The application of a resin impregnation technique to dentin using a vacuum

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ABSTRACT:

Background: There is a technique in the industry called resin impregnation, which is used for procedures like resin coating. For example, epoxy resin is injected to repair cracks in concrete of 0.2 mm or larger. In addition, a casting product can be strengthened when resin is injected to fill in a blowhole. A vacuum can be utilized to allow the resin to penetrate into every corner. In this study, we investigate whether bonding resin can deeply penetrate with the use of a vacuum.

Methods: Six non-carious extracted human first premolars were used. For bonding resin penetration into dentin, one-step adhesive was used. The root of each tooth was cut at the cement-enamel junction and soaked in bonding resin. Immersion was performed under the conditions of atmospheric pressure and vacuum (-70 kPa). The fluorescent dye Rhodamine B was mixed into the bonding resin at a concentration of 0.1% for confirming resin penetration. Each tooth underwent about 200 μm of polishing and was placed on glass slides. Images of the completed specimens were obtained by fluorescent microscopy.

Results: The dyed resin that penetrated into the dentin tubules under vacuum formed a long and dense resin tag. On the other hand, the dyed resin that penetrated into the dentin tubules under atmospheric pressure formed a sparse and unformed resin tag.

Conclusion: This study suggests that a vacuum is effective for deep penetration of bonding resin.

Keywords: Fluorescent microscope, Resin impregnation, Resin tag, Vacuum.

INTRODUCTION

Dentin bonding systems have been markedly simplified and improved over the past few decades. In recent years, bonding resin, which combines etching, priming, and bonding into one application step, has been widely accepted by dentists for the bonding of direct composite restoration.[1]

Bonding resin has been described in the literature. For example, a resin impregnated dentin layer only extends a few micrometers into dentin and is commonly referred to as a hybrid layer, a description that was originally conceived by Nakabayashi, Nakamura, and Yasuda[2] and also by Nakabayashi, Ashizawa, and Nakamura.[3] However, deep penetration bonding resin has not yet been examined.

A resin impregnation technique in currently used in the industry. Concrete is repaired by injecting epoxy resin when the concrete crack is 0.2 mm or grater.[4,5] In addition, blow holes are filled by injecting resin, thereby strengthening the cast product.[6-9] A vacuum is applicable to these steps and promotes the penetration of resin in cracks. Therefore, the deep penetration of bonding resin may be enhanced by a vacuum. Furthermore, bonding resin studies have commonly used a scanning electron microscope (SEM) or transmission electron microscope (TEM) to observe the bonding resin interfacial structure.[10-12] However, few studies have investigated the penetration of bonding resin using a fluorescence microscope.

Therefore, we herein employed a fluorescent microscope to determine whether the deep penetration of bonding resin is promoted by a vacuum.

MATERIAL AND METHODS

Materials

Six extracted non-carious human first premolars were used. The bonding resin used was beautybond multi (shofu Co., Kyoto, Japan) of one step adhesive. The composition of beautybond multi is shown in Table 1.

Table1: All-in-one adhesive systems used in this study

Adhesive	Manufacturer	Composition
one step adhesive beautybond multi	Shofu Kyoto Japan	Bis-GMA,TEGDMA,water acetone Carboxylic acid-based monomer, Phosphonic acid-based monomer

Bis-GMA:bisphenol-A-glycidyl methacrylate; TEGDMA: triethyleneglycol dimethacrylate

A vacuum was achieved with a vacuum hand pump (Lincoln Industrial Co., St. Louis, USA) (Figure 1).

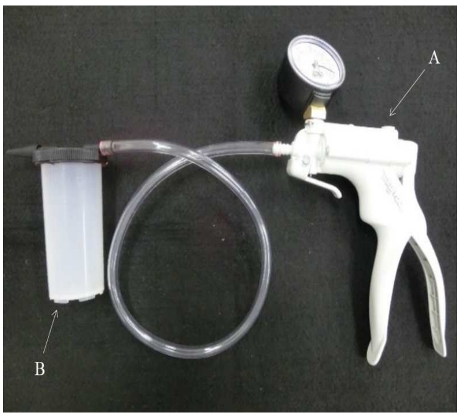

Figure 1: Vacuum hand pump (MV8000, Lincoln, USA), Pulling hand pump get vacuum in cup A, Vacuum pump. B, Vacuum bottle

Specimen preparation

The root of each tooth was cut at the cement-enamel junction, and the pulp was using removed a diamond bur mounted on a high-speed hand piece under a water coolant. Etching was performed for one minute, followed by ultrasonic cleaning for ten minutes in order to remove the smear layer.

Immersion of specimens in bonding resin

The fluorescent dye Rhodamine B was mixed with bonding resin at a concentration of 0.1 % in order to confirm the penetration of resin. Immersion was performed under the condition of atmospheric pressure, vacuum (-70 kPa). The immersion process is shown in Figure 2.

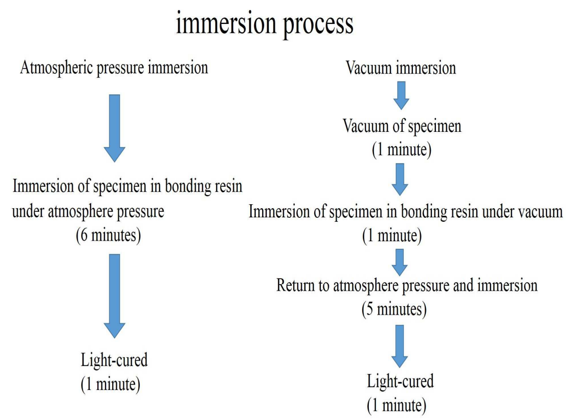

Figure 2: Immersion process

Polishing of specimens

In the present study, #600 and #2000 grindstones were used on all specimens with light manual pressure. Each specimen was polished to a thickness of approximately 200 μm. Polished specimens was sealed on glass slides.

