






ORIGINAL RESEARCH

Comparison of children's dentofacial esthetic perception by two- and three-dimensional methods of observation

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Abstract

Background: This study aimed to compare the dentofacial esthetic perception of children using two-dimensional (2D) and three-dimensional (3D) methods of observation. **Methods:** A total of 176 children aged 6–13 years were included in the study after obtaining parental consent and child assent. Participants were asked to evaluate a set of five two-dimensional (2D) intraoral photographs, which were displayed individually on a computer screen. Additionally, three-dimensional (3D) digital dental models obtained using an intraoral scanner (TRIOS, 3Shape®, Copenhagen, Denmark) were presented in video format, showing a 180-degree rotation of each model. Both the presentation sequence (whether 2D or 3D was viewed first) and the order of the individual cases within each modality were randomly assigned for every participant to minimize potential order-related bias. For both the 2D photographs and the 3D videos, participants were instructed to rate the esthetic appearance using a 0–10 Numeric Rating Scale (NRS), where 0 indicated “least attractive” and 10 indicated “most attractive”. **Results:** Normal dental alignment obtained the highest score for 3D (boys: 6.59 ± 0.29 , girls: 6.27 ± 0.30) and 2D (boys: 8.40 ± 0.23 , girls: 8.16 ± 0.25) compared with other alignment types. In nearly all cases, 2D images received significantly higher ratings than 3D models, demonstrating a clear modality effect. Boys provided higher scores than girls across all conditions ($p < 0.001$). **Conclusions:** Children’s esthetic judgments differed substantially between 2D and 3D representations. Higher ratings for 2D images may reflect greater perceptual familiarity, more complete visual information, and reduced cognitive load for young viewers. These findings highlight the need to consider visualization format when communicating dental esthetic conditions to pediatric patients.

Keywords

Esthetic perception; Dental esthetics; 2D; 3D; Intraoral scan; Children

1. Introduction

Physical appearance has become one of the most important aspects for people in their social perception and interaction. Social media actively pushes a perfect appearance as the only acceptable look, which has a negative impact on particularly children and young adults [1]. Smile esthetics, crucial to physical appearance, plays a significant role in quality of life. Dental esthetics influences children’s self-confidence, socializing abilities, psychological well-being, and even academic achievement [2]. Many studies have demonstrated that perceptions of dental esthetics from early childhood through adulthood can affect psychological development [2, 3].

Esthetic perception is not only individual but also influenced by factors such as race, nationality, and culture [4]. Conditions that affect dental appearance such as tooth crowding, discoloration of the teeth and diastema can affect how the patient feels about dental esthetics [5]. Children pay too

much attention to even the smallest physical changes in their smile and teeth which are very important for building their self-esteem. Many children experience bullying, harassment, nicknames and hurtful comments from their friends and other students in schools because of their dental appearance [6]. Al-Bitar *et al.* [7] observed that 47.0% of children between the ages of 11 and 12 reported being bullied due to their teeth with diastemas, teeth with shape and color anomalies, missing teeth and large maxillary teeth. Therefore, this condition may have a negative effect on the psychological development of children manifesting in anxiety, depression or psychosomatic disorder.

The perception of dental esthetics is an important factor for patients while seeking dental therapy and deciding treatment options. Dental malocclusion can affect social interactions and self-confidence, which can negatively influence every aspect of quality of life. This suggests that patients’ psychological needs should be considered in order to provide the best possible treatment [8]. Irregular tooth alignment and

malocclusions, which have negative psychosocial outcomes are considered as urgent needs to maintain dental esthetics and increase acceptance of orthodontic treatment by patients [9]. Numerous studies have investigated the relationship between children's oral health-related quality of life (OHRQoL) and their self-perception of dental esthetics, and malocclusion [10–12]. Verdecchia *et al.* [13] investigated whether anterior tooth alignment affected the initial perceptions of peers in 8- to 10-year-old children and found that properly aligned teeth were more positively related to intelligence, honesty, and general well-being. Furthermore, it has been reported that how others perceive children can affect their behavior and potentially cause long-term developmental abnormalities [2, 6].

