Original Article

Analysis of smile esthetics in American Board of Orthodontic patients

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ABSTRACT

Objective: To investigate the common denominators of an esthetically pleasing smile in patients who were considered to be successfully treated upon the submission to American Board Orthodontics (ABO) clinical examination.

Material and Methods: A total of 462 patients were examined. Ninety subjects that fulfilled the inclusion criteria were included. Standardized digital smile photographs of the subjects were rated by 30 panel members, including orthodontists, general dentists, and parents of orthodontic patients, using a numeric version of the visual analog scale. Three groups were formed using the mean esthetic score ± standard deviation range: unattractive (n = 21), average (n = 47), and attractive (n = 22) smiles. Eleven smile characteristics were digitally measured on the photographs and compared between the groups using one-way analysis of variance and χ^2 tests. Additionally, regression analyses were used to investigate the association of the smile characteristics with the esthetic score.

Results: A significant difference was found between the three groups for the comparison of smile arc relationship ($P < .001$). When all the variables used in this study were entered in the regression analysis, a positive association was found ($r = 0.658$; $r^2 = 0.434$; $P < .001$). Additionally, two models were defined using stepwise regression. The first model included the smile arc ($r = 0.478$; $r^2 = 0.228$; $P < .001$), and the second model had both the smile arc and right gingival display/visible dentition display ratio ($r = 0.567$; $r^2 = 0.321$; $P < .001$).

Conclusions: A harmonious smile arc relationship and less gingival display during a smile are significantly associated with smile attractiveness in patients considered successfully treated according to ABO standards. (*Angle Orthod.* 2014;84:486–491.)

KEY WORDS: Smile esthetics; ABO; Smile arc; Gingival display; Buccal corridors

INTRODUCTION

The success of orthodontic treatment can be determined by various objective measures. However, society and patients predominantly focus on the final esthetic outcome,[1] which can be quite subjective to judge. Therefore, numerous clinical and experimental studies have attempted to define how an esthetically pleasing smile can be achieved after orthodontic treatment. As a result, buccal corridors,[2–5] smile arc,[6,7] incisor protrusion,[1,8] and gingival display[1,9] have commonly been cited as the potential characteristics that influence the esthetic outcome of an orthodontically treated patient. Our current knowledge suggests that alterations in these variables directly affect a person's esthetic perception.

In the United States, the American Board of Orthodontists (ABO) developed the Objective Grading System (OGS)[10] as a valid and reliable index to evaluate the posttreatment occlusal outcome. The components of the OGS are based on evaluations made on dental casts and panoramic radiographs and are used in the clinical part of the board-certification process. Although board certification is not required for orthodontists to practice,[11] it is almost a necessity today for calibration and technical acuity considering the increasing number of orthodontists in the country. Although OGS has been a great tool integrated into

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clinical practice, a well-designed study by Schabel et al.[12] demonstrated only extremely weak relationships among all factors of the OGS and smile esthetics. Furthermore, both the total score and the individual components of the index failed to predict whether the smiles were attractive or not.

Plaster models and panoramic radiographs are not valuable information when judging complex facial features and the smile itself. Moreover, Ackerman et al.[13] suggested that not all successfully treated orthodontic patients with excellent occlusal relationships and exemplary plaster models have acceptable esthetics during smiling. Accordingly, as orthodontists in the United States are striving to treat their patients according to the ABO standards from the beginning of their clinical training, additional information is required to differentiate between attractive and unattractive smiles that possess board-quality occlusal outcomes. Therefore, the objective of the present study was to investigate the common denominators of an esthetically pleasing smile in patients who were considered successfully treated upon the submission to ABO clinical examination.

MATERIALS AND METHODS

Institutional Review Board approval was obtained for the study under the exempt status. The study subjects were recruited from the University of Texas at Houston School of Dentistry Graduate Orthodontic Clinic and were all treated between the years 2001 and 2012. Buccal corridor relationship was used for sample size calculation because of its questionable variability in a given sample of actual subjects.[14] Based on a pilot study evaluating the differences between three groups of varied buccal corridor ratios, an effect size of 0.41 was estimated. Using the G*Power 3.1[15] statistical program, (Heinrich Heine Universitat Dusseldorf Institute Experimentelle Psychologie, Dusseldorf, Germany) we determined a total sample size of 69 was required to detect this effect with 85% power and a significance level of $P < .05$. A total of 462 patients successfully treated by ABO standards were examined. The following criteria were used for inclusion in the study: age 14 to 24 years, Angle Class I or II malocclusions before treatment, no craniofacial anomalies and missing teeth, no evident asymmetry, treatment with 0.022'' slot full-fixed edgewise appliances, and a complete set of records including a full frontal smile photograph. Ninety subjects who fulfilled the criteria were included in the study. Total treatment times were between 1.8 and 2.2 years with an average of 2.01 years. The total scores of the OGS ranged from 11 to 23 in the study sample.