Observation of specimens

Completed specimens were observed using a fluorescence microscope (Keyence, Tokyo, Japan).

RESULTS

Figure 3 shows images of polished specimens, which were obtained using fluorescence microscope under each condition. Structures labeled with Rhodamine B were yellow –white in color, with brighter appearance indicating a higher dye content.

Bonding resin penetrated dentin tubules under the vacuum and formed a long and dense resin tag (Figure 3 d,e). A shorter and more sparse resin tag was also observed (Figure 3 f).

Under atmosphere pressure, bonding resin sparsely penetrated dentin tubules and a resin tag was not observed (Figure 3 a, b, c).

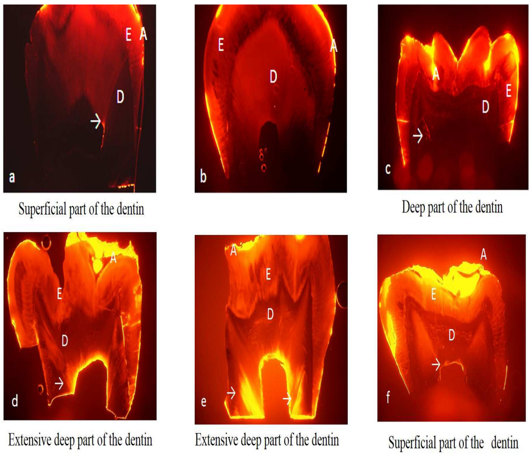

Figure 3: Fluorescent microscope images of polished specimens in fluorescent mode: enamel (E), dentin (D), adhesive (A) resin tag (arrow). a and b and c: Immersed specimen in bonding resin under atmosphere pressure. d and e and f: Immersed specimen in bonding resin under vacuum.

DISCUSSION

The penetration of bonding resin into dentin tubules and its polymerization in situ creates a resin tag, which is essential for obtaining good bonding to dentin. Resin tags suppress dentin hypersensitivity.[13] Resin tags are considered to be very important for bonding systems. In the present study, we achieved the deep penetration of bonding resin.

Commonly used methods to observe bonding resin interfacial structures such as the hybrid layer and resin tags in dentin are SEM and TEM. SEM shows the surface details of samples by etching and drying processes. TEM requires an embedding process.[14] These procedures may lead to shrinking or cracking artifacts in the bottom bonding interface and alterations in the bonding structure.[15] These process are also complex. We herein used fluorescence microscopy, which was performed using an ultrahigh pressure mercury lamp as the light source with the sample being excited at a specific wavelength in order to observe fluorescence.[16] The fluorescence microscope was easy to use and allowed for observations of the penetration of bonding resin.

A vacuum is utilized in the resin impregnation technique in the industry, and involve the principle of Boyle's law (The volume of a gas varies inversely with pressure).[17-19] This principle was applied in the present study. The mechanism of resin impregnation is shown in Figure 4. Specifically, a small amount of air escaped from the dentinal tubules by vacuum, and bonding resin penetrated into the gap. Therefore, bonding resin penetrated dentin tubules under the vacuum and formed a long and dense resin tag. In contrast, under atmosphere pressure bonding resin sparsely penetrated dentin tubules and didn't form a resin tag. This result showed that the resin impregnation technique used in the industry is applicable to dentin. However, in some sample, the bonding resin did not penetrate deeply, or at all, in some regions, and this may have been due to a smear plug or transparent dentin.[20]

Deep penetration of bonding resin may extend the effects of resin materials for hyperesthesia and improve tooth structures and composite resin adhesion. In the present study, the resin impregnation technique in the industry was found to be useful for promoting the deep penetration of bonding resin.

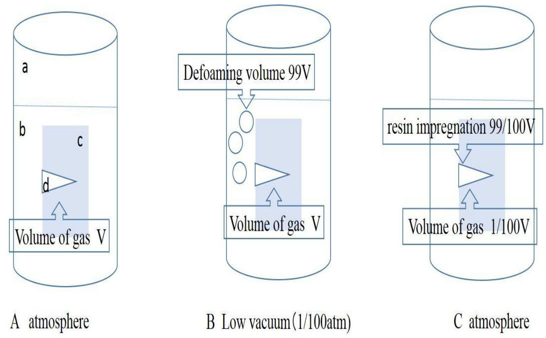

Figure 4: A, In the atmosphere of constant temperature, gap volume in the dentinal tubules is treated as V. Under atmospheric pressure, the gas volume is equal to the gap volume V. B, When the pressure was reduced to a low vacuum of 1/100 atm, gas volume V becomes 100V in accordance with Boyle`s low. Gas of 99V is defoamed because gap volume is a V. C, When returning to the atmospheric pressure, gas volume becomes 1 / 100V, a bonding resin is injected in the gap 99 / 100V. a: container b: resin liquid c: sample d: gap

CONCLUSION

The results of the present study suggest that a vacuum effectively promotes the deep penetration of bonding resin. Furthermore, fluorescence microscopy allows for the penetration of bonding resin to be observed.

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