The studies reviewed above found that there are many factors affecting the perception of dental esthetics [1, 10–13]. A limited number of studies have evaluated the impact of two-dimensional (2D) and three-dimensional (3D) images on the esthetic perception of dental professionals and dental students [14–17]. These studies have demonstrated that 3D facial and dental simulations may offer a more realistic and comprehensive representation of dental discrepancies, improving both self-perception and esthetic evaluations among dental professionals and students [14–17]. Nonetheless, children's esthetic judgments are shaped by developmental, perceptual, and cognitive factors that differ substantially from those of adults [18], suggesting that their responses to 2D and 3D stimuli may not align with those of older evaluators [17]. However, no studies have directly evaluated the effect of 2D and 3D images on the perception of dental esthetics in children. Therefore, this study aimed to compare the effects of 2D intraoral photographs and 3D scanned images on the perception of dental alignment in children aged 6–13 years.

2. Material and methods

2.1 Sample selection and data collection

The protocol for this study was approved by the Institutional Ethics Committee (Approval No: 56665618-204.01.07). This cross-sectional study was conducted with 176 children recruited from patients presenting for routine dental examinations in the pediatric dentistry department. Data were collected from participants between January and July 2023. Healthy children without any intellectual or cognitive disabilities and those who did not use any psychological or systemic medications were selected for the study. Eligible participants were randomly selected from children presenting to the pediatric dentistry clinic for routine dental examinations. Children with known developmental, neurological, or systemic disorders, or those under medication affecting cognitive or sensory functions, were excluded. Inclusion and exclusion criteria were applied through initial screening and parental interviews to ensure eligibility. A minimum sample size of 176 subjects was calculated using G*Power 3.1.9.2 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, NRW, Germany, <https://www.psychologie.hhu.de>), based on a medium effect size (Cohen's $d = 0.5$), a statistical power of 80% ($1 - \beta = 0.80$), and a significance level of $\alpha = 0.05$. The effect size represents the anticipated standardized difference in esthetic perception

scores between groups (*e.g.*, 2D vs. 3D image evaluations), which is considered clinically meaningful based on previous literature. Informed consent was obtained from the parents after explaining the purpose of the study. Before starting, the study was explained to the children in a way that they could understand. For this study, a set of five scanned images obtained with a 3D scanner (TRIOS, 3Shape®, Copenhagen, Denmark) and five frontal intraoral photographs (taken with a Nikon™ D610 DSLR camera, Tokyo, Japan) of five children previously seen in the orthodontic department were selected to evaluate dental esthetic perception. The selection criteria aimed to include cases representing a range of dental alignment conditions to ensure variability: severe crowding (case 1), moderate crowding (case 2), mild crowding (case 3), diastema (case 4) (Fig. 1), and normal alignment (case 5).

Before the evaluation, the children were instructed to focus only on the esthetic appearance of the teeth in all images and to ignore peripheral borders or unscanned areas in the 3D images. This instruction was simplified for younger children as “Please look only at the teeth” to ensure better understanding. In the same examination room, 2D intraoral photographs were shown on a computer screen (300 dpi resolution) via Windows photo viewer while 3D images were shown in video format (Fig. 2).

Each image—whether 2D or 3D—was presented for a fixed duration of 20 seconds, during which the 3D rotation sequence repeated three times to ensure full visualization. Repetition or rewatching of any image was not allowed to minimize recall bias. The children were asked to score each image based on a 0–10 rating scale whether they thought it was esthetically pleasing or not. In a random order all the images were presented by the same investigator individually, child-by-child. The children's ratings for each image were recorded. The Numeric Rating Scale (NRS) was used, where 0 indicated “least attractive” and 10 indicated “most attractive” (Fig. 3).

Respondents had to choose only one of the presented values between 0 and 10 for each image. Demographic data such as gender and age were also recorded.

