Wettability of Dentin Structure after Exposure to Excimer UV Irradiation

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Abstract: Improvement of the dentin surface is an important factor in successful restorative or endodontic treatments because of the requirement for adhesion to dental tissue, or increased bonding strength. This study was undertaken to observe the radicular dentin surface contact angle during exposure to ultraviolet (UV) light from an excimer lamp. Additionally, we investigated the structural and mechanical properties of dentin after UV lamp irradiation. The roots of 30 bovine lower central incisors were sectioned 1.5 mm below the cementoenamel junction, and a 1-mm-thick radicular dentin slab was cut from each tooth. Polished specimens were randomly divided into three groups: no treatment (n = 10), irrigation with NaOCl and EDTA (3% NaOCl for 1 min, 17% EDTA for 1 min, then 3% NaOCl for 1 min; n = 10), and xenon excimer UV irradiation for 180 sec (n = 10). Pure water was dropped onto the dentin slabs and water contact angles were immediately measured for each specimen. For nanohardness and Young’s modulus, the dentin at the center, between the outer surface and the pulp chamber, was measured. Results were statistically analyzed by one-way ANOVA and Tukey tests (P < 0.05). The contact angle of dentin exposed to endodontic irrigants was significantly lower than that of normal dentin. Furthermore, the contact angle of dentin exposed to excimer UV irradiation was significantly lower than that of dentin exposed to endodontic irrigants. Mean hardness and mean Young’s modulus measurements did not differ between the groups. UV-irradiated dentin exhibited increased surface wettability. However, UV irradiation did not change the mechanical or structural properties of dentin. Thus, excimer UV irradiation might be useful in endodontic treatment.

Key words : dentin, UV irradiation, UV excimer lamp, surface wettability, root canal irrigation

Introduction

Surface wettability is defined as the ability of a liquid to wet a solid surface¹. Surface wettability is an important property in biomaterials², and it is similarly important in human teeth. Teeth are comprised of enamel, dentin, and pulp; dentin is the most abundant mineralized tissue

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by both weight and volume. Thus, improvement of the dentin surface is an important factor in the success of restorative or endodontic treatments because of the requirement for adhesion to dental tissue and increased bonding strength.

Ultraviolet (UV) radiation is used for a variety of applications, including lithography and curing. Several studies have reported the use of UV irradiation for dental applications, and notably, how such irradiation can improve adhesive properties. However, dentin wettability after UV irradiation has been primarily examined in coronal dentin, and few studies have investigated the wettability of radicular dentin. Indeed, this is important as coronal dentin differs from radicular dentin with respect to structural and mechanical properties. Increased wettability of the radicular dentin surface is important for the success of endodontic therapy or adhesion to the radicular dentin. A root canal irrigant should facilitate proper contact between the sealer and dentin walls. Root canal sealers are used to adhere to the core-filling material in the obturation of the root canal and seal the spaces between the dentin wall and the core-filling material. Thus, an ideal root canal irrigant should be able to enhance the wettability of dentin to sealers.

Additionally, we were interested in the effects of UV irradiation, as there have been few reports regarding the effects of UV lamps compared to UV lasers. UV lamp technology is inexpensive and irradiates a wider area than that of a UV laser; therefore, such lamps might be applicable in dentistry. UV lamps often constitute low-pressure mercury lamps (\( \lambda_{\text{max}} = 185 / 254 \text{ nm} \)), however, the use of xenon excimer lamps (\( \lambda_{\text{max}} = 172 \text{ nm} \)) has recently been described. Xenon excimer lamps comprise mercury-free gas-discharge sources of UV irradiation with high radiant power and extended lifetimes which might be particularly useful in dentistry. The wettability of a material is typically determined by measurement of the contact angle formed between the surface of the material and the line tangent to the curved surface of a liquid drop at the point of contact. Thus, the first objective of this study was to observe the radicular dentin surface contact angle during exposure to UV light from an excimer lamp, in comparison to the radicular dentin surface after ordinary root canal irrigation.

Additionally, minimal information is available regarding the mechanical properties of dentin after UV lamp irradiation. Nanohardness and Young’s modulus may be appropriate mechanical test methods for the investigation of tooth microstructure; therefore, the second objective of this study was to investigate the structural and mechanical properties of dentin after UV lamp irradiation using these two measurements.

