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Perception of Differences in Lip Profile between 2-D and 3-D

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Perception of Differences in Lip Profile between 2-D and 3-D

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

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Table of Contents

List of Tables

List of Figures

Abstract

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Background

Past studies evaluating the esthetics of orthodontic treatment have been done using 2-D images. New 3-D imaging offers an improved, real-life representation of a subject. The purpose of this study was to determine how laypeople perceived differences in lip position (flat versus ideal lip fullness) in 2-D compared to 3-D.

Materials and Methods

3dMD images of 8 Caucasian subjects were adjusted to an ideal and flat lip position in 3-D and then in 2-D from the profile view. 2 surveys were created with paired ideal and flat images on the screen, either in 2-D or 3-D, and evaluators were asked to choose which image they preferred and by how much.

Results and Conclusions

Evaluators were more likely to be neutral, and were less decisive of their preference in 3-D compared to 2-D. People might be less sensitive to small differences in facial soft tissue and esthetics than previous research in 2-D has led orthodontists to believe.

Introduction

An individual's face plays an important role in determining overall attractiveness, aids in interpersonal communications, and has been shown to have a profound influence on judgements by peers.[1] Additionally, there is a symbiotic relationship that exists between the dentition and the face. This dental-facial relationship, specifically the role the dentition plays in the esthetics of the face, is of particular interest to dentists and orthodontists.[2] What is currently defined as attractive becomes even more important to contemporary orthodontists when taking into consideration that patients seeking orthodontic treatment are frequently motivated more by esthetics than an improvement in masticatory function.[3]

In 1968, Ricketts defined the "esthetic plane" (E-plane) as a line extending from the tip of the nose to the tip of the chin when a subject is seen in a two dimensional (2-D) profile view. He found the lower lip in mature Caucasians to be positioned at a mean distance of 4mm $\pm$ 3mm posterior to the E-plane.[4] Since then, the E-plane has become a common reference in analysis of lip position in orthodontic evaluation. Coleman et al,[5] using 2-D soft-tissue profiles, found that patients, parents and orthodontists preferred the lower and upper lip to be on average about 5 mm and 7 mm posterior to the E-plane, respectively, for Class I subjects.

The use of three-dimensional (3-D) surface imaging has gained clinical acceptance and popularity among oral and maxillofacial surgeons, plastic surgeons and, more recently, orthodontists as a useful adjunct in the treatment planning process.[6-10] This technology provides clinicians with an anthropometric representation with greater precision and accuracy than other commonly used images, such as 2-D photographs. The 3dMD imaging system (3dMD, Atlanta, GA) in particular is one of the fastest 3-D surface-imaging systems. It captures images within 1.5

ms, creating very reliable 3-D computer-generated replicas of patients' facial soft tissues with a mean global error of 0.2 mm.[8] The system also has the ability to fuse computed tomography (CT)/cone-beam computed tomography (CBCT) images with 3-D surface-imaging data, further enhancing the treatment planning process by allowing clinicians to better understand, compare and predict various orthodontic or surgical treatment outcomes.[6,9]

Some orthodontic treatment options such as premolar extraction, have been shown to produce changes in a patient's facial soft-tissue.[11-16] The decision to extract teeth in orthodontics involves many factors including the amount of tooth size-arch length discrepancy, incisor and lip protrusion, severity of skeletal discrepancies, curve of Spee present, growth potential, and esthetics. The use of premolar extraction in orthodontics was initially shunned in the early 20th century but gained popularity later on as a method for achieving greater long-term stability.[17] Toward the end of the 20th century, however, controversy developed regarding the possible negative side effects of this treatment. Claims that premolar extraction resulted in "dished-in" or flat faces, making patients look less youthful or less esthetic, were made based on the assumption that soft-tissue changed in a particular manner in response to the hard-tissue changes associated with orthodontic treatment.[18,19]

Numerous researchers have attempted to settle this debate through extensive profile studies using pre- and post-treatment cephalometric measurements[11,12,14-16] as well as through esthetic evaluation by panels of laypeople and dental professionals of 2-D photographs,[20,21] silhouettes,[22] and profile tracings.[15] However, in 2008, Shafiee et al[20] attempted to identify the relative strengths of the full-face, smiling, and profile photographs individually in predicting facial attractiveness and found that the profile view is not the optimum perspective from which to evaluate facial attractiveness. Most studies analyzing incisor and lip retraction in response to premolar extraction have shown relationships of varying strength, but it is generally agreed that the correlation between soft tissue and hard tissue change is subject to large variation in such cases.[23] Relative to Ricketts E-plane, some of the greatest average retractions reported following four premolar extraction were 3.4 mm for the upper lip and 3.8 mm for the lower lip.[12,14] At times, extraction of four premolars resulted in the perception of substantial improvements in profile while other times they were considered to induce a flatter, less esthetic profile, and this was dependent on the initial protrusion.[15,16]

