Influence of a new denture cleaning technique based on photolysis of H₂O₂ on the mechanical properties and color change of acrylic denture base resin

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The purpose of this study was to evaluate the influence of a disinfection technique based on photolysis of H₂O₂ on the mechanical properties and color change of acrylic denture base resin. Resin specimens were immersed in 1 M H₂O₂ irradiated with light-emitting diode (LED) light at 400 nm for 1 week. The immersion duration of 1 week (168 h) corresponded to performing approximately 500 times of 20-min cleaning. Hydroxyl radicals are potent oxidants and they were generated *via* the photolysis of H₂O₂. Oxidative damage caused by these radicals included reduced flexural strength and altered color for the acrylic resin. Nonetheless, the degraded flexural strength and altered color of acrylic resin after 500 times of cleaning in the disinfection system would be within clinically acceptable levels.

Keywords: Denture cleaning, Hydroxyl radical, Hydrogen peroxide, Acrylic resin, Flexural strength

INTRODUCTION

Accumulation of denture plaque containing bacteria and fungi due to poor oral hygiene and poor denture cleanliness causes denture stomatitis in many denture wearers¹. It is also suggested that the wearing of removable partial dentures or overdentures increases the incidence of caries and periodontal diseases in remaining teeth^{2,3}. For elderly people and immunocompromised patients, the continuous swallowing or aspiration of microorganisms from denture plaque exposes them to the risk of systemic infections such as aspiration pneumonia and gastrointestinal infection². Therefore, regular and efficient denture cleaning is indispensable for the prevention of oral and systemic diseases.

Mechanical denture cleaning methods generally use a brush with or without dentifrice⁴. However, mechanical cleaning alone fails to effectively reduce microorganisms in denture plaque. It is recommended that proper denture cleaning should include chemical disinfection^{5–7}. In our laboratory, we developed a new chemical disinfection method based on the photolysis of hydrogen peroxide (H₂O₂)^{8,9}. When removable dentures were immersed in H₂O₂ irradiated with light-emitting diode (LED) light at a wavelength of 405 nm, microorganisms in denture plaque were rapidly and effectively killed by hydroxyl radicals generated from the photolysis of H₂O₂¹⁰.

Hydroxyl radicals are a strong oxidant species. Repeated exposure to hydroxyl radicals for daily cleaning might cause dental materials used for removable dentures to corrode or degrade. In a previous study, we investigated the corrosive effect of a disinfection solution containing hydroxyl radicals generated by photolysis of 1 M H₂O₂ (≅3%) on these dental metals: Ti, stainless steel, Ag-Pd-Cu-Au alloy, and Co-Cr alloy¹¹. None of the

metals corroded except Ti, and that the corrosive effect of the disinfection solution did not exceed that of 1 M H₂O₂ alone without LED light irradiation at 400 nm wavelength. Therefore, our new chemical disinfection method would not cause problematic metal corrosion if the concentration of H₂O₂ were 1 M or less¹¹. However, it remains to be seen if our new denture cleaning technique, which entails long-term exposure to H₂O₂ with LED light irradiation, would cause acrylic denture base resins to degrade.

Several studies have investigated the effects of chemical denture cleaning solutions on the properties of acrylic denture base resins^{12–15}. Peracini *et al.* demonstrated that commercially available alkaline peroxide denture cleansers altered the color, increased the surface roughness, and reduced the flexural strength of heat-polymerized acrylic denture base resin¹⁶. Among the plethora of over-the-counter denture cleansers, peroxide-based solutions are the most widely used because they generate H₂O₂ to kill microorganisms in denture plaque¹⁷. Thus, the generated H₂O₂ might contribute to the degradative change in the acrylic resin because H₂O₂ is a well-known oxidant.

Light irradiation at about 400 nm wavelength, which is the boundary between visible light and ultraviolet light, is another factor that might degrade the properties of acrylic resins. It has been shown that ultraviolet irradiation caused significant color changes in dental resins^{18–20}.

