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Layperson and Dental Professional Perception When Evaluating Their Own Virtually 2D or 3D Simulated Esthetic Discrepancies

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Abstract

Purpose: To analyze the perceptions of laypersons, dental students, and dentists regarding disparities of the maxillary dental midline and the occlusal plane (OP) when analyzing their own 2D or 3D clinical simulation.
Material and Methods: 20 participants per group volunteered (N = 60). Intraoral and facial scans, and a photograph were obtained from each participant. Two simulation groups were created: 2D and 3D groups, which were subdivided into two subgroups. In the first subgroup, the OP was modified by 1-degree increments without changing the maxillary midline. In the second subgroup, the OP was modified by the same increments, but the maxillary midline was altered to match the OP inclination. Participants were asked to rate the simulations on a 1-to-6 scale and a question survey. Ordinal logistic regression (OR) was used to analyze the ratings.

Results: Tilt of the OP had the strongest negative effect on the ratings which was further amplified by the dental midline inclination (OR = 0.122). Midline modification alone did not affect the ratings (OR = 0.744). 3D simulations had a stronger positive effect on the ratings compared to 2D simulations. For dental students, the positive rating effect of 3D simulations was similar to dentists. For laypersons, the positive rating effect of 3D simulations compared to the 2D simulations decreased relative to dentists. The survey revealed that 45% of the dentists, 80% of the students, and 50% of the laypersons preferred the 3D simulation.
Conclusions: The type of dimensional representation affected the esthetic perception of all participants. 3D simulations obtained higher esthetic ratings for the same esthetic discrepancy than 2D simulations. However, all participants' ratings decreased with increased tilt of the OP and were further decreased with the inclination of the dental midline.

The integration of digital technologies into treatment planning procedures allows for the elaboration of a facially driven diagnostic design,[1,2] in which the outcome of a planned treatment can be integrated into a patient´s full-face 2D image or 3D facial representation.[3-7] However, how subjects perceive those 2D and 3D treatment planning outcome representations remains unclear.

Previous studies found that dental professionals and laypersons were able to detect discrepancies in smile characteristics at differing levels whereas laypersons were less discriminating than practitioners.[8-22] Those studies used 2D smile images of an unknown model in which a specific feature was modified with editing software.[10] However, the ideal symmetric model virtually created with a specific esthetic parameter as an evaluation target does not necessarily represent a real clinical situation.[11] Furthermore, a layperson´s awareness and acceptance of esthetic parameters may change when considering their own dental treatment options and outcomes.

Previous studies have analyzed esthetic subjective perception with step-wise addition of discrepancies involving the occlusal plane (OP) in relation to facial references and the facial and maxillary dental midline.[10-13,19-23] The majority of these protocols displayed only the lower third of the face, and the maxillary occlusal plane and dental midline were altered together. Any deviations in OP were not observable by laypersons unless they exceeded 3[9,10] or 4 degrees.[19] However, if the OP was tilted, maintaining an unaltered maxillary dental midline, laypersons still rated up to 5 degrees tilt of the OP as esthetically appealing.[22,23] None of the previous studies analyzed the perception of those dental alterations participant analysis of such discrepancies on their own dento-facial digital simulation.

The purpose of this observational study was to analyze the perceptions of laypersons, dental students, and dentists regarding disparities between the occlusal plane and maxillary dental midline when those digital discrepancy simulations were performed on their own full-face photograph and 3D facial representation. The null hypothesis was that no significant differences in perception of disparities between the occlusal plane and maxillary dental midline exists between laypersons, dental students, or dentists evaluating their own 2D and 3D digital simulations.

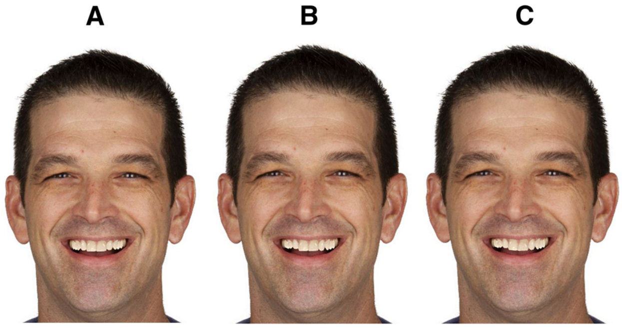

Figure 1 2-Dimensional (2D) simulations were performed using intraoral scans and a photograph of each participant using a dental CAD software (Dental systems; 3Shape). A, 0 degrees of inclination of the maxillary dental midline and maxillary occlusal plane. B, Post subgroup image with 5 degrees of inclination of the occlusal plane down to the patient's left; the maxillary dental midline and the position of both maxillary central incisors were not manipulated. C, Post+Midline subgroup image with 5 degrees of inclination of the occlusal plane; the position of both maxillary central incisors was modified to match the inclination of the occlusal plane by changing 5 degrees the inclination of the maxillary dental midline.

