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RESEARCH ARTICLE

Evaluation of Color Stability according to Shade of Temporary Crown Resin Using Digital Spectrophotometer: In Vitro Study

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Background: Temporary crown resins are used prior to prosthesis placement, indicating the importance of aesthetics. The aim of this study was evaluate the color stability of various staining solutions according to the color of temporary crown resins using VITA Easyshade® V.

Methods: The temporary crowns used were the powder-liquid type and included four shades. A total of 36 specimens were fabricated in the form of disks with a diameter of 1.8 mm and a depth of 2 mm. They were divided into four groups of nine each, and staining was performed for seven days by precipitation in 3 mL of three staining solutions composed of distilled water, black coffee, and red wine. Color and color stability evaluations were performed by a trained examiner using a digital spectrophotometer (VITA Easyshade® V). Color stability was analyzed using the ΔE value.

Results: Because of the color stability evaluation using the ΔE value, the difference between three and seven days was significant in the specimen Ⅰ and Ⅲ groups ($p<0.05$). Further, post hoc analysis showed that the ΔE value of red wine was significant, indicating that the color stability in red wine was low. The ΔE values in group Ⅱ between days three and seven were statistically significant ($p<0.05$). Post hoc analysis showed that distilled water, coffee, and wine had the highest ΔE values on day three. On day seven, the ΔE value for wine was significant, and the color stability was low. There was no significant difference in group Ⅳ according to the staining period and staining solution; therefore, color stability was high ($p>0.05$).

Conclusion: This study showed that most temporary resin restorations exhibited color stability in the staining solution. The darker the color of the temporary resin restoration, the higher the color stability against extrinsic staining.

Key Words: Acrylic resins, Color, Staining

Introduction

1. Background

A tooth is generally lost due to dental caries, tooth fractures, or tooth wear. After a tooth loss, restorative treatment is performed using restorative materials to replace the lost hard tissue. Then, a period is required to achieve permanent restoration, especially after extensive tooth crown loss occurs. During this time, a temporary resin crown restoration is used to protect the oral tissue and remaining tooth material from physicochemical irritation until a permanent crown restoration can be achieved. The temporary resin preserves masticatory function and aesthetic restoration[1)]. A resin restorative material is frequently used for temporary dental restoration because it has a convenient operation method with excellent plasticity. When anterior crown restoration is required, an aesthetic temporary resin restoration is required until permanent restoration can be achieved.

Acrylic resins are mainly used as provisional dental restorative materials, and they can be made of, but not limited to, poly methyl methacrylate (PMMA), poly ethyl

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methacrylate (PEMA), and bis-acryl[2,3]. These materials have different polymerization methods, filler compositions, and monomer types. Conventionally, self-polymerizing PMMA resin restorative materials are used for temporary crowns.

PMMA resins are synthesized by mixing a polymer powder, wherein the powder mixture facilitates the curing of the methyl methacrylate monomer. PMMA resins possess high strength but undergo significant shrinkage during polymerization. On the other hand, PEMA resin has the advantage of less polymerization shrinkage but has the disadvantage of discoloration.

Traditionally, aesthetic dental restoration emphasized the aesthetics of the final prosthesis. With the development of modern dental treatment, patients' interest in aesthetics restoration has increased, and the demand for the aesthetics of provisional anterior restorations has also increased[4]. However, the color shades of temporary resin restorative materials are not diverse, resulting in aesthetic dissatisfaction with the patient. According to previous studies, the temporary restorative resin can cause discoloration and color changes after consuming various food and beverages. Extrinsic discoloration may be caused by foods such as coffee, tea, and wine. Previous studies have reported that the adsorption of these staining factors and the degree of absorption to water were related[5,6]. In addition, previous studies reported that extrinsic staining for temporary restoration was caused by drinking red wine, coffee, tea, and mouthwash[1,7].

According to a study evaluating the color stability of temporary resin restorations, the color of temporary resin restorations changed and color stability decreased as the frequency of beverage intake increased. Temporary resin restoration may also be affected by extrinsic sources of staining[4]. Color stability must be evaluated because the resin material may be eluted or discolored in the oral cavity owing to various environmental changes.

However, most previous studies have evaluated only a single color of temporary crown restorative materials, and it is insufficient to compare and evaluate various temporary resin restoration colors. In addition, it is necessary to study color stability, which is the property of maintaining the unique color of the restoration material in various environments.