**Materials and methods**

**Materials**

Thirty bovine lower central incisors were extracted immediately after sacrifice from animals estimated to be 2–2.5 years of age, according to their dental age. Teeth were stored in Hank’s balanced saline solution at 4°C, and were used within 1 month of extraction, in accordance with previous reports.
Preparation of specimens

The roots of the 30 bovine incisors were sectioned 1.5 mm below the cementoenamel junction, and were transversely sectioned along the long axis with a low-speed cutting machine (Isomet, Beuhler, Lake Bluff, IL, USA; Fig. 1A). A second cut was then performed 1.0 mm below the first (Fig. 1B) to produce a 1-mm-thick radicular dentin slab from each tooth.

After sectioning, the side near the cementoenamel junction was used in this study. Specimen surfaces were sequentially polished and stored in Hank’s balanced saline solution at 4°C, prior to use, in accordance with a previous report. The polished specimens were randomly divided into three groups: no treatment (n = 10), irrigation with NaOCl and EDTA (3% NaOCl for 1 min, 17% EDTA for 1 min, then 3% NaOCl for 1 min; n = 10), and excimer UV irradiation for 180 sec (n = 10; Table 1).

UV irradiation

A xenon excimer lamp (E500-172-110, Excimer Inc., Kanagawa, Japan) was used for UV irradiation. The wavelength of the lamp was 172 nm. The distance between the dentin surface and the lamp was 5 mm in air at ambient temperature. Exposure time was 180 sec. The UV lamp intensity at a distance of 0 mm was 20 mW/cm².

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Table 1. Experimental groups

| Groups | Dentin surface                                      |
|--------|----------------------------------------------------|
| 1      | No treatment                                       |
| 2      | 3% NaOCl (60 sec) → 17% EDTA (60 sec) → 3% NaOCl (60 sec) |
| 3      | Excimer ultraviolet irradiation (180 sec)          |
Contact angle test

Pure water (1 µl) was dropped onto the surfaces of the dentin slabs and water contact angles were immediately measured for each specimen with contact angle equipment (SImage Standard 100, Excimer Inc., Kanagawa, Japan).

Contact angle, $\theta$, is given by Eq. (1) as follows:

$$\theta = 2 \tan^{-1}(h/r),$$

where $\theta$ is the contact angle, $h$ is height, and $2r$ is outer diameter (Fig. 2).

Three drops were placed on the surface of each specimen and the contact angle was measured; average data from the three drops was then recorded for each specimen. Measurements were performed immediately after sample preparation for each group. The results were statistically analyzed by one-way ANOVA and Tukey tests; $P$-values $< 0.05$ were considered significant.

Nanohardness and Young’s modulus measurements

After the contact angle was measured, nanohardness and Young’s modulus were measured for each specimen, using nanoindentation tests as previously described. Nanohardness and Young’s modulus were measured by using a force of up to 0.5 mN. Furthermore, a central position of dentin, between the outer surface and the pulp chamber, was measured for nanohardness and Young’s modulus. Average data for each specimen were then recorded from five indentations, which were made at distances of 10 µm from each other. The indentation depth was less than 10 nm. The results were statistically analyzed by one-way ANOVA and Tukey tests. $P$-values $< 0.05$ were considered significant.

Results

Contact angle

The water contact angles of all the groups are shown in Fig. 3. The data shown represent the
mean and standard deviation. The contact angle of Group 1 (normal dentin) was $82.5^\circ \pm 4.2^\circ$, that of Group 2 (endodontic irrigants) $54.8^\circ \pm 5.3^\circ$, and that of Group 3 (excimer UV irradiation) $23.2^\circ \pm 5.6^\circ$. The contact angle of dentin exposed to endodontic irrigants was significantly lower than that of normal dentin ($P < 0.05$). Furthermore, the contact angle of dentin exposed to excimer UV irradiation was significantly lower than that of dentin exposed to endodontic irrigants ($P < 0.05$).

