Smile Esthetics from the Patients' Perspective

A Thesis
Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of The Ohio State University

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2010

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Abstract

Computer-based smile esthetic surveys based on emoticon (slider) technology allow control of variables and the possibility of obtaining continuous data. However, differences in the perception of smiles using different facial perspectives have not been resolved. **Objectives**: To quantify the ideal values and the range of acceptability for specific smile variables judged by laypersons from a full face perspective for comparison to lower face data. **Methods**: Ninety-six laypersons judged each smile variable that was digitally embedded in mirrored and symmetric male or female full faces, which had previously been determined by peers to be of average attractiveness. Smile arc, buccal corridor fill, maxillary gingival display, maxillary midline to face, maxillary to mandibular midline discrepancy, overbite, central incisor gingival margin discrepancy, maxillary anterior gingival height discrepancy, incisal edge discrepancy and cant were manipulated by the raters using emoticon technology that allowed the variable to morph and appear continuous on a computer monitor. Medians for each smile variable were compiled and Fleiss-Cohen weighted kappa statistic was used to measure reliability. Multiple randomization tests with adjusted p-values were used to compare these data with those for lower face views. **Results**: Reliability ranged from 0.25 for ideal overbite to 0.60 for upper midline to face, except in the case of the buccal corridor limits, which each had a K_W near 0. There were no statistically significant differences between ratings for the male and female raters. The following variables showed statistically significant differences when compared with the lower face view: ideal smile arc, all 3 buccal corridor measures, gingival display up and down, U to L midline, minimum overbite, lateral gingiva up and down, maximum and ideal lateral step, and occlusal cant. In all but 5 cases (ideal smile arc, ideal buccal corridor, maximum gingival display, upper to lower midline and occlusal cant), these differences were not considered to be clinically meaningful due to the small magnitude of the differences (less than 1 mm) and therefore similar to the lower face perspective. While the smile arc numbers differed from those found with the lower face perspective due to a model with different lip curvature, the principle of tracking the curve of the lower lip was consistent for both perspectives. For the full face view, raters preferred less maximum gingival display than the lower face rater by several millimeters. Full face raters favored less buccal corridor than lower face raters, and allowed more upper to lower midline discrepancy. The full face raters allowed less cant of the occlusal plane than the lower face raters. **Conclusion**: Reliability was fair to moderate with the exception of the buccal corridor limits. Most variables showed no clinically meaningful differences from the lower face view. The acceptable range is quite large for most variables. Detailed knowledge of the ideal values of the various variables is important and can be incorporated into orthodontic treatment to produce an optimal esthetic smile.

Dedicated to my family

Acknowledgements

I would like to thanks my thesis committee, Dr. Henry Fields, Dr. Mike Beck, Dr. Stephen Rosenstiel, and Dr. Allen Firestone for their support and guidance. Dr. Fields was a pleasure to work with and was an excellent advisor for my research.

I would like to thank my classmates of the Class of 2010: Matthew Ames, Nathan Helm, Sahira Kortam, Latisha Randall, and Dan Walton. I couldn't have asked for a better group to work with, and I'm proud to be associated with them.

I would like to thank Dr. Rich Chan, Dr. AJ Kerr and Dr. Jay Parekh for their work which preceded this project. Many of the images and much of the design of the study came from their work.

I would like to thank Dr. Chan Chang for her help and dedication to the project. I couldn't have done it without her.

I would like to thank the Delta Dental Masters Thesis Award Program for funding the project. This research would not have been possible without Delta Dental's support.

Finally, I thank my family for their love and support through all of the time I've spent with my research.

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Chapter 1

Introduction

Facial and dental esthetics have been documented to affect people's perception of others and have impact on some forms of quality of life.[1,2]

In the last decade there has been a movement to consider esthetics as a critical focus in diagnosis and treatment planning in orthodontics.[3] Until recently, little objective information has been available on how different variables affect the perception of esthetic smiles.

