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The effect tooth color in female smiles imparts on male and female dental students

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In recent years, there has been a tremendous increase in interest in dental esthetics. In prosthodontic clinical practice, patients are highly concerned with tooth color, among other esthetic requirements, and they have a strong desire to have white teeth. However, it is not clear what impression a person's tooth color gives to others, nor is it clear whether there is a difference between the impression men and women have. The purpose of this study was to determine the influence of different teeth colors have on the impression female smiles give by using the semantic differential method and factor analysis. The subjects were 52 students undergoing clinical training at the School of Dentistry, Osaka Dental University. The average face of 10 adult women whose tooth color had been converted by image processing to C4, A2 or NW0 according to the shade guide was used as the stimulus image, and an impression measurement was performed. As part of the statistical analysis, an exploratory factor analysis was conducted on the impression structure of different tooth colors on the impression of female smiles. The extracted factors were subjected to two-way analysis of variance (mixed design), with tooth color and gender as factors. In the factor analysis, two factors were extracted: "gorgeous" and "natural." The analysis of variance revealed a difference in the main effect of tooth color for both factors. These findings suggest that differences in tooth color have an influence on the impression female smiles give to dental students, irrespective of their gender. (J Osaka Dent Univ 2023; 57: 31-40)

Key words: Average face; Semantic differential method; Esthetic dentistry; Tooth color; Factor analysis

INTRODUCTION

Interest in dental esthetics has increased significantly in recent years. Previous reports have shown that when subjects presented with images of smiles of varying intensity were eye-tracked, their gaze lingered on the mouth for a longer time, especially when they were presented with images of smiling faces with exposed teeth.[1] The results of research on attitudes toward perioral esthetics indicate that many adults in the general population consider white teeth to be ideal.[2] Furthermore, according to the results of research on patients' satisfaction with the esthetics of their teeth and on the dental treatment they would like to receive to improve their dental esthetics,[3,4] the largest number of patients were dissatisfied with their own tooth color, with a large number wishing to have their teeth whitened. Thus, in dental clinical practice, too, patients are highly concerned with tooth color, among other esthetic requirements, and they are strongly inclined to have white teeth. So, what impression does the color of a person's exposed teeth make on others? While there have been reports on impression evaluation based on the shade guide colors,[5] there have been no reports on detailed evaluation of the impression of smiles with exposed teeth conducted with a focus on tooth color.

Impression evaluations related to dental esthetics have involved patients or laypersons, dental stu-

dents, and dentists as subjects,[6-9] and the results of the impression evaluations have been compared among the groups. The ultimate goal of impression measurements based on the esthetics of the teeth and mouth is to determine what impressions patients, or laypersons who do not attend dental clinics, have based on the facial features and mouths of others. However, it is also important for dentists to know the differences, if any, that exist between the impressions patients and ordinary people form and those formed by dentists and dental students.

To determine what impression a person's tooth color gives to others, and whether there is a difference between the impression men have and the impression women have, this study first aimed to elucidate the influence of tooth color on the impression female smiles give to male and female dental school students by using factor analysis and the semantic differential (SD) method, which is a means of impression measurement.

MATERIALS AND METHODS

Subjects

We enrolled in this study 52 students undergoing clinical training at the Osaka Dental University, 26 men and 26 women, who had a mean age of 24±3.7 years. They were fully informed of the purpose of the study and agreed to participate. The study period was from May to August 2020.

Stimulus image

The stimulus image was an average female smiling face with three different tooth colors. To reproduce the tooth color in the average female face, the smiles of 10 women in their 20s, who had a mean age of 27±1.5 years, were first photographed with their teeth exposed using a digital camera (EOS M 100; Canon, Tokyo, Japan). The images were obtained under the same lighting conditions. The tooth colors of the 10 women were then converted into 3 colors using image-editing software (Adobe Photoshop ver. 12.0; Adobe, San Jose, USA). Finally, an average face creation tool (Average Face Pro, Junichiro Seyama, Japan) was used to create an average face. Three colors were adopted from among the colors of the shade guide (Noritake Shade Guide; Kuraray Noritake Dental, Tokyo, Japan) as the tooth colors: C4, with tetracycline-induced discoloration taken into consideration, which is the least bright color, A2, which is a closest color to the tooth color of women in their 20s in terms of color value,[10] and NW0, which is used as the brightest whitening color. Stimulus images were printed at 127 mm in height and 90 mm in width before use (Fig. 1).

