ORIGINAL ARTICLE

Subjective vs objective evaluations of smile esthetics

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Introduction: The aim of this study was to analyze the relationships between subjective evaluations of posttreatment smiles captured with clinical photography and rated by a panel of orthodontists and parents of orthodontic patients, and objective evaluations of the same smiles from the Smile Mesh program (TDG Computing, Philadelphia, Pa). **Methods:** The clinical photographs of 48 orthodontically treated patients were rated by a panel of 25 experienced orthodontists and 20 parents of patients. Independent samples *t* tests were used to test whether objective measurements were significantly different between subjects with "attractive" and "unattractive" smiles, and those with the "most attractive" and "least attractive" smiles. Additionally, logistic regression was performed to evaluate whether the measurements could predict whether a smile captured with clinical photography would be attractive or unattractive. **Results:** The comparison between groups showed no significant differences for any measurement. Subjects 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, and a significantly smaller smile index than did those with the "most attractive" smiles. As shown by the coefficients of logistic regression, smile attractiveness could not be predicted by any objectively gathered measurement. **Conclusions:** No objective measure of the smile could predict attractive or unattractive smiles as judged subjectively. (Am J Orthod Dentofacial Orthop 2009;135:S72-9)

The subjectivity of beauty makes it difficult to establish clear-cut esthetic goals for diagnosis and treatment planning. This observation contradicts the historical framework regarding treatment decisions, whereby occlusal relationships and cephalometric measurements were regarded as scientific laws. Although rules that define esthetics rigidly might be difficult to determine, it is possible to formulate general guidelines to optimize dentofacial esthetics (with special regard to the smile) while satisfying other treatment goals.[1,2] These guidelines must consider both subjective and objective methods of evaluation.

In terms of subjective evaluation, esthetic preferences typically are measured by ordinal and interval scales because they represent a rank order of judgment from least preferred to most preferred.[3] Historically, interval scales (eg, visual analog scale), rank-order scales, rating scales, and categorical rating scales (eg, Q-sort) have been used to measure dentofacial attractiveness.[4-6]

One method used to quantify the variables associated with the smile is the Smile Mesh (TDG Computing, Philadelphia, Pa). This program was introduced to the orthodontic community by Ackerman et al[7] to quantify smile characteristics from photographs in a clinical orthodontic setting that capture the so-called "posed social smile." This morphometric tool was created to measure the lip-tooth characteristics of anterior tooth display at 1 time. The Smile Mesh program uses an adjustable grid consisting of vertical and horizontal lines that overlay a smile image that are used to measure various lip-tooth relationships associated with anterior tooth display.

Our aim in this study was to analyze the relationships between subjective evaluations of posttreatment smiles captured with clinical photography and rated by orthodontists and parents of orthodontic patients with the Q-sort method, and objective evaluations of the same smiles from the Smile Mesh program.

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Partly funded by the LeGro Fund and sources made available through the Thomas M. and Doris Graber Endowed Professorship of the University of Michigan.
The authors report no commercial, proprietary, or financial interest in the products or companies described in this article.
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Submitted, August 2007; revised and accepted, October 2007.
0889-5406/$36.00

doi:10.1016/j.ajodo.2007.10.040

Fig 1. A standardized smile image with the 3 × 5-in template.

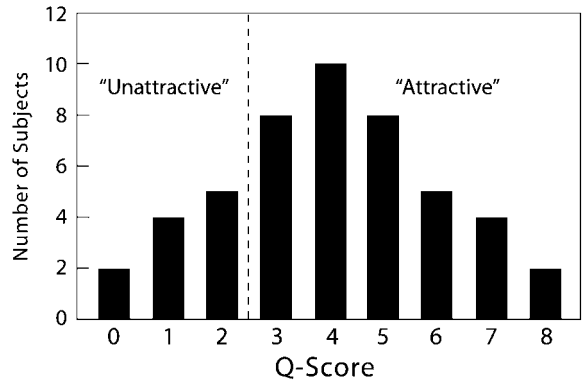

Fig 2. Q-sorting: assignment of scores to the cut-off point used to separate attractive from unattractive smiles. A cut-off line drawn between columns 2 and 3 was given a numeric score of 2.5.