Materials and methods

Three populations participated in the study: laypersons, dental students, and dentists. Twenty participants per group (n = 20) were recruited at the Texas A&M Health Science Center. The protocol was approved by the Institutional Review Board (IRB) committee of the College of Dentistry at Texas A&M University (IRB 2018-1652D). The participants were all over 18 years of age, but non-English speakers, pregnant women, and prisoners were excluded. All participants were completely dentate and presented with healthy oral conditions. For each participant, 2 simulations were created: a 2D simulation using a full-face maximum smile photograph (2D group) and a 3D simulation using a facial scanner (3D group).

In the 2D image group, a full-face frontal smile of each participant was obtained with a digital camera (EOS 70D DSLR Camera; Cannon). In addition, a digital scan was obtained using an intraoral scanner (IOS) (iTero Element; Cadent) following the manufacturer´s recommended scanning protocol under room light (1000 lux) ambient lighting conditions.[24-27] A standard tessellation language file (STL_1 file) was obtained. The STL_1 file was imported into a CAD software program (Dental Systems; 3Shape) to create 2 groups of simulations. In the first subgroup (Post subgroup), the OP was modified in incremental inclinations of 1 degree (0, 1, 2, 3, 4, and 5 degrees) down to the patient's left but the maxillary dental midline and the position of both maxillary central incisors were not manipulated (Fig 1). In the second subgroup (Post+Midline subgroup), the OP was modified by the same increments as in the Post group; however, in addition, the position of both maxillary central incisors was also modified to match each degree of inclination of the OP by changing the inclination of the maxillary dental midline (Fig 1). The diagnostic waxing casts were superimposed on the 2D photograph using a specific CAD tool (Real View of Dental Systems; 3Shape). A total of 12 images were obtained for each participant.

For the 3D image group, a facial scanner (Bellus3D Face Camera PRO; Bellus3D) was used to digitalize the participant´s extraoral facial soft tissues. A reference scan and smile scan were obtained using extraoral (ScanBodyFace; AFT Dental System) and intraoral (ScanBodyMouth; AFT Dental System) scan bodies. For the reference scan, the intraoral scan body was positioned in the participant´s mouth and stabilized using polyvinyl siloxane impression material (virtual putty and low viscosity; Ivoclar Vivadent). The reference scan was taken using both scan bodies, following the manufacturer´s instructions. For the smile scan, the intraoral scan body was removed from the participant´s mouth, the forehead scan body remained in the same position, and a new facial scan of the smiling patient was taken. When the facial scans were completed, the software created a geometry definition (OBJ) file for each reference (OBJ_R file) and smile (OBJ_S file) scans.

The STL_1, the OBJ_R, and OBJ_S files were imported to a CAD software program (Matera 2.4; Exocad GmBH). The facial and the intraoral scans were superimposed using the extraoral and intraoral scan bodies as common references.[11] As with the 2D image group, the exact same two subgroups of digital simulations (Post and Post+Midline) were created for the 3D image group (Fig 2). A total of 12 videos were obtained for each participant.

To estimate the sample size from power analysis data from a previous study were used[26] as well as data from a simulation study that was performed to reproduce layperson and dental professionals' responses to the face with varying degrees of OP tilt. From the simulation it was concluded that the sample size should be between 25 and 35 persons per group. Due to time and monetary constraints, 20 participants per group could be recruited. A total of 60 individuals were asked to evaluate each image and video according to their own esthetic criteria using a visual analog scale from 1 to 6, where 1 was the least esthetically appealing and 6 was the most esthetically appealing. The