The 2D photographs were displayed on the 13 inches (3000 × 2000 resolution) screen of a laptop computer (Huawei Matebook X Pro, Huawei Technologies Co., Ltd., Shenzhen, China) Each image—whether 2D or 3D—was presented for a fixed duration of 20 seconds, based on previous studies [15–17]. At the end of each photograph, the child's score according to the scale was recorded. The 3D images of the five cases were evaluated using the same procedure as the 2D photographs. To standardize the evaluation process and ensure that every aspect of the 3D image could be observed equally, each 3D image was converted into a video format in which the images rotated about 180° around the y-axis. For dental alignment evaluation, the rotation was repeated three times within 20 seconds for thorough evaluation. Both the order of the five cases and the modality order (2D first vs. 3D first) were randomly assigned for each participant to minimize potential order-related bias. To avoid investigator bias, the randomization sequence was generated by an independent researcher using a computer-based random number generator, and this sequence was then applied consistently within both modalities (2D and 3D). A single trained examiner conducted all sessions to ensure standardized instructions. A pilot test with 20 children was con-



FIGURE 1. Intraoral images of different dental alignments. (a) case 1 (severe crowding); (b) case 2 (moderate crowding); (c) case 3 (mild crowding); (d) case 4 (diastema).

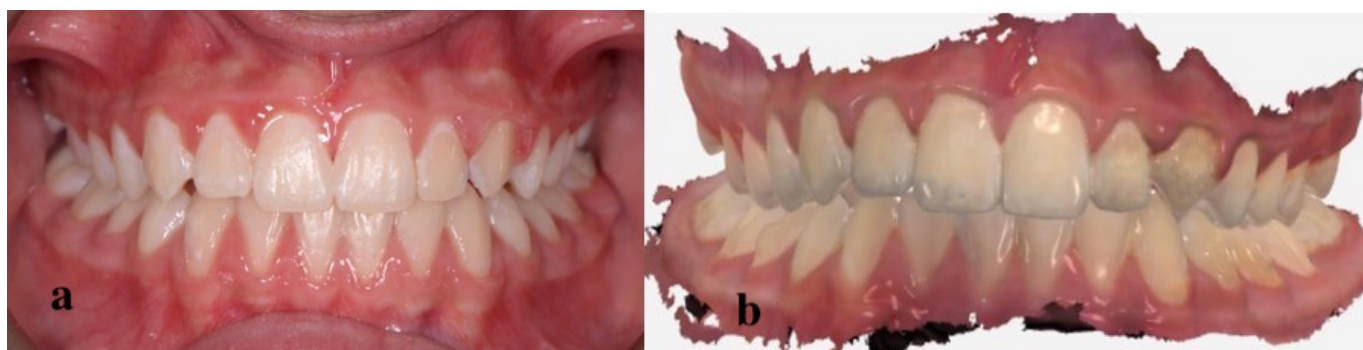


FIGURE 2. The set of 2D and 3D images of a dental appearance. (a) 2D image of normal alignment (case 5). (b) 3D image of normal alignment (case 5).

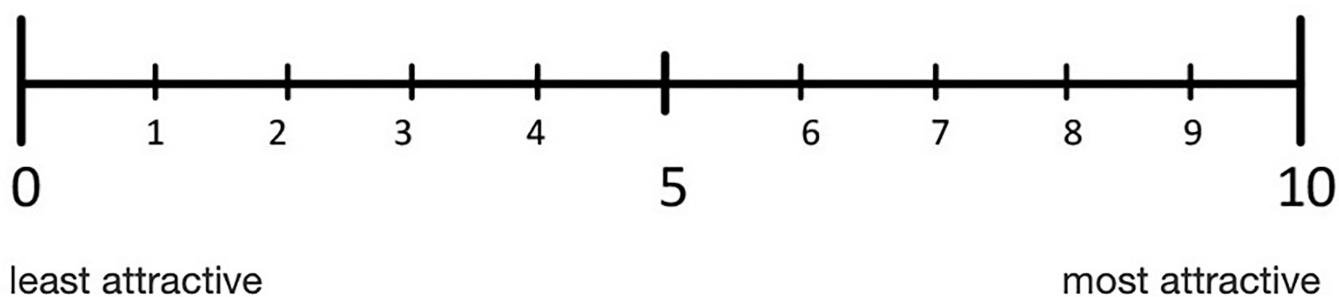


FIGURE 3. Numeric rating scale (NRS).