All photographs were taken at an object-to-lens distance of 30 inches with a Canon EOS SLR digital camera (Canon USA Inc, Lake Success, NY) in JPEG file format. To ensure natural head posture, patients were instructed to look through a point at their eye level during image capture. Adobe Photoshop CS5, Ver 12.0x64, (Adobe Systems Inc, San Jose, CA) was used to edit the photographs. A 2×3 standardized template was used to crop the images, leaving a proportionate area around the lips. Skin areas were edited to remove irregularities and/or blemishes to avoid any distraction during the evaluation process. The images were then converted to black and white and copied to slides in PowerPoint for Mac 2011 Ver 14.2.5, (Microsoft, Redmond, WA) for evaluation.

The evaluation panels consisted of 10 parents, 10 general dentists, and 10 orthodontists with equal gender distribution in the groups. The ages of the panel members ranged from 40 to 62 years with a mean of 51.3 years. The panel members were asked to evaluate smile attractiveness using a segmented numeric version of the visual analog scale in which a respondent selects a whole number (0–10 integers in which 0 = least attractive and 10 = most attractive) that best reflects their choice. The evaluation time was 20 seconds for each slide, and panel members were allowed to go back and revise their scores at the end.

Eleven characteristics (Table 1) were evaluated digitally on frontal smile photographs. Image Tool for Windows version 3.00 (UTHSCSA, San Antonio, TX) was used for the measurements. A demonstration of the measurements used in this study is shown in Figure 1. Spatial measurements were calibrated by drawing a line of known length (width of the central incisors). The same examiner repeated all measurements after 3 or 4 weeks for testing intraexaminer reliability.

Statistical Analysis

All of the statistical tests were performed using SPSS for Mac (version 21, IBM, Armonk, NY). Pearson product-moment correlation coefficients (Pearson's r) were used to determine the agreement between the panel groups. There was a significant correlation between the ratings of each possible pair of panel groups with a mean $r(88) = 0.86$ ($P < .05$). Therefore, the ratings of the panels were pooled ($n = 30$) for the rest of the analysis. The reproducibility of the evaluation process was evaluated by asking all panel members to reevaluate 10 randomly selected images at 1-month intervals using intraclass correlation (ICC) analysis.

Three groups were formed using the mean esthetic score ± standard deviation range: unattractive ($n = 21$), average ($n = 47$), and attractive ($n = 22$) smiles. One-way analysis of variance (ANOVA) was used to compare

Table 1. Definitions of the Smile Esthetics Variables Used in the Study

Variables	Definition
Visible incisor height / Smile height ratio (%)	Visible height of the maxillary central incisor / Vertical height of the smile between the upper and lower lips measured ay the contact point of maxillary central incisors
Smile arc (consonant, nonconsonant)	Presence of a harmonious relationship between the curvature of the lower lip to the curvature of the maxillary incisor edges and the canine tips during the smile
Smile arc discrepancy / Smile frame (%)	Area of mandibular teeth showing below the curvature of the maxillary incisor edges and the canine tips / Total area between the upper and lower lips during the smile
Gummy smile (present, not present)	Presence of maxillary gingival tissues showing during the smile
Gingival display / Visible dentition display (%)	Area of maxillary gingival exposure between inferior border of upper lip and marginal gingiva of maxillary teeth/ Area of maxillary and mandibular teeth between the lips during the smile
Gingival display (right) / Visible dentition display (%)	Area of maxillary gingival exposure between the inferior border of the upper lip and the marginal gingiva of the maxillary teeth on the right side / Area of maxillary and mandibular teeth between the lips during the smile
Gingival display (left) / Visible dentition display (%)	Area of maxillary gingival exposure between the inferior border of the upper lip and the marginal gingiva of the maxillary teeth on the left side / Area of maxillary and mandibular teeth between the lips during the smile
Visible dentition width / Intercommissure width (%)	Distance between the most lateral left and right points of visible maxillary dentition during smiling / Distance between the left cheilion to right cheilion during smiling
Visible dentition display/ Smile frame (%)	Area of maxillary and mandibular teeth between the lips during the smile / Total area between the upper and lower lips during the smile
Right buccal space/ Visible dentition display (%)	Area inside the corner of the lips and lateral to the visible maxillary and mandibular dentition on the right / Area of maxillary and mandibular teeth between the lips during the smile
Left buccal space / Visible dentition display (%)	Area inside the corner of the lips and lateral to the visible maxillary and mandibular dentition on the left / Area of maxillary and mandibular teeth between the lips during the smile

the numeric variables measured from the smile photos between the groups. A χ^2 test was used to compare the categoric variables. Additionally, linear regression analyses were used to investigate the association of the smile characteristics with the esthetic score.