MATERIAL AND METHODS

Our subjects were recruited from the University of Michigan Graduate Orthodontic Clinic during routine posttreatment appointments (final records or retainer check). Each subject (or guardian if a minor) reviewed and signed a consent form created in accordance with the rules and regulations of the Institutional Review Board. Each subject also reviewed and completed a consent form created by the University of Michigan in accordance with the Health Insurance Portability and Accountability Act (HIPAA) for the use and disclosure of protected health information. No subject received compensation for participation.

To be included in the study, each subject had to have the following characteristics: age from 12 to 20 years, white ancestry, orthodontic treatment completed within the last 6 months, no missing or malformed teeth, and a complete set of diagnostic posttreatment records including dental casts, panoramic x-rays, and intraoral and extraoral photographic series of the smile. The protocol for the study required 48 subjects to satisfy the design of the Q-sort. A test was performed to determine the power of this sample size with respect to correlation tests (type I error = 0.05). For a bivariate normal distribution and a sample size of 48, a test of H_0: $\rho = 0$ (ie, the correlation coefficient under the null hypothesis) was found to have a power of 0.80 to detect a linear correlation of $r = 0.38$. Thus, the default sample size for the Q-sort procedure was judged to be adequate for testing for correlation.

An EF 35-mm SLR camera (Canon, Lake Success, NY) was mounted to a frame set at a fixed distance. The camera was connected to a 2-strobe lighting source that illuminated the subject indirectly from a flash that reflected from a photographic umbrella. Before taking the smiling image, the photographer instructed the subject to smile. The reproducibility of the posed smile derived from static photograph was demonstrated by Ackerman et al.[7] Each image was captured on Kodak EV-100 slide film (Eastman Kodak, Rochester, NY). The slides were scanned later by using the Super Coolscan 4000 ED (Nikon, Melville, NY) and imported directly into a commercially available image editing software program (Photoshop version 7.0, Adobe, San Jose, Calif).

A 3 × 5-in template (Fig 1) was created to standardize the size and location of each image. Images were opened in Photoshop, and the template was superimposed on top of the image. The smile images were enlarged until the outer commissures of the lips matched the vertical tick marks inset .75 inch from the border of the template. The images then were positioned so that the maxillary incisal edges coincided with the horizontal line of the template (Fig 1).

After enlarging and positioning the image correctly, the portion of the image outside of the template was cropped. The resulting images were edited further in Photoshop by using the healing brush tool to remove blemishes, skin irregularities, and other extraneous marks that could influence the rater when evaluating the image. Each image was labeled with a 4-digit number from a random number generator. After the number, the still photos were denoted with "p," and those from digital video clips were denoted with "v." Once the editing was complete, each image was compressed to approximately 150 KB and saved as a JPEG file.

Esthetic judgments were given by a panel of raters that included both orthodontists and parents of orthodontic patients. The orthodontic panel comprised 25 full- and part-time orthodontic faculty members from the University of Michigan Graduate Orthodontic Program. This panel included 15 men and 10 women with clinical experience of 1 to 35 years, with an average of 17 years. Their ages ranged from 29 to 64 years, with an average age of 46 years. Sixteen panelists were certi-