ducted to confirm the clarity and feasibility of the evaluation procedure and to ensure that participants could reliably follow the task instructions. This pilot phase served solely to verify procedural adequacy rather than to generate formal reliability metrics.

2.2 Statistical analysis

Descriptive statistics for each variable were calculated and presented as “Mean \pm Standard Error of Mean”. Data were subjected to three-factor mixed-design ANOVA (analysis of variance) using General Linear Model procedure for repeated cases. The model included “Case”, “Image Type”, and “Gender” as the main effects and their 2-way and 3-way interaction terms. In cases where Mauchly’s test revealed that the assumption of sphericity violated, the Greenhouse-Geisser adjustment was applied. Simple effect analysis with Sidak adjustment was used to break down any significant interaction effect terms as post hoc analysis. Pearson correlation analysis was applied to reveal any significant correlation between age and scores. A probability value of less than 0.05 was considered significant, unless otherwise noted. SPSS 21 (version 21.0; IBM Corp., Armonk, NY, USA) was used for statistical analysis.

3. Results

A total of 176 children (96 (54.5%) boys and 80 (45.5%) girls) aged 6–13 years (mean age: 9.02 ± 0.15 years) were included in the study. Descriptive statistics for esthetic perception scores by case, image type, and gender are presented in Table 1. Across both modalities, case 5 (normal alignment) received the highest mean scores for boys (2D: 8.4 ± 0.23 ; 3D: 6.59 ± 0.29) and girls (2D: 8.16 ± 0.25 ; 3D: 6.27 ± 0.30). Conversely, case 2 (moderate crowding) received the lowest scores in both modalities for both genders (girls; 2D: 1.69 ± 0.24 ; 3D: 1.75 ± 0.25 and boys; 2D: 2.93 ± 0.26 ; 3D: 2.69 ± 0.26). When examining the influence of gender on esthetic perception, it was observed that in all cases, regardless of the case and image type, esthetic perception scores of boys were significantly higher than those of girls ($p < 0.001$). Regardless of gender, statistically significant differences were found between 2D and 3D images in all cases, except case 2. In the 2D images, all cases differed significantly from one another. In contrast, in the 3D images, only Case 1 (severe crowding) and Case 2 (moderate crowding) showed similar ratings, while all other pairwise comparisons demonstrated statistically significant differences ($p < 0.001$). The primary effects of gender, image type and case were found to be statistically significant ($p < 0.001$). When the double and triple interactions regarding the data were examined, it was observed that only the interaction of image type and case was significant ($p < 0.001$).

Correlation analyses between age and esthetic perception scores for each case and image type are shown in Table 2. Across all evaluations, correlations were weak and statistically non-significant ($p > 0.05$), with the exception of case 5 (normal alignment) in 3D images ($r = 0.19$, $p = 0.012$), which indicated only a very small positive association.

4. Discussion

Younger generations begin to focus on their appearance in their early childhood. Smile esthetics, one of the most important elements of appearance, drastically affects the children’s self-confidence and social life [19]. It has been reported that children have developed a dental awareness and tended to be dissatisfied with their dental esthetics [20]. Esthetic perception is closely related to an individual’s natural senses, including taste, touch, smell, sight, and hearing. However, esthetic perception is not only an individual preference, but also a concept that is affected by cultural, geographical, social and psychological factors. The perception of dental esthetics is also affected by variables such as the size, color and alignment of the teeth [21].