2. Objectives

The purpose of this study was to compare the degree of staining with different colors of temporary resin crown restorative materials and to evaluate the color stability in different staining solutions.

Materials and Methods

1. Fabrication of specimens

A randomized in vitro study was designed following the CRIS (checklist for reporting in vitro studies) statement guidelines. The temporary crown resin used in this study was a powder-liquid type and included four shades. The product specifications are shown in Table 1.

The specimen was prepared in the form of a disk with a diameter of 1.8 mm and a depth of 2 mm using a polyvinyl siloxane mold made of putty (CharmFlex®; Dentist Ltd., Seongnam, Korea). After weighing the powder and liquid at a weight ratio of 1:0.7 for the four types of resin, a plastic spatula was used to mix the powder to ensure that it was sufficiently wetted with the liquid and then filled in the mold. After mixing, it was stored in a constant temperature water bath maintained at 37±1°C and 100% relative humidity for 10 minutes. After separating the specimen from the mold, a clinical surface polishing process was performed to form a uniform surface, and 36 specimens were manufactured.

Table 1. Characteristics of Temporary Resin Evaluated in the Study

Group	Name	Shade	Manufacturing company	Composition
I	Alike	59(B1)	G.C AMERICA/USA	Poly methyl methacrylate
II	Alike	62(A1)	G.C AMERICA/USA	Poly methyl methacrylate
III	Snap	62(A2)	PARKELL/USA	Poly ethyl methacrylate
IV	Jet	66(A3)	LANG/USA	Poly methyl methacrylate

2. Staining solution and procedure

The staining solution used to evaluate color stability consisted of distilled water, black coffee (Kanu Mild Roast Americano; DongSuh Food, Seoul, Korea), and red wine (G7 Cabernet Sauvignon; ShinSeGae Group, Maule, Chile). Black coffee was prepared according to the manufacturer's instructions. A total of 36 specimens were divided into four groups of nine each, placed on a nine-well plate (SPL, Seoul, Korea), precipitated in 3 mL of the three staining solutions each, and stored in an incubator at 37°C. The solution was changed daily during the experiment.

3. Evaluation using a digital spectrophotometer

1) Color measurement device

The digital spectrophotometer used in this study was VITA Easyshade® V (VITA Zahnfabrik, Bad Sackingen, Germany), which was operated by a trained examiner. Before measurement, calibration was performed according to the manufacturer's instructions. The measurement mode of the temporary crown resin shade was set to the ceramic restoration mode. Then, the probe tip was vertically placed in the center of each specimen, and measurements were repeated three times. The baseline was measured after storing the specimen in distilled water for 24 hours before the staining process. The color was measured again three and seven days after the specimen was precipitated in each staining solution. Before the color measurement, the specimen was washed for 3 minutes using an ultrasonic cleaner, dried with wet gauze, and the color was measured.

2) Evaluation of L, C, H, and ΔE values

To evaluate the color of each specimen, the L value indicating lightness, the C value indicating chroma, and the H value indicating hue were used. The average of three measurements was used as a representative value. The ΔE value, which quantifies the difference in the color of each specimen, was automatically calculated and recorded using a digital spectrophotometer after three measurements. The formula for calculating the automatically calculated ΔE value is as follows:

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

4. Statistical analysis

The data collected in this study were analyzed using IBM SPSS Statistics (version 22.0; IBM Corp., Armonk, NY, USA). The statistical significance level was set at α=0.05. For the difference in the color index and the ΔE values according to the staining solution of each resin group, a Kolmogorov-Smirnov test was performed to evaluate normality. If the normality was not satisfied, a

Table 2. Change of Lightness Value (L) of Temporary Crown Resin according to Immersion in Different Staining Solution

