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In Vitro Effect of Warm Air Stream Solvent Evaporation Method on Microtensile Bond Strength of the Fifth Generation Adhesive Systems

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Abstract

Objectives: This study aimed to evaluate the effect of warm air solvent evaporation on microtensile bond strength of composite restorations bonded with fifth-generation adhesive systems.

Methods: Twenty-four sound human molars were randomly assigned into two groups according to the type of bonding adhesive used: Adper Single Bond (3M ESPE, USA) or Solobond M (VOCO, Germany) (N = 12). Subsequently, each group was randomly divided into three subgroups according to the solvent evaporation time (0, 5, and 20 minutes). Composite build-ups were conducted incrementally on the dentin substrate fixed in a circular mold. Micro-tensile bond strength evaluation was conducted using the Isomet microtensile machine. Statistical analysis was performed using one-way ANOVA, Tukey's, and Student's t-test at p<0.05.

Results: At 20 minutes, Maximum and minimum microtensile bond strength were observed in Adper single bond and Solobond M, respectively. The mean microtensile bond strength of Adper single bond and Solobond M adhesives during 20 minutes of solvent evaporation were significantly different (p < 0.05).

Conclusion: In both ethanol and water-based adhesives, increasing the solvent evaporation time enhanced the microtensile bond strength. In contrast, in acetone-based adhesives, the optimum amount of solvent with other components must be present in the bonding solution to maintain bonds.

Keywords: Solvent Evaporation; Microtensile Bond Strength; 5th Generation Adhesives; Thermocycling

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Introduction

With the increasing demand for resin composite restorations, their clinical efficacy has become more crucial than ever. One of the significant challenges in this context is their mechanical and chemical bonding to the dentin substrate.[1] Adhesive systems have emerged as the best choice with their promising hydrophobic and hydrophilic characteristics and high amounts of solvents.[2] Solvents, a key component of adhesive systems, play a crucial role in enhancing the wetting ability of resin monomers into the dentinal substrate.[1-3] However, residual solvents can be detrimental to bonding strength, as they can hinder the polymerization process and create voids inside the adhesive interface.[4, 5]

Various methods exist to evaporate the excess solvent [6-11]; warm air stream vaporization is unique due to its reliable outcomes.[12] The heating generated during this process is in the acceptable biological range [12-18], and the final solvent volume is reduced significantly in this method.[16] Moreover, there is evidence that this technique increases resin infiltration into the dentin matrix and improves microtensile bond strength. Besides, it is noteworthy that the heat generated in this technique is out of the danger zone for pulp cell degeneration.[19-21] Previous meta-analysis studies have confirmed warm air efficacy in enhancing dentin microtensile bond strength.[22] This advantage is more prominent in silane-based adhesive systems.[23-26]

Due to its promising strength, the fifth-generation adhesive system is one of the most popular systems, especially in Class V restorations. The present study aimed to investigate the role of warm air solvent evaporation of two different fifth-generation adhesive systems on microtensile bond strength of the final restoration in an in-vitro study.

Methods

A total number of 24 extracted human molar teeth were included in the study. The included teeth were free from caries, restorations, enamel cracks, and abrasions. They were stored in distilled water until the experiment. The specimens were first assigned randomly into two main groups (N = 12) based on the dental adhesive used, either Adper Single Bond (3M ESPE, USA) or Solobond M (VOCO, Germany). Each group was then divided into three subgroups according to the time needed to evaporate the bonding agents (0, 5, and 20 minutes). The same solvent (ethanol and water) was used for both adhesive systems.

The specimens were mounted on an acrylic cylinder to the level of cementoenamel junction. The occlusal preparation was conducted using a handpiece-mounted fissure carbide bur with a 5400-rpm speed to make a flat occlusal surface. The bonding adhesives were applied according to the manufacturer's instructions. A plastic water pipe with 4.5 mm diameter was placed 6 mm above the flattened occlusal surface. The bonding primer was applied on the occlusal surface, and the prepared solvent was evaporated in three different time intervals (0, 5, and 20 minutes) using the air syringe of the dental chair. The evaporation was conducted at 39-50 °C at a 5-mm distance and 30 mph speed.

Resin Composite restoration was conducted using nanohybrid composite (Z250, shade A2, 3M, ESPE.USA), which was incrementally packed and light-cured according to manufacturer's instructions.

All the prepared specimens were sectioned using diamond discs to form composite discs bonded to dentin. Sectioning was conducted in buccolingual and mesiodistal directions to provide blocks with 1-mm thickness. The microtensile test was performed using a microtensile test machine (SANTAAM, Mashhad, Iran) with a speed of 0.5 mm/min until failure. The needed force to make failure was calculated and divided by the specimen surface area and reported in Megapascal (MPa).