Most of the studies evaluating the perception of dental esthetics include adults [2, 8, 22–24], studies on the children’s perception of dental esthetics are limited in the literature [1, 10, 11]. In a study by Tole *et al.* [25], it was reported that the level of dentofacial esthetic perception is related to the gender, age, and psychosocial context of evaluation and increases with age. According to Tiro *et al.* [19], younger children typically express more criticism of dental imperfections whereas older children and adults are more moderate in their expression of criticism. However, in the present study, no significant association was found between age and esthetic perception across the 6–13-year sample. This discrepancy may be attributable to differences in age distribution, stimulus type, cultural context, or methodological approaches. Rather than indicating developmental stability, the absence of an age effect in our results simply suggests that, within this study’s age range and assessment framework, age did not emerge as a significant predictor of esthetic ratings.

Although some studies reported that the dental esthetic perception of girls and boys was identical [26], other authors stated that females were more concerned with dental esthetics than males [27]. In a study by Fragelli *et al.* [5] more negative perceptions were found in female patients. Consistent with these reports, girls in the present study assigned lower esthetic scores than boys across all conditions, possibly reflecting heightened esthetic self-awareness or stricter evaluative criteria among female participants.

Diastema between the anterior teeth has been reported to be more acceptable for younger children than for older children [19, 25]. Our findings support this observation, as the diastema case received higher ratings than cases with severe or moderate crowding. Children with mixed dentition do not perceive this type of dental appearance as unattractive because they are used to seeing it in both themselves and their peers [19]. It has been reported that smile with protruding incisors and crowding were the least attractive and smile with normal alignment gained higher scores in children aged 8–11 years old [9]. The findings of the present study align with these reports: normal alignment was consistently rated as the most attractive, whereas moderate crowding involving the maxillary central incisors received the lowest scores.

In epidemiological and clinical studies, the Visual Analog Scale (VAS) is used to measure subjective phenomena such as the severity of pain, weariness, psychological distress, itching

TABLE 1. Effect of case, image type and gender on dentofacial esthetic perception of children.

Case	Image type	Gender			
		Male (n = 96)		Female (n = 80)	
		Mean ± SEM	SD	Mean ± SEM	SD
1	2D	3.46 ± 0.24 ^{a,A}	2.35	2.51 ± 0.25 ^{a,A}	2.24
2	2D	2.93 ± 0.26 ^{a,B}	2.55	1.69 ± 0.24 ^{a,B}	2.14
3	2D	5.78 ± 0.27 ^{a,C}	2.65	5.44 ± 0.27 ^{a,C}	2.41
4	2D	5.36 ± 0.34 ^{a,D}	3.33	3.79 ± 0.34 ^{a,D}	3.04
5	2D	8.40 ± 0.23 ^{a,E}	2.25	8.16 ± 0.25 ^{a,E}	2.24
1	3D	3.14 ± 0.27 ^{b,F}	2.65	1.96 ± 0.21 ^{b,F}	1.88
2	3D	2.69 ± 0.26 ^{a,F}	2.55	1.75 ± 0.25 ^{a,F}	2.24
3	3D	5.41 ± 0.28 ^{b,G}	2.74	4.68 ± 0.30 ^{b,G}	2.68
4	3D	3.82 ± 0.29 ^{b,H}	2.84	3.12 ± 0.32 ^{b,H}	2.86
5	3D	6.59 ± 0.29 ^{b,I}	2.84	6.27 ± 0.30 ^{b,I}	2.68

p values for the effects in the three way mixed design ANOVA: Image Type (I): <0.001; Gender (G): <0.001[†]; Case (C): <0.001; I*G: 0.733; C*G: 0.102; I*C: <0.001; I*C*G: 0.173.

[†]: Main effect of gender was statistically significant ($p < 0.001$), without any significant interaction effects. No superscript letters were used for gender to avoid confusion, as in all conditions—regardless of case and image type—males consistently scored higher than females.