In light of the potential of H₂O₂ to cause oxidative degradation and that of LED light irradiation to cause color changes, the purpose of the present study was to evaluate the influence of a new disinfection technique based on photolysis of H₂O₂ using LED light irradiation at 400 nm. The hypothesis of this study was that disinfection immersion in 1 M H₂O₂ with LED irradiation

would affect the mechanical properties and color of acrylic denture base resin.

MATERIALS AND METHODS

Acrylic denture base resin specimens

A commercially available plastic plate was cut into small dies of 31×11×2.5 mm each. The dies were invested with a dental stone (Advastone, GC, Tokyo, Japan) in a plastic flask to make stone molds. After the dental stone had set, the flasks were opened and the dies removed. A microwave-curing acrylic denture base resin (Acron MC No. 3, GC) was manipulated, pressed into a mold, and polymerized in a microwave oven according to manufacturer's instructions. After polymerization, the flask was opened and the resin specimen was removed from the mold.

Polymerized resin specimens were trimmed using a tungsten bur. Then, all surfaces of each specimen were ground and polished with silicon carbide papers up to 1000-grit. One surface (henceforth known as the 'thoroughly polished surface') was further polished using an automatic grinder-polisher (MetaServ 250, Buehler, Dusseldorf, Germany) and a power head (Vector LC 250 Power Head, Buehler) with 3- μ m diamond suspension. Specimen dimensions were measured using a digital caliper (Digimatic Caliper 500-444, Mitutoyo, Kawasaki, Japan) and adjusted to 30×10×2 mm with a maximum tolerated difference of 0.3 mm in each dimension.

After the specimens were rinsed with pure water, they were left to dry in an incubator at 37°C for at least 12 h.

Experimental LED irradiation device

In the present study, photolysis of 1 M H₂O₂ was carried out using an experimental LED irradiation device as described in our previous study¹¹⁾. Each chamber of the experimental device was equipped with two LED light sources, which emitted light with a wavelength of 400 nm (NHH105UV, Lustrous Technology, Shiji, Taipei, Taiwan)²¹⁾. 1 M H₂O₂, which corresponded to a concentration of 3.4% (wt/vol) used in oral disinfectants, was prepared by diluting 31% H₂O₂ (Santoku Chemical Industries, Tokyo, Japan) with pure water.

LED light irradiation was performed toward both sides of a specimen immersed in H₂O₂ or pure water and in a direction perpendicular to the long axis of the specimen (Fig. 1). LED output powers were set at 30 or 50 mW using a power meter (FieldMate, Coherent, Santa Clara, CA, USA), corresponding to irradiances of 10 and 16 mW/cm² respectively for an irradiation distance of 10 mm.

Immersion test

A nylon string was attached to each specimen to prepare for immersion. Specimens were immersed in a glass container containing either 12 mL of 1 M H₂O₂ or pure water according to the following five test groups in this study:

Fig. 1 Schematic illustration of photolysis of 1 M H₂O₂ using experimental LED irradiation device.

- Group 1: Five specimens were immersed in 1 M H₂O₂ and irradiated with LED light at an irradiance of 16 mW/cm².
- Group 2: Five specimens were immersed in 1 M H₂O₂ and irradiated with LED light at an irradiance of 10 mW/cm².
- Group 3: Five specimens were immersed in pure water and irradiated with LED light at an irradiance of 16 mW/cm².
- Group 4: Five specimens were immersed in 1 M H₂O₂ without LED irradiation.
- Group 5: Five specimens were immersed in pure water without LED irradiation.

Immersion test for all groups was performed at room temperature for 1 week. During the immersion test, H₂O₂ and pure water were daily replaced with fresh supply. After the immersion test, specimens in all groups were rinsed with pure water and then left to dry in an incubator at 37°C for at least 12 h.