In the past, studies evaluating esthetic preferences were done using 2-D photographs because that was all that was available. Given the superiority of 3-D imaging, this technology should be investigated for its use in analyzing the impact of orthodontic treatment on facial soft tissues and esthetics. In 2005, Todd et al[24] attempted to compare the perceptions of facial esthetics between 2-D and 3-D images, but found inconclusive evidence that there was a difference between them. More recently, Stebel et al[25] compared the 2-D and 3-D evaluations of nasolabial esthetics, and found greater reproducibility of ratings when evaluated in 3-D, and that 3-D images were regarded by layperson evaluators as more informative than 2-D images. Analyzing treatments in 3-D might be more appropriate than 2-D because real-life social interactions and interpersonal communications occur in 3-D. Moreover, a treatment result deemed as unesthetic in 2-D might be perceived differently in 3-D.

Therefore, the purpose of this study was to determine how laypeople perceived esthetic differences in lip position (flat versus ideal lip fullness) in 2-D versus 3-D. This was accomplished specifically by evaluating whether laypeople identified ideal lip fullness as being superior as often and as decisively in 3-D than in 2-D. If a difference were detected, it would provide a rationale for using 3-D technology to evaluate treatment results.

Materials & Methods

Before beginning the study, approval was obtained from the Institutional Review Board of Virginia Commonwealth University. After obtaining consent, 3dMD (3dMD, Atlanta, GA) images were taken of 8 adult Caucasian volunteers (4 male, 4 female) at Virginia Commonwealth University in Richmond, Virginia. The mean ages of the volunteers were 26.8 $\pm$ 1.4 years for the males and 27.3 $\pm$ 2.8 years for the females. Inclusion criteria were: Caucasian adults between the ages of 24 and 34, who had no history of orthognathic surgery or extractions other than third molars and had no facial hair or distracting markings.

Using the 3dMD Vultus 2.2.025 imaging software, the 8 subjects had the positon of their lips digitally altered to an "ideal" (ideal) position, based on the results of a previous study.[5] Each subject's upper and lower lips were placed 7 mm and 5 mm posterior to Ricketts E-plane, respectively. Following this alteration, each subject's lips were retracted an additional 3.5 mm to a "flat" (flat) position, based on the results of previous studies.[12,14] The resulting flat group had their upper and lower lips placed 10.5 and 8.5 mm posterior to Ricketts E-plane. This created an ideal and flat version of all 8 subjects in 3-D.

20 second animation videos were created of each subject's ideal and flat 3dMD images. The videos began with the 3dMD image at the facial front view. As the video progressed, the image slowly rotated on a fixed vertical axis until it reached the right-facing profile view, at which point the rotating image paused for 2-3 seconds. This allowed a brief static view of the subject's profile, and then the image began rotating again, back to the facial front view, and then all the way to the left-facing profile view where the 3-D video ended.

In order to obtain the 2-D images for the study comparison, each subject's altered 3dMD images (ideal and flat) were positioned in right-facing profile view within the Vultus software. Screenshots were then taken of this profile view, and the resulting images were cropped to include only the subject's profile with a black background.

Two parallel surveys were created using Microsoft Access 2013 (version 15.0.4797.1003, Microsoft, Redmond, WA). Each survey contained an ideal vs. flat comparison for each of the 8 subjects, either using 3-D videos or 2-D static images. If a subject's 2-D comparison appeared in survey 1, then their 3-D comparison was used in survey 2. It was randomized as to which image (ideal or flat) appeared on the left and right of the screen. The characteristics and order of the images used in the 2 surveys are shown in Table 1.