Statistical Analysis was conducted using IBM SPSS 24.0 (IL, Chicago, USA). Descriptive data were introduced using mean and standard deviation. An intragroup comparison of the vaporization rate at different time intervals was analyzed using one-way ANOVA and a Tukey post-hoc test. Intergroup analysis was conducted using the Student's t-test. In this study, the significance level was set at $p < 0.05$.

Results

The mean and standard deviation of microtensile bond strength in mentioned specimens are illustrated in Table 1.

Table 1- Mean and standard deviation of microtensile bond strength of specimens (MPa)

Time (min) / Strength	Baseline	5 min	20 min	P-value [1]
Adper Bond	23.18 ± 7.90 [a]	28.20 ± 8.17 [b]	29.50 ± 9.59 [b]	0.028
Solobond M	22.40 ± 5.98 [a]	28.46 ± 9.84 [b]	19.67 ± 5.54 [a]	0.017
p-value [2]	0.372	0.137	0.02	

The results of the one-way ANOVA test indicated a significant difference in the vaporization rate of both systems in different time intervals ($p < 0.05$). The results of the Tukey posthoc test suggested that the vaporization rate in the Adapter Single Bond group after 5 minutes was significantly higher than baseline ($p < 0.001$). In contrast, there was no significant difference between 5 and 10 minutes ($p > 0.05$). However, for the Solobond M group, there was no significant difference between baseline and 5 to 20-minute time intervals ($p > 0.05$). The results of the intergroup analysis suggested that the difference was not statistically significant in both baseline ($p = 0.372$) and 5 mins ($p = 0.157$), but the difference was significant in 20 mins ($p = 0.02$).

The significant difference between the three time intervals led us to perform a by-group analysis using the Tukey post hoc test. The results suggested a significant difference in the adhesives of the Solobond group in the 5—to 20-minute time interval ($p = 0.026$). In other cases, the results were not statistically significant ($p > 0.05$).

Discussion

The present study aimed to investigate the role of the warm air stream technique in solvent evaporation of fifth-generation adhesive systems to dentin substrates. It was demonstrated that in the Adapter Bond System, microtensile bond strength significantly increased after 5 minutes, while in Solobond systems, it decreased to baseline after 10 minutes.

A study conducted by Al-Salamoony et al. suggested that adhesive system type affected solvent evaporation rate.[28] In the present study, fifth-generation adhesive systems were included due to their promising properties. A study conducted by Poptani et al. observed that the microtensile bond strength of the fifth-generation adhesive systems was similar to the seventh generation.[29]

The results of different studies suggested that excess water leads to hybrid layer deterioration and reduces microtensile bond strength over time.[30,31] Solvent evaporation is inevitable for composite resin restoration success.[13] A systematic review and meta-analysis study suggested that using the warm water stream technique significantly enhanced microtensile bond strength.[32] In adhesive bond systems, loss of strength is much more challenging due to chemical bonds between hydroxyl groups of ethanol and water, which need higher temperatures.[33]

The present findings indicated that prolonged time leads to higher evaporating efficacy of the mentioned technique in the Adapter Bond. Prolonged air drying is vital in solvent evaporation.[34,35] Insufficient vaporization time lowers microtensile bond strength because of excess solvents (such as water, alcohol, and monomer) penetration. [36, 37] Solvent concentration does not affect the relationship between time and evaporation rate.[38]

Somasundaran et al., in their study, suggested that two-step adhesive systems have higher microtensile bond strength in ethanol and water-based systems.[39] In this study, the Adapter Single Bond, a two-step adhesive system, also showed a higher microtensile bond strength in all time spans than Solobond M.

Altogether, the present findings suggested that the warm air stream increased the solvent evaporation of the fifth-generation adhesive system in dentinal interface. Adapter Single Bond had a higher evaporation rate than Solobond systems. However, this study had limitations, including its in-vitro nature, limited sample size, and duration of vaporization. Furthermore, our study only evaluated microtensile bond strength, while other parameters like chemical interaction with the tooth surface and bond stability over time can be more reliable.

Conclusion

As the evaporation time of the solvent increased, the micro tensile bond strength rose in adhesives containing ethanol but decreased in adhesives containing acetone. Solobond M adhesive showed the highest micro-tensile bond strength during 5 minutes of solvent evaporation and significantly less than 20 minutes of solvent evaporation. Due to the high evaporation pressure of the acetone solvent in this adhesive, it must be applied at the optimal time.

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