Flexural strength measurement

After the immersion test, flexural strength was measured using a three-point bending test in a universal testing machine (AG-IS, Shimadzu, Kyoto, Japan). Five specimens per group were used for flexural strength measurement. The thoroughly polished surface of each specimen was positioned in the tensile zone, then loaded with a 1-kN load cell at a crosshead speed of 1 mm/min and with a 20-mm support span. Maximum load (N) of each specimen was recorded, and flexural strength (MPa) was calculated according to JIS T6501-2012 standard for acrylic denture base resins²²⁾ using the formula below:

$$\sigma = 3FL/2bh^2$$

where σ is flexural strength (MPa), F is maximum load (N), L is length of support span (mm), b is specimen width (mm), and h is specimen thickness (mm).

Elastic modulus measurement

Modulus of elasticity was also determined using the three-point bending test based on five specimens per group. It is calculated using the formula below:

$$E = [F_1/d] \times [L^3/4bh^3]$$

where E is modulus of elasticity (MPa), F_1/d (N/mm) is the slope of the linear portion of load-deflection line, L is the length of support span (mm), b is specimen width (mm), and h is specimen thickness (mm).

Color analysis

Using five specimens per group, the thoroughly polished surface of each specimen was subjected to color analysis before and after the immersion test. Color analysis was performed using a portable colorimeter (ShadeEye NCC, Shofu, Kyoto, Japan) and the CIE (Commission Internationale de l'Eclairage) $L^*a^*b^*$ colorimetric system. A color is expressed in the CIE system with three parameters, L^* , a^* and b^* , which represent lightness, red-green value, and yellow-blue value respectively. The colorimeter was calibrated according to manufacturer's instructions before each analysis.

Color analysis was performed in duplicate for each specimen, and the mean value was regarded as the representative value of the specimen. Color difference (ΔE) of each specimen was calculated as follows:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

where ΔL^* , Δa^* , and Δb^* represent the differences in L^* , a^* , and b^* obtained before and after the immersion test.

Hardness measurement

Using five specimens per group, the hardness of each specimen was determined using the micro-Vickers hardness test after the immersion test. Indentation was produced on the thoroughly polished surface under a load of 200 g for 15 s in a digital microhardness tester (MVK-H2, Akashi, Mitutoyo, Japan). Vickers hardness (HV0.2) was calculated from the mean diagonal length of the indentation. Micro-Vickers hardness test was performed in duplicate for each specimen, and the mean value was regarded as the representative value of the specimen.

Surface roughness measurement

Using five specimens per group, surface roughness of the thoroughly polished surface was measured using a surface profilometer (Surfcom 130A, Tokyo Seimitsu, Tokyo, Japan) before and after the immersion test. The stylus moved across the surface for a distance of 2.5 mm, and mean arithmetic roughness (Ra) was recorded. Resolution of recorded data was 0.001 μm . Surface roughness measurement was conducted in duplicate for each specimen, and the mean value was regarded as the representative value of the specimen. Roughness difference (ΔRa) for each specimen before and after the

immersion test was calculated by subtracting from the roughness values (Ra) obtained.

Quantification of hydroxyl radical and H_2O_2

To estimate the amounts of hydroxyl radicals generated and remaining H_2O_2 after the immersion test, two additional experiments as described in our previous studies^{11,23)} were conducted:

Experiment 1: To quantify hydroxyl radical yields for different concentrations of H_2O_2 irradiated by LED light.

Experiment 2: To measure the concentration of H_2O_2 before and after 24-h LED irradiation.

Based on the results of Experiment 1, a calibration curve was plotted to calculate the generation rate of hydroxyl radicals from H_2O_2 . Based on the calibration curve and results of Experiment 2, the yield of hydroxyl radicals for each day was estimated.

