Title	Clinical observation of the tooth surface during air-drying of self-etching primer under 3D video microscope
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Journal	Applied Adhesion Science, 4(): 1-6
URL	http://hdl.handle.net/10130/3966
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Abo *et al. Appl Adhes Sci (2016) 4:7*
DOI 10.1186/s40563-016-0064-6

Applied Adhesion Science

RESEARCH **Open Access**

Clinical observation of the tooth surface during air-drying of self-etching primer under 3D video microscope

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Abstract

To clarify the optimal amount of air-drying time, this study measured the time taken to remove residual excess solvent from self-etching primer under observation with a 3D video microscope. One hundred teeth were restored with direct resin composite restorations (16 upper anterior teeth, three lower anterior teeth, 14 upper premolars, 13 lower premolars, 16 upper molars, and 38 lower molars) under observation with a 3D video microscope. In all restorations, Clearfil SE Protect was used for bonding of the resin composite under controlled environmental conditions (intra-oral temperature and humidity) using an intra-oral vacuum device. The duration of air-drying needed to evaporate the residual solvent from the self-etching primer solution was simultaneously measured. The data obtained were statistically evaluated by one-way ANOVA and Tukey's HSD multiple comparisons ($p < 0.05$). The duration for complete air-drying of the 100 cases was 40.9 ± 18.7 s. The air-drying durations in lower molar and upper anterior restorations were 48.1 ± 21.7 and 27.3 ± 14.6 s, respectively, with a statistically significant difference ($p = 0.002$). This study revealed that a greater air-drying duration was needed to evaporate solvent from the self-etching primer than routine air-drying in the clinical situation. It also indicated that a greater air-drying duration was required for posterior cavities than for anterior cavities.

Keywords: Self-etching primer, 3D video microscope, Solvent evaporation, Direct resin composite restoration, Air-drying, Duration

Background

Restoration of teeth using a direct composite technique has progressed markedly in recent years. The color of restorative composite materials can simulate that of real teeth, and improvements in the properties associated with reduction in filler sizes have enhanced material performance [1]. The development of several kinds of 3D-shaped matrices has facilitated the reconstruction of proximal shape, thereby facilitating direct posterior restorations using resin composite [2]. Furthermore, the establishment of layering techniques that reconstruct the anatomical/chromatic tooth shape using multiple shades has enhanced the demands of anterior esthetic reconstruction using direct composite bonding [3].

Major developments in tooth–resin bonding have also contributed to the increased use of direct composite restorations in almost all situations. Traditionally, three steps (etching, priming, and bonding) were needed to adhere resin composite to the tooth substrate composed of both enamel and dentin [4]. The advent of self-etching primer containing an acidic adhesive monomer such as 10-MDP has not only simplified the bonding procedure, but has also improved the bond durability achieved by the decalcification of interfacial dentin [5, 6].

Current dental adhesive systems consist of the etch-and-rinse system and the self-etch system [7, 8]. Two-step self-etch adhesives have generally been recognized as being less technique-sensitive than etch-and-rinse adhesives [4]. However, insufficient air-drying of self-etching primer could leave residual solvent that could subsequently cause incomplete polymerization of the bonding resin. While some manufacturers provide instructions about the duration of air-drying, the extent of the removal of the solvent might be affected by several factors, such as the quality of the dry-field technique/isolation, the site and form of the cavity, because oral cavity is very humid [9, 10], and therefore it is difficult to remove the solvent by air-drying [11]. Although there are many factors that affect solvent removal [11–15], the actual duration required for solvent evaporation in the clinical situation has not yet been established.

The purpose of this study was to clarify what duration of air-drying time is sufficient to evaporate the excess solvent remaining after application of self-etching primer. Therefore, we observed the drying process for self-etching primer applied in the dental cavity under a 3D video microscope. The duration of the solvent drying was also measured.

Methods

One hundred cases being treated with direct resin composite restorations at ABO Dental Clinic, Sanda City, Hyogo Prefecture, during May and September 2013 were investigated in this study (16 upper anterior teeth, three lower anterior teeth, 14 upper premolars, 13 lower premolars, 16 upper molars, and 38 lower molars).