Group	Staining solution	Experimental solution			p-value*	Post hoc test†
		Distilled water[a]	Black coffee[b]	Red wine[c]		
I	Base line	0.67±0.21	0.13±0.55	0.62±0.68	0.43	
	3 days	1.75±100	1.52±0.64	−1.50±1.87	0.04	a,b>c
	7 days	0.82±1.27	−0.30±0.33	6.75±16.37	0.64	
II	Base line	0.93±0.81	−0.63±1.20	−1.55±0.30	0.05	
	3 days	2.63±0.96	0.40±1.04	−2.56±0.57	<0.001	a>b>c
	7 days	4.17±1.89	0.70±1.48	54.25±3.66	<0.001	a,b<c
III	Base line	3.07±0.31	3.37±0.28	3.12±0.80	0.29	
	3 days	4.53±0.60	4.22±0.69	−2.00±2.73	<0.001	a,b>c
	7 days	3.13±1.11	3.87±1.04	45.25±17.46	<0.001	a,b<c
IV	Base line	1.55±1.07	−0.08±0.40	0.50±0.35	0.07	
	3 days	1.63±2.25	2.72±1.31	0.60±1.54	0.39	
	7 days	2.00±1.30	1.78±1.64	−2.43±1.99	0.03	a,b>c

Values are presented as mean±standard deviation.
*p-value obtained from Kruskal-Wallis test.
†Post hoc obtained from Mann-Whitney U-test.

Kruskal-Wallis test was performed. Post-hoc analysis was tested using the Mann-Whitney test. A comparison of the ΔE values before and after staining was performed using a paired sample t-test.

Results

1. Change in the L, C, and H values for various staining solutions

Table 2 shows the changes in the L value of the temporary crown resin according to the staining solution. There was a difference in the L values according to the staining solution for each group. On the seventh day of discoloration in groups II and III, wine-treated specimens shows the highest L value at 54.25±3.66 and 45.25±17.46, respectively, and there is a statistically significant difference between distilled water and black coffee ($p < 0.001$).

Table 3 shows changes in the C value of the temporary crown resin according to the staining solution. There is a difference in the C values according to the staining

Table 3. Change of Chroma Value (C) of Temporary Crown Resin according to Immersion in Different Staining Solution

Group	Staining solution	Experimental solution			p-value*	Post hoc test†
		Distilled water[a]	Black coffee[b]	Red wine[c]		
I	Base line	0.17±1.00	−0.33±0.49	−0.25±0.22	0.63	
	3 days	0.55±0.53	1.10±0.79	−1.87±0.72	<0.001	a,b>c
	7 days	0.32±1.30	0.87±0.72	0.22±6.92	0.98	
II	Base line	0.52±0.76	−0.25±0.45	0.03±0.49	0.34	
	3 days	1.48±1.444	0.50±0.93	−3.53±0.99	<0.001	a,b>c
	7 days	−0.23±0.65	0.30±0.20	17.42±0.50	<0.001	a,b<c
III	Base line	1.77±0.91	1.30±0.31	1.75±0.78	0.68	
	3 days	2.23±1.55	3.34±1.85	−0.32±1.15	0.07	a,b>c
	7 days	2.42±1.64	3.42±1.71	15.65±5.80	0.01	a,b<c
IV	Base line	0.32±0.46	−0.14±0.68	0.95±0.85	0.22	
	3 days	0.92±0.63	2.13±1.01	0.82±1.04	0.22	
	7 days	0.90±0.45	2.45±0.53	0.62±0.55	0.01	a,c<b

Values are presented as mean±standard deviation.
*p-value obtained from Kruskal-Wallis test.
†Post hoc obtained from Mann-Whitney U-test.

Table 4. Change of Hue Value (H) of Temporary Crown Resin according to Immersion in Different Staining Solution

Group	Staining solution	Experimental solution			p-value*	Post hoc test†
		Distilled water[a]	Black coffee[b]	Red wine[c]		
I	Base line	1.27±1.75	1.73±1.12	1.62±0.63	0.90	
	3 days	−1.05±1.23	1.07±0.43	−12.98±1.41	<0.001	a,b>c
	7 days	0.88±1/14	2.13±0.64	1.57±21.53	0.99	
II	Base line	−1.17±0.33	−0.13±0.35	−0.38±0.16	0.05	
	3 days	0.62±0.98	0.56±0.74	−12.68±1.09	<0.001	a,b>c
	7 days	10.7±0.85	−0.92±1.00	65.62±2.08	<0.001	a,b<c
III	Base line	1.98±0.56	2.03±0.75	1.88±0.26	0.95	
	3 days	0.23±0.23	2.57±3.12	−10.67±3.18	<0.001	a,b>c
	7 days	−1.22±0.54	2.29±3.60	55.35±22.39	<0.001	a,b<c
IV	Base line	0.00±1.28	1.60±1.00	1.08±1.48	0.35	
	3 days	−2.67±0.26	−2.03±1.07	−9.03±2.16	<0.001	a,b>c
	7 days	−2.63±0.77	−5.15±1.34	−8.13±7.39	0.37	