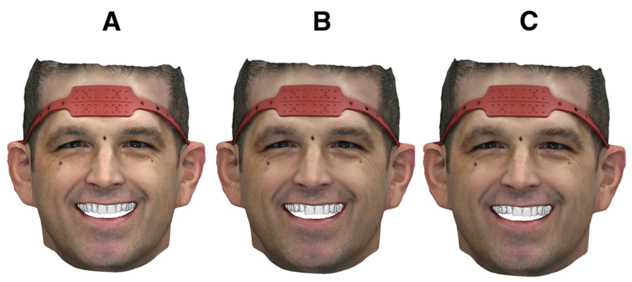

Figure 2 3-Dimensional (3D) simulations were performed using intraoral scans and a photograph of each participant using a dental CAD software (Dental systems; 3Shape). A, 0 degrees of inclination of the maxillary dental midline and maxillary occlusal plane. B, Post subgroup image with 5 degrees of inclination of the occlusal plane down to the patient's left; the maxillary dental midline and the position of both maxillary central incisors were not manipulated. C, Post+Midline subgroup image with 5 degrees of inclination of the occlusal plane; the position of both maxillary central incisors was modified to match the inclination of the occlusal plane by changing 5 degrees the inclination of the maxillary dental midline.

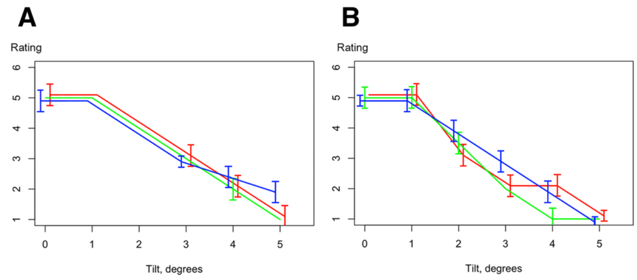

Figure 3 A, Occupation group medians (solid line) and their 95% CI (error bars) as a function of the occlusal plane tilt for unchanged midline and 2D image type. B, Occupation group medians (solid line) and their 95% CI (error bars) as a function of the occlusal plane tilt for modified midline and 2D image type. Dentists: red line, students: green line, laypersons: blue line. Note: the lines for the dental student and those not in the dental field groups are staggered by plus or minus 0.1 to prevent line overlap.

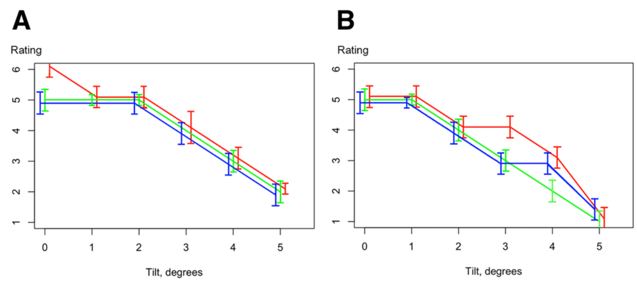

Figure 4 A, Occupation group medians (solid line) and their 95% CI (error bars) as function of the occlusal plane tilt for unchanged midline and 3D image type. B, Occupation group medians (solid line) and their 95% CI (error bars) as a function of the occlusal plane tilt for modified midline and 3D image type. Colors are the same as in Figure 3.

sequence of presentation of the simulations was randomized for each participant. After completion of the rating of the 2D and 3D groups, participants were asked to answer two survey questions: "What method did you prefer to visualize a dental treatment outcome?" and "What method would you prefer to use or be used by your dentist in private practice?"

Medians were used to summarize the rating data, and 95% confidence intervals for the medians were calculated as 1.78 times the interquartile range.[27] Effects of occupation, gender, age, image type, midline modification, OP tilt, and their interactions on the ratings were evaluated. Ordinal logistic regression was employed to account for the ordinal nature of the response variable.[28] This was a repeated measures design, and individuals were nested within occupation levels. To identify significant effects while accounting for repeated measures and random effects of individuals, a linear mixed model with all main effects and their pairwise interactions and a random individual component was used. Significant terms from the linear mixed model were then incorporated in the ordinal regression model. A proportional odds assumption was made because it allowed the estimation of the parameters of the logistic regression and the odds ratios (OR). Goodness of fit was assessed using R2 coefficient for the linear predictor of the ordinal regression following McKelvey and Zavoina.[29] All analyses were performed in R statistical environment[30] using VGAM software package.[31]