Impression measurement

Impression measurements were performed using the SD method. After being presented with stimulus images at random, the subjects were asked to

Fig. 1 Stimulus images with different tooth shades.

Table 1 Fifteen pairs of adjectives

1. Dislike-Like
2. Static-Dynamic
3. Dark-Bright
4. Unnatural-Natural
5. Poor-Rich
6. Fragile-Strong
7. Masculine-Feminine
8. Sick-Healthy
9. Passive-Aggressive
10. Not attractive-Attractive
11. Unrealistic-Realistic
12. Old-Youthful
13. Sordid-Fresh
14. Cold-Warm
15. Sloppy-Neat

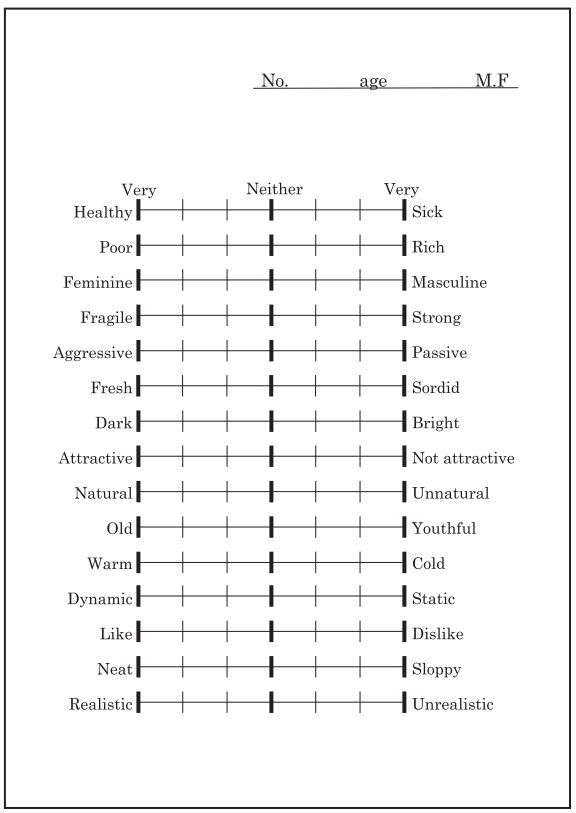

Fig. 2 Evaluation form.

evaluate their impression of each image on a 7-point scale based on 15 adjective pairs (Table 1), including “dislike-like” and “unnatural-natural,” which were extracted from previous studies[1, 11] and a preliminary experiment. In the evaluation, 1 point was given for the most negative impression represented by the adjectives on the left side of Table 1, and 7 points were given for the most positive impression represented by the adjectives on the right side. If neither of the two contrasting adjectives was applicable, 4 points were given. An example of the form used in the evaluation is shown in Fig. 2. The order of the adjective pairs and the placement of the adjectives on the left and right sides of the evaluation form were randomly determined for each subject and for each stimulus image. The scene where the impression measurement was performed is shown in Fig. 3. The impression measurement was performed in a quiet room, and no specific time limit was set for the evaluation.

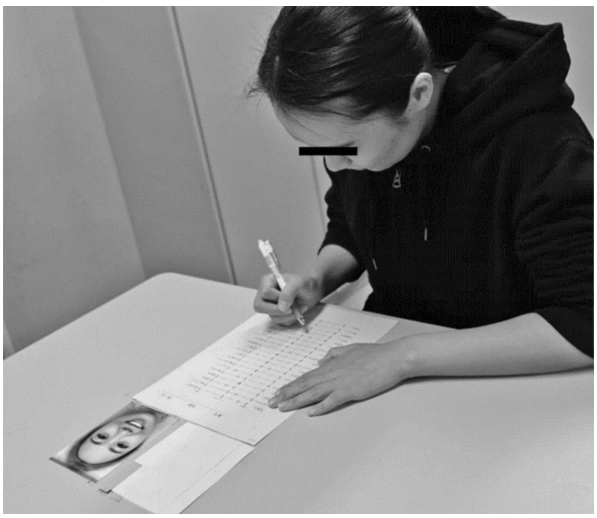

Fig. 3 Experimental set-up.