Experiment 1: Quantification of hydroxyl radical yields

Different concentrations of H_2O_2 were prepared by diluting 31% H_2O_2 (Santoku Chemical Industries) with pure water. To quantify hydroxyl radical yields for different concentrations of H_2O_2 , electron spin resonance (ESR) spin trapping technique was used in this study with the following protocol:

1. 250 μL of H_2O_2 and 250 μL of 5,5-dimethyl-1-pyrroline N-oxide (DMPO; Labotec, Tokyo, Japan), which is a spin trap agent, was mixed in a glass vessel to reach final concentrations of 0.125–1 M for H_2O_2 and 300 mM for DMPO.
2. Glass vessel was placed in the experimental LED irradiation device and reaction mixture was irradiated with LED light for 1 min.
3. Mixture was transferred to a quartz cell and ESR spectrum was recorded using an X-band ESR spectrometer (JES-FA-100, JEOL, Tokyo, Japan).
4. Measurement conditions for ESR spectroscopy were as follows —field sweep: 330.50–340.50 mT; field modulation frequency: 100 kHz; field modulation width: 0.1 mT; amplitude: 80; sweep time: 2 min; time constant: 0.03 s; microwave frequency: 9.420 GHz; microwave power: 4 mW.
5. 20 μM 4-hydroxy-2,2,6,6-tetramethylpiperidine (TEMPOL; Sigma-Aldrich, St. Louis, MO, USA), a spin label, was used as a standard to calculate the concentration of DMPO-OH (a hydroxyl radical spin adduct). Concentration of DMPO-OH was then determined using Digital Data Processing (JEOL, Tokyo, Japan) by comparing its signal intensity with that of TEMPOL.
6. Yield of DMPO-OH obtained in duplicate measurements was plotted against the concentration of H_2O_2 to produce the calibration curve.

Experiment 2: Quantification of remaining H_2O_2 after LED irradiation

The concentration of H_2O_2 was expected to decrease with

LED irradiation time. Therefore, the concentrations of H_2O_2 before and after 24-h LED irradiation were further examined in this experiment. Twelve milliliters of 1 M H_2O_2 was irradiated with LED light at an irradiance of 10 or 16 mW/cm² or was kept without LED irradiation for 24 h. Quantitative determination of H_2O_2 content was performed by measuring the decrease in absorbance at 240 nm using a spectrophotometer (Nanovue plus, GE Healthcare, Buckinghamshire, UK). This experiment was conducted in triplicate.

Statistical analysis

Statistical significances ($p < 0.05$) in flexural strength, modulus of elasticity, HV2.0, ΔE , and ΔRa of each group were assessed by one-way analysis of variance (ANOVA) followed by Dunnett's multiple comparison test using Group 5 as a control group. To quantitatively estimate the relationships among these five parameters, a correlation coefficient matrix was produced by standardizing these variables/parameters to have a mean of 0 and a standard deviation of 1.

RESULTS

Flexural strength

Figure 2 shows the flexural strength results. After resin specimens were immersed in 1 M H_2O_2 irradiated with LED light, their flexural strengths decreased. Flexural strengths of Groups 1 and 2 were 86 and 90 MPa respectively, which were significantly lower than that of Group 5 (101 MPa).

On the other hand, LED irradiation alone (Group 3) and immersion in 1 M H_2O_2 without irradiation (Group 4) did not significantly affect the flexural strength of resin specimens.

Modulus of elasticity

Figure 3 shows the modulus of elasticity results after the immersion test. One-way ANOVA showed that there were no statistically significant differences among the groups.

Color change

Table 1 shows the mean values of L^* , a^* , and b^* of each group before and after the immersion test. After resin specimens were immersed in 1 M H_2O_2 irradiated with LED light, L^* increased but a^* and b^* decreased. This meant that the color of resin specimens became whiter and tended to shift to green and blue. Consequently, the ΔE values of Groups 1 (2.02) and 2 (1.25) were significantly higher than that of Group 5 (0.53) (Fig. 4).

LED irradiation alone (Group 3) also slightly changed the color of resin specimens (Table 1). However, there was no significant difference in ΔE value between Group 3 (0.99) and Group 5 (Fig. 4).