This study was carried out after the subjects were informed of the aims and procedures involved in the study, and had given their consent. Only one dentist (H.A.) carried out the restorations. After cavity preparation, the oral cavity was isolated using an intra-oral vacuum device (Coolex Mini-alpha, APT Inc., Osaka, Japan), and Clearfil SE Protect self-etching primer (Kuraray Noritake Dental, Osaka, Japan; Table 1) was applied with agitation method; generous amount of self-etching primer was applied to the entire cavity wall with vigorous scrubbing using a disposable brush tip, in expectation of the improving of bond strength [16]. After the tooth surface was conditioned for 20 s, the cavity was air-dried using a dental three-way syringe connected to the dental chair (M1-F, Sirona Dental Systems, Long Island City, NY, USA) until the liquid surface was observed to have stopped rippling under magnification of 10× through a 3D video microscope (MoraVision™ 2 3D video microscope system, Mora Micro Instruments, Santa Barbara, CA, USA). A Dental assistant also observed the conditioning step through MoraVision 2, and measured the duration of the air-drying using a stopwatch.

The data obtained were statistically evaluated by one-way analysis of variance (ANOVA) and Tukey's HSD comparing location (upper anterior, lower anterior, upper premolar, lower premolar, upper molar and lower molar) at a significance level of 0.05. All analyses were carried out using IBM SPSS 18 (IBM Japan Inc., Tokyo, Japan).

Table 1 Adhesive used in this study and its components

Adhesive (Manufacturer) [Classification]	Component
Clearfil SE Protect (Kuraray Noritake Dental, Osaka, Japan) [2-step self-etch]	[Primer] HEMA, 10-MDP, MDPB, hydrophilic dimethacrylate, water [Bond] 10-MDP, Bis-GMA, HEMA, hydrophobic dimethacrylate, CQ, N,N-diethanol-p-toluidine, silanated colloidal silica, surface-treated sodium fluoride

Bis-GMA, Bis-phenol A-diglycidyl methacrylate; CQ, camphorquinone; HEMA, 2-hydroxyethylmethacrylate; 10-MDP, 10-methacryloyloxydecyl dihydrogen phosphate; MDPB, 12-methacryloyloxydodecylpyridinium bromide

Results

The mean ± standard deviation (SD) duration for air-drying in each site is summarized in Table 2.

The average duration for complete air-drying was 40.8 s. The results of one-way ANOVA revealed that the duration required for air-drying depended on the site of the restoration. The air-drying duration in lower molar restorations was 48.1 ± 21.7 s. One case required 90 s to reach the point at which rippling of the primer liquid ceased. The air-drying duration in upper anterior restorations was 27.3 ± 14.6 s, and was significantly shorter than the duration for lower molar restorations ($p = 0.002$).

Discussion

A three-way syringe is always used for the component with solvent in adhesive systems. However, the distance and angle at which the air is blown might vary with the operator, which would cause significant effect on solvent evaporation [13, 14, 17]. Therefore, all cases were performed by the same operator. In addition, since the temperature of the blown air affects the bond strength of self-etching primer [15, 18, 19], all cases were performed in the same unit (Silona M1-F).

Clearfil SE Protect 2-step self-etch adhesive was used in all 100 cases. Clearfil SE Protect has a similar composition to Clearfil SE Bond, which is well known for its excellent bonding performance and durability [6, 20, 21]. These adhesives contain 10-MDP, which chemically bonds to calcium ions; thereafter the calcium-phosphate monomer salt co-polymerizes with the monomer of the adhesive resin [22, 23]. These adhesives are reported to have a high polymerization rate [24–26] resulting in a high level of mechanical performance of the polymer itself because of the high filler loading [27, 28]. Therefore, both Clearfil SE Bond and Clearfil SE Protect are known for their excellent bonding properties [20].

Table 2 Air-drying time at each site (mean ± S.D.; s)

	Anterior (*n*)	Premolar (*n*)	Molar (*n*)
Upper	27.3 ± 14.6 (16)^{b}	38.3 ± 15.9 (14)^{ab}	43.5 ± 13.5 (16)^{ab}
Lower	26.7 ± 8.5 (3)^{ab}	39.2 ± 13.7 (13)^{ab}	48.1 ± 21.7 (38)^{a}

The same superscript letters indicate no statistically-significant difference ($p > 0.05$, Tukey's HSD test)

