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Effect of smile index and incisal edge position on perception of attractiveness in different age groups

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SUMMARY **Changes in occlusal vertical dimension (OVD) and age have been found to affect Smile Index (SI, width/height of smile). Limited information is available regarding the aesthetic effects of these changes. The objective of this study was to evaluate the attractiveness of digitally manipulated smile images with differences in SI and incisal edge position (IEP) judged by respondents in different age groups. A total of 12 smile images were generated with varying SI (3·5, 5·3, 7·2, 9·0) and IEP (High, Medium, Low). Fifty respondents each in four age groups (15–24, 25–39, 40–54, 55+) evaluated the attractiveness of the 12 images using a 0–10 visual analog scale (VAS, 10 being most attractive). A repeated-measures three-factorial mixed model assessed differences. SI, IEP and age of respondents were found to significantly influence attractiveness score ($P < 0·01$ for all). With all age groups combined, SI = 7·2/IEP = Medium was most attractive (VAS = 7·22), followed by SI = 9·0/IEP = Medium, and SI = 5·3/IEP = Medium (VAS = 6·53 and 6·48, respectively). SI = 3·5/IEP = High and SI = 3·5/IEP = Low were least attractive (VAS = 1·99 and VAS = 2·58, respectively). Age group significantly influenced aesthetic perception, with younger respondents more critical in differences in SI and IEP. SI and IEP significantly influenced attractiveness of the smile in all respondent age groups. Low SI (i.e. 3·5) combined with high or low IEP was unattractive. Medium SI to high SI (i.e. 5·3–9·0) combined with medium IEP were considered attractive.**

KEYWORDS: **smiling, facial expressions, dental aesthetics, vertical dimension, dental occlusion, prosthodontics**

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Introduction

For a smile to be considered aesthetic, three factors have been thought to be important: teeth, gingiva and lips (1). These factors are important independently, but they may also affect each other. For example, small tooth size, gingival hyperplasia and excessive lip mobility may all contribute to excessive gingival display. Much research had been carried out on aesthetic effects of variations in teeth, such as tooth-to-tooth proportions (2), presence and absence of decay (3), midline position (4, 5), tooth spacing (6), tooth angulation (4), buccal corridor size (5, 7), and smile arc (5, 7, 8). Several studies have evaluated the aesthetic effects of variations in gingival display (5, 8, 9). Few have studied the aesthetic effects of the lips (10). The studies that did evaluate variations in the lip framework often did so by manipulating the gingival margins of teeth in relation to the lips (11, 12), or looking at the thickness of the lips (10), rather than the positioning of the lips as a factor. Additionally, display of the mandibular teeth or gingiva has received little attention (13, 14).

The dimensions of the smile have been extensively studied in the literature (15–19). It has been found to change with age (16–18). With increasing age, lip mobility decreases (16). This leads to a decrease in maxillary incisor display (16, 17). In a recent study, occlusal vertical dimension (OVD) was found to affect

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lip positions at smile (19). Specifically, increasing the OVD shifts the lower lip downwards, increases the interlabial gap height, increases the display zone area and lowers the smile index (SI, intercommissural width/interlabial gap height) (19). The width of the smile and position of the upper lip were not found to be affected by changes in OVD (19).

SI was first proposed by Ackerman (20) to describe dimensions of the smile. The average SI in a young adult is approximately 6·73–7·16 (16, 21). Studies have found the SI to be higher in female magazine models compared to female orthodontic patients (22), higher in 'most attractive' smiles compared to 'least attractive' smiles (23), higher in men than in women (24), and higher with increasing age (16). SI had been correlated with facial growth pattern (vertical versus horizontal) variations (21). As discussed, SI has been found to decrease as OVD is increased (19). However, little information is available on the influence of SI on aesthetic perception. A lower SI (3·4) had been claimed to be desirable, because it appears more youthful (25).

Computer-based image modification had been used to evaluate the aesthetic impact of different variations in the smile (4, 5, 14). This method enables the generation of test images with controlled alterations (4, 5, 14). In many studies evaluating dental aesthetics, the visual analog scale (VAS) was used (4, 6, 7, 9).

Currently, there is little information on the aesthetic effects of varying SI. It is not known whether an optimal (most aesthetic) SI exists. The aim of this study was to evaluate the attractiveness of digitally manipulated smile images with differences in SI and IEP judged by evaluators in different age groups.