Statistical analysis

Impression structure of female smiles with different tooth colors

An exploratory factor analysis (maximum likelihood method, promax rotation) was performed to clarify the impression structure of female smiles with different tooth colors.[12] Factors with an eigenvalue of 1 or higher were explored, and if three or more factors were extracted, two factors with higher explanatory power were selected. Each factor was then given a name. To examine the validity of the factor analysis, Kaiser-Meyer-Olkin’s measure of sample validity (KMO)[13] was calculated, and

Table 2 Factors and levels

Factors	Levels		
Tooth color	C4	A2	NW0
Gender	Male		Female

Bartlett's sphericity test[14] was also conducted. Cronbach's α coefficient[12] was calculated to check the internal consistency of the extracted factors.

Influence of tooth color and gender on the two factors

For each factor, factor scores were calculated in each subject. A factor score distribution chart was created by plotting the factor scores for each subject, and the trend of impression was evaluated for each stimulus image. A two-way analysis of variance (mixed design)[15] was performed with subjects' factor scores as the dependent variable and tooth color (3 levels, repeated measures) and gender (2 levels, factorial) as factors (Table 2). If there was a significant difference in the interaction, a simple main effect was tested and multiple comparisons were carried out using the Bonferroni method. A statistical hypothesis was formulated that there was no difference in factor scores between levels in the tooth color and gender factors and that there was no interaction between the two factors. The statistical significance level (α) was set at 0.05. In a priori power analysis for variance analysis,[16] the effect size (f) was set to 0.25, α was set to 0.05, and power (1-β) was set to 0.8, resulting in a required sample size of 28 being calculated.

Statistical analysis was performed using G*power ver. 3.1 (Heinrich Heine University, Dusseldorf, Nordrhein-Westfalen, Germany)[17] and IBM SPSS Statistics ver. 26 (IBM, Armonk, NY, USA).

This study was conducted with the approval of the Ethics Committee of Osaka Dental University (Approval No.111045).

RESULTS

Impression structure of female smiles with different tooth colors

Factor analysis identified three factors with an eigenvalue of 1 or higher. The KMO for factor validity was 0.93, and the result of Bartlett's sphericity test was significant ($p < 0.001$). Factor 1, which had the highest explanatory power, was named "gorgeous" based on the adjective pairs "bright-dark," "neat-sloppy," and "healthy-sick." Factor 2, which had the second highest explanatory power, was named "natural" based on the adjective pairs "natural-unnatural" and "realistic-unrealistic" (Table 3). The α coefficients were 0.93 (95% CI: 0.92-0.95) for Factor 1 and 0.60 (95% CI: 0.46-0.71) for Factor 2.

Table 3 Factor loadings for the average female facial images

Factor name / Pairs of adjectives	Factor loadings 1	2	3
Factor 1: Gorgeous			
3. Dark-Bright	**.921**	−.149	.015
15. Sloppy-Neat	**.834**	.070	−.201
8. Sick-Healthy	**.831**	−.042	−.002
12. Old-Youthful	**.775**	.037	−.072
5. Poor-Rich	**.725**	−.124	.218
10. Not attractive-Attractive	**.694**	.102	−.072
6. Fragile-Strong	**.677**	−.296	.161
7. Masculine-Feminine	**.670**	.105	−.138
1. Dislike-Like	**.635**	.227	.024
13. Sordid-Fresh	**.618**	.175	.019
14. Cold-Warm	**.579**	.271	.031
9. Passive-Aggressive	**.560**	−.028	.289
Factor 2: Natural			
4. Unnatural-Natural	−.015	**.734**	.230
11. Unrealistic-Realistic	−.005	**.618**	−.084
Factor 3			
2. Static-Dynamic	−.068	.083	**.984**

Factor extraction method: Maximum likelihood method, Rotation method: Promax rotation.

