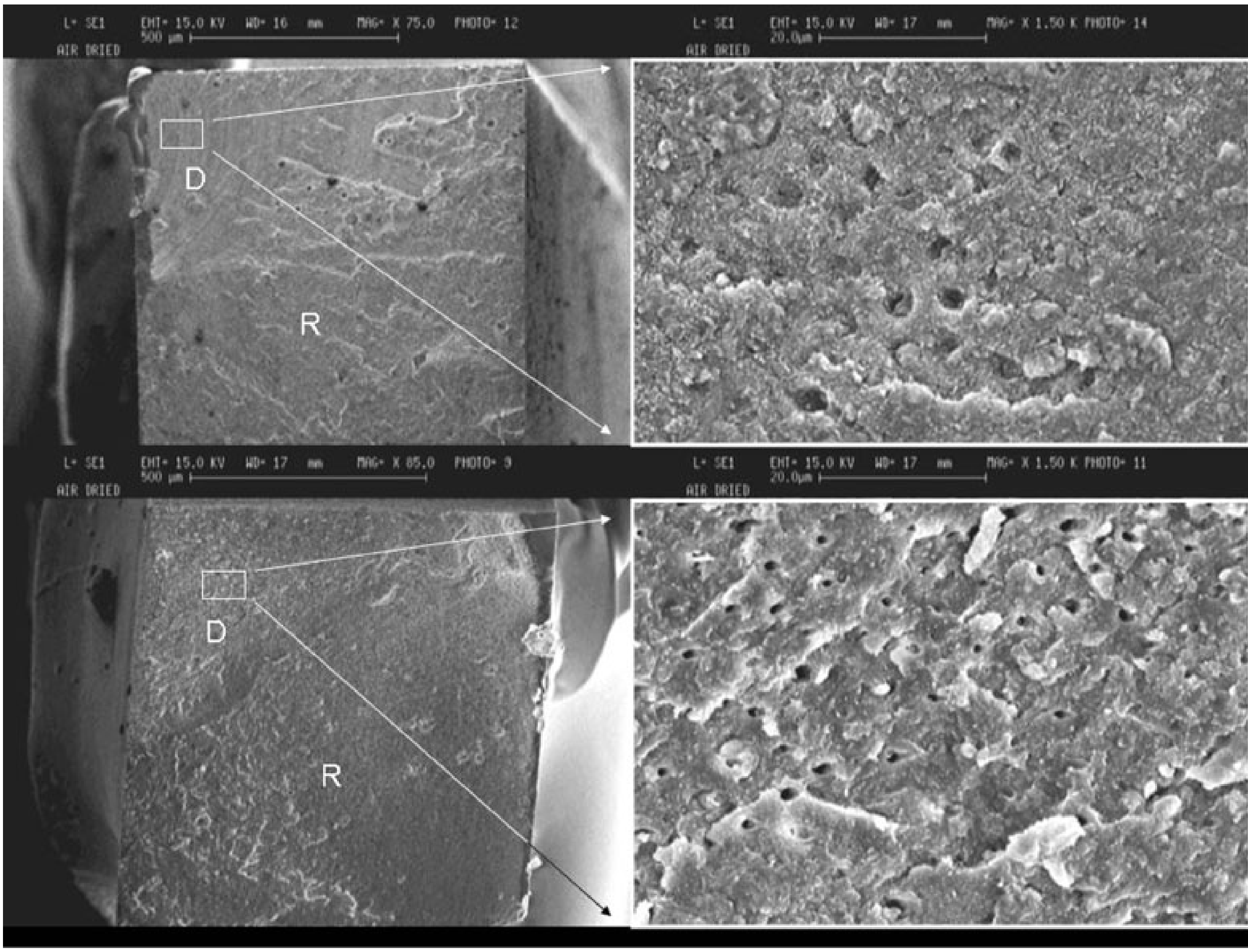

Figure 3. Typical scanning electron microscope micrograph of the dentin side of fractured beams for group 2 (MOD air drying), which failed, and 69.3 MPa (top left) and 69.6 MPa (bottom left). Note the similar aspect of beams with mixed interfacial failure in dentin (D) and in filled adhesive resin (R). Original magnification ×75 and ×85, respectively (top left and bottom left). Higher magnification of dentin areas (top right and bottom right) showing cohesively failed dentin. Original magnification ×1,500 (top right and bottom right).