Micro-Vickers hardness

Figure 5 shows the micro-Vickers hardness results after the immersion test. The mean HV0.2 value of each group ranged between 21.3 and 21.5. One-way ANOVA

Fig. 2 Flexural strengths of acrylic denture base resin specimens after the immersion test expressed in mean value with standard deviation ($n=5$). Significant differences from Group 5 are denoted with '*' ($p < 0.05$) or '**' ($p < 0.01$).

Fig. 3 Modulus of elasticity of acrylic denture base resin specimens after the immersion test expressed in mean value with standard deviation ($n=5$). There were no significant differences from Group 5.

Table 1 Mean L^* , a^* , and b^* values of each group before and after the immersion test

	Before immersion			After immersion		
	L^*	a^*	b^*	L^*	a^*	b^*
Group 1	43.7	20.9	11.5	44.3	19.8	10.2
Group 2	43.6	20.6	11.0	44.1	20.0	10.5
Group 3	43.7	20.8	11.4	43.8	20.1	10.8
Group 4	43.7	20.9	11.1	43.7	21.1	11.3
Group 5	43.6	20.9	11.3	43.8	20.6	11.4

showed that there were no statistically significant differences among the groups.

Fig. 4 Color differences (ΔE) of acrylic denture base resin specimens after the immersion test expressed in mean value with standard deviation ($n=5$). Significant differences from Group 5 are denoted with '*' ($p<0.05$) or '**' ($p<0.01$).

Fig. 6 Differences in surface roughness (ΔRa) of acrylic denture base resin specimens after the immersion test expressed in mean value with standard deviation ($n=5$). There were no significant differences from Group 5.

Fig. 5 Micro-Vickers hardness (HV0.2) results of acrylic denture base resin specimens after the immersion test expressed in mean value with standard deviation ($n=5$). There were no significant differences from Group 5.

Fig. 7 Calibration curve between the yield of DMPO-OH and the concentration of H_2O_2 . Each data point represents the mean of duplicate measurements.

Surface roughness

Before the immersion test, mean value of Ra was less than $0.05 \mu m$ for Groups 1–5. After the immersion test, absolute value of ΔRa of each group was below $0.01 \mu m$ (Fig. 6). One-way ANOVA showed that there were no statistically significant differences in ΔRa among the groups.

Hydroxyl radical yield versus content of remaining H_2O_2

The amount of hydroxyl radicals generated linearly increased with the concentration of H_2O_2 (Fig. 7). Equations for the linear relationships between the concentrations of DMPO-OH and H_2O_2 when irradiated at irradiances of 10 and 16 mW/cm² were $y=8.1151x+0.9848$ and $y=12.773x+1.2363$ respectively.

The concentration of H_2O_2 decreased after 24-h LED irradiation (Fig. 8). Upon exposure to irradiances of 10

Fig. 8 Changes in concentration of H_2O_2 with and without LED irradiation at an irradiance of 10 or 16 mW/cm². Each concentration value represents the mean with standard deviation ($n=3$).

and 16 mW/cm², 1 M H₂O₂ degraded to about 0.93 and 0.81 M H₂O₂ respectively.

Hydroxyl radical yield after 24 h was calculated using the calibration curve plotted in Fig. 7. For example, when the concentration of H₂O₂ decreased from 1 M to 0.81 M after LED irradiation at 16 mW/cm² for 24 h, average H₂O₂ concentration was calculated to be 0.91 M if it linearly decreased. On a per minute basis, yield of hydroxyl radicals generated by photolysis of 0.91 M H₂O₂ was calculated to be 13 μM (=12.773×0.91+1.2363). In 24 h, hydroxyl radical yield was calculated to be 19 mM (=0.013×60×24). In the same manner, hydroxyl radical yield after irradiation of H₂O₂ at 10 mW/cm² for 24 h was calculated to be 13 mM.