Influence of tooth color and gender on the two factors

Factor scores for the 52 subjects were calculated and plotted on a factor score distribution chart (Fig. 4). Factors 1 and 2 are represented by the horizontal and vertical axes, respectively. When A2 was compared with C4, the number of applicable subjects was greater in the quadrant where both Factors 1 and 2 were positive, while it was fewer in the quadrant where both Factors 1 and 2 were negative. When NW0 was compared with A2, the num-

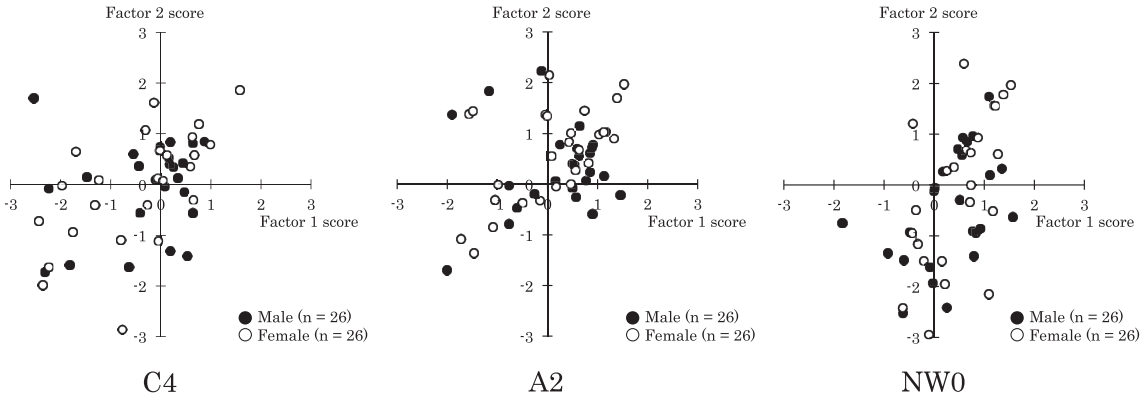

Fig. 4 Factor score distribution for the average female facial images (n＝52).

Table 4 Analysis of variance (Factor 1)

Factor	Sum of squares	Degrees of freedom	Mean squared	F	η_p^2	1-β
Tooth color	20.352	2	10.176	10.660**	.227	.999
Error	69.250	100	.692			
Gender	.180	1	.180	.122	.002	.064
Error	73.935	50	1.479			
Interaction	.736	2	.368	.532	.011	.136

**p＜0.01

Table 5 Analysis of variance (Factor 2)

Factor	Sum of squares	Degrees of freedom	Mean squared	F	η_p^2	1-β
Tooth color	18.685	2	9.342	8.992**	.152	.970
Error	103.899	100	1.039			
Gender	.435	1	.435	.248	.005	.078
Error	87.555	50	1.751			
Interaction	.709	2	.355	.341	.007	.103

**p＜0.01

ber of applicable subjects was fewer in the quadrant where Factor 1 was negative and Factor 2 was positive, while it was greater in the quadrant where Factor 1 was positive and Factor 2 was negative. There were no significant gender-related features in C4, A2 or NW0.

Although two-way analysis of variance revealed no significant differences either in the interaction between tooth color and gender or in the main effect of gender in Factors 1 and 2, there was a significant difference in the main effect of tooth color (Tables 4 and 5). The mean and standard deviation of the factor scores for Factor 1 “gorgeous” were −0.49±1.19, 0.12±0.95, and 0.37±0.72 for C4, A2, and NW0, respectively. Multiple comparison revealed significantly higher values (p＝0.002) in A2 and NW0 than in C4 (Fig. 5). The mean and standard deviation of the factor scores for Factor 2 “natural” were −0.08±1.04, 0.46±0.89, and −0.38 ±1.38 for C4, A2, and NW0, respectively. Multiple comparison revealed significantly higher values (p ＝0.005) in A2 than in C4 or NW0 (Fig. 6).