Results

The results showed that the ratings became lower with increased tilt of the OP (Figs 3 and 4). Also, group ratings stayed very similar among the groups as the OP tilt increased in both unchanged midline and tilted midline presentations (Table 1). Based on significance of the terms (significance level after Bonferroni correction for 15 terms = 0.05/15 = 0.0033), occupation, tilt, image type, midline modification, and midline: tilt, image type: tilt and occupation: image type pairwise

Table 1 Analysis of variance of the linear mixed regression model including occupation, gender, age, image type, midline modification, occlusal plane tilt, all of their pairwise interactions as fixed effects, and individuals as random effects. The terms were sorted in increasing order of *p*-values

Term	Chisq	Df	Pr(>Chisq)
image.type	392.5213	1	< 2.20E-16
midline	118.2788	1	< 2.20E-16
tilt	6328.5071	1	< 2.20E-16
midline:tilt	29.2192	1	6.46E-08
image.type:tilt	25.6029	1	4.19E-07
occupation:image.type	12.1955	2	0.002248
gender:image.type	8.5063	1	0.003539
population:tilt	9.6373	2	0.008078
occupation:midline	4.7594	2	0.092578
occupation:gender	4.6178	2	0.09937
gender	1.4668	1	2.26E-01
gender:midline	1.3328	1	0.248307
image.type:midline	0.86	1	0.353731
gender:tilt	0.7033	1	0.401676
occupation	1.5185	2	4.68E-01

Table 2 Analysis of deviance (Type II) for the reduced ordinal logistic regression model

	Df	Deviance	Pr(>Chi)
occupation	2	6.36	0.041482
tilt	1	2045.83	< 2.2e-16
image.type	1	285.1	< 2.2e-16
midline	1	97.39	< 2.2e-16
occupation:image.type	2	11.08	0.003917
tilt:image.type	1	8.75	0.003103
tilt:midline	1	20.9	4.84E-06

Table 3 Odds ratios (ORs) and their 95% CIs based on the regression coefficients ordinal logistic regression from Table 2. Reference levels: occupation: dentist, image type: 2D, midline: unchanged

Term	OR	Lower 2.5% bound	Upper 2.5% bound
Occupation-student	0.938	0.652	1.348
Occupation-layperson	1.762	1.227	2.529
Tilt	0.122	0.104	0.143
image.type – 3D	5.520	3.373	9.036
Midline – modified	0.733	0.501	1.073
Occupation-student:image. image.type – 3D	0.809	0.488	1.342
Occupation-layperson:image. image.type – 3D	0.439	0.265	0.728
tilt: image.type – 3D	1.216	1.068	1.384
tilt: Midline – modified	0.744	0.655	0.845

interactions in the ordinal logistic model of the image ratings were included (Table 2); odd ratios (OR) for corresponding terms and their 95% confidence intervals are presented in Table 3. R^2 of the linear predictor of the latent variable was 0.8183.

Tilt of the OP had the strongest negative effect on the ratings of the image appeal (OR per degree = 0.122). The negative effect was amplified by modification of the midline inclination (OR tilt-midline = 0.744) but lessened when 3D images were evaluated (OR tilt: image.type-3D = 1.216). Therefore, 3D images had a strong positive effect on the ratings (OR = 5.520) compared to 2D images. For students the effect of 3D images was similar to dentists (OR occupation-student: image.type.3D = 0.809) but for laypersons the positive effect of 3D images decreased relative to dentists (OR occupation-layperson: image.type-3D = 0.439). Students rated images similar to dentists (OR occupation-student = 0.938) but laypersons rated the same images higher (OR occupation-layperson = 1.762). Midline modification by itself did not affect the ratings (OR = 0.733).

Survey subject personal preferences on the type of visualization to use as part of dental treatment were different among the groups where 45% of the dentists, 80% of the dental students, and 50% of the laypeople preferred 3D image simulations. However, 35% of the dentists and 80% of the dental students would prefer to use 3D image simulations in their practice; while 50% of the laypersons said they would prefer their dentist use a 3D facial scan over a 2D photograph in treatment visualization.

Discussion

Significant differences in perception of disparities between the OP and maxillary dental midline existed among all participants evaluating their own 2D and 3D digital simulations. Consequently, the null hypothesis was rejected. Laypersons, dental students, and dentists' ratings-maintained similarity among each of the groups as the occlusal plane tilt increased in both unchanged midline and tilted midline presentations. Therefore, the acceptability ranges of esthetic dental discrepancies might not be followed by all patients when analyzing their own dental esthetic discrepancies.