Materials and methods

This study was approved by the institutional review board of the University of Louisville (University of Louisville IRB Number 15.0366) and was conducted at the University of Louisville School of Dentistry. The participant whose smile was photographed and all evaluators received informed consent. None of the participants received compensation for taking part in this study.

Generation of smile images

Computer-generated smile images were made using digital photographs taken of one male participant. The participant had an aesthetically pleasing smile with high smile index. A retracted view of the teeth was taken using a digital single-lens reflex camera (D7000*) with macro lens (Micro-NIKKOR 105 mm f/2·8VR*) and ring flash (EM-140 DG†). A smile view image was taken, along with smile view images with increased OVD. To increase the OVD, silicone occlusal registration material (Regisil Rigid‡) was injected between the posterior teeth. This was carried out in 2-mm increments: 0 mm; 2 mm; 4 mm; 6 mm; 8 mm, measured from the incisal edge of the mandibular central incisors to the lingual surface of the maxillary central incisors. To obtain these thicknesses, a leaf gauge (Leaf Gauge§) was used. It was measured with a digital calliper (model 500-170¶) to determine the number of leafs for the OVD increase. Silicone occlusal registration material was then injected on the occlusal surfaces of posterior teeth, and the participant was instructed to 'bite and hold' for the material to set. The leaf gauge was then removed from the mouth, and a digital photograph of the smile was taken (Fig. 1). At the 0-mm increment, no occlusal registration material was used.

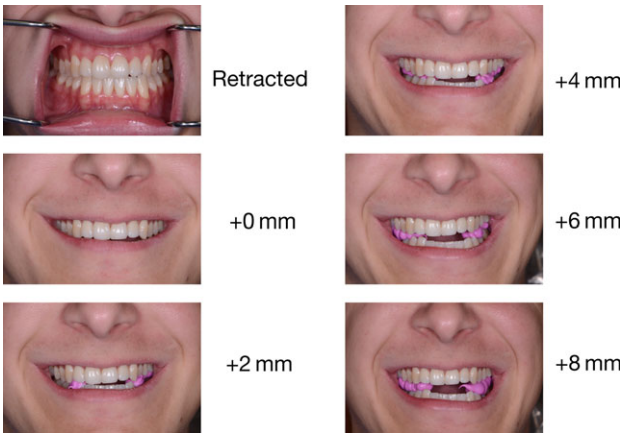

Fig. 1. Original digital photographs prior to digital manipulation. One retracted view image was taken, along with smile views at different occlusal vertical dimension openings (+0 mm, +2 mm, +4 mm, +6 mm, +8 mm).

The smile images, along with the image of the retracted view, were imported into software

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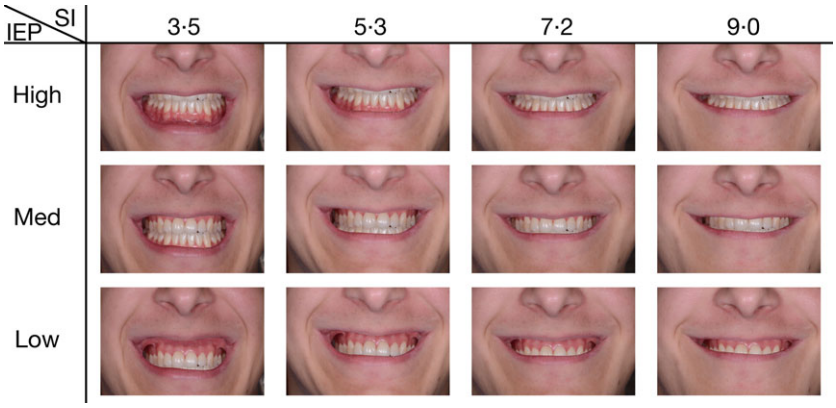

Fig. 2. Digitally manipulated images used for assessment. The 12 images varied in Smile Index (SI) at four increments, and incisal edge position (IEP) at three increments.

(Photoshop CS5**) to create digitally manipulated smile images with varying SI and IEP. The image of the retracted view was digitally enhanced to crop out the face and lips, and to create digitally simulated mucosa in areas that were hidden from view. The interlabial gap height and intercommissural width were measured on each smile image (in pixels), and the smile index was determined for each by dividing width by height. The closest fitting image for each of the following SI increment was chosen: SI = 3·5; 5·3; 7·2; 9·0. The smile images were enhanced by adjusting the vertical position of the lower lip only (no adjustments to intercommissural width and upper lip position) to obtain smile images at each of the four increments. The portion of the display zone (teeth, gingiva, buccal corridors) was cropped out, and the retracted view image was inserted.