DISCUSSION

In our previous study, Kanno *et al.* developed a novel denture cleaning system based on photolysis of H₂O₂ and demonstrated that viable bacterial counts on the surfaces of removable dentures achieved a 7-log reduction after 20-min cleaning¹⁰. In the present study, the immersion test in H₂O₂ was performed for 1 week (168 h), which corresponded to about 500 times of 20-min cleaning. Moreover, the experimental conditions applied in the present study were harsher than those used in our previous study¹⁰. Whereas dentures were immersed in 0.5 M H₂O₂ irradiated at an irradiance of 5 mW/cm²¹⁰, acrylic resin specimens were immersed in 1 M H₂O₂ irradiated at irradiance of 16 or 10 mW/cm² in the present study.

In the present study, immersion in 1 M H₂O₂ with LED irradiation for Groups 1 and 2 reduced their flexural strengths and resulted in their color changes being significantly higher than that of Group 5 (immersion in pure water without LED irradiation). Based on these results, the hypothesis of this study was accepted because immersion in 1 M H₂O₂ with LED irradiation affected the flexural strength and color of acrylic denture base resin. Hydroxyl radicals were generated when 1 M H₂O₂ was irradiated with LED light, as reported in our previous studies^{8,11}. Therefore, hydroxyl radical appeared to be the main contributor to the degradation of acrylic denture base resins.

Hydroxyl radical yield was determined using the ESR-spin trap technique in which hydroxyl radicals were spin trapped by DMPO to form DMPO-OH, a relatively stable radical. However, DMPO-OH is not permanently stable. The half-life of DMPO-OH is about several dozen minutes, depending on its initial concentration²³. For this reason, it was not possible to accurately measure the yield of DMPO-OH after LED irradiation for 24 h. In this study, hydroxyl radical yield after 24 h was estimated based on the generation rate of hydroxyl radicals and the change in H₂O₂ concentration after 24-h LED irradiation. It was estimated that photolysis of 1 M H₂O₂ at irradiances of 16 and 10 mW/cm² generated 19 and 13 mM of hydroxyl radicals per 24 h respectively.

Diffusion distance of hydroxyl radicals is quite short: it was estimated to be 6 nm²⁴. Therefore,

hydroxyl radicals could hardly penetrate the bulk of a material. In contrast, H₂O₂ and light at 400 nm could penetrate denture base acrylic resins because of their high water absorption rate and translucency property respectively. In this study, hydroxyl radicals were generated by photolysis of H₂O₂ which probably had already penetrated the bulk of acrylic denture base resin. These radicals generated within the acrylic resin then initiated oxidative degradation of the high-molecular-weight resin, causing a decrease in flexural strength and a change in color.

Apart from the influence of hydroxyl radicals, LED irradiation alone at an irradiance of 16 mW/cm² also slightly affected the color of acrylic denture base resin (Group 3), although the change was not significantly different from Group 5. LED light sources used in the present study emitted light at a wavelength of 400 nm with a full width half-maximum of <14 nm²¹. This meant that the LED light emitted in this study contained ultraviolet (UV) light (wavelength <400 nm). This study's finding that light irradiation alone affected the color of acrylic denture base resin agreed with those of previous studies which claimed that UV irradiation of acrylic resins caused a color change^{18,19}.

Flexural strength is an important physical property of denture base resins because they could clinically fail due to flexural fatigue^{25,26}. The life span of a removable denture depends on the flexural strength of its denture base resin, which could be degraded by immersion in cleansing/disinfecting solutions²⁷. In the present study, flexural strength degradation was observed in Groups 1 and 2 after the immersion test. Whereas the flexural strength of acrylic denture base resin immersed in pure water was 101 MPa (Group 5), it significantly decreased to 86 MPa (Group 1) and 90 MPa (Group 2) after immersion in 1 M H₂O₂ and irradiated at 16 and 10 mW/cm² respectively for 1 week. Nonetheless, these decreased flexural strength values exceeded the minimum value of 65 MPa set forth by ADA specification no. 12²⁸ and JIS T6501-201²². Therefore, although the disinfection technique based on photolysis of H₂O₂ would decrease the flexural strength of acrylic denture base resin after 500 times of cleaning, the reduced flexural

Table 2 Critical marks of color change according to the National Bureau of Standards