Values are presented as mean±standard deviation.
*p-value obtained from Kruskal-Wallis test.
†Post hoc obtained from Mann-Whitney U-test.

solution used for each group. On the seventh day of discoloration in groups II and III, the wine-treated specimens show the highest C value at 17.42±0.50 and 15.65±5.80, respectively. There is a statistically significant difference between distilled water and black coffee ($p < 0.001$). In contrast, the coffee-treated specimens in group IV exhibited a C value of 2.45±0.53, which is higher than the value measured in wine ($p=0.01$).

Table 4 shows the changes in the H value of the temporary crown resin according to the staining solution. There is a difference in the H value according to the staining solution used for each group. On the seventh day of discoloration in groups II and III, the wine-treated specimens exhibits the highest H value (65.62±2.08 and 55.35±22.39, respectively), which is a statistically significant difference compared to distilled water and black coffee ($p < 0.001$).

2. Change of ΔE value for various staining solutions

Table 5 shows the change in the ΔE value of the temporary crown resin according to the staining solution. As the immersion period increases, there is a difference in color between groups II and III. On the seventh day of staining, the wine-treated specimens display a higher ΔE value than those of the distilled water- and black coffee-treated specimens ($p < 0.001$). There is no statistically significant difference in the ΔE values in group IV ($p > 0.05$).

3. Evaluation of color stability according to various staining solutions

As a result of the color stability evaluation according to the staining solution, group I show a statistically significant difference in discoloration of black coffee, and groups II and III showed a statistically significant difference in discoloration of wine ($p < 0.05$). In group IV, the ΔE values for black coffee and red wine are not statistically significant and are evaluated to have color stability ($p > 0.05$) (Fig. 1).

Discussion

It is important to restore masticatory function and aesthetics in cases of missing teeth. Recently, there has been increasing interest in and demand for anterior restorations for the aesthetics of temporary resin restorative materials before the final restoration[8]. It is necessary to preserve the inherent color of the restoration materials to maintain the aesthetics of dental materials because enviro-nmental changes may occur in the oral cavity.

Table 5. Change of ΔE Value (ΔE) of Temporary Crown Resin according to Immersion in Different Staining Solution

Group	Staining solution	Experimental solution			p-value*	Post hoc test†
		Distilled water[a]	Black coffee[b]	Red wine[c]		
I	Base line	1.20±0.36	0.93±0.23	0.97±0.43	0.63	
	3 days	2.15±1.15	2.10±0.56	4.95±0.85	0.01	a,b < c
	7 days	1.55±0.76	1.60±0.05	14.73±15.32	0.19	
II	Base line	1.55±0.23	2.20±0.30	1.62±0.28	0.05	
	3 days	3.19±1.30	1.45±0.30	6.02±0.54	< 0.001	a < b < c
	7 days	4.23±1.89	1.55±0.63	57.00±3.45	< 0.001	a,b < c
III	Base line	3.75±0.26	4.08±0.25	3.75±0.44	0.42	
	3 days	5.17±1.10	4.32±0.67	4.93±1.83	0.72	
	7 days	4.08±1.68	4.06±0.82	49.47±15.65	< 0.001	a,b < c
IV	Base line	1.73±0.99	0.95±0.22	1.47±0.25	0.34	
	3 days	2.52±1.80	3.72±0.70	3.73±0.29	0.38	
	7 days	2.63±0.84	4.13±0.28	4.68±1.89	0.18	

Values are presented as mean±standard deviation.
*p-value obtained from Kruskal-Wallis test.
†Post hoc obtained from Mann-Whitney U-test.