For each of the four SI increments, three images each with different IEP were made: IEP = High; Medium; Low. For IEP = Medium, the following parameters were used: gingival zeniths of the maxillary central incisors covered by the upper lip; incisal edges of the maxillary central incisors not covered by the lower lip. For IEP = High, the following parameters were used: less than 75% of the total length of the maxillary central incisors displayed; incisal edges of the maxillary central incisors not covered by the upper lip. For IEP = Low, the following parameter was used: gingival zeniths of the maxillary central incisors not covered by the upper lip (Fig. 2). The images were randomly assigned alphabetical designations, and 4 × 6 inch glossy prints were made for each.

Evaluation

Four groups of 50 evaluators each were recruited according to age: 15–24; 25–39; 40–54; 55+. Some evaluators included first- or second-year dental students, having not yet received formal dental aesthetic training. The remaining evaluators were laypersons recruited from the waiting room and other public areas at the School of Dentistry. The 4 × 6 inch prints were randomly arranged, and the evaluators were asked to evaluate the attractiveness of each image on a 10-point VAS, with 10 being 'Very Attractive', 5 being 'Somewhat Attractive' and 0 being 'Not Attractive'.

Statistical analysis

The data were analysed using statistical software (SAS version 9.4[††]). The VAS scores were treated as a continuous value. A repeated-measures three-factorial mixed model was used to assess the contribution of SI, IEP and age of the evaluator on attractiveness rating ($\alpha = 0{\cdot}05$). If a statistically significant difference was found, pairwise comparison of means was performed with the Tukey's HSD test.

Results

The interactions between SI and IEP; evaluator age and SI; evaluator age and IEP were statistically significant ($P < 0{\cdot}01$ for all). The significance of sex was tested in the model, and as it was not significant, it was excluded from further analysis. Descriptively,

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Table 1. Evaluator characteristics by gender and age

	Gender			
	Female		Male	
	Participants	Percentage	Participants	Percentage
Total (n = 200)	111	56	89	44
Age (years)				
15–24	34	68	16	32
25–39	22	44	28	56
40–54	27	54	23	46
55+	28	56	22	44

more females than males participated overall (56% versus 44%, respectively) and for most age groups. The only exception is the 25–39 age group, where 44% were female (Table 1).

Effect of smile index and incisal edge position

With all age groups combined, SI = 7·2/IEP = Medium yielded the highest attractiveness rating (7·22) overall (Table 2). The next most attractive combinations were SI = 9·0/IEP = Medium and SI = 5·3/IEP = Medium (6·53 and 6·48, respectively, no significant difference between these 2, Table 2). The least attractive smile image was SI = 3·5/IEP = High (1·99), followed by SI = 3·5/IEP = Low (2·58, Table 2). Within each SI, the scores of the IEP = Medium images were more attractive than either the IEP = High or IEP = Low images (Table 2).

Evaluator age and smile index

All age groups found SI = 3·5 to be least attractive, when all IEP groups were combined (Table 3, Fig. 3). Few significant differences were found between age groups with respect to SI (Table 3, Fig. 3). However, within the IEP = Medium groups, significant age-related differences were found. Within IEP = Medium, all age groups rated SI = 3·5 and 9·0 similarly, but the 15–24 age group found the SI = 5·3 and SI = 7·2 images significantly more attractive than 55+ age group (Table 4).

Evaluator age and incisal edge position

All age groups found IEP = Medium to be most attractive. The IEP = High and IEP = Low images were rated similarly for all age groups except for 55+, who rated IEP = High less favourably than IEP = Low (Table 5).

Discussion

Recently, OVD was found to affect the positions of the lips during smile (19). With an increase in OVD, the position of the upper lip and the intercommissural width stay the same while the lower lip moves downwards, leading to a lower SI (19). Therefore, it may be important to understand the aesthetic effects of SI, as it is a factor that may be under the control of the clinician (19).

To the authors' knowledge, the present study was the first to evaluate the aesthetic effects of SI in controlled increments. Within the range and increments studied, SI = 7·2/IEP = Medium was found to be most attractive, followed by SI = 5·3/IEP = Medium and SI = 9·0/IEP = Medium (no significant difference between these two groups, Table 2).