Critical marks of color change	NBS unit
Trace	0.0–0.5
Slight	0.5–1.5
Noticeable	1.5–3.0
Appreciable	3.0–6.0
Much	6.0–12.0
Very much	>12.0

Table 3 Correlation coefficient matrix of five parameters (flexural strength, modulus of elasticity, color alteration, micro-Vickers hardness, and roughness difference) produced after standardizing variables to have a mean of 0 and a standard deviation of 1

	Flexural strength	Modulus of elasticity	Color alteration	Micro-Vickers hardness	Roughness difference
Flexural strength	1				
Modulus of elasticity	−0.1601	1			
Color alteration	−0.5983	0.2985	1		
Micro-Vickers hardness	0.0863	0.5286	−0.045	1	
Roughness difference	−0.2013	−0.1037	0.0147	0.019	1

strength value would be clinically acceptable.

Color differences were observed in acrylic denture base resin after 1-week immersion in 1 M H₂O₂ with LED irradiation. ΔE values were 2.02 (Group 1) and 1.25 (Group 2) for irradiation at 16 and 10 mW/cm² respectively. According to critical marks of color change quantified by the National Bureau of Standards (NBS) (Table 2)²⁹, NBS units of color differences can be calculated using the following formula: NBS unit= $\Delta E \times 0.92$. Therefore, ΔE values of 2.02 and 1.25 obtained in the present study were calculated to be 1.86 and 1.15 respectively. These NBS units of 1.86 and 1.15 were classified as “noticeable” and “slight” respectively, meaning that these color changes were not severe. In terms of clinical implications, the ΔE values observed in the present study were within the clinically acceptable ΔE range of 1.1–3.3^{30–33}. In a study by Gross and Moser³⁰, they reported that ΔE values in the ranges of 0–2 and 2–3 represented color differences that were imperceptible and just perceptible respectively³⁰.

Apart from flexural strength and color, other physical properties such as modulus of elasticity, hardness, and surface roughness were not affected by the disinfection technique based on photolysis of H₂O₂. Most notably and importantly, our new disinfection technique did not roughen the surface of acrylic denture base resin even under the condition where hydroxyl radicals were generated. It has been reported that immersion in a commercial denture cleanser increased the surface roughness of acrylic denture base resin¹⁶. It has also been numerously reported that bacteria and fungi accumulate on the rough surfaces of acrylic denture base resins^{34,35}. Rough surfaces are more difficult to clean properly and hence favor biofilm formation^{35,36}. Therefore, if a denture cleaning treatment were to cause increased surface roughness, it would also cause bacterial plaque retention.

Relationships among the five parameters examined in this study were analyzed using a correlation coefficient matrix (Table 3). Relatively strong correlations were observed between flexural strength and color alteration, and between modulus of elasticity and micro-Vickers hardness, with correlation

coefficients of −0.5983 and 0.5286 respectively. The former correlation between flexural strength and color alteration suggested that oxidative stress induced by hydroxyl radicals caused color change of the acrylic resin concomitant with reducing its flexural strength. For modulus of elasticity and micro-Vickers hardness, no significant changes were observed for these parameters after immersion in H₂O₂ with LED irradiation. Their strong correlation suggested that irrespective of the presence or absence of oxidative stress, hardness of the resin might be an important factor to keeping its elasticity.

CONCLUSIONS

Within the limitations of the present study and based on the results obtained, the following conclusions were drawn:

1. New disinfection technique based on the photolysis of H₂O₂ could be applied to denture cleaning as it caused minimal degradation of acrylic denture base resin.
2. Degraded flexural strength and altered color after 500 times of cleaning in the new disinfection system would be within clinically acceptable limits.
3. A higher irradiance (16 mW/cm² versus 10 mW/cm²) and increase in the number of cleaning times would exacerbate the degradation of acrylic denture base resin. Therefore, optimal usage of the denture cleaning device—developed from the new disinfection technique—must be carefully determined and specified in full consideration of denture cleaning efficacy and adverse effects on denture materials.

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