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The effects of common errors on sealing ability of total-etch adhesives

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Summary *Objectives*: This study evaluated the effect of errors commonly made in using total-etch adhesives, on the resulting bond strength, fluid movement and nanoleakage of resin dentin bonds.
Methods: Two total-etch adhesives were used for bonding to dentin according to the manufacturers' recommendations, with meticulous solvent evaporation (control), or with the introduction of common bonding errors—wet bonding without solvent evaporation (no evaporation), and dry bonding.
Results: The 24-hour bond strength of the control was significantly higher than the other groups ($p < 0.05$). For all groups, the higher initial permeability declined significantly after 24 h. The fluid movement across bonded dentin was similar in the control and dry bonding for both adhesives, whereas significantly higher permeability ($p < 0.05$) was recorded for the no evaporation groups even after 24 h. Extensive silver impregnation within hybrid layers was seen by TEM in the no evaporation and dry bonding specimens after 24 h. Dry bonding caused collapse of the collagen matrix and interfered with resin infiltration. In contrast, inadequate solvent evaporation and/or residual water during dentin bonding results in dilution or incomplete polymerization of the resin, leading to severe nanoleakage formation.
Significance: Increased permeability associated with incomplete solvent

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evaporation in total-etch adhesives may lead to poor bond strength.
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Introduction

The use of contemporary total-etch adhesives involves a degree of technique sensitivity that may compromise bonding efficacy and marginal seal of these adhesives [1,2]. Excessive air-drying and incomplete adhesive solvent removal are common errors associated with wet bonding on vital dentin [3]. The air-drying of acid-etched dentin (dry bonding) prevents optimal resin infiltration within the demineralized collagen network [4, 5]. Water has the highest solubility parameter for hydrogen bonding among polar resin solvents [6,7]. Water molecules form hydration clusters around the functional groups on collagen peptides [8–10] and proteoglycans [11], resulting in the full expansion of interfibrillar spaces that are used for permeation of resin monomers. Conversely, interpeptide or peptide-proteoglycan hydrogen bonding that develops during air-drying causes collapse of interfibrillar spaces in the demineralized matrix [12–15]. Incomplete evaporation of solvents results in dilution [16,17], poor polymerization [18], or phase separation of the resin components [19]. Recent total-etch adhesives contain high concentrations of water or organic solvents [20,21]. After light-curing of the adhesives, residual water or solvents may become pathways for water movement within the hybrid or resin layers [22,23], increasing the permeability of the resin-dentin interfaces [24], and their subsequent susceptibility to degradation via resin hydrolysis [25,26] and collagen degrading enzymes [27,28]. Although both bonding efficacy and the seal of bonded dentin may be compromised by excessive air-drying or incomplete solvent evaporation, it is not known whether these variables are affected to the same extent by these two common errors of wet bonding.

Therefore, the purpose of this study was to evaluate microtensile bond strengths, water permeability and nanoleakage of resin-dentin bonds made with two total-etch adhesives, using the wet bonding technique, versus the two common errors of wet bonding. The null hypothesis tested was that there are no differences in bonding and sealing under the conditions of excessive air-drying or incomplete solvent removal.

Materials and methods

Test teeth

Unerupted, caries-free human third molars were collected after the patients' informed consent had been obtained under a protocol reviewed and approved by the Human Assurance Committee of the Medical College of Georgia, Augusta, Georgia, USA. The teeth were stored in thymol-saturated isotonic saline at 4 °C to inhibit microbial growth, and used within two months following extraction. Each tooth was sectioned perpendicular to its longitudinal axis using a diamond disk (Isomet, Buehler Ltd., Lake Bluff, IL, USA) under water, to expose a flat bonding surface in the mid-coronal dentin. Each dentin surface was ground with 600-grit silicon carbide paper under running water for 30 s just prior to bonding.

Test materials and bonding procedures

Two commercially available total-etch adhesives (Excite/EX, Ivoclar Vivadent, Schaan, Liechtenstein and OptiBond Solo Plus/OP, Kerr Corp., Orange, CA, USA) were used in this study (Table 1). The prepared dentin surfaces were acid-etched with phosphoric acid (37% for EX and 37.5% for OP) for 15 s and then thoroughly washed using a water spray

Table 1 Compositions of the two simplified total-etch adhesives investigated.

Material (manufacturer)	Etchant	Adhesive
Excite (Ivoclar Vivadent, Schaan, Liechtenstein)	37% phosphoric acid gel	Bis-GMA, HEMA, ethanol, water, filler, CQ
OptiBond Solo Plus (Kerr Corp., Orange, CA, USA)	37.5% phosphoric acid gel	Bis-GMA, GPDM, GDM, HEMA, ethanol, water, filler, CQ

Bis-GMA, bisphenol A-glycigyl methacrylate; HEMA, 2-hydroxyethyl methacrylate; GPDM, glycerophosphate dimethacrylate; GDM, glycerol dimethacrylate; CQ, dl-camphorquinone.

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