Smile index

Comparing smiles of female orthodontically treated patients with female magazine models, Murakami *et al.* (22) found an average smile index of 7·0 ± 1·26

Table 2. Average ratings for interactions of incisal edge position (IEP) with smile index (SI)

	Smile index (SI)			
	3·5 Mean (s.e.)	5·3 Mean (s.e.)	7·2 Mean (s.e.)	9·0 Mean (s.e.)
Incisal edge position (IEP)				
High	1·99 (0·13)	2·99 (0·137)^{a}	3·83 (0·13)^{Ab}	3·44 (0·13)^{Bab}
Medium	4·95 (0·13)	6·48 (0·13)^{c}	7·22 (0·13)	6·53 (0·13)^{c}
Low	2·58 (0·13)	3·59 (0·13)^{d}	3·64 (0·13)^{Ad}	3·80 (0·13)^{Bd}

The same capital letter in a column denotes no statistical difference. The same lower-case letter in a row denotes no statistical difference (Tukey's HSD test, $P > 0·05$).

Table 3. Average ratings for interactions of evaluator age with smile index (SI)

	Smile index (SI)			
	3·5 Mean (s.e.)	5·3 Mean (s.e.)	7·2 Mean (s.e.)	9·0 Mean (s.e.)
Age group				
15–24	2·85 (0·19)	4·26 (0·19)^{a}	5·16 (0·19)	4·46 (0·19)^{a}
25–39	2·54 (0·19)	3·87 (0·19)^{b}	4·59 (0·19)^{c}	4·36 (0·19)^{bc}
40–54	3·78 (0·19)	4·79 (0·19)^{d}	5·06 (0·19)^{d}	4·55 (0·19)^{d}
55+	3·53 (0·19)	4·49 (0·19)^{e}	4·78 (0·19)^{e}	5·01 (0·19)^{e}

The same lower-case letter in a row denotes no statistical difference (Tukey's HSD test, $P > 0·05$).

for models, compared to an average SI of 5·37 ± 1·18 for patients. In another study that looked at orthodontically treated patients, aged 12–20 years, Schabel *et al.* (23) found an average SI of 6·3 ± 2·4 for 'most attractive' smiles compared with SI of 4·5 ± 1·0 for 'least attractive' smiles. Looking at smile photographs of winners of Time magazine's 100 most influential people, Orce-Romero *et al.* (24) found an average SI of 8·04 ± 4·10 for male and 6·23 ± 1·66 for female 'most influential' people. Grover *et al.* (21) studied dental students with horizontal, vertical and average growth patterns, determined from cephalometric analysis. In males, average growth individuals had SI of 7·16 ± 1·50, whereas individuals with horizontal and vertical growth patterns had SI of 9·47 ± 1·38 and 5·49 ± 1·97, respectively. In females, average growth individuals had SI of 7·86 ± 0·88, whereas individuals with horizontal and vertical growth patterns had SI of 8·93 ± 1·62 and 5·90 ± 0·92, respectively. The present study corroborates these findings, suggesting SI = 7·2 to be most attractive. This study's results contradict previous statements that a low SI (3·4) is ideal because it is more youthful (25).

A study by Desai *et al.* (16) found SI to increase with age. SI was found to increase from 5·63 ± 1·67 in the 15–19 age group to 8·05 ± 3·98 in the 50 and over age group. According to the authors, three factors were most important in this change. First, the length of the upper lip at rest becomes longer. Second, the change in upper lip length from rest to smile decreases. This was thought to be associated with a

