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Original article

The effect of warm air-blowing on the microtensile bond strength of one-step self-etch adhesives to root canal dentin

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ABSTRACT

Purpose: The use of warm air-blowing to evaporate solvents of one-step self-etch adhesive systems (1-SEAs) has been reported to be a useful method. The purpose of this study was to evaluate the effect of warm air-blowing on root canal dentin.
Methods: Four 1-SEAs (Clearfil Bond SE ONE, Unifil Core EM self-etch bond, Estelink, BeautiDualbond EX) were used. Each 1-SEA was applied to root canal dentin according to the manufacturers' instructions. After the adhesives were applied, solvent was evaporated using either normal air (23 ± 1 °C) or warm air (80 ± 1 °C) for 20 s, and resin composite was placed in the post spaces. The air from the dryer, which could be used in normal- or hot-air-mode, was applied at a distance of 5 cm above the root canal cavity in the direction of tooth axis. The temperature of the stream of air from the dryer in the hot-air-mode was 80 ± 1 °C, and in the normal mode, 23 ± 1 °C. After water storage of the specimens for 24 h, the μTBS were evaluated at the coronal and apical regions. The μTBSs were statistically analyzed using three-way ANOVA and Student's t-test with Bonferroni correction ($\alpha = 0.05$).
Results: The warm air-blowing significantly increased the μTBS of all 1-SEAs at the apical regions, and also significantly increased the μTBS of two adhesives (Estelink and BeautiDualBond EX) at coronal regions.
Conclusions: The μTBS of 1-SEAs to root canal dentin was improved by using warm air-blowing.

1. Introduction

Based on the concept of MI (minimal intervention) and developments in adhesive technology, direct resin composite build-up restorations are increasingly performed for endodontically treated teeth. In order to simplify the procedure, one-step self-etching adhesive (1-SEA) systems are now frequently applied to root canal dentin. Generally, 1-SEAs contain acidic functional monomers, hydrophilic and hydrophobic monomers, dissolved in solvents (water, ethanol or acetone) [1,2]. The water is essential as a component of adhesives to generate hydrogen ions which are necessary for effective demineralization. The organic solvents such as ethanol or acetone, improve the miscibility of hydrophilic and hydrophobic components and the diffusion of monomer into the hydrated demineralized matrix. On the other hand, they play an important role in the removal of water from the adhesive surface owing to azeotropic dehydration [3,4]. In general, solvents have to be evaporated from the resin-infiltrated dentin matrix, as any remaining solvents can lead to inferior properties of the resulting polymer [5,6], have a negative effect on the polymerization of adhesives [1,7] and consequently, the quality and durability of the adhesive bonds [8,9]. Ideally, air-drying after adhesive application can facilitate the evaporation of solvents from the applied dentin surface and thinning of the adhesive layer, leading to decreasing amounts of solvents in the adhesive layer [10,11]. However, as the air-blowing procedure is affected by restriction in the oral environment, complete solvent evaporation is clinically difficult to obtain [12].

Several studies have demonstrated that the residual solvents of 1-SEAs after air-blowing dilute the monomer and hinder the polymerization, leading to reduced bond strengths [1,13]. On the other hand, the application of warm air-blowing to evaporate solvents from 1-SEA has been introduced instead of normal air-blowing to obtain stable dentin bonding in clinical situations. Higher bond strengths to coronal flat dentin surfaces were obtained with warm air-blowing of the adhesives [14–16] as the

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heat from warm air-blowing increases the kinetic energy of the molecules in the solvents [17,18].

Unlike coronal flat dentin, the root canal cavity appears to be a more challenging bonding substrate owing to various factors, such as attenuation of the light energy in the deeper area [19–21] and limited accessibility to any posts placed in the root canal for bonding application, which would adversely influence bonding performance [22]. Moreover, the narrow orifice of a post cavity and/or further distance from the air-blowing source to the deeper regions of root canal post would interfere with solvent evaporation from the adhesives and polymerization although spreading of the adhesive by air-blowing would aid evaporation [13,23]. Therefore, it has been reported that the bond strength of self-etch adhesives decreases especially at apical regions, compared to the coronal regions in the root canal dentin [20,24–27]. The use of warm air-blowing for solvent evaporation of 1-SEAs could ideally evaporate more solvent in the root canal dentin as well as in coronal flat dentin surfaces, however, this is not clearly understood.

Thus, the objective of this study was to investigate the effect of warm air-blowing on the bond strength of 1-SEAs to root canal dentin. The null hypotheses were that applying warm air-blowing had no effect on the bond strength of one-step self-etch adhesives to root canal dentin.

2. Materials and methods

The materials used in this study and their compositions are shown in Table 1.