Table 1. Survey Order and Image Characteristics

Survey 1			Picture Order	
Order	Subject	Dimension	Left	Right
1	Male 1	3D	Flat	Ideal
2	Female 4	3D	Flat	Ideal
3	Male 2	3D	Ideal	Flat
4	Female 1	2D	Flat	Ideal
5	Female 3	2D	Ideal	Flat
6	Male 3	2D	Ideal	Flat
7	Female 2	3D	Ideal	Flat
8	Male 4	2D	Flat	Ideal
Survey 2			Picture Order	
Order	Subject	Dimension	Left	Right
1	Female 4	2D	Ideal	Flat
2	Male 4	3D	Ideal	Flat
3	Male 1	2D	Flat	Ideal
4	Female 2	2D	Ideal	Flat
5	Female 1	3D	Flat	Ideal
6	Male 3	3D	Flat	Ideal
7	Male 2	2D	Flat	Ideal
8	Female 3	3D	Ideal	Flat

A total of 209 evaluators completed the surveys by indicating the 3-D video or 2-D image from each pair that he or she preferred and signifying how much they preferred their selection. The evaluators were asked to participate if they were between the ages of 18 and 30. No other inclusion or exclusion criteria were applied. Evaluators were recruited on the undergraduate campus of Virginia Commonwealth University in Richmond, VA. In exchange for their participation, evaluators were given a bottle of water. They were not told the purpose of the study or that it was related to the position of the lips. Each evaluator randomly received either survey 1 or survey 2.

Evaluators received directions on how to compete the survey, which was administered on a laptop computer. They were asked to fill out basic demographic information including age, sex, and race. The remainder of the survey featured the subjects' comparisons. Under each pair of images or videos was the statement: "Please select the image you prefer from the above pair by sliding the bar below toward your preference. The extent to which you slide the bar signifies how much you prefer your selection over the other image." This statement was accompanied by a visual analog scale (VAS), scaled from -100 to +100, and labeled "Much Better" at each end. A sliding bar was initially placed in the middle at 0 (neutral). The corresponding numeric value of each evaluator's selection was recorded in an Excel 2013 (version 15.0.4797.1003, Microsoft) file. In testing for the differences between the 2-D and 3-D comparisons, the absolute value of these numbers was used. The relative magnitude of the response was used to assess "decisiveness". There were 8 comparisons in each survey, for a total of 8 ratings by each evaluator. No evaluator viewed both the 2-D image and 3-D video of the same subject, since those appeared in different surveys. An example of the survey showing an ideal and flat 2-D image comparison is given in Figure 1.