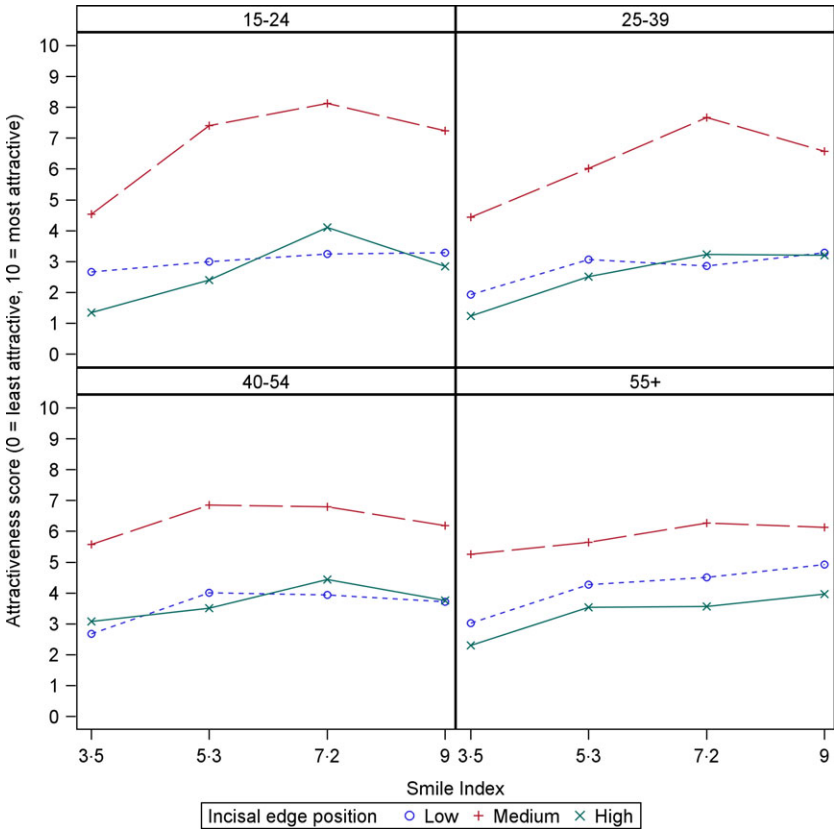

Fig. 3. Attractiveness ratings in the four age groups. All age groups found SI = 3·5 to be least attractive ($P < 0·05$ for all). The 15–24 age group found SI = 7·2 to be more attractive than all other SI groups ($P < 0·05$). All age groups found IEP = Medium to be more attractive than either IEP = High or IEP = Low ($P < 0·05$ for all).

Table 4. Average ratings for interactions of evaluator age and smile index (SI) for incisal edge position (IEP) = Medium only

	Smile index (SI)			
	3·5 Mean (s.e.)	5·3 Mean (s.e.)	7·2 Mean (s.e.)	9·0 Mean (s.e.)
Age group				
15–24	4·54 (0·26)^{A}	7·40 (0·26)^{B}	8·12 (0·26)^{E}	7·23 (0·26)^{H}
25–39	4·44 (0·26)^{A}	6·02 (0·26)^{BCD}	7·67 (0·26)^{EFG}	6·58 (0·26)^{H}
40–54	5·57 (0·26)^{A}	6·86 (0·26)^{BCD}	6·80 (0·26)^{EFG}	6·19 (0·26)^{H}
55+	5·26 (0·26)^{A}	5·64 (0·26)^{D}	6·27 (0·26)^{G}	6·13 (0·26)^{H}

The same capital letter in a column denotes no statistical difference (Tukey's HSD test, $P > 0{\cdot}05$).

Table 5. Average ratings of interactions of evaluator age with incisal edge position (IEP)

	Incisal edge position (IEP)		
	High Mean (s.e.)	Medium Mean (s.e.)	Low Mean (s.e.)
Age group			
15–24	2·67 (0·18)^{a}	6·82 (0·18)	3·05 (0·18)^{a}
25–39	2·54 (0·18)^{b}	6·18 (0·18)	2·79 (0·18)^{b}
40–54	3·7 (0·18)^{c}	6·35 (0·18)	3·59 (0·18)^{c}
55+	3·35 (0·18)	5·83 (0·18)	4·18 (0·18)

The same lower-case letter in a row denotes no statistical difference (Tukey's HSD test, $P > 0{\cdot}05$).

decrease in muscle tonicity. Lastly, the intercommissural width at rest increases with age. The combination of these factors leads to a smile that is narrower vertically and wider transversely (16). The present study found SI = 3·5 to be least attractive for all IEP variations studied (Table 2). Although a low smile index may appear to be youthful, SI below 5·3 may appear unnatural, as it is below a teenager's average SI (16).

Incisal edge position

When comparing groups with IEP = Medium, the SI = 3·5/IEP = Medium image was significantly less attractive than the other three images. Because the IEP was placed ideally relative to the upper lip in all four images, the major difference was display of the mandibular arch. The SI = 3·5/IEP = medium group displayed close to the total length of the mandibular incisors. This yielded an average score of 4·95 on the VAS (5 being 'somewhat attractive'), compared to 7·22 in the SI = 7·2/IEP = Medium group. The least attractive image in this study was SI = 3·5/IEP = High, which displayed not only the full length of the mandibular teeth, but mandibular gingiva as well. Display of mandibular incisors at smile is a factor that is seldom discussed in the literature (13, 14). The results of the present study suggest that excessive display of the mandibular arch during smile may be an aesthetic compromise and should be avoided if possible.