Kokich et al.[4] renewed and revived the movement to quantify these issues using digital modification of oral images. Newer tools are now available to digitally present images and control variables[5, 6] that had not been previously available.

Among important issues that remain to be studied is the effect that various perspectives, lower face or full face, can have on perceptions of variables related to smile esthetics.

Comprehensive literature review and statement of the problem

Facial and dental esthetics make a difference in people's lives. Shaw[1] studied the relationship between dental and facial esthetics and believed it was a factor in social success. He used a frontal full head photograph of two boys and two girls, with an attractive and unattractive model chosen for each gender. He then altered (without a computer!) the images so that he had a series of five photographs for each face: normal incisors, prominent incisors, missing upper lateral incisor, severely crowded incisors, and unilateral cleft lip. Each photo was shown to 42 different children (age 11-13) and they were asked a series of questions including these, “If this boy (girl) was coming to your class, do you think you would like him (her) for a friend?” and “Do you think that this boy (girl) is good looking?”

The same photos were each shown to 42 different adults and questions in addition to these were asked, “Do you think that this boy (girl) would attract friends easily?” and “Do you think that this boy (girl) would be intelligent?” The results from this study showed that photographs of children with a normal dental appearance were judged to be more attractive, less aggressive, more intelligent, and more likely to be good friends. Shaw was concerned that poor dental/facial esthetics could prove to be socially handicapping, and even drag children into a spiral of self-fulfilling prophecy as to their lack of social skills. Clearly, dental esthetics makes a difference.

Kiyak[2] recently reviewed the effects of orthodontic treatment on patients’ quality of life. She indicated that patients who seek orthodontic treatment wish to improve their esthetics and social acceptance more than oral function or general health. She discussed the importance of facial attractiveness on interpersonal success in settings such as school and employment. She referred to a meta-analysis[7] that concluded that attractive children and adults receive more positive judgments and academic and performance reviews than do unattractive individuals. This results in greater self-confidence among attractive individuals. The appearance of the teeth and the smile are essential components of facial attractiveness.[2] She also reported results of pre and post orthodontic self-assessments completed by children receiving interceptive orthodontic treatment. They showed significant improvements in the facial image and teeth sub scores, even though their overall body image score was unchanged. Her conclusion was that orthodontic patients experience a real improvement in esthetics and function, with social change not as significantly affected.

Havens et al.[8] showed raters 6 different photographs to investigate the role of the smile in overall facial esthetics - 3 pretreatment and 3 post-treatment. They showed a close up of the smile (lower face), a full face photo with the smile area blocked out, and an unblocked full face photo, for both pre and post treatment. The pretreatment full face photo was ranked as less attractive than the full face with the smile blocked, showing that the malocclusion detracted from the facial attractiveness. This difference was not seen in the post-treatment photos, indicating that correction of the malocclusion brought the smile into harmony with the rest of the face. With the improvement in the smile, the post-treatment photos were judged to be more attractive than the pretreatment photos.

There are data to demonstrate how much dental esthetics contributes to facial esthetics. Kiekens et al.[9] showed that dental esthetics only contributed 25% to overall facial esthetics. Even adding in a horizontal measure (in an A-P direction) only increased the explained variance to 31%. This means than 69% of the variance was due to other facial features, such as eyes, hair, and skin. Indeed, Hickman et al.[10] reported in their eye tracking study that less than 10% of the viewer's visual attention was directed towards the mouth, even when smiling. Study participants viewed the eyes and nose more than the mouth. Dunn et al.[11] found that tooth color was the most important factor in smile attractiveness, more than the number of teeth displayed, presence of an unrestored dentition, the lip height, or symmetry of the lips.   McNamara et al.,[12] using the Smile

Mesh, showed the vertical thickness of the lips to be the most important variable in smile esthetics. Havens et al.[8] calculated a rank list of the importance of several different facial characteristics. The layperson rank list was quite similar to the orthodontist list. Overall harmony and tooth alignment were at the top of both lists, and hair and skin were at the bottom of both lists. Kokich et al.,[4] on the other hand, showed that the most noticeable dental or perioral feature to orthodontists and dentists, tooth position, was ranked quite low for laypersons, who listed hairstyle as the most noticeable. It appears that the oral area does contribute to overall facial esthetics, but that it is not paramount in all features presented to the viewer or rater.