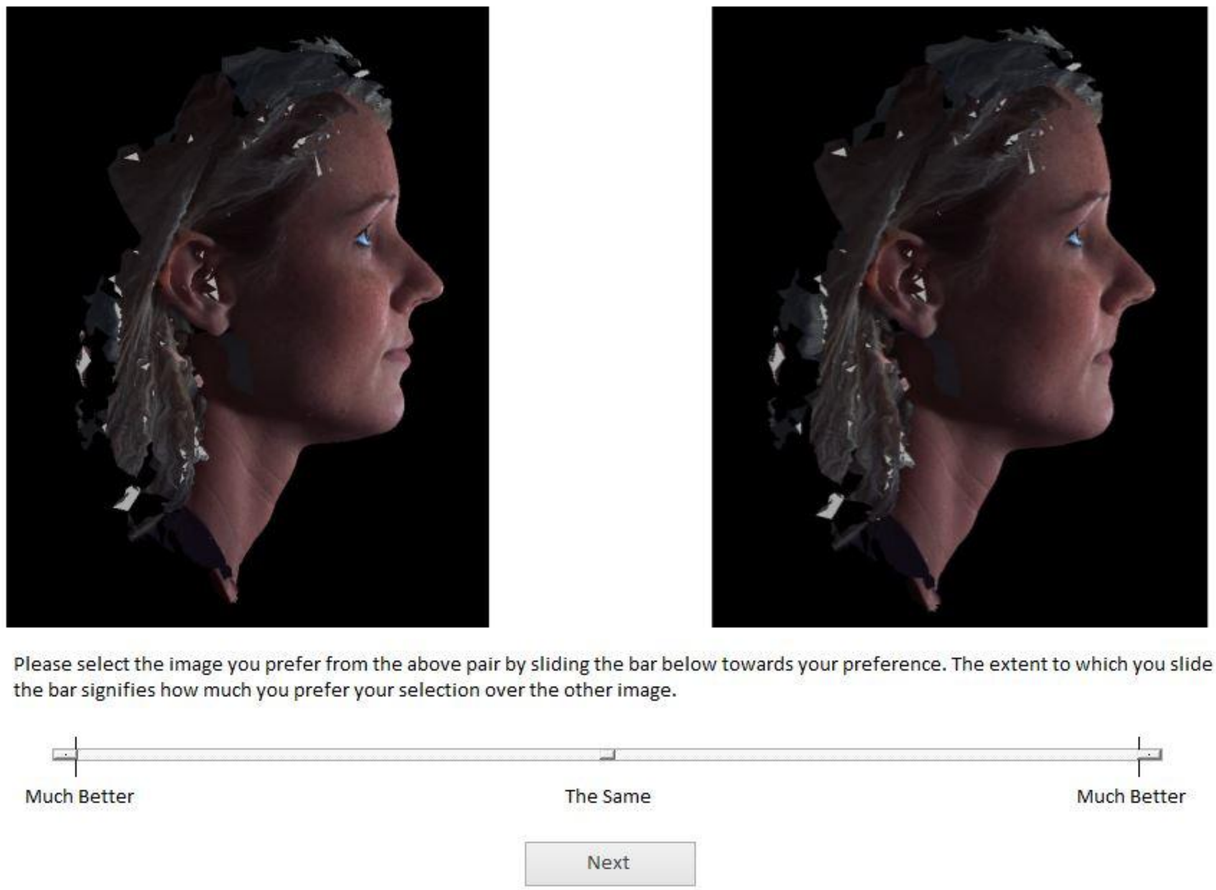

Figure 1. Survey Example

Basic demographic data were summarized and compared between the two survey versions to ensure there was no evidence of bias as a result of the randomization. Categorical variables were compared using chi-square tests and continuous variables were assessed using t-tests. The primary focus of this research was to determine if laypeople were less critical of a flat profile in 3-D versus 2-D. A repeated-measures analysis of variance (ANOVA) was fit which accounted for the inherent correlation between responses from the same reviewer. Pairwise comparisons were performed to determine specific differences in levels of categorical variables and were adjusted for multiple comparisons where appropriate. When all pairwise comparisons were of interest, Tukey's HSD adjustment was used and where only a specific number of pairwise comparisons were of interest, Bonferoni's adjustment was used. Additionally, a chi-square test was used to evaluate differences in the preference (ideal, flat, neutral) for the two dimensions. Neutral was defined as being in the middle, or 0, on the VAS. SAS EG version 6.1; SAS Institute, Cary, NC) was used for all analyses with a significance level of 0.05.

Results

A total of 209 responses were collected. Of those, 196 were included for analysis after removing subjects outside of the targeted age range (18-30) along with those who did not answer the questions appropriately (invalid responses for sex, race, etc.). Demographics (age, sex, and race) were compared across respondents of the two surveys to determine if subjects were randomly distributed between the two surveys. There were no differences in the demographics between the evaluators completing the surveys (Table 2).

Table 2. Demographic Summary Statistics, Evaluators

Variable		**Survey 1**	**Survey 2**	**P-Value**
Sample Size		99	97	
Average Age		20.9	20.73	0.6562
Sex (% Male)		50%	48%	0.8282
Race				0.4455
	Asian	18%	11%	
	Black	20%	14%	
	Hispanic	8%	8%	
	Other	8%	9%	
	White	45%	57%	

Table 3 presents the breakdown of the evaluators' preference for both the 2-D images and the 3dMD videos. The results showed the majority preferred the ideal profile: 62% when viewing 2-D images and 50% with 3-D images. The differences in distribution for 2-D and 3-D preferences were statistically significant (*P* <0.0001).

Table 3. Evaluators Profile Preference in 2-D and 3-D

Profile	**2-D**	**3-D**
Ideal (VAS>0)	62%	50%
Flat (VAS<0)	22%	27%
Neutral (VAS=0)	16%	22%

Since the primary research question included how decisive evaluators were, an absolute value of the VAS rating preference value was used for analyses of 2-D vs. 3-D rather than the original signed measurement. The results of the repeated-measures analysis of variance (ANOVA) indicated a significant interaction between the image and the dimension in which it was presented (P = 0.0005). Table 4 presents the estimated difference in VAS preference score for each subject. There were three cases for which there was a significant difference between the dimensions, all of which had a significantly higher score, meaning a stronger preference indicated, for the 2-D comparison than for the 3-D comparison. The results of these significant pairwise comparisons are presented in Figure 2. In these cases, respondents were on average over 10 units more decisive with 2-D images than they were for 3-D images.

