Cold Atmospheric Plasma Treatment of Tooth Enamels for Bonding Enhancement with Self-Etch Adhesive

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Abstract: The plasma treatment effects of tooth enamels were studied on their bonding performance with mild self-etch adhesive. Findings demonstrate that plasma treatment enhanced the interface bonding after 6-month immersion in 37°C de-ionized (DI) water, and reduced the micro-leakage (ML) after 1,000 thermal cycles in 5°C and 55°C DI water bathes.

1. Introduction

Several contemporary adhesive systems have been used to achieve adequate immediate bonding strength for resin-based composite dental restorations. However, the higher failure rates in resin composite restorations are mainly caused by the inferior bonding between adhesive resins and the surrounding tooth structure [1, 2]. In mild self-etch adhesive systems, no pre-etching treatment is typically required [3, 4]. However, with self-etch adhesives, the bonding between composite and enamel is usually unsatisfied because the enamel surface is not sufficiently "wet" for composite resin bonding [5]. Hence, applying phosphoric acid prior to mild self-etch adhesive on enamel (also named "selective-etching") is often used to increase the wettability of cavity enamel margins, which was reported only had a slight positive effect on marginal integrity [6]. Therefore, there is a need to improve the resin-enamel bonding performance.

This study evaluated the effectiveness of plasma treatment for improving interfacial bonding performance between mild self-etch adhesive and tooth enamel.

2. Methods

Plasma treatment of bovine incisor enamels was performed using a cold atmospheric argon plasma brush [7]. Micro-tensile bonding strength (μTBS) and micro-leakage (ML) tests were conducted to evaluate the enamel-adhesive bonding longevity performance. Three experimental groups of "Unetched" (self-etching), "Etched" (selective-etching) and "Unetched/Plasma-treated" were assigned in these tests.

3. Results and Discussion

Table 1 summarizes the μTBS test results and failure modes (cohesive, mixed and interfacial failure). From the μTBS results, significant difference was observed among the groups of *Unetched* (38.2 ± 11.8 MPa), *Etched* (43.8 ± 8.8 MPa) and *Unetched/plasma-treated* (52.2 ± 10.5 MPa) (One-way ANOVA Tukey's test, $p<0.01$). Considering the mean strength values, *Unetched/plasma-treated* samples exhibited significant bonding performance than the other two groups. Furthermore, the *Unetched/plasma-treated* enamel presented the lowest interfacial failure percentage and the highest mixed and cohesive failure percentage, which suggested that much stronger adhesive-enamel interfacial bonding was obtained. After 1000 5°C/55°C thermal cycles, the Unetched, Etched and Unetched/plasma-treated restorative teeth displayed a dye penetration score of 62, 38, and 22 respectively. The lower of the dye penetration score indicates less ML.

Table 1. μTBS test results and fracture surface analyses after 6-month immersion in 37 °C DI water.

Characteristic Factors	Unetched	Etched	Unetched/ Plasma-Treated
Tooth Number	8	8	8
Number of Micro-Bars	87	89	107
Bonding Strength (MPa)	38.8 ± 11.8	43.8 ± 8.8*	52.2 ± 10.5**
Cohesive Failure (%)	18.4	20.2	22.4
Mixed Failure (%)	52.9	55.1	68.3
Interfacial Failure (%)	28.7	24.7	9.3

* with significant difference from Unetched group;
** with significant difference from both the Unetched and the Etched groups.

4. Conclusion

This study demonstrated that argon plasma treatment improved enamel-adhesive (all-in-one mild self-etch) bonding longevity performance. Higher bonding strength and less ML were observed in the plasma-treated samples than other groups. The mechanistic study confirmed that plasma treatment enhanced adhesive-enamel bonding, induced higher degree of conversion for the adhesive monomers, and reduced water sorption and resin solubility of adhesive layer. These results indicated plasma treatment improved the mild self-etch adhesive-enamel bonding interface quality and adhesive layer stability, consequently improving the durability of adhesive bonding to enamel.

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