Sarver and Ackerman[3] spearheaded a dramatic shift in orthodontics with their article on the re-emergence of the esthetic paradigm. They argued that esthetic considerations are of principal importance in orthodontic treatment planning, and that there are no rigid rules to guide us in achieving an esthetic outcome. They went on to propose guidelines for optimization of facial esthetics in orthodontic treatment. These guidelines included a careful clinical facial evaluation, determination of anterior tooth to lip relationships, and consideration for the effect of dental and skeletal volume on the soft tissue “mask.” They stated that cephalometrics cannot be used to evaluate facial esthetics, and expressed hope that the profession would be able to develop tools to measure the hard and soft tissue factors that are responsible for oral and facial esthetics.

Sarver[13] was also at the forefront of a returned attention to the smile arc and many other mini esthetic details such as anterior tooth proportionality, contacts, connectors, embrasures, and gingival contours[14]. Many of these variables do not have concrete objective data to pinpoint the ideals.

He re-emphasized the definition of the smile arc as the relationship of the curve of the incisal edges of the upper anterior teeth to the curve of the lower lip on a posed smile. He also advocated the ideal smile arc to be when the incisal edges of these teeth parallel the lower lip when smiling. He explained how orthodontic treatment can adversely affect the smile arc in some cases, and showed how consideration for the smile arc can be built in to diagnostic and clinical applications so that it is optimized during treatment.

Sarver[15] also offered some suggestions for ideals in smile esthetics. He set 80% as the ideal width to height ratio of the upper central incisors, while admitting that there is some disagreement on this ratio. He said that the connectors (the area in which the anterior teeth appear to touch) should be about 50% between the maxillary central incisors, and then decrease posteriorly; while the embrasure space (black triangles) should increase posteriorly. While these are good starting points, concrete data could validate these ideals.

Kokich et al.[4, 16] did some of the first studies on smile preferences using digitally altered images, with only the lips and teeth visible. The nose and chin were eliminated to limit confounding variables, and the gender and skin tone were kept constant for the same reason. They altered 8 different photographs to fabricate 5 variations of each of the 8 variables, and asked participants to rate the attractiveness of the altered images on a VAS. They found that laypersons, dentists, and orthodontists have different levels of detection of changes in smile characteristics, and that laypersons were the most forgiving. The following are their results for the amount of alteration of the variables that was needed to significantly affect the rater's evaluation of the attractiveness of the image:

TABLE 1. THRESHOLD LEVELS OF SIGNIFICANT DIFFERENCE.

Parameter	Orthodontists	General Dentists	Lay People
Crown length (mm)	1.0	1.5	2.0
Crown width (mm)	3.0	3.0	4.0
Incisor angulation (mm)	2.0	2.0	2.0
Midline (mm)	4.0	ND	ND
Open gingival embrasure (mm)	2.0	3.0	3.0
Gingival margin (mm)	ND	ND	ND
Incisal plane (mm)	1.0	1.0	3.0
Gingiva-to-lip distance (mm)	2.0	4.0	4.0

ND = nondetectable.

Kokich et al.. *J Esthet Dent* 1999

Johnston et al.[17] also showed a difference between orthodontist and layperson ratings. These differences highlight the importance of focusing on patient-centered goals in orthodontic treatment, since they ultimately must be satisfied as long as their goals are clinically acceptable.

One drawback to the Kokich et al. studies was the large increments they used to alter the images - in some cases 2 mm between images. This makes detection of small differences impossible, and also leaves open the possibility that the optimum value for the variable is between the choices offered.