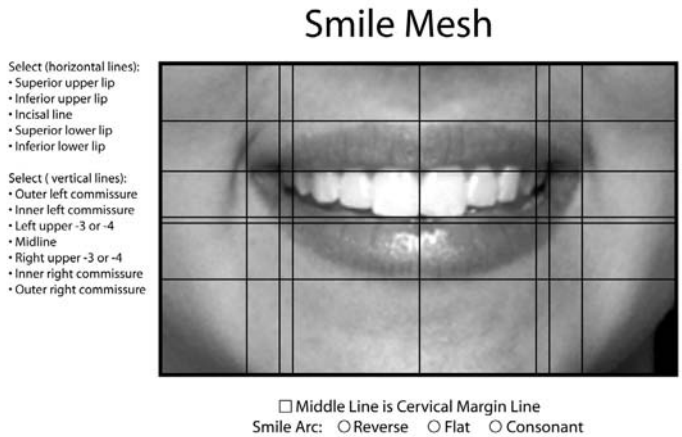

Fig 3. The Smile Mesh program used to measure various lip-tooth relationships of anterior tooth display.

fied by the American Board of Orthodontics. Of the 25 orthodontic raters, 13 were graduates of the University of Michigan, and 2 had received their orthodontic specialty training internationally.

The nonorthodontic panel comprised 20 parents whose children currently were receiving orthodontic treatment at the University of Michigan Graduate Orthodontic Clinic. This panel consisted of 12 women and 8 men whose ages ranged from 36 to 52 years, with an average of 43 years. Of the 20 parent panel members, 9 had undergone orthodontic treatment themselves.

The Q-Sort method originally proposed by Stephenson[8] is an alternative approach that generates a valid 9-category ordinal ranking of large samples based on a variety of subjective criteria. Although originally intended for a sample size of 96, the Q-sort technique has been applied to samples of 48 to rank items according to complex, subjective criteria.[9] The Q-sort method is a progressive forced-choice winnowing of the sample to create a quasi-normal distribution to rate subjects on an esthetic scale from "least pleasing" to "most pleasing."

The panelists were asked to apply the Q-sort technique to rate the attractiveness of the 48 subjects on the smile images captured with clinical photography. Rating sessions for the parents coincided with consecutively scheduled orthodontic appointments; the rating sessions for the orthodontists occurred sporadically over a 2-month period.

Panelists were verbally given the following instructions: (1) from the 48 images, select the 2 least and the 2 most attractive smiles and set them aside; (2) from the remaining 44 photographs, choose the 4 least and the 4 most attractive smile photographs and set them aside; (3) continue this process and set aside 5 and then 8 smile photographs from each extreme; (4) the remaining 10 photos should represent smiles that you consider to have neutral attractiveness from the group; (5) once the Q-sort is completed, survey the distribution and draw a line (cut-off point) between the 2 columns separating unattractive from attractive smiles; and (7) after drawing your line, leave the Q-sort intact to be scored by the principal investigator (B.J.S.).

After the verbal instructions, the panelists were given written instructions to review before beginning. The cut-off point between unattractive and attractive smiles was marked on the distribution located on a written instruction form.

Each of the 9 groups of images was given a score ranging from 0, for the 2 images with the least perceived attractiveness, to 8, for the 2 images with the greatest perceived attractiveness. The scores that each subject received from the various judges were averaged to generate each subject's overall Q-sort score for the smile captured with clinical photography. The assignment of scores to each Q-sort distribution is shown in Figure 2. The x-axis represents the score assigned to each photograph in a group, and the y-axis, the number of subjects. The cut-off point separating the unattractive and attractive images was also given a numeric value. For example, a line drawn between columns 2 and 3 on the Q-sort distribution was given a score of 2.5 (Fig 2), which represented the esthetic boundary for that panel member. The cutoff points received from the various judges were averaged to generate the overall demarcation between attractive and unattractive images.