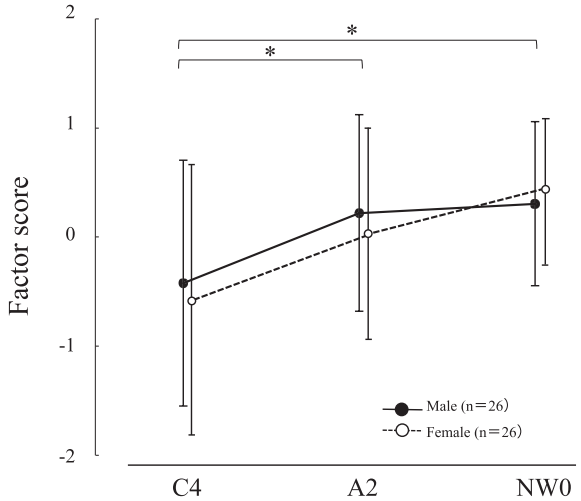

Fig. 5 Comparison of factor scores for the three tooth colors in factor 1 (n=52, *p<0.05, ⊥ Mean±SD).

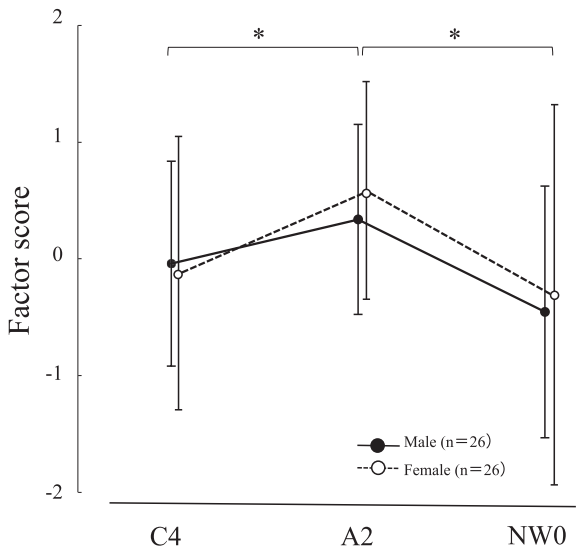

Fig. 6 Comparison of factor scores for the three tooth colors in factor 2 (n=52, *p<0.05, ⊥ Mean±SD).

DISCUSSION

Beautiful teeth alignment is important for people to make a favorable impression on others in social life,[18] and in particular, the impression of the mouth is believed to play the most prominent role during communication.[19] For example, one report has shown that in job interviews, employers have a favorable impression of candidates with more esthetically pleasing mouths, while they perceive candidates with less esthetically pleasing mouths as less competent for the job.[20] There have been several reports on how mouths affect impressions. Gummy smiles are supposed to negatively affect smiles and impart an unattractive impression in many cases.[21] It has been reported that patients with a gummy smile are self-conscious about their mouths, resulting in decreased sociability.[22] Shaw[23] reported that people with normal dentition have a better facial appearance and are perceived as more desirable friends than those with dental crowding. In addition, smiling is believed to impress others with a great sense of happiness.[24]

In a previous study, we investigated the impression that smiles with or without exposed teeth make on others in communication and found that smiles with exposed teeth on an average male face give a sociable and active impression, and that smiles with exposed teeth on an average female face give a friendly and elegant impression.[11] These impressions were formed by subjects looking at mouths with exposed teeth.[1] Based on the premise that whether or not teeth are exposed plays a role in impression formation, we hypothesized that tooth color is also involved in impression formation and undertook this study accordingly.