Table 4. Estimated Difference in 2-D and 3-D VAS Rating Preferences for Each Subject (|2-D| - |3-D|)

Image	**Estimated Difference (2-D vs 3-D)**	**P-value**
1F	5.66	0.1802
1M	-0.54	0.8983
2F	2.87	0.497
2M	-0.66	0.8768
3F	12.70	0.0027*
3M	13.85	0.0011*
4F	-6.24	0.1397
4M	15.63	0.0002*

Note: Bonferoni adjustment was used to account for the 8 comparisons of interest (α=0.00625).

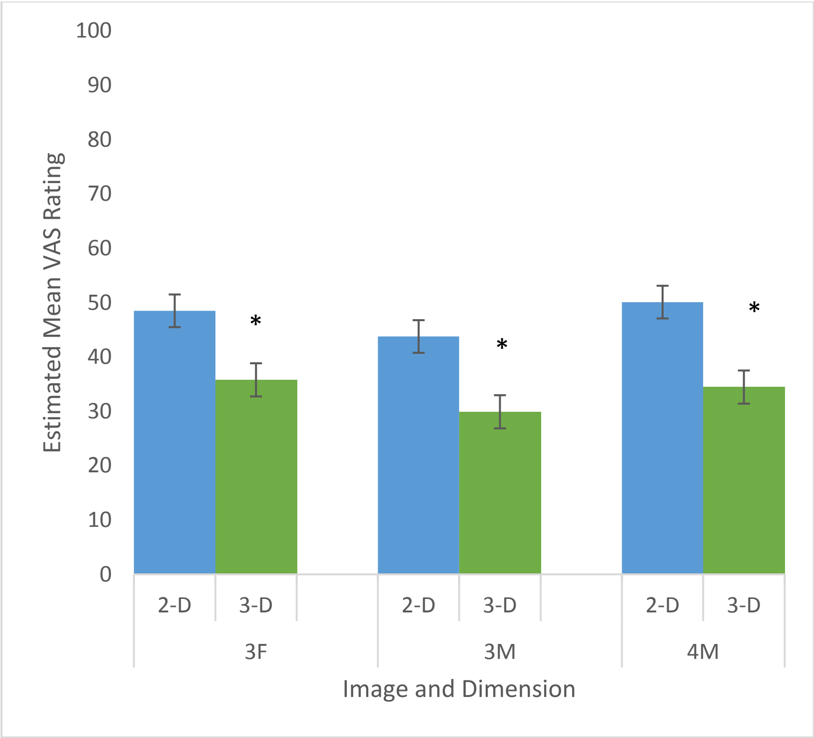

Figure 2. Cases with Significant Differences in 2-D and 3-D Ratings

*Indicates significant at 0.00625 level (Bonferoni adjusted p-value for multiple comparisons)

Additionally, sex and race of the evaluator were also associated with differences in the absolute value of the VAS scores (P = 0.0361; <0.0001, respectively). Female respondents' scores were on average 3 points more decisive than males. Hispanic respondents gave significantly higher scores to rate differences than Asian, Black, White, and Other races; and Asian respondents gave significantly higher scores than White and Other respondents, but were not significantly different from Black respondents after adjusting for multiple comparisons. Table 5 includes the statistically significant pairwise comparison results for both sex and race.

Table 5. Pairwise Comparison of Ratings for Significant Evaluator Race and Sex Differences

Variable	Estimated Difference	P-value
Race		
Hispanic-Asian	9.05	0.0293
Hispanic-Black	14.37	<.0001
Hispanic-White	15.68	<.0001
Hispanic-Other	18.55	<.0001
Asian-White	6.63	0.0150
Asian-Other	9.50	0.0168
Sex		
Female-Male	3.00	0.0362

Discussion

The results of the current study provide new insight in an area of research where little previous work has been done. Some aspects of this study, such as the findings on preferred lip position, are supported by previous research.[15,26] Other findings, such as how preferences differ depending on which dimension they are evaluated in, are new and unique.

In the current study, the 2-D evaluation showed a significantly greater preference for the ideal profile (62%) rather than the flat profile (22%) (Table 3). Foster[26] found that laypeople considered the most pleasing profile for an adult female to be one with the lower lip about 5 mm posterior to the E-plane, with males being slightly flatter. This supports the findings of the current study in which laypeople evaluators preferred the profiles with the lower lip placed 5 mm posterior to E-plane. Bowman et al[15] found that extraction treatment and the associated lip retraction hurt profiles where the lower lip was greater than 3.5 mm behind the E-plane. This also supports the findings of the current study in which lip retraction beyond the lower lip position of 5 mm posterior to E-plane negatively affected the profile. The ideal lip positions used in the current study were chosen based on what Coleman et al[5] found as being the most preferred lip position by patients, parents, and orthodontists. The current study's findings support those findings.