Different lowercase letters (a,b) in the same column indicate statistically significant differences between image types (2D vs. 3D) within each case ($p < 0.05$).

Different uppercase letters (A–E for 2D images, F–I for 3D images) in the same column represent statistical significance between cases (1–5) within each image type ($p < 0.05$).

2D: two-dimensional; 3D: three-dimensional; SD: standard deviation; SEM: standard error of the mean.

TABLE 2. Correlation between age and esthetic perception of children for each case and image type.

Case	Image type	Age	
		<i>r</i>	<i>p</i>
1	2D	0.120	0.112
2	2D	0.055	0.470
3	2D	0.051	0.498
4	2D	−0.136	0.071
5	2D	−0.063	0.407
1	3D	0.050	0.510
2	3D	−0.121	0.111
3	3D	−0.117	0.121
4	3D	−0.006	0.937
5	3D	0.190	0.012

r: Pearson correlation coefficient; 2D: two-dimensional; 3D: three-dimensional.

intensity, facial esthetics, and changes in dental and smile esthetics. Although the VAS is a fast and trustworthy method, it can be interpreted in several ways depending on the respondents' ages because of its lack of self-explanation [28]. A numerically segmented version of the VAS is called the Numerical Rating Scale (NRS). The NRS has the advantage of verbal use and simplified scores over the VAS [29]. Although studies investigating how 2D and 3D images affect the perception of esthetics used the VAS scale [17, 30], the NRS was considered more appropriate for children in this study due

to its greater clarity and ease of interpretation.

Furthermore, the significant interaction between image type and case observed in this study suggests that the impact of the three-dimensional (3D) visualization on children's esthetic perception differed according to the specific dental condition being assessed. Although the 3D images generally received lower esthetic scores than the two-dimensional (2D) photographs, the magnitude of this difference varied across cases. For example, the discrepancy between 2D and 3D scores was minimal in the case of moderate crowding (case 2),

whereas it became more pronounced in the normal-alignment case (case 5). This finding implies that the 3D visualization enhances the perception of spatial form and contour depth, potentially making certain morphological features more noticeable to children. Similar observations have been reported in previous studies, indicating that the 3D representations can modify esthetic assessments by emphasizing surface irregularities, asymmetries, or volumetric details that are less perceptible in the 2D images [31]. Therefore, when interpreting esthetic perception data derived from the 3D visualizations, it is essential to consider the underlying dental condition, as the three-dimensional rendering may either accentuate or attenuate perceived esthetic differences depending on the case characteristics.

Lombardo *et al.* [9] evaluated the influence of background attractiveness and sexual traits on the perception of dental alignment and smiles in a sample of 180 children and 150 parents by using video presentations and photographs. They found that background attractiveness and sexual characteristics determined how much of a smile was valued and in addition the normal alignment received higher scores in the videos, while the scores of other smiles were higher for the photographs. Similarly, in the present study, 2D intraoral photographs were rated higher than 3D images. This may be attributed to the greater visual completeness and familiarity of 2D images, whereas 3D scans can appear less uniform because of surface artifacts or incomplete regions. Children tend to evaluate facial images rather than focusing solely on tooth alignment, which may further contribute to differences in how 2D and 3D images are judged. Another plausible explanation could be the technical limitations of 3D scans, such as unscanned or rough areas (*e.g.*, vestibular regions), which may reduce the perceived esthetic quality.

Although 3D models provide a more realistic representation of dental morphology and spatial relationships, their perception by children may differ from that of adults due to developmental and cognitive factors. Children's ability to interpret virtual 3D stimuli continues to mature with age; thus, younger participants may find two-dimensional (2D) images more familiar and visually complete. Similar findings have been reported in studies suggesting that children's spatial reasoning and visualization of 3D structures improve progressively through adolescence [32, 33]. This developmental immaturity may help explain why children in the present study consistently assigned higher scores to 2D images. Although 3D simulations offer a valuable and objective tool for dental esthetics research, their perceptual interpretation is influenced by the viewer's age and prior visual experience. Moreover, 2D photographs provide contextual cues such as borders, color uniformity, and image completeness, which may guide children's esthetic judgments more effectively than isolated and rotatable 3D renderings.