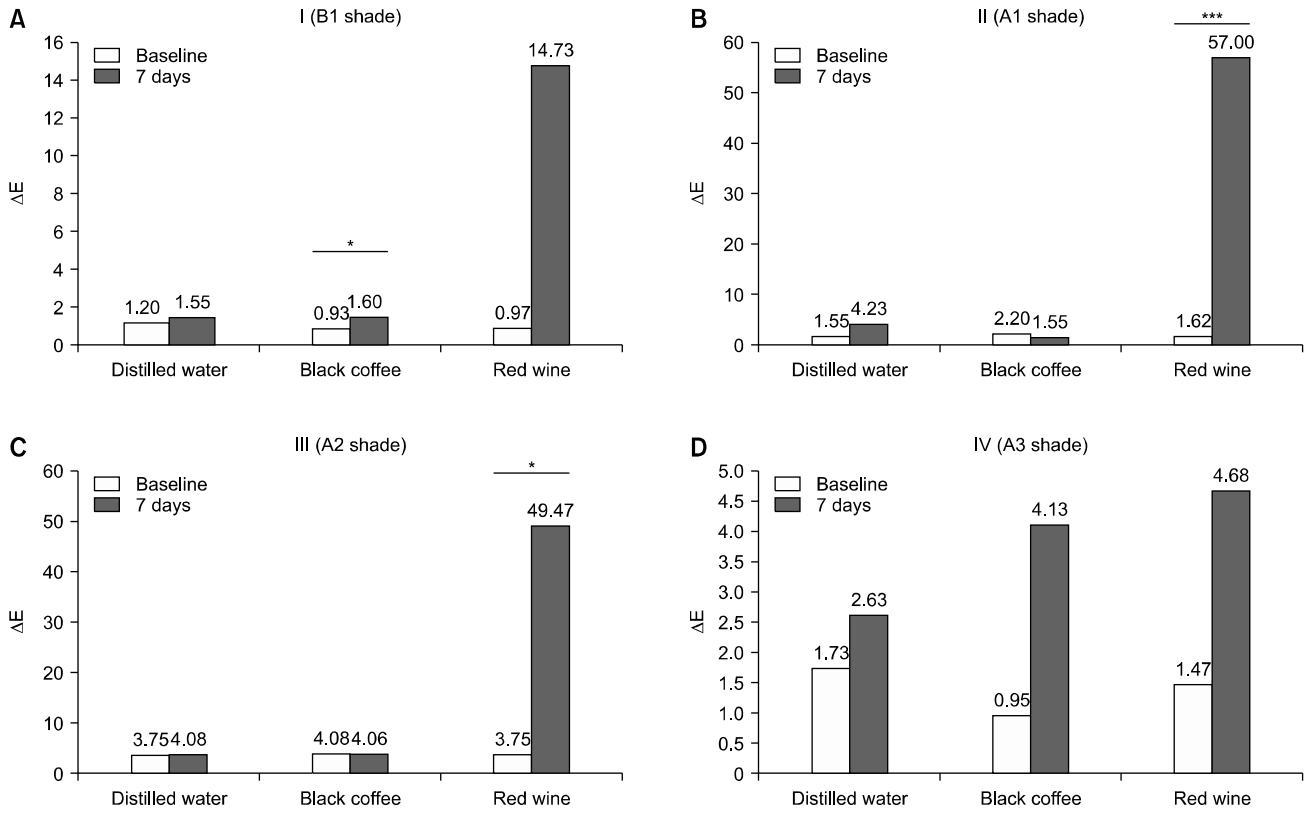

Fig. 1. Evaluation of color stability according to the shade of temporary crown resins. ΔE differences during 7 days according to the staining solution in (A) group I, (B) group II, (C) group III, and (D) group IV. *p<0.05, ***p<0.001.

1. Interpretation and comparison with previous studies

This study evaluated the color change in various temporary resin crown resins caused by staining solutions. The beverage that caused the most significant color change was red wine. Previous studies have considered extrinsic staining beverages, such as coffee, wine, and water[9]. Among the previously studied extrinsic staining beverages, black coffee, red wine, and distilled water were reported to cause staining of the restorative material and as such were selected for evaluation in this study.