We used an updated version of the Smile Mesh program to quantify and compare the characteristics of anterior tooth display in attractive and unattractive smiles. Edited

Table I. Characteristics of anterior tooth display from the Smile Mesh program

Smile attribute	*Description*
Maximum incisor exposure	Amount of vertical display of the maxillary central incisors
Upper lip drape	Amount of vertical coverage of the maxillary central incisors by the upper lip (or amount of gingival display)
Lower lip to maxillary incisor	Vertical distance from the incisal edge of the maxillary right central incisor to the deepest midline point on the superior margin of the lower lip
Interlabial gap	Distance between the most inferior portion of the tubercle of the upper lip to the deepest midline point on the superior margin of the lower lip
Visible posterior tooth width	Distance from the most lateral aspect of the most visible maxillary posterior tooth on the right and left sides
Smile width	Distance from the right outer commissure to the left outer commissure
Smile index	Ratio of smile width divided by interlabial gap
Commissure corridor left	Horizontal distance from the left inner commissure to the left outer commissure
Commissure corridor right	Horizontal distance from the right inner commissure to the right outer commissure
Buccal corridor left	Horizontal distance from the most lateral aspect of the left most posterior visible tooth to the left inner commissure
Buccal corridor right	Horizontal distance from the most lateral aspect of the right most posterior visible tooth to the right inner commissure
Buccal corridor ratio	Distance between the most visible maxillary right and left tooth:distance between the right and left inner commissure
Smile arc	Curvature of the incisal edges of the maxillary incisors, canines, and first premolars relative to the curvature of the lower lip
Upper lip thickness	Vertical distance from the most superior margin of the upper lip to the most inferior portion of the tubercle of the upper lip
Lower lip thickness	Vertical distance from the deepest midline portion of the superior margin of the lower lip to the most inferior portion of the lower lip

Table II. Descriptive statistics for the Smile Mesh measurements in the 48 subjects

Smile Mesh measurements	*Mean*	*SD*	*Range*	
			Minimum	*Maximum*
Maximum incisor exposure (mm)	8.5	1.5	4.5	10.9
Upper lip drape (mm)	0.9	1.9	–3.2	5.9
Lower lip to maxillary incisor (mm)	3.0	1.9	0.0	9.37
Interlabial gap (mm)	11.9	2.9	4,5	20.7
Visible posterior tooth width (mm)	49.5	4.2	37.3	58.2
Smile width (mm)	60.0	5.0	46.2	68.5
Smile index (mm)	5.3	1.6	2.9	12.6
Commissure corridor left (mm)	5.3	1.8	1.8	8.9
Commissure corridor right (mm)	5.0	1.6	2.5	8.3
Buccal corridor left (mm)	5.0	1.6	2.8	9.8
Buccal corridor right (mm)	4.5	1.3	2.6	8.5
Buccal corridor ratio	0.8	0.0	0.7	0.9
Upper lip height (mm)	7.4	1.8	3.7	10.8
Lower lip height (mm)	10.1	1.8	6.7	15.4

smile images captured with clinical photography of each of the 48 subjects were scanned into the Smile Mesh program. The height and width of the maxillary right central incisor for each corresponding image was entered into the program before starting. Two adjustable vertical lines, superimposed on the smile image, were moved to correspond with the mesial and distal borders of the right central incisor to enable a computer-generated algorithm to calibrate the smile measurements to actual life size.[10-12] The Smile Mesh consisted of an adjustable grid system of 7 vertical lines and 5 horizontal lines that were superimposed on the smile image. These lines were adjusted to correspond with specific hard- and soft-tissue landmarks (Fig 3). The Smile Mesh then generated 15 lip-tooth characteristics associated with anterior tooth display (Table I).

Statistical analysis

Means, standard deviations, and ranges were calculated for the Smile Mesh measurements of all subjects. Independent samples *t* tests were used to test whether the objective measurements were significantly different between subjects with attractive and unattractive smiles, and subjects with the most attractive and least attractive smiles. Additionally, logistic regression was performed to evaluate whether the Smile Mesh measurements could predict whether a smile captured with clinical photography would be attractive or unattractive.

The type I error rate for all statistical tests was set at 0.05. All statistical tests were performed with statistical software (version 12.0, SPSS for Windows, Chicago, Ill).