The IEP = Medium images were significantly more attractive than either IEP = High or IEP = Low. These findings agree with previous studies (4, 5, 14). For the SI = 7·2 and SI = 9·0 images, no significant differences were found between high and low IEP, indicating either too much or too little gingival exposure as being similarly unaesthetic. For the SI = 3·5 and SI = 5·3 images, high IEP scored significantly lower than low IEP, indicating that excessive display of the mandibular arch (showing mandibular gingiva or mucosa) as being less attractive than excessive display of maxillary gingival tissue.

Evaluator age

In the literature, age-related differences have been inconclusive, with some studies finding younger age groups to be more critical (6), and others finding no differences between age groups (14). The present study found several age-related differences. Younger age groups tended to have a more pronounced preference towards SI = 7·2 (Tables 3 and 4, Fig. 3). Older evaluators tended not to rate SI = 7·2 or 5·3 as favourably as younger evaluators did (Table 4). For example, SI = 7·2/IEP = Medium was rated at 8·12 in the 15–24 age group, whereas it was rated at only 6·27 in the 55+ age group (Table 4). Similar to findings in preferences in SI, younger age groups tended to rate IEP = Medium higher than either IEP = High

or IEP = Low, whereas older evaluators tended to have less preference (no significance between high, medium or low in the 55+ age group). In clinical practice, these results may suggest that younger patients are far more critical in evaluating differences in both SI and IEP, whereas older patients may have a less pronounced preference.

One possible reason for younger evaluators having a pronounced preference towards SI = 7·2 may be that the younger persons have an average SI close to this range (16, 19). Older persons have a higher average SI [i.e. SI = 8·05 (16)] and may not associate more 'youthful' appearing SI to be more 'attractive'. Another possible reason may be that older persons have impaired vision and may not perceive slight differences as strongly as younger persons (6).

Research design and recommendations for future studies

In this study, one male participant served as a model for creating the computer-generated images. This model's smile had the following attributes: high smile index; no missing teeth; no spaces between teeth; no tooth discoloration; no gingival recession; small buccal corridors; consonant smile arc; medium lip line; upwards curving upper lip. In particular, high smile index was especially important in this study, because the range of SI was accomplished by increasing the OVD (Fig. 1). Increasing the OVD only lowers the SI, so a higher SI could not have been attained if the model had presented with a medium SI. Additionally, the model presents with a slight midline deviation in the lower arch. This slight imperfection was thought to be acceptable, or desirable, as the majority of individuals 15–50 years in the United States have been found to have some incisor irregularity, with only 17% of individuals having no incisor irregularity (26). The sex of the participant may have played a role in the optimal SI range found because of several factors: (i) differences in population SI averages; (ii) differences in size of teeth; (iii) size and shape of lips; (iv) facial attributes. As the images used included part of the nose, the appearance of the nose and part of the chin may have also played a role in the determination of attractiveness. Future studies may be necessary to assess differences in sex, age, race, size of teeth, size of arch, etc., in relationship to varying SI.

The range of SI chosen for the present study was based on two factors. First, the model naturally presented with an SI close to this range following manipulation of occlusal vertical dimension. Therefore, this range allowed for the least amount of image manipulation. Secondly, the mid-point, upper limit and lower limit were based on three previous studies: Schabel *et al.* (23), which found average SI of 6·3 ± 2·4 for 'most attractive' smiles; Desai *et al.* (16), which found an average SI of 8·05 ± 3·98 in the 50 and over age group; Chou *et al.* (19), which found an average SI of 4·38 ± 1·29 in the +8 mm OVD group, respectively. The range of SI chosen in the present study, 3·5–9·0, was thought to encompass most SI found in the literature.

Currently, most studies focusing on specific dental and facial attributes have utilised two-dimensional imaging (4–6, 11).The present study also used two-dimensional imaging. This allowed for comparison with previous studies and a more simplified process for the generation of computer-modified images. As three-dimensional stereophotogrammetrical camera set-ups gain popularity (27), future studies may re-evaluate currently accepted standards, such as the aesthetic implications of midline deviation, buccal corridor, smile index, using three-dimensional methodology.

Conclusions

Smile index of about 7·2 with medium incisal edge position was found to be most attractive. Smile index of 3·5 with high or low incisal edge position was found to be least attractive. Younger evaluators were more critical than older evaluators. In full-mouth reconstruction and orthodontic treatment, smile index and incisal edge position should both be taken into consideration to achieve optimal aesthetics.

Disclosure

The authors declare no conflict of interest.

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