adhesive layer, resulting in the rapid degradation of the bond.[12] Solvent evaporation is hard to achieve, especially when primer and adhesive resin are mixed.[13] With one-step adhesives, the situation is further complicated by the high concentration of solvent used to dilute hydrophilic and hydrophobic monomers, resulting in significantly lower bonding effectiveness.[14] All the aforementioned problems are minimized with etch-and-rinse adhesives such as OptiBond FL. Only 5-second air drying is recommended because these adhesives show higher evaporation of primer components (separate from the adhesive resin), which may explain the absence of sensitivity to the moisture control methods in this study.

The main difference between air syringe and suction drying lies in the direction of the air flow—that is, from the syringe tip onto the tooth surface under positive pressure versus from the tooth surface into the suction tip under negative

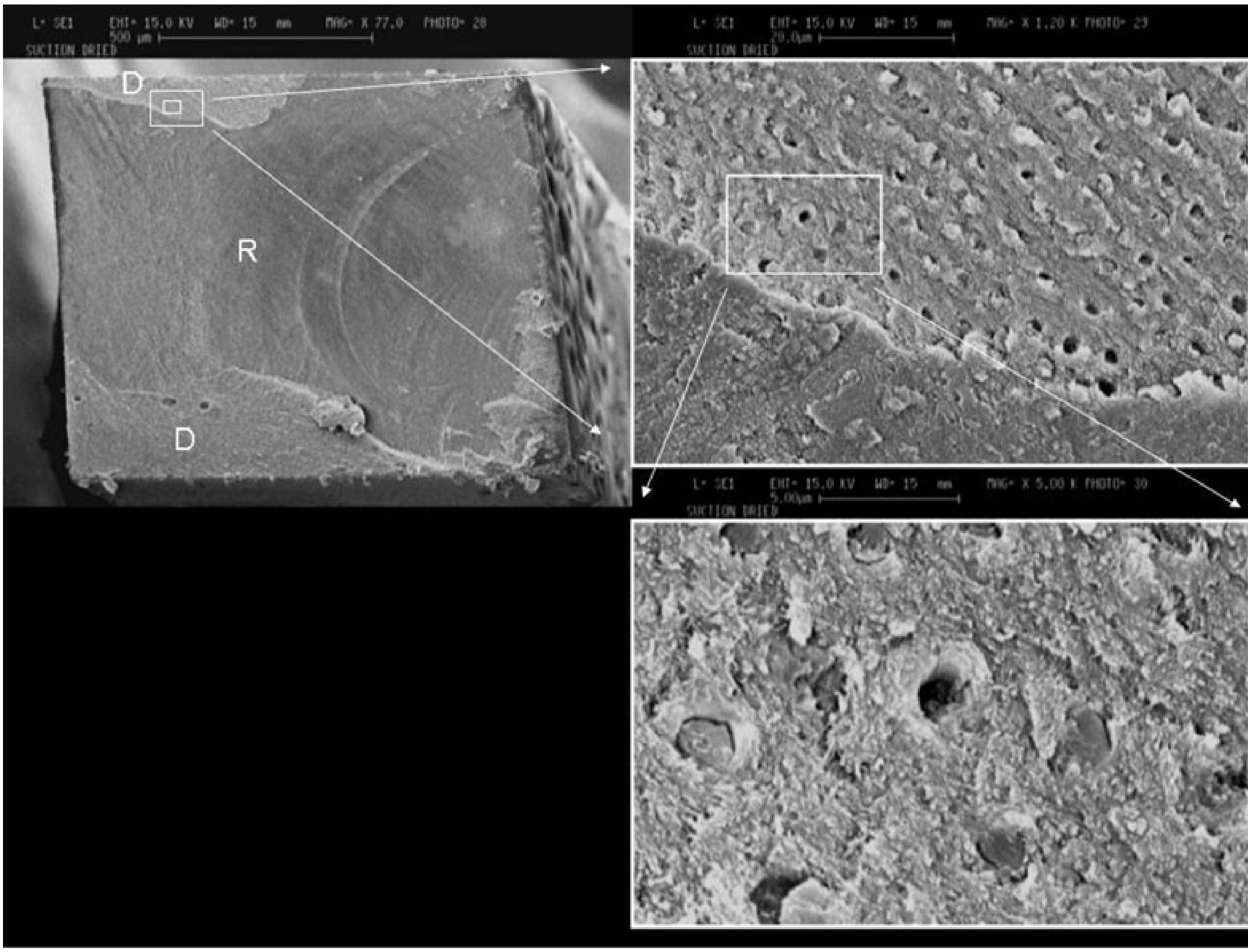

Figure 4. Typical scanning electron microscope micrograph of the dentin side of fractured beam for group 3 (MOD suction drying), which failed, and 50.2 MPa. Note again the mixed interfacial failure in dentin (D) and in filled adhesive resin (R). Original magnification ×77 (left). Higher magnification of dentin area (right) showing cohesively failed dentin beneath the hybrid layer (note the blocked hybridized resin plugs and ragged collagen fibrils between, bottom). Original magnification ×1,200 and ×5,000 (top right and bottom right, respectively).

pressure. It is believed that thorough air drying using the syringe may result in collapsed collagen matrix and preclude optimal resin infiltration. This type of problem, however, might not be as detrimental as the deficient solvent evaporation that would result from short or insufficient air drying.[8,9] Suction drying, which seems much less vigorous, might better prevent collapse of the collagen matrix. However, the suction tip might not have delivered enough negative pressure in order to prevent the accumulation of residual water or other solvents. This might explain the slightly lower (but not significantly different) bond strength values and decreased percentage of cohesive substrate failures observed with suction drying.

Another interesting result of the present study is the absence of differences in MTBS between the flat tooth preparation (C-factor ca. 1) and the MOD preparation (C-factor ca. 3). This is in