Subjects

Fifth-year dental students were selected as the subjects for this study. Many of the studies that have measured the impressions of beautiful teeth and mouths involve patients or the general public, dental students, and dentists, with their impression being compared with one another.[6-9] Regarding the mouth in a smile, for example, the general public, as compared with dentists and dental students, rated a smile without exposed gingiva as the most attractive, whereas dentists and dental students rated a smile with partially exposed gingiva as the most attractive.[9] It has been reported that dentists perceive dental crowding as less esthetically pleasing than the general public.[6] Thus, there are differences between patients or the general public, and dental students and dentists in terms of the impressions they form, and it can be inferred that these differences are related to the subjects' interest in

teeth and their awareness, knowledge, and clinical experience. Although fifth-year dental students who are in the midst of their clinical training do not have as much clinical experience as dentists, they have a higher level of awareness and greater knowledge of teeth than patients. This is the reason why dental students were chosen as the subjects in this study.

The sample size for this study was 52. In factor analysis, it is recommended that the sample size be set to 100 or greater.[25] Given that the KMO was 0.93 in this study and that a value of 0.9 or higher is considered the best value,[13] we judged the factor validity of the study to be the highest. The results of Bartlett's sphericity test indicate a significant correlation between the variables, which also supports the validity of the factor analysis. The sample size of this study for variance analysis was adequate because the required sample size was 28 as indicated by the a priori power analysis.

Stimulus images

Stimulus images used in the evaluation of impressions based on facial appearance are sometimes prepared by using a specific individual's photograph; [26] otherwise, an average face created by combining photographs of two or more individuals is used.[27, 28] Although stimulus images based on a photograph of a specific individual are clear and real, there is likely to be a large variability in the results of impression evaluation due to the facial features of the individual. Therefore, the results obtained are less than generalizable. In contrast, results obtained from impression evaluation using stimulus images containing an average face are more generalizable since individual facial features are eliminated by merging multiple photographs. However, this can make the images somewhat blurred. This also minimizes the variability of impression evaluation results. Nishitani *et al.*[29] reported that individual features were eliminated by combining 10 or more facial photographs in the process of creating an average face. Accordingly, we performed impression measurement using an average face generated from 10 face photographs as stimulus images. All facial photographs used to create the average face were of 10 women in their 20s. This was done in view of the fact that a higher proportion of women than men are dissatisfied with the appearance of their teeth,[4] and that dissatisfaction with the appearance and color of their teeth is particularly high among young people.[30]

The tooth colors we adopted for women in their 20s were C4, which represents discolored teeth with less brightness, A2 as the average color, and NW0 as the post-whitening color (used as the whitening color in the Noritake Shade Guide). For the reproducibility of the tooth colors in the stimulus images, the color difference was calculated using colorimetric data from the shade guide in the application software (Crystaleye Application Master, Tokyo, Japan) of a dental color analysis system, and data obtained by colorimetrically measuring the tooth crown in printed stimulus images with a dental measuring instrument (Rayplicker, Borea Dental, Limoges, France). In C4, A2 and NW0, the color difference between the shade guide and stimulus images was 3 or less, a difference that was nearly impossible to perceive with the naked eye. In other words, the reproducibility of tooth colors in the stimulus images was high.

Impression measurement

The SD method is a social psychological measurement developed by the American psychologist Osgood *et al.*[31] to assess the meaning of word concepts and to quantitatively characterize the psychological properties of a person's impression. In the SD method, an individual's impression of a matter is measured by using pairs of opposite adjectives, such as "dark-bright" and "cold-warm." Currently, the SD method is used as a means of evaluation in product development in various fields[32] and in questionnaire surveys on clothing.[33] Because the SD method is also used in impression evaluation in the field of dentistry,[5, 34] we employed it in this study. Inoue *et al.*[35] reviewed articles on the SD method published thus far in Japan and noted frequently used adjective pairs. With the help of several researchers, we picked a total of 15 adjective pairs

from those described by Inoue *et al.,*[35] those used in previous studies,[1, 11] and those extracted from a preliminary experiment.

Statistical analysis

Factor analysis, a type of multivariate analysis, is an analytical technique that explore factors common to multiple elements within data,[36] and is also widely used as a tool to look into psychological scales.[34, 37, 38] In this study, factor analysis was used to estimate the potential background of the impressions that subjects have when presented with stimulus images, based on their choices of various adjective pairs.