In a study by Revilla-León *et al.* [15], the opinions of laypeople, dental students, and clinicians on differences in the maxillary dental midline and the occlusal plane when analyzing the dental discrepancies on 2D- and 3D-clinical simulations were investigated. They found that the type of dimensional representation affected esthetic perception, with 3D simulations receiving higher scores than 2D photographs

among adult participants. The authors attributed these findings to the greater difficulty in detecting subtle discrepancies in 3D models and to participants' limited experience with 3D facial visualization. On the other hand, Xiao *et al.* [17] reported that 3D dentofacial images were rated lower than traditional 2D photographs in smile evaluation as perceived by orthodontists and graduate students. Similarly, the present study found higher scores for 2D intraoral photographs than for 3D images in children. The differences between 2D and 3D perceptions might be related to the limited spatial cognitive development of children, as younger individuals may find 3D digital images more difficult to interpret than 2D representations. This pattern is also consistent with prior findings suggesting that children rely on holistic visual impressions rather than isolated morphological details. Studies on children's multisensory and spatial perception have shown that visual processing in the early developmental stages integrates contextual and global information rather than discrete structural components [32, 33]. When the visual stimulus lacks completeness or presents irregular surfaces—as may occur in 3D models—their esthetic interpretation may shift toward lower ratings. Thus, visual integrity and realism appear to be essential determinants of esthetic perception in younger populations. However, as digital technology advances, more refined 3D systems with enhanced realism and complete surface rendering could minimize these perceptual discrepancies, allowing future studies to benefit from both the objectivity of 3D analysis and the natural familiarity of 2D images.

One of the limitations of the present study is related to the visual characteristics of the 3D digital models. Although the 3D images allow spatial rotation and provide detailed surface information, some areas—especially in the vestibular regions—may remain unscanned or appear irregular due to technical limitations of intraoral scanners. As a result, the 3D simulations may seem incomplete or less realistic to the naked or untrained eye, particularly for children. In contrast, the 2D photographs provide a visually complete and smooth image with clear borders, which might enhance esthetic perception, thereby contributing to higher esthetic ratings in this modality. This discrepancy in visual integrity may have functioned as a confounding factor influencing children's evaluations. Future studies using improved scanning technologies, higher rendering fidelity, or child-friendly 3D visualization interfaces could help minimize this limitation and better clarify the cognitive factors underlying children's esthetic perception.

5. Conclusions

This study is the first to compare children's perceptions of dental esthetics using both the 2D intraoral photographs and 3D digital models. The findings revealed that children rated the 2D images significantly higher than the 3D models for almost all alignment types, suggesting that the visual completeness, perceptual familiarity, and reduced cognitive load in 2D photographs may influence their esthetic judgment. In both modalities, normal dental alignment was perceived as the most esthetic, while crowding—particularly moderate crowding involving the maxillary incisors—received the lowest scores. These results indicate that 2D images may better reflect how

children naturally evaluate smiles in daily life, whereas current 3D models may require further refinement to achieve comparable perceptual realism. From a clinical perspective, 2D intraoral photographs appear to better represent children's natural perception of dental esthetics and may therefore be more suitable for use in pediatric patient communication and esthetic evaluation. Nevertheless, continuous improvement of 3D imaging technology and more child-friendly visualization formats could further enhance its utility for treatment planning in pediatric dentistry.

AVAILABILITY OF DATA AND MATERIALS

The datasets supporting the findings of this study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

EK—designed the study and performed the surveys. GA and NCO—analyzed the data. HEO and MGE—wrote the manuscript. All authors contributed to the revision of the manuscript and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Ethics Committee of Istanbul Okan University (Approval No: 56665618-204.01.07). Written informed consent was obtained from the parents of all participants.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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