A study of red wine, which causes extrinsic staining, showed the most severe discoloration effect compared to coffee, mouthwash, and black tea. It has been reported that this factor is controlled by the adsorption or absorption of the staining agent in the beverage and the affinity of the resin to the staining agent due to moisture absorption[10,11]. In addition, wine is a beverage made by fermenting grapes and contains alcohol, organic acids, and tannins. Lussi et al.[12] reported that the pH of red wine ranged from 3.43 to 3.68. The low pH of beverages can affect the surface roughness of organic acid resins and increase pigment absorption[13]. Therefore, it was determined that the pigment in red wine adsorbed on the surface of the temporary resin restoration and the inherent acidity of the wine caused corrosion on the resin surface and subsequent formation of a rough surface. As a result, it was suggested that red wine had the lowest color stability and the most severe color change because of pigmentation in the acidic environment. Therefore, it is crucial to minimize the contact time between wine containing various acids with low pH and temporary resin restoration, and also reduce the exposure frequency.

The study period was seven days after deposition in the staining solution to create an environment similar to the period when the actual temporary crown was placed on the tooth. The color stability of the resin restorative material was evaluated using a staining solution. A previous study indicated that the color change increased when immersed in a staining solution and no significant difference in color

change appeared over seven days[14]. Cooley et al.[15] reported that the maximum duration of coffee staining was seven days, and no further color change was observed. Similar to the previous study, color change due to staining appeared in all temporary resin restoration colors until the seventh day of the study. The restorative material A1 (group II), a bright color, exhibited the most significant color change when exposed to the staining solutions (especially red wine). The order from highest to lowest color stability was A1 (group II), A2 (group III), B1 (group I), and A3 (group IV). If the color stability is low, the patient's aesthetic satisfaction will decrease because the maxillary anterior of adult permanent teeth resembles the A2 resin color[16], which can be represented by three attributes: L, C, and H[17]. There are various color representation methods. The most widely used CIE color system was used, and the color of the resin restorative materials used in this study was measured using a spectrophotometer. A spectrophotometer displays color by measuring the amount of light absorbed or reflected by an object[17]. According to previous studies, spectrophotometry is more stable and accurate for color measurement than colorimetry, which is a color measurement method[18]. Color stability was measured using the Commission Internationale del'Eclairage (CIE) L*a*b* system to calculate ΔE, which was used as the standard for color stability. An increase in the calculated value of ΔE indicates a decrease in color stability. When evaluating dental restorative materials, it is generally reported that Δ E values exceeding 2.75 or 3.3 are visible to the naked eye.

The results showed that the A3 resin color, a dark shade, had little color change after exposure to the staining solutions, and had a high color stability over seven days. A previous study reported an increase in chroma in shade A3 compared to shade A2. There are metal oxides used as tints, which are dyes that can be added to resin materials that lead to high chroma or low brightness that can change the CIE a* (red-green axis) or CIE b* (yellow-blue axis) levels[19].

When a blue or black tint filler was used to darken the tint, the color of the tint was prominent. The CIE L* (lightness) decreased when the tint color was prominent. In other words, chroma increases as more pigments are added to darken colors in the resin color[20].

Therefore, it is believed that the extrinsic staining solution did not significantly cause the A3 (group IV) color change compared to A2 (group III) and A1 (group II) because the A3 shade, which is originally dark in color, is a product manufactured that already contains dyes with high chroma.

In general, the color of teeth becomes darker with age[16]. When the A3 resin with high color stability was used, the color change caused by extrinsic staining beverages was not significant during the period of temporary material restoration. Therefore, middle-aged and elderly patients may be satisfied with the high color stability of dark temporary resin restorative materials. However, when bright color shades of temporary resin anterior restorations at a young age are selected, patients may experience poor color stability and less aesthetic satisfaction.

2. Limitation

Various resin color shades are necessary because there is not a wide variety of colors currently available for temporary crown resin restorative materials. This study found that the darker the temporary restorative material, the less the color change caused by extrinsic staining factors, and the higher the color stability. In future studies, temporary resin restorations with various colors will be developed, and it the color stability evaluated.

3. Conclusion

This study showed that most temporary resin restorations exhibit color stability in distilled water and black coffee. However, it was confirmed that red wine caused temporary resin discoloration, which was visually observable by the naked eye. The darker the color of the temporary resin restoration, the higher is the color stability against extrinsic staining.

Notes

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Ethical approval

Not applicable as an experimental study.

Author contributions

Conceptualization: Mi-Kyoung Jun. Data collection and analysis: Mi-Kyoung Jun. Formal analysis: Mi-Kyoung Jun and Hye-min Ku. Writing–original draft: Mi-Kyoung Jun and Hye-min Ku. Writing–review & editing: Mi-Kyoung Jun.

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