RESULTS

The test-retest ICC between the first and second rating evaluations was 0.86 (95% confidence interval 0.82–0.94), which indicated a high level of repeatability for the judges. Based on the ratings of the 30 judges, mean and median esthetic scores of the sample group were 6.66 and 6.61, respectively, with a standard deviation of 1.02; these scores were used to form the study groups. Intraexaminer reliability demonstrated a near perfect agreement between the first and second measurements of the study variables (ICCs ranging between 0.92 and 0.99). Table 2 presents the descriptive statistics of the variables investigated in this study for the three groups. One-way ANOVA revealed no significant differences between the groups (Table 2; Figure 2). A χ^2 test demonstrated a significant difference between the three groups for the comparison of smile arc relationship (Table 3; $P < .001$).

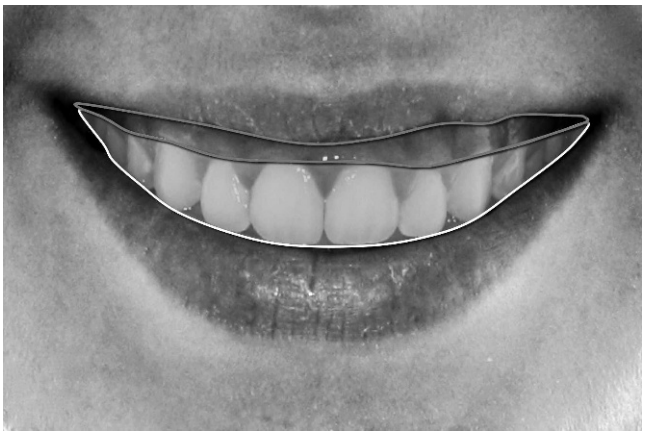

Figure 1. The measurements used in the study: gingival tissue area divided by the area of maximum visible dentition.

When all the variables used in this study were entered in the regression analysis, a positive association was found ($r = 0.658$; $r^2 = 0.434$; $P < .001$), which could only explain 43% of the esthetic score variance. Additionally, two models were defined using the stepwise technique. The first model included the smile arc ($r = 0.478$; $r^2 = 0.228$; $P < .001$), and the second model had both the smile arc and right gingival display/visible dentition display ratio ($r = 0.567$; $r^2 = 0.321$; $P < .001$).

Table 2. Mean Values of the Smile Esthetic Variables in the Study Groups

Variables	Attractive Smiles (n = 22)		Average Smiles (n = 47)		Unattractive Smiles (N = 21)		
	Mean	SD	Mean	SD	Mean	SD	*P*
Visible incisor height / Smile height ratio (%)	78.7	12.2	76.0	12.2	72.2	9.3	.21
Smile arc discrepancy / Smile frame (%)	17.7	3.6	19.0	4.3	19.3	4.5	.89
Gingival display / Visible dentition display (%)	3.8	3.4	7.8	5.6	10.7	6.2	.07
Gingival display (right) / Visible dentition display (%)	1.7	1.8	2.9	2.6	4.6	3.6	.77
Gingival display (left) / Visible dentition display (%)	1.7	1.6	2.9	2.5	3.7	3.2	.87
Visible dentition width / Intercommissure width (%)	82.2	4.7	81.7	3.2	81.2	3.5	.42
Visible dentition display/ Smile frame (%)	93.0	4.5	92.6	3.0	92.4	4.1	.18
Right buccal space/ Visible dentition display (%)	2.4	0.9	3.6	1.1	4.1	1.6	.88
Left buccal space/ Visible dentition display (%)	2.7	0.9	3.4	1.2	3.8	1.2	.87

DISCUSSION

Smile is a complex feature to analyze. Because it is not a fixed concept, esthetic prediction of dynamic facial features upon the completion of the treatment can be a lot harder to judge than any other physical processes. However, clinicians require objective measures and guidance to be able to fully evaluate the outcome of the orthodontic treatment, which commonly starts with esthetic concerns. Although the ABO's OGS was developed to provide clinicians with an objective index for outcome assessment, clinical research[12] in this area clearly demonstrates that OGS criteria have no evident link to the smile. It was, therefore, of interest to us to explore the distinguishing characteristics of the smiles that are perceived as more attractive than others in a sample of patients who were treated according to ABO standards.