Results

Factor 1 "gorgeous" and Factor 2 "natural" were extracted as a result of factor analysis. The α coefficients were 0.93 (95% CI: 0.92-0.95) for Factor 1 and 0.60 (95% CI: 0.46-0.71) for Factor 2, demonstrating that the two had high internal consistency and slightly low internal consistency, respectively. Given that a small number of scale items is generally associated with a small α coefficient, the small α coefficient for Factor 2 may be explained by the fact that there were only two adjective pairs, namely "natural-unnatural" and "realistic-unrealistic." However, these adjective pairs were semantically approximate, and we believe that internal consistency was ensured as a measure.

Comparison of factor scores for tooth colors showed that the score for Factor 1 "gorgeous" was significantly improved in A2 and NW0 compared with C4. According to one report on the esthetics of tooth color, a survey on dental esthetics involving 206 adults in the general population found that at least 80% of the subjects considered the absence of stain buildup and the whiteness of the teeth to be conditions for a beautiful mouth.[39] Another report[2] showed that many general adults considered white teeth to be ideal in a survey of attitudes toward perioral esthetics. Thus, the general public is highly interested in tooth color among other esthetic requirements in dentistry, which naturally leads them to appreciate white teeth. Against this background, A2 and NW0 were perceived as colors representing white teeth among the three colors, and the factor score for "gorgeous" became higher in our study. The factor score for Factor 2 "natural" was significantly improved in A2 compared with C4 or NW0. Possible reasons are that A2 is close in color value to the tooth color of the anterior teeth of women in their 20s, and that A2 is a tooth color people are used to seeing in their daily lives. In fact, shade type A is the most common tooth color in the Japanese population.[40]

Based on the results of Factors 1 and 2, A2 was found to be the most "gorgeous" and "natural" color for dental students. Nevertheless, one report[4] showed that patients tend to prefer whiter and shinier teeth over a natural appearance, and another report[41] indicated that white teeth exposed in smiles create a positive impression, including beauty, freshness, and cleanliness, because white teeth are associated with cleanliness and health. These results suggest that impressions may vary depending on the attributes of the subjects.

For Factors 1 and 2, although there were no significant differences in the interaction between tooth color and gender or in the main effect of gender, there was a difference in the main effect of tooth color. It has thus been found that differences in tooth color in female smiles result in both male and female subjects having similar impressions. Sugahara *et al.*[42] evaluated the impression given by smiles of different intensities on an average female face with the same tooth color and reported that there were no gender-related differences in the results. In our study, a female average face with different tooth colors was used, and the gender of the subjects did not affect the evaluation results. However, the above results are all derived from research involving young men and women as subjects.

A report on the investigation of intergenerational differences in the results of evaluation of facial impressions among the general public indicates that the evaluation results were comparable between men and women in the younger age group, but were not in the older age group.[43] It has been sug-

gested that these results may reflect the gender awareness held by the older generation. In our study, too, if subjects from different generations had been included, differences in the impression evaluation results attributable to gender-related differences may have been observed. The lack of gender-related differences in the results of impression evaluation among young people may be attributed to the concept of gender equality, which has received increasing attention in recent years.[44] Also, since a previous study found that an average male face with exposed teeth gave an impression of being sociable and active and that an average female face with exposed teeth gave an impression of being friendly and elegant,[11] it is possible that an average male face and an average female face with different tooth colors may offer different impressions. Further research is needed in this regard. It has been reported that the brightness of the tooth color decreases and the saturation increases with increasing age of the individual, regardless of gender.[45] When adjusting the age of the person displayed by a stimulus image, due consideration should be given to the choice of tooth color.

Had the attributes and generation of the subjects or the gender and age of the person displayed by the stimulus images been different in this study, the impression evaluation results might have been different as well. This speculation is left for detailed verification in the future.

CONCLUSION

Among the colors of tooth exposed in female smiles, A2 and NW0 were perceived as more gorgeous than C4, and A2 was perceived as more natural than C4 or NW0 by male and female dental students. There were no gender-related differences in the results of this impression evaluation.

The authors declare no conflicts of interest.

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