Clearfil SE Protect has strong antibacterial activity owing to 12-methacryloyloxy dodecyl-pyridinium bromide (MDPB) contained in the primer solution [29, 30], and releases fluoride ions from the sodium fluoride in the bonding agent [31]. The presence of these components in Clearfil SE Protect has been reported to prevent long-term deterioration of the adhesive interface to a greater extent than Clearfil SE Bond [20, 32, 33]. Recent studies have revealed Clearfil SE Protect inhibits mineral loss from the walls of the lesion [34]. Despite the excellent results described for this adhesive system, its performance can potentially be compromised if the air-drying is incomplete. Primer solution of Clearfil SE Protect contains an acidic 10-MDP monomer and hydrophilic components (such as HEMA) dissolved in water. Hydrogen ions (H^+) derived from 10-MDP attributes the self-etching effect, and water contained in the self-etching primer allows to generate the hydrogen ions [5]. During application of primer solution and subsequent air-drying of primer, a large portion of contained water is removed. However, insufficient air-drying of applied primer might contaminate the residual water into the hydrophobic adhesive resin, might inhibit the polymerization of hydrophobic adhesive resin [35]. Residual monomer might provide defects within the polymerized adhesive layer and pathways for nanoleakage [36].

This study observed the air-drying of self-etching primer using the MoraVision™ 2 3D video microscope system. This system has two main components: MoraScope™ and MoraVu3D™. The MoraScope is made of two self-contained digital stereoscopic microscopes in one housing. It combines two zoom stereo microscopes and their high definition (HD) video cameras into one compact (applox. 13 cm) cube to provide magnification levels from 0.5 to 30× [37]. The MoraVu3D is a real time stereoscopic display module. 3D real-time images are projected to the liquid crystal display (LCD) monitor when the dentist and their dental assistants wear 3D glasses [38]. With typical microscopes, it is necessary to illuminate the surgical field with a high intensity LED light source when the expanded surgical field of view is used, because the high magnification images are darker than the normal images. Since restorative composite material will be polymerized by the LED illuminator, it is impossible to spend a long time shaping and contouring the composite restoration under the expanded surgical microscope field. On the other hand, MoraVision 2 microscope can project a clear image even with relatively weak illumination. Therefore, in a clinical situation, it is possible to spend more time shaping the anatomical contours under the expanded operating view.

For molar restorations, 46.7 ± 19.6 s of air-drying was needed to evaporate the solvent. Relative humidity at molar sites is close to 100 % [9–11]. Resin bonding in a high humidity environment has been reported to reduce bond strength [11, 12, 39]. Therefore, it is recommended to restore posterior teeth under humidity-controlled conditions. Alternatively, rubber dam isolation is effective in reducing the relative humidity of the operating field [9]. However, when multiple teeth are simultaneously isolated, it might be difficult to control the relative humidity of the operating field using a rubber dam [10]. We used an intra-oral vacuum device (Coolex Mini-alpha) in all 100 cases. This device has been reported to reduce the relative humidity of the molar region by up to 50 % and maintain it until the restorative procedure is finished [9].

For anterior restorations, 27.2 ± 13.6 s of air-drying was needed to evaporate the solvent. Saraiva et al. [11] reported that both temperature and relative humidity in incisor site was significantly lower than molar site under the room condition. Therefore, the evaporation of the remaining solvent in the anterior cavity might be easier than at other sites, even when the intra-oral vacuum device was used. Additionally, it is also easier to visualize the remaining solvent in the anterior region than in posterior sites.

The results indicated that 48.1 ± 21.7 s of air-drying was required for the mandibular posterior cavities even when the intra-oral vacuum device was used. Although the manufacturer's guide only recommends evaporating the volatile ingredients for 20 s with a mild oil-free air stream after conditioning the tooth surface, a definite drying time has not been specified. The duration of air-drying has been reported as one of the factors affecting the bond strength [39–41]. This study clarified the necessity of extended air-drying for solvent evaporation. Further extended air-drying might be needed if no dry-field technique has been applied.

Conclusion

This study revealed that a greater air-drying duration was needed to evaporate solvent in the self-etching primer than is routinely performed in clinical situations. It also revealed that the duration of air-drying required for mandibular posterior cavities was greater than for maxillary anterior cavities.

Authors' contributions

HA designed the study and carried out the experimental measurements. AK designed and prepared the manuscript. AH performed data analysis and prepared the figure. All authors reviewed the paper critically for content and approved it for submission. All authors read and approved the final manuscript.

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Acknowledgements

This study was supported by a Grant-in-Aid for Scientific Research from MEXT, Japan [(C) 25462466] (AK).

Competing interests

Brother of HA is CEO of APT Inc. which is manufacturer of "Coolex mini-alpha". All other authors have no competing interests.

Received: 18 March 2016 Accepted: 25 May 2016

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