The panel members included dental professionals and parents of orthodontic patients. A segmented numeric version of the visual analog scale was preferred as the evaluation method, because high test-retest reliability was observed in both literate and illiterate persons with the use of the segmented numeric version.[16,17] Our initial findings were parallel to that of previous research[1,8,18–20] that reported high similarity in the ratings of the panel groups when evaluating photos of smiles. Therefore, the esthetics scores of the three panel groups were pooled. Based on the ratios used in this study, persons with attractive smiles had more maxillary teeth and more mandibular teeth, gingiva, and buccal corridors showing during a posed smile. However, none of these characteristics showed significant difference between the three groups. This is partly due to the individual variations as our sample comprised real subjects and not

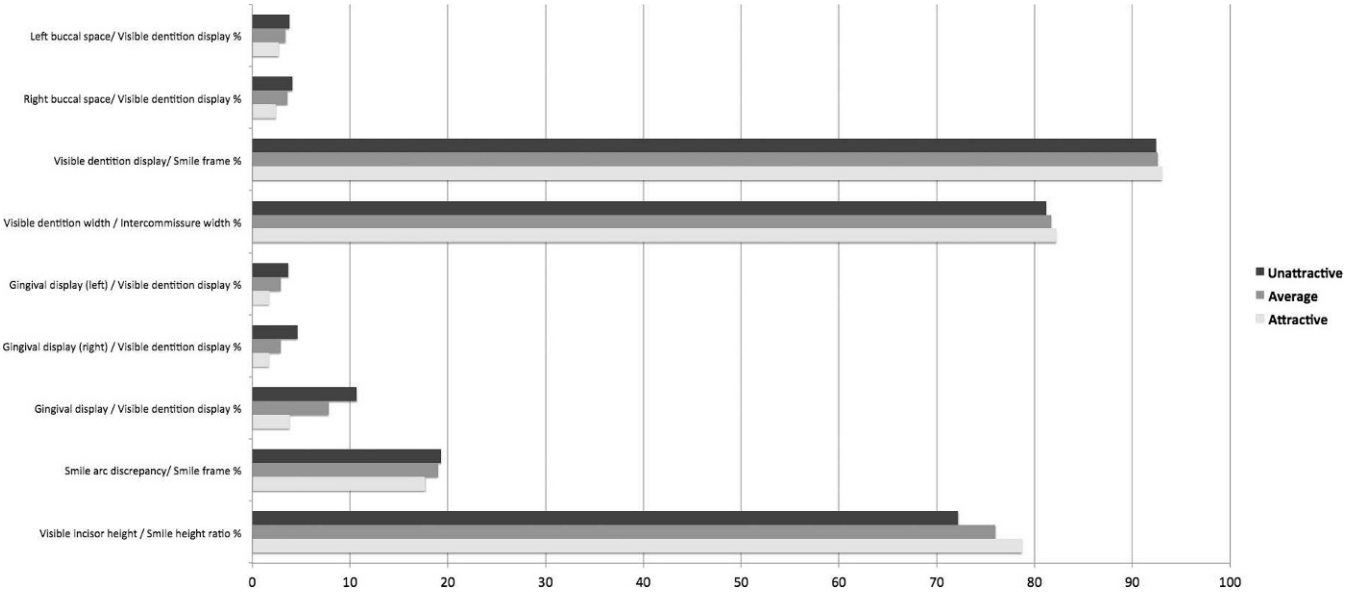

Figure 2. Visual comparison of the mean values in the study groups.