Similar to previous studies using 2-D profile images, the 3-D evaluation in this study also showed that evaluators more often preferred the ideal profile (50%) compared to the flat one (27%) (Table 3). The 3dMD imaging system used in this study has been shown to be more precise and accurate than 2-D photography for making measurements.[8] The superiority of 3-D imaging has also been demonstrated in studies comparing cone-beam computed tomography

(CBCT) and conventional lateral cephalograms. CBCT facilitates more precise identification of cephalometric landmarks, particularly bilateral landmarks such as orbitale, condylion, and gonion.[27] It also gives more accurate data regarding the specific location of impacted teeth, pathologic lesions, and identifying possible root resorption. Compared to 2-D lateral cephalograms, 3-D imaging with CBCT allows orthodontists to more accurately analyze airway volume changes resulting from treatments such as maxillary expansion.[28] The results of the 3-D evaluation in the current study show that 3-D imaging can be successfully used to evaluate lip position preferences, a new finding in this area of research.

The results of the current study demonstrated that the overall impact of lip position on esthetics is viewed differently in 3-D than in 2-D. The 3-D evaluation showed a significantly more frequent preference for the ideal profile rather than the flat profile, but less often than in 2-D (Table 3). Additionally, evaluators tended to prefer the flat profile in 3-D (27%) more often than in 2-D (22%). Furthermore, a greater percentage of evaluators tended to responded neutrally when viewing 3-D videos (22%) than 2-D images (16%). Using a logistic regression model, the odds ratios for selecting various profiles were calculated. The odds that a viewer was rating a 2-D picture was 1.77 (95% CI: 1.36-2.29) times higher if they selected the ideal image rather than neither (neutral), indicating a significantly greater incidence of neutrality in 3-D ($P < 0.0001$). Similarly, evaluators were 0.66 (95% CI: 0.52-0.83) times as likely to be viewing a 2-D image if they selected the flat compared to ideal profile, demonstrating a significant increase in preference frequency for the flat profile in 3-D ($P = 0.0004$). This showed that not only were evaluators less likely to be critical of a flat profile, they also tended to be less decisive as a whole when evaluating esthetics in 3-D vs. 2-D.

The results in Table 4 indicate that the ability for laypeople to discern differences between the two images was different depending on the subject and the dimension in which the images were presented. In each of the three cases where there was a significant difference between the dimensions, the 2-D VAS value was greater and thereby evaluated more decisively than the 3-D images (Figure 2). The clear pattern found between the 2-D and 3-D images contrasted the findings of some previous studies comparing esthetic evaluation between 2-D and 3-D images.[24,25]

Todd et al[24] took facial scans of two Caucasian adult males and females using a 3-D photogrammetric face scanner (3dMD LLC, Harefield, Middlesex, UK) and created 5 different profiles using computer software. Evaluators were asked to rank the images in order of preference from most favorable to least favorable in 2-D and 3-D. When comparing the results for the 2-D and 3-D images, no clear pattern was found. Evaluators preferred one profile significantly more frequently than the rest in 2-D, but not in 3-D, for one of the subjects. For another subject, evaluators preferred a profile significantly more frequently over the others in 3-D, but not in 2-D. In the current study, evaluators showed a significantly more frequent preference for the ideal profile rather than the flat profile in both 2-D and 3-D formats (Table 3). Stebel et al[25] compared the reliability of rating nasolabial appearance on cropped 2-D and 3-D images (3dMD, Atlanta, GA) in prepubertal children. The mean rater scores showed no difference between 2-D and 3-D formats. This is different than what was found in the current study where raters were less decisive in 3-D than in 2-D (Table 3). The study also asked evaluators two questions regarding which image format (2-D or 3-D) provided more information and was easier to evaluate. The raters of the study chose 3-D images as providing significantly more information than 2-D images, and there was a non-significant tendency to consider 2-D images as being easier to use in evaluating esthetics.