RESULTS

Descriptive statistics for the Smile Mesh measurements are reported in Table II. Standard descriptive statistics for Smile Mesh for subjects with attractive and

Table III. Independent samples *t* test between the Smile Mesh measurements for subjects with attractive and unattractive smiles

	Attractive (n = 31)		*Unattractive (n = 17)*		
Smile Mesh measurements	*Mean*	*SD*	*Mean*	*SD*	P *value*
Maximum incisor exposure (mm)	8.6	1.6	8.5	1.4	0.82
Upper lip drape (mm)	1.1	1.9	0.6	2.0	0.47
Lower lip to maxillary incisor (mm)	2.9	2.1	3.2	1.5	0.56
Interlabial gap (mm)	11.7	3.2	12.2	2.4	0.63
Visible posterior tooth width (mm)	49.9	4.0	48.6	4.6	0.30
Smile width (mm)	59.4	4.9	58.3	5.3	0.48
Smile index (mm)	5.5	1.7	5.0	1.2	0.33
Commissure corridor left (mm)	5.2	1.7	5.4	2.0	0.65
Commissure corridor right (mm)	5.1	1.6	4.9	1.5	0.59
Buccal corridor left (mm)	4.9	1.5	5.2	1.7	0.58
Buccal corridor right (mm)	4.5	1.3	4.5	1.4	0.99
Buccal corridor ratio	0.8	0.0	0.8	0.0	0.53
Upper lip height (mm)	7.4	1.8	7.5	1.8	0.93
Lower lip height (mm)	10.0	1.7	10.1	2.0	0.86

unattractive smiles, and subjects with the most attractive and least attractive smiles are summarized in Tables III and IV, respectively. These tables also describe the statistical significance of between-group independent *t* tests. The most attractive and least attractive smiles represent the 11 smile images captured with clinical photography that were rated at the extremes of the normal Q-sort distribution (ie, the 26 smile images with an average Q-sort score around the central tendency were excluded). The 11 most attractive and the 11 most unattractive smiles are shown in Figures 4 and 5.

Of the 31 subjects with attractive smiles, 14 were male and 17 were female. Thirteen patients had extractions of at least 2 premolars during orthodontic treatment, and 18 were treated nonextraction. Of the 11 subjects with the most attractive smiles, 5 were male, 6 were female, 5 had extractions of at least 2 premolars, and 6 were treated nonextraction. These differences were not statistically significant. The comparison between attractive and unattractive groups did not show significant differences for any Smile Mesh measurement (Table III). Subjects 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, and a significantly smaller smile index than those with the most attractive smiles (Table IV).

The coefficients for the logistic regression equations with "attractive" or "unattractive" smiles as the dependent variable and each Smile Mesh measurement as the predictor are summarized in Table V. Smile attractiveness could not be predicted by any Smile Mesh measurement.

DISCUSSION

The contemporary reemergence of the so-called esthetic paradigm in orthodontics has resulted in greater emphasis on facial esthetics. We focused on the smile and the interplay between hard- and soft-tissue components of the smile (objective evaluation) and smile attractiveness (subjective evaluation).

Some methodologic remarks need to be made before discussing our findings. The Q-sort technique was used because a previous study indicated higher reliability for this method than the visual analog scale when analyzing the esthetics of the smile.[13] The same investigation reported that orthodontists and parents of orthodontic patients agree about attractive and unattractive smiles. Therefore, the 2 different panels of raters were pooled in our study for the evaluation of smile attractiveness.

Logistic regression showed that none of the Smile Mesh measurements could predict whether a smile was attractive or unattractive. Also the direct comparison between attractive and unattractive smiles failed to find any significant differences between the 2 groups of subjects. Interestingly, however, the comparison of the 11 smiles considered most attractive and the 11 smiles classified as most unattractive (Figs 4 and 5) had significant differences for 2 objective measurements of the Smile Mesh analysis. Smiles with a greater distance between the incisal margin of the maxillary incisors and the lower lip were considered the most unattractive. In other words, these subjects showed at least part of the crowns of the mandibular incisors in their posed smiles. This result agrees with Zachrisson,[14] who described the greater display of mandibular teeth as an unattractive characteristic of aging. The second significant variable of the Smile Mesh analysis was the smile index, with the most unattractive smiles characterized by a significantly smaller value for this measurement (ratio of smile width divided by the interlabial gap). There-