Table 3. Distribution of Categoric Variables in the Groups

Variables	Attractive Smiles (n = 22)		Average Smiles (n = 47)		Unattractive Smiles (N = 21)		*P*
Smile arc	Consonant	Nonconsonant	Consonant	Nonconsonant	Consonant	Nonconsonant	<.001
	18 (81.8%)	4 (18.2%)	21 (44.6%)	26 (55.4%)	4 (19.0%)	17 (81%)	
Gummy smile	Yes	No	Yes	No	Yes	No	.48
	11 (50%)	11 (50%)	27 (57.4%)	20 (42.6)	15 (71.4)	6 (28.6)	

computer-simulated images. A recent systematic review[14] revealed that studies that used digitally altered images bring out more conclusive results than those studies with actual patient photographs in the evaluation of smile characteristics. Moreover, the variables evaluated in this study together were only able to explain 43% of the esthetic score variance in the sample group. It is evident from this finding that other factors also contributed to the esthetic perception of the smiles. For instance, Heravi et al.[21] found that the shape of the maxillary incisors played a significant role in esthetic perception of the smile in a group of laypeople regardless of sex and age. McNamara et al.[8] concluded that vertical lip thickness proved to be the most influential variable in smile esthetics. It may not be possible for orthodontists to control for such variables during the course of the treatment.

Perhaps the most important characteristic affiliated with smile esthetics in our sample was the smile arc relationship. We found that a significant number of persons in the attractive smiles group had consonant smile arc relationships, and most of the persons with unattractive smiles had nonconsonant smiles. This was also supported by the finding that the smile arc was significantly correlated with the esthetic score ($r = 0.478$; $r^2 = 0.228$; $P < .001$) using stepwise regression analysis. In the second model defined by the same analysis, only gingival display/visible dentition ratio for the right side added up to this effect ($r = 0.567$; $r^2 = 0.321$; $P < .001$). Less gingival display enhanced the esthetic score. This finding is in agreement with previously published research.[1,22–24] Although gingival display/visible dentition display and left gingival display/visible dentition display ratio measurements may be equally important, no statistical significance for these variables were demonstrated in the sample, possibly because of the individual variability, for example, slight asymmetry.

Ackerman et al.[13] and Sarver[6] signified the importance of smile arc, which can be best defined as the harmonious relationship between the curvature of the lower lip to the curvature of the maxillary incisor edges and the canine tips during a smile. Although this relationship was significantly associated with the esthetics of the smile in experimental studies,[25,26] McNamara et al.[8] failed to identify a direct relationship in actual patients. However, Schabel et al.[27] found that persons with the most unattractive smiles had a significantly greater distance between the incisal edge of the maxillary central incisors and the lower lip during smiling, which may indicate the presence of a nonconsonant smile. In our study, 81.8% of the persons in the attractive group and only 19% of the persons in the unattractive group had consonant smiles ($P < .001$). Interestingly, the average smile group had an almost equal distribution of consonant and nonconsonant smile arcs. Our results are contrary to the findings of Janson et al.,[14] who claimed that smile arc does not affect smile attractiveness in studies with actual patients.

In smile esthetics, arch form and buccal corridors have gained great interest in the past decade. Although the panel members favored less buccal corridor space in the group of attractive smiles, buccal corridor ratios did not significantly affect the esthetic perception of the posttreatment outcome in our study. It was already shown in a well-designed study[28] that orthodontists and laypeople rated smiles with small buccal corridors as significantly more attractive than those with large buccal corridors. However, Maulik and Nanda[29] revealed that in a group of orthodontically treated and untreated subjects, most demonstrated a buccal corridor ratio of 11%. Similarly, studies[2,4,7] that focused on the acceptable threshold of this variable indicated a significant decrease in the esthetic score when the buccal corridor ratios were altered more than 10%. Based on our calculations, buccal corridor ratios in all three groups evaluated in this study, on the average, are limited to 7% to 8%. This may explain the lack of statistical significance between the three groups of actual patients. Additionally, Chang et al.[5] found that among nine other smile variables, buccal corridor ratios showed the least test-retest reliability in a group of adult model photographs. As argued before, in actual patients it is difficult to judge such relationships as smile discrepancies may be within a tolerable range in contrast to the ranges shown in smiles that are digitally generated.[14]

This study confirms that in any group of subjects, even with the most excellent occlusal relationships, there is individual variability—shape of the teeth, curl of the lips, and mouth expression—that would lead the smile to be perceived as esthetically pleasing or not.[1] Our findings also represent the difficulty of identifying objective parameters to evaluate the esthetics of a dynamic facial trait—the smile using two-dimensional photographs of actual patients. Future studies should

be planned to evaluate smile characteristics using three-dimensional photographs and analyses to confirm the current results and to further expand our knowledge in this field.

CONCLUSIONS

- Esthetic score variance in a group of subjects treated to an excellent occlusal outcome could not be fully explained with all the objective parameters used in this study.
- Harmonious smile arc relationship and less gingival display during a smile are significantly associated with smile attractiveness in orthodontically treated patients who were considered successfully treated upon the submission to ABO clinical examination.

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