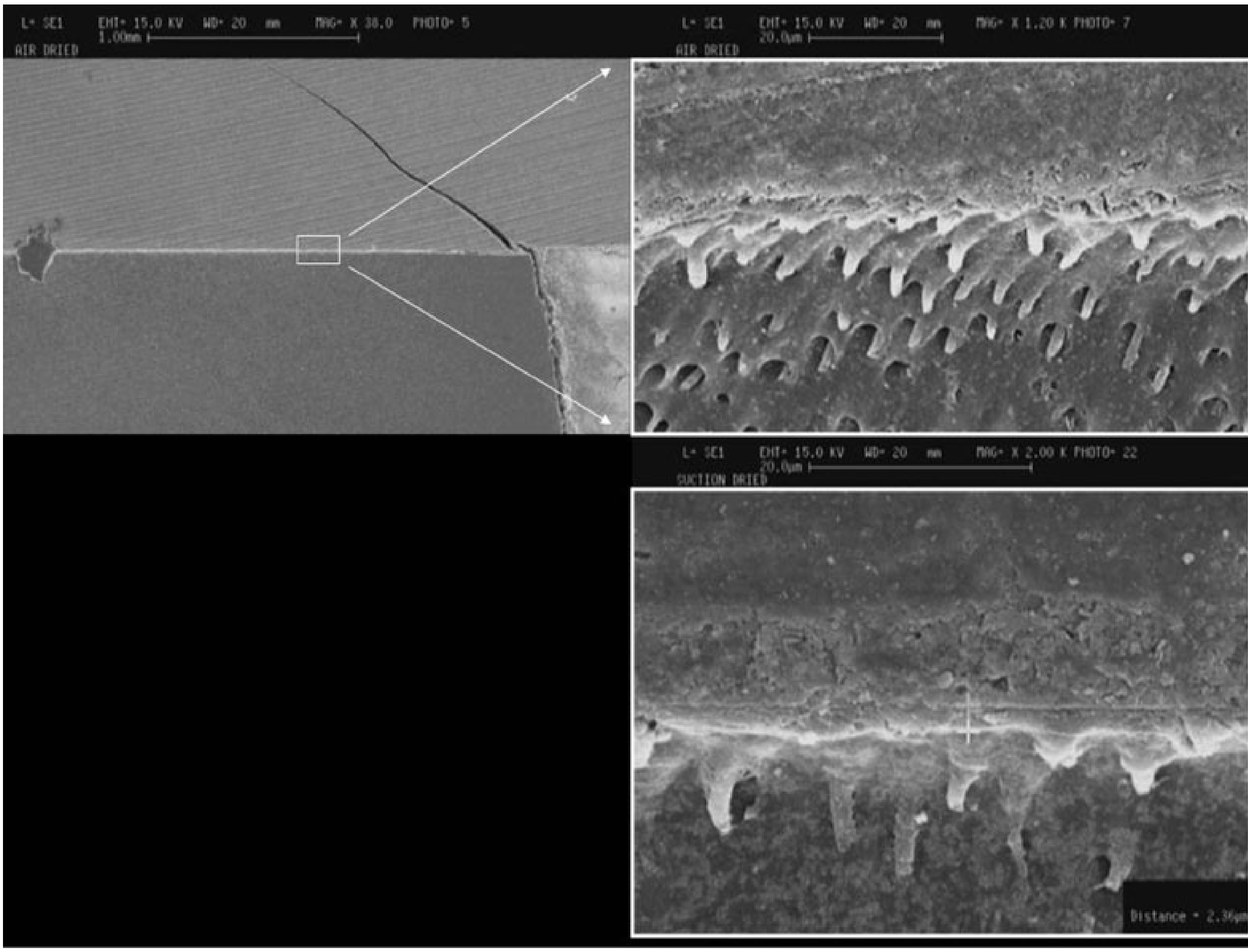

Figure 5. Typical scanning electron microscope micrograph of intact slab for group 2 (MOD air drying, top). Note the cohesive failure within the composite and dentinoenamel junction caused by sample dehydration (top left). The adhesive interface is left intact despite the intense stress generated by sample preparation and dehydration (top right). Original magnification ×38 and ×1,200, respectively (top left and top right). Higher magnification of intact slab for group 3 (MOD suction drying, bottom). Note the 2- to 3-μm-thick well-organized hybrid layer and resin tags; the interface is intact despite dehydration from sample preparation. Original magnification ×2,000.

agreement with another study by Shirai and colleagues[4] showing that OptiBond FL is not sensitive to the effects of increased polymerization shrinkage stress (C-factor up to 5). The similar results (flat preparation versus MOD) are also explained by another phenomenon: in a large MOD cavity, the tooth's resistance against polymerization shrinkage diminishes with loss of dental hard tissue, resulting in lower stress levels in the restoration and tooth-restoration interface, but increased stresses in the tooth.[15] Thus, cracks were typically observed within the remaining cusps during the curing of the composite (Figure 1, right panel).

Existing scientific evidence, along with the present study, demonstrate that the conventional three-step application procedure of Optibond

FL seems to guarantee a low technique-sensitive application procedure, both from the perspective of moisture control (collagen matrix collapse and solvent evaporation) and polymerization shrinkage stress (C-factor). Only one adhesive was evaluated, which makes the generalization of the findings difficult. Further studies using simulated fatigue testing will allow the evaluation of the stability of the bond strength. With insufficient solvent evaporation and increased permeability being the main issues with one-step adhesives, further investigations on the effect of moisture control methods are paramount to the optimization of the bond strength and durability of these recent generations of products.

CONCLUSION

Within the limits of the study design, there are no differences in MTBS to human dentin using either the air syringe or the suction tip to control the amount of moisture before and after application of the primer/adhesive components of Optibond FL. The conventional three-step dentin bonding agent used in the present study not only proved insensitive to the moisture control method but also to the effect of increased polymerization shrinkage stress (ground-flat versus MOD preparation).

DISCLOSURE AND ACKNOWLEDGMENTS

The authors do not have any financial interest in the companies whose materials are discussed in this article.

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