**Nanohardness and Young’s modulus**

Measurements of hardness and Young’s modulus in each group are indicated in Figs. 4A and 4B. The hardness of Group 1 (normal dentin) was $0.9 \pm 0.2$ GPa, that of Group 2 (endodontic irrigants) $0.7 \pm 0.1$ GPa, and that of Group 3 (excimer UV irradiation) $0.9 \pm 0.2$ GPa. Moreover, the Young’s modulus of Group 1 (normal dentin) was $21.3 \pm 2.1$ GPa, that of Group 2 (endodontic irrigants) $18.8 \pm 1.5$ GPa, and that of Group 3 (excimer UV irradiation) $22.3 \pm 2.5$ GPa. Mean hardness and mean Young’s modulus measurements did not differ between the groups ($P > 0.05$). However, dentin exposed to endodontic irrigants exhibited a tendency for lower values of both measurements. Exposure to excimer UV irradiation did not appear to change the mechanical properties of dentin.

**Discussion**

The results of the present study indicate that the contact angle test is a useful method for evaluation of dentin surface wettability. Moreover, the contact angle of dentin exposed to endodontic irrigants was lower than that of normal dentin, and thus ordinary root canal treatment is a useful method for increasing surface wettability. As mentioned above, improved
wettability of dentin enhances proper contact between the sealer and dentin walls. Some studies have previously evaluated dentin wettability\(^{13}\), as well as the wettability of root canal sealers on root canal dentin\(^{14-17}\). However, there have been few studies investigating the effect of endodontic irrigation and UV irradiation on dentin. In this experimental study, the root canal was irrigated with NaOCl and EDTA (3% NaOCl for 1 min, 17% EDTA for 1 min, and then 3% NaOCl for 1 min). We followed the irrigation protocol to simulate clinical conditions\(^{18-20}\). UV irradiation time was the same period as irrigation with NaOCl and EDTA.

The contact angle of dentin exposed to excimer UV irradiation was the lowest among all the experimental groups; thus, excimer UV irradiation may be a particularly useful method to increase the surface wettability of dentin. Contact angle measurements are the most popular method of determining the hydrophobicity and hydrophilicity of the surfaces of materials. A greater contact angle indicates hydrophobicity (poor wetting); a contact angle of <65° indicates a hydrophilic material, whereas a contact angle >65° indicates a hydrophobic material\(^{21}\). Thus, dentin exposed to either root canal irrigation or UV irradiation is considered a hydrophilic material.

Excimer UV irradiation was confirmed to be useful for increasing the surface wettability of dentin. UV photons are partially energetic. Photons at the xenon wavelength (172 nm) can break organic bonds, and can generate free radicals. The resulting hydroxyl radicals may freely react with organic molecules to cause partial ionization or full oxidation to CO\(_2\) and H\(_2\)O.
Fig. 5. Schematic illustration of the dentin surface after excimer ultraviolet irradiation

(Fig. 5). UV light is also used in titanium implants in clinical dentistry where it can lead to the removal of organic contamination and increase the wettability of the implant surface in order to attract proteins and cells without changing the surface properties\(^{22}\). High-energy photons break the bonds between the carboxyl groups and titanium, thereby enhancing the chance of bonding with the oxygen, nitrogen, and sulphur atoms on proteins, enhancing the subsequent attachment of cells.

Importantly, the hardness and modulus of dentin exposed to excimer UV irradiation were not changed, in comparison with normal dentin. In this study, hardness and Young's modulus were measured by creating superficial indentations on the specimen surface; the indentation depth was less than 10 nm. Thus, analysis of the surface (within 10 nm) showed no changes in mechanical properties after excimer UV irradiation.

These results confirm the increased surface wettability of dentin exposed to UV irradiation. However, the mechanical properties of the dentin structure were not altered after exposure to UV irradiation. As noted above, UV lamp irradiation is less expensive and more easily applied for improved wettability. Thus, excimer UV irradiation after root canal irrigation might be a useful method in endodontic treatment. However, a UV lamp is needed to improve the tip in root canal treatment in the future. Further, it has been reported that dentin wettability increases after acid etching\(^{23}\). Thus, excimer UV irradiation is expected to increase the bonding strength of dental materials to radicular dentin.

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Conflict of interest disclosure

The authors have no conflict of interest to declare.

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