The evaluation of facial soft-tissue esthetics in 2-D compared to 3-D is a relatively new area of research and additional investigation is needed to confirm the findings of the current study. This study was able to provide preliminary evidence that there is in fact a difference in how esthetic appearance is perceived by laypeople, depending on whether it is evaluated in 2-D or in 3-D. More importantly, there is evidence to suggest that laypeople judging a flat profile are less likely to be critical of that profile in 3-D. Shafiee et al[20] suggested that the 2-D profile view is not the optimal method for evaluating facial attractiveness. While it might be most accurate to evaluate facial attractiveness on a live person, this is usually not possible or practical for research purposes. Nevertheless, the use of a 3-D image incorporating the profile, full-face, and every angle in between is probably closer to reality than the 2-D alternative.

One limitation to the current study design that should be acknowledged is that the 3-D videos used were 20 seconds long and repeated themselves up to 3 times until a decision was made by an evaluator. When taking the survey, however, the evaluators were able to make their selection before the 20 second video completed. In future studies using this design and 3-D videos, it might be better to have the video complete at least once before evaluators are able to make their selection on the VAS or simply have the 3-D images available and allow the evaluators to rotate them at their own pace.

The results of this study demonstrated an increase in neutrality and a decrease in decisiveness of esthetic evaluation in 3-D compared to 2-D. 3-D images are likely to facilitate a more accurate representation of the real-life perception of lip position changes that can occur as a result of orthodontic treatment. Previous studies in 2-D have demonstrated that evaluators are sensitive to small differences in facial soft tissue and esthetics.[5,11-16,26] However, based on the findings of the current study, evaluators might be less sensitive to small differences in facial soft tissue and esthetics than previous research in 2-D has led orthodontists to believe.

Conclusions

- Lip positions (lip fullness) identified in previous studies as being ideal were more frequently preferred by evaluators than flatter lips in both 2-D and 3-D images.
- Ideal lip fullness was less often identified as superior to flat lips when viewed in 3-D images than in 2-D profile images.
- Ideal lip fullness was less decisively considered as superior to flat lips when viewed in 3-D images than in 2-D profile images.
- Evaluators were more likely to have no preference (neutral) of lip position in 3-D images than in 2-D profile images.

References

1. Shaw WC. The influence of children's dentofacial appearance on their social attractiveness as judged by peers and lay adults. *Am J Orthod*. 1981;79(4):399-415.

2. Davis LG, Ashworth PD, Spriggs LS. Psychological effects of aesthetic dental treatment. *J Dent*. 1998;26(7):547-554. doi: S0300-5712(97)00031-6 [pii].

3. Shaw WC, Gbe MJ, Jones BM. The expectations of orthodontic patients in South Wales and St Louis, Missouri. *Br J Orthod*. 1979;6(4):203-205.

4. Ricketts RM. Esthetics, environment, and the law of lip relation. *Am J Orthod*. 1968;54(4):272-289.

5. Coleman GG, Lindauer SJ, Tufekci E, Shroff B, Best AM. Influence of chin prominence on esthetic lip profile preferences. *Am J Orthod Dentofacial Orthop*. 2007;132(1):36-42. doi: S0889-5406(07)00327-7 [pii].

6. Karatas OH, Toy E. Three-dimensional imaging techniques: A literature review. *Eur J Dent*. 2014;8(1):132-140. doi: 10.4103/1305-7456.126269 [doi].

7. Kau CH, Richmond S, Zhurov A, et al. Use of 3-dimensional surface acquisition to study facial morphology in 5 populations. *Am J Orthod Dentofacial Orthop*. 2010;137(4 Suppl):S56.e1-9; discussion S56-7. doi: 10.1016/j.ajodo.2009.04.022 [doi].

8. Lubbers HT, Medinger L, Kruse A, Gratz KW, Matthews F. Precision and accuracy of the 3dMD photogrammetric system in craniomaxillofacial application. *J Craniofac Surg*. 2010;21(3):763-767. doi: 10.1097/SCS.0b013e3181d841f7 [doi].

9. Metzger TE, Kula KS, Eckert GJ, Ghoneima AA. Orthodontic soft-tissue parameters: A comparison of cone-beam computed tomography and the 3dMD imaging system. *Am J Orthod Dentofacial Orthop*. 2013;144(5):672-681. doi: 10.1016/j.ajodo.2013.07.007 [doi].

10. Tzou CH, Artner NM, Pona I, et al. Comparison of three-dimensional surface-imaging systems. *J Plast Reconstr Aesthet Surg*. 2014;67(4):489-497. doi: 10.1016/j.bjps.2014.01.003 [doi].