To the knowledge of the authors, this is the first study where analysis of the perception of dental discrepancies simulated on each participant's own 2D and 3D representation occurs. The authors of the present study previously developed two studies evaluating the laypersons, dental students, and dentist's perception of the same dental disparities evaluated in the present study but with a different simulation approach.[22,23] In the first study, a symmetric woman model was created and participants rated the simulations performed on the unknown 2D image.[22] In the second study, a woman was selected as a model for creation of the 2D and 3D simulations of the dental discrepancies, and participants were asked to rate the simulations performed on the unknown 2D and 3D representations.[23] The present clinical study represents the final project in the series, where the dental disparities were performed on each participants own 2D and 3D representations. The dental disparities were maintained as a constant in an attempt to analyze the perception differences between known and unknown models and the dimensional representation of the dental disparities.

The results of the present study showed that the ratings of all participants became lower with increased tilt of the OP, which is in agreement with previous studies.[12,21,24] Furthermore, each participant rated their own dental discrepancy simulations, which resulted in very similar ratings among the groups as the OP tilt increased in both unchanged midline and tilted midline presentations. This could be interpreted as the individual´s criticism and esthetic demands being heightened when analyzing one's own image as opposed to evaluating images of an unknown person. Likewise, the familiarity of one's own facial and dental features could make the participant more sensitive to detection of dental alterations in their 2D and 3D image representations. This study more closely simulates a clinical environment compared with previous perception studies as clinicians would use their actual patient's 2D and/or 3D image representations to communicate treatment planning and procedure outcomes to their patients.

Based on the results obtained, the type of dimensional representation affected the perception of the participants. Regarding the 3D simulations from 1 to 4 degrees of inclination of the OP, all participants provided higher ratings at the same degree of inclination compared with the 2D representations. The higher ratings of the 3D simulations could be attributed to the detection of the discrepancy being more difficult, given the lack of experience of all the study participants in accurately visualizing a 3D facial representation.

Even though 3D facial representations obtained higher ratings in all groups, 45% of the dentists, 80% dental students, and 50% of the laypersons preferred the facial scan over a 2D picture in treatment outcome visualization. However, only 35% of the dentists and 80% of the dental students would implement the facial scanner while 50% of the laypersons would prefer their dentist use the facial scanner in private practice. Analyzing the questionnaire results, dental students showed a high preference of the 3D representation while dentists demonstrated a 2D representation predilection. Laypersons seems to be more neutral regarding their technology choice. However, as 3D representations become more commonly adopted, it can be expected that individual perception would also evolve, adapt, and contribute to a change in preference of one technology over another.

With incorporation of digital technologies clinicians must overcome the learning curve to visualize and elaborate 2D and 3D representations. In the present study, participants did not receive any specific training before rating the simulations. This was intentional in order to simulate the clinical environment where patients come without any training. Furthermore, the assumption or generalization of esthetic dental perception thresholds of previous studies should be taken into consideration carefully as it has been shown in the present study that laypersons, dental students, and dentists presented with similar ratings in the 2D and 3D simulations, which could be explained by a higher esthetic demand when analyzing one's own image compared with evaluation of an unknown persons image, or by a greater sensitivity to detection of changes due to familiarization with one's own dental features. Also, clinicians may consider a 2D representation as a more understandable dimensional tool from the patient standpoint compared with the 3D reconstructions.

The inclination of the maxillary dental midline with concurrent tilt of the OP presented a negative effect on the ratings, which is in accordance with previous studies.[12,21] Further studies are recommended to analyze dimensional perception differences when evaluating different dental discrepancies. In addition, simulations performed with different design software, which may utilize different color schemes, or present simulations with different facial digitizers may render different outcomes.

Conclusions

Laypersons, dental students, and dentists' ratings-maintained similarity among each of the groups as the occlusal plane tilt increased in both unchanged midline and tilted midline presentations. All participant ratings decreased with increasing tilt of the occlusal plane and the concurrent inclination of the maxillary dental midline yielded an increased negative effect on the participant´s ratings. Furthermore, the type of dimensional representation affected the esthetic perception of the participants where 3D image representations obtained higher ratings than 2D image simulations.

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