Table IV. Descriptive statistics and significance of mean differences of the Smile Mesh measurements of subjects with the most and least attractive smiles

	Most attractive (n = 11)		*Least attractive (n = 11)*		
Smile Mesh measurements	*Mean*	*SD*	*Mean*	*SD*	P *value*
Maximum incisor exposure (mm)	8.6	2.0	8.7	1.6	0.90
Upper lip drape (mm)	1.3	1.8	0.2	1.9	0.18
Lower lip to maxillary incisor (mm)	1.8	2.7	4.1	2.1	0.04*
Interlabial gap (mm)	10.4	4.2	13.3	2.7	0.07
Visible posterior tooth width (mm)	48.6	5.4	48.9	4.5	0.91
Smile width (mm)	58.6	5.9	58.6	5.3	0.99
Smile index (mm)	6.3	2.4	4.5	1.0	0.03*
Commissure corridor left (mm)	6.1	1.6	5.0	1.7	0.14
Commissure corridor right (mm)	5.5	1.7	4.7	1.4	0.24
Buccal corridor left (mm)	5.1	1.4	5.1	2.0	0.96
Buccal corridor right (mm)	4.9	1.4	4.7	1.6	0.76
Buccal corridor ratio	0.8	0.0	0.8	0.1	0.81
Upper lip height (mm)	7.7	1.7	7.5	1.8	0.72
Lower lip height (mm)	10.0	1.7	10.6	2.1	0.42

*$P < 0.05$.

Table V. Logistic regression: regression coefficients (B) and probabilities (P) for the Smile Mesh measurements with attractive and unattractive smiles as the dependent variables

Smile Mesh measurements	*B*	*SE (B)*	P
Maximum incisor exposure (mm)	0.05	1.05	0.81
Upper lip drape (mm)	0.12	1.13	0.46
Lower lip to maxillary incisor (mm)	–0.10	0.91	0.55
Interlabial gap (mm)	–0.05	0.95	0.62
Visible posterior tooth width (mm)	0.08	1.08	0.29
Smile width (mm)	0.04	1.05	0.47
Smile index	0.24	1.27	0.33
Commissure corridor left (mm)	–0.08	0.92	0.64
Commissure corridor right (mm)	0.11	1.11	0.58
Buccal corridor left (mm)	–0.11	0.90	0.57
Buccal corridor right (mm)	0.00	1.00	0.99
Buccal corridor ratio	0.09	0.90	0.52
Upper lip height (mm)	–0.02	0.99	0.93
Lower lip height (mm)	0.03	0.97	0.86

fore, subjects with excessive height of the smile or deficient smile width were considered most unattractive. These 2 findings are concordant, in that an excessive interlabial gap can be the consequence or the cause of excessive exposure of the mandibular dentition in the posed smile. Additionally, the excessive interlabial distance could reflect excessive gingival display, an aspect that was described as a determinant of unattractive smiles.[15] Moreover, from visual inspection of the 2 groups, it appears that symmetry or asymmetry of the smile might play a role in smile attractiveness. Seven of the 11 least attractive smiles were definitely asymmetric, whereas only 2 of the most attractive smiles were asymmetric. The issue of symmetry of the smile in relation to esthetics should be investigated further.

In a previous study that used the Smile Mesh program to evaluate the esthetic determinants of the smile in growing patients before treatment, McNamara et al[16] found that fuller lips were associated with more attractive smiles, thus focusing on the role of the lips in the evaluation of the smile. Our study, performed on post-treatment records, did not corroborate these findings. It could be speculated that aligned teeth after orthodontic treatment attracted the attention of raters more than the features of the lips, whereas the lips played a major role in the overall esthetics of the smile in subjects who needed orthodontic treatment. As in the studies by McNamara et al[16] and Ritter et al,[17] we did not find that smaller buccal corridor widths were correlated with a more pleasant smile, as stated in previous reports.[18-20] However, studies that reported a significant effect of buccal corridors on smile esthetics featured an analysis of smile attractiveness based on computerized variations of smile characteristics.