11. Erdinc AE, Nanda RS, Dandajena TC. Profile changes of patients treated with and without premolar extractions. *Am J Orthod Dentofacial Orthop*. 2007;132(3):324-331. doi: S0889-5406(07)00497-0 [pii].

12. Drobocky OB, Smith RJ. Changes in facial profile during orthodontic treatment with extraction of four first premolars. *Am J Orthod Dentofacial Orthop*. 1989;95(3):220-230. doi: 0889-5406(89)90052-8 [pii].

13. Bishara SE, Cummins DM, Jakobsen JR, Zaher AR. Dentofacial and soft tissue changes in class II, division 1 cases treated with and without extractions. *Am J Orthod Dentofacial Orthop*. 1995;107(1):28-37. doi: S0889-5406(95)70154-0 [pii].

14. Bravo LA. Soft tissue facial profile changes after orthodontic treatment with four premolars extracted. *Angle Orthod*. 1994;64(1):31-42. doi: 10.1043/0003-3219(1994)0642.0.CO;2 [doi].

15. Bowman SJ, Johnston LE,Jr. The esthetic impact of extraction and nonextraction treatments on caucasian patients. *Angle Orthod*. 2000;70(1):3-10. doi: 10.1043/0003-3219(2000)0702.0.CO;2 [doi].

16. Kocadereli I. Changes in soft tissue profile after orthodontic treatment with and without extractions. *Am J Orthod Dentofacial Orthop*. 2002;122(1):67-72. doi: S0889540602000367 [pii].

17. Tweed CH. A philosophy of orthodontic treatment. *Am J Orthod*. 1945;31(2):74-103.

18. Proffit WR. Forty-year review of extraction frequencies at a university orthodontic clinic. *Angle Orthod*. 1994;64(6):407-414. doi: 10.1043/0003-3219(1994)0642.0.CO;2 [doi].

19. Case CS. The question of extraction in orthodontia. *Am J Orthod*. 1964;50(9):660-691.

20. Shafiee R, Korn EL, Pearson H, Boyd RL, Baumrind S. Evaluation of facial attractiveness from end-of-treatment facial photographs. *Am J Orthod Dentofacial Orthop*. 2008;133(4):500-508. doi: 10.1016/j.ajodo.2006.04.048 [doi].

21. Spyropoulos MN, Halazonetis DJ. Significance of the soft tissue profile on facial esthetics. *Am J Orthod Dentofacial Orthop*. 2001;119(5):464-471. doi: S0889-5406(01)74498-8 [pii].

22. Bishara SE, Jakobsen JR. Profile changes in patients treated with and without extractions: Assessments by lay people. *Am J Orthod Dentofacial Orthop*. 1997;112(6):639-644. doi: S0889-5406(97)70229-4 [pii].

23. Zierhut EC, Joondeph DR, Artun J, Little RM. Long-term profile changes associated with successfully treated extraction and nonextraction class II division 1 malocclusions. *Angle Orthod*. 2000;70(3):208-219. doi: 10.1043/0003-3219(2000)0702.0.CO;2 [doi].

24. Todd SA, Hammond P, Hutton T, Cochrane S, Cunningham S. Perceptions of facial aesthetics in two and three dimensions. *Eur J Orthod*. 2005;27(4):363-369. doi: cji024 [pii].

25. Stebel A, Desmedt D, Bronkhorst E, Kuijpers MA, Fudalej PS. Rating nasolabial appearance on three-dimensional images in cleft lip and palate: A comparison with standard photographs. *Eur J Orthod*. 2015. doi: cjv024 [pii].

26. Foster EJ. Profile preferences among diversified groups. *Angle Orthod*. 1973;43(1):34-40. doi: 10.1043/0003-3219(1973)0432.0.CO;2 [doi].

27. Ludlow JB, Gubler M, Cevidanes L, Mol A. Precision of cephalometric landmark identification: Cone-beam computed tomography vs conventional cephalometric views. *Am J Orthod Dentofacial Orthop*. 2009;136(3):312.e1-10; discussion 312-3. doi: 10.1016/j.ajodo.2008.12.018 [doi].

28. Zhao Y, Nguyen M, Gohl E, Mah JK, Sameshima G, Enciso R. Oropharyngeal airway changes after rapid palatal expansion evaluated with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2010;137(4 Suppl):S71-8. doi: 10.1016/j.ajodo.2008.08.026 [doi].

Vita

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