2.1. Specimen preparation

Thirty-two single-rooted human mandibular premolar teeth were collected following ethical approval under protocol No. 725 by the Ethics Committee of Tokyo Medical and Dental University and stored in water at 4 °C before being tested. The crowns of teeth were sectioned just above the cemento-enamel junction using a low speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA). Pulpal tissue was removed using endodontic files and the post spaces were then prepared using FibreKor drills (Pentron Corporation, Wallingford, CT, USA) in a low-speed handpiece using copious water cooling to a depth of 8 mm and a diameter of 1.5 mm. Afterwards, the root canals were rinsed with distilled water using a syringe, followed by drying with paper points according to previous studies [19,20,24,25,27]. Before adhesive application, the external root surfaces were built-up using a composite resin (Clearfil AP-X, Kuraray Noritake Dental Inc., Tokyo, Japan) in order to prevent the effect of external light from the curing tip, which can pass through the thin portion of dentin wall to the adhesive resin during light curing procedures and to make grips for testing (Fig. 1).

2.2. Bonding procedure

Four resin core systems, consisting of a 1-SEA and a resin composite material, Clearfil Bond SE ONE (SEO) and Clearfil DC Core Automix ONE (Kuraray Noritake Dental Inc.), Unifil Core EM self-etch bond (UC) and Unifil Core EM (GC Corp., Tokyo, Japan), Estelink (EL) and Estecore (Tokuyama Dental Corp., Tokyo, Japan), and BeautiDualbond EX (BDB) and Beauticore LC Post Paste (Shofu Inc., Kyoto, Japan), were used in this study. Regarding the curing modes of the 1-SEAs and composite core materials used in this study, SEO was light-cured, EL was chemical-cured, and UC and BDB were dual-cured. Beauticore LC Post Paste was only light-cured, and other resin composites were dual-cured materials. After the adhesives were applied to the root canal dentin according to the manufacturers' instructions, solvent was evaporated using either normal air (23 ± 1 °C) or warm air (80 ± 1 °C) using a dryer (HUGE, Koizumi seiki corp., Osaka, Japan) for 20 s. Air-blowing was performed at a distance of 5 cm above the root canal cavity in the direction of the tooth axis using normal or hot-air-modes of the dryer. The supplied temperatures of the generated streams of air by the dryer were 80 ± 1 °C in the hot-air-mode and 23 ± 1 °C in the normal mode. The diameter of air-blowing port was 40 mm, and the air flow (provided by the manufacturer) was 1.6 m^3/min

Table 1
Materials used in this study.

Materials	Manufacturer	Composition	Application protocol	Polymerization mode
Clearfil Bond SE ONE (SEO) and Clearfil DC Core Automix ONE	Kuraray Noritake Dental Inc., Tokyo, Japan	<Adhesive> 10-MDP, HEMA, water, ethanol, Bis-GMA, silica micro-filler, photo/chemical initiator <Core> Silanated barium glass filler, silanated silica, Bis-GMA, TEGDMA, CQ, chemical catalyst, accelerators	1: Apply adhesive for10 s, mild air-blow for more than 5s, light cure for 10 s. 2: Light cure of resin composite for 10–20 s.	<Adhesive> Light cure <Core> Dual cure
Unifil Core EM Self-etch Bond (UC) and Unifil Core EM	GC Corp., Tokyo, Japan	<Adhesive> 4-MET, dimethacrlate, water, ethanol, silicon dioxide, photo/chemical initiator <Core> Fluoro-aluminosilicate glass, UDMA, di-methacrylate, photo/chemical initiators, chemical catalyst	1: Mix equal amounts of liquid A and B, apply and leaving 30 s, mild air-blow for more than 10 s, light cure for 10 s. 2: Light cure of resin composite for 10 s.	<Adhesive> Dual cure <Core> Dual cure
Estelink (EL) and Estecore	Tokuyama Dental Corp., Tokyo, Japan	<Adhesive> 3D SR-monomer, HEMA, phosphoric acid monomer, water, isopropyl alcohol, acetone, Bis-GMA, TEGDMA, borate catalyst, peroxide <Core> Silica–zirconia filler, Bis-GMA, TEGDMA, Bis-MPEPP, peroxide, CQ, radical amplifier	1: Mix equal amounts of liquid A and B, apply and leaving 10 s, mild/strong air-blow for 5-10 s. 2: Light cure of resin composite for more than 10 s.	<Adhesive> Chemical cure <Core> Dual cure
BeautiDualbond EX (BDB) and Beauticore LC Post Paste	Shofu Inc., Kyoto, Japan	<Adhesive> Carboxylic acid adhesive monomer, water, acetone, dehydrated ethanol, TEGDMA, initiator <Core> S-PRG filler, Bis-GMA, TEGDMA, initiator	1: Mix equal amounts of liquid A and B, apply and leaving 10 s, enough air-blow, light cure for 10 s. 2: Light cure of resin composite for 20 s.	<Adhesive> Dual cure <Core> Light cure

10MDP:10-methacryloxy-decyl-dihydrogen phosphate; HEMA: 2-hydroxyethyl methacrylate; Bis-GMA: bisphenol A diglycidyl methacrylate; TEGDMA: triethyleneglycol dimethacrylate; CQ: camphorquinone. 4-MET: 4-methacryloxyethyl trimellitic acid; UDMA: urethane dimethacrylate; 3D SR monomer: three dimensional surface-reinforcing monomer; Bis-MPEPP: 4-methacryloxy polyethoxyphenyl propane; S-PRG: surface reaction-type pre-reacted glass-ionomer.

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