The subjectivity of esthetics has led to conflicting reports regarding the influence of specific characteristics of anterior tooth display on the esthetics of the smile. This study was not an exception to this rule. Only when analyzing extreme cases in terms of smile esthetics was it possible to identify some associations between certain smile variables and smile attractiveness.

CONCLUSIONS

The findings of this investigation showed the following.

1. Mean differences of the Smile Mesh measurements between subjects with attractive or unattractive smiles were not significant.
2. Extremely unattractive smiles were characterized by a greater distance between the incisal margin of the

Fig 4. The 11 most attractive smiles.

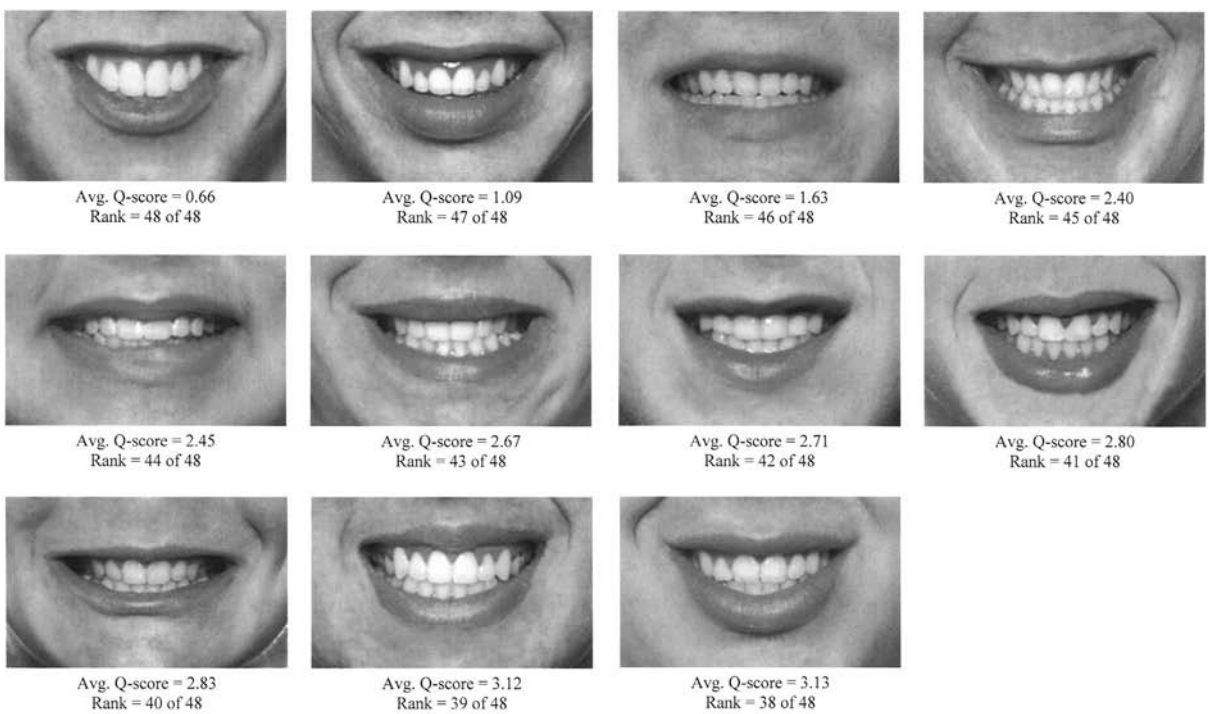

Fig 5. The 11 most unattractive smiles.

maxillary incisors and the lower lip, and by excessive height of the smile or deficient smile width.

3. No Smile Mesh measurement could predict an attractive or unattractive smile.

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