Parekh et al.[5,18] used innovative technology for their pilot studies called emoticons. This was a method of linking a slider to a lower face image so that moving the slider altered selected portions of the image. The raters (all orthodontists) were asked to move the slider to choose the image representative of the ideal smile. Parekh et al.[5] studied smile arc and buccal corridor in this project, and showed a similar perspective as Kokich et al.[4] – the lips and teeth only. In the actual study with both laymen and orthodontists as raters, they used a series of incremental photographs with different combinations of ideal, decreased, and increased smile arcs and buccal corridors, similar to Kokich et al.'s[4] method. Raters were asked to rate the attractiveness of each of the 9 smiles on a VAS. They found that raters disliked large buccal corridors and flat smile arcs. They also emphasized the concept of acceptability in smile esthetics. When viewing the same smiles, the raters were asked if the smile was acceptable or not. Excessive buccal corridors were judged to be acceptable more than 70% of the time, even though they were significantly less acceptable than ideal or absent buccal corridors. Flat smile arcs, on the other hand, had a more significant effect and were judged to be acceptable only 50-60% of the time compared to 84-95% acceptability for ideal or excessive smile arcs. Flat smile arcs also overpowered buccal corridor regardless of which corridor was shown; that is, a flat smile arc overwhelmed the attractiveness of any buccal corridor.

Ker et al.[6] also used digital images to study smile variables. They used the lower face perspective so they could compare their data to Parekh et al.[5] and examine the issue of perspective while expanding the number of variables investigated. Ker et al.[6] used the posed smile due to its reproducibility and looked at the following variables: buccal corridor fill, smile arc, maxillary anterior gingival height discrepancy, maxillary gingival display, incisal edge discrepancy, overbite, central incisor gingival margin discrepancy, canine torque in broad and narrow smiles, posterior crown torque in narrow and broad smiles, maxillary central incisor crown width to height ratio, maxillary lateral to central incisal ratio, maxillary midline to face, maxillary to mandibular midline discrepancy, and cant. Their study refined or defined the ideal for each of these variables, and also a range within which the raters still considered the images to be acceptable. It is important to note the difference between ideal and acceptable. An acceptable range of values would be quite useful to clinicians in evaluating the smiles of their patients, especially understanding that we cannot always achieve the ideal.

Ker et al.[6] also introduced nearly continuous data collection with regard to the images by using the slider technology. They were the first to use sliders for the full survey with lay raters – Parekh et al.[5] used it only for the pilot study with professionals. This technology allowed the raters to manipulate the variables themselves through a seamless range of possibilities, and to choose the ideal and the acceptable limits exactly instead of merely making judgments on preselected images.

The slider also was a change from the traditional use of VAS to quantify esthetic judgments. VAS is advantageous in that it is well established as reliable. It is an absolute rating of the variable, and it is anchored to concrete concepts to make it valid. One drawback is that people use the center of the VAS scale more than the ends. The slider basically allows raters to compare a large series of photographs quickly, and to choose the ideal easily. This is much more efficient in terms of designing a survey, since much more precise information can be obtained in a shorter survey.

Schabel et al.[19] used the Q-Sort method. It is described as "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."' According to Schabel et al.[19] it is more reliable than the VAS. One limitation is that a Q-Sort is a relative rating or ranking of the materials presented within the specific study.

There is ample evidence that rater gender and age do not influence ratings of esthetics. In a study on the influence of buccal corridors on smile attractiveness, Martin et al.[20] showed no influence of rater gender or age on the ratings. In a study that looked at symmetry, tooth shade, number of teeth displayed, and height of maxillary lip line, and included both restored and unrestored teeth, Dunn et al.[11] found no differences in any of the demographic data that was collected, which were: age, sex, race, educational level, income level, and geographic regional area. Moore et al.[21] also did a buccal corridor study, and found no gender differences for rater or model.

Nomura et al.[22] did a recent study on how raters' race and gender, and models' race and gender influence laypersons' ratings of profile esthetics. Significant differences were found for rater race and model race and gender. Care must be taken in generalizing esthetic preferences across cultural groups.

There are few studies of smile characteristics using a full face perspective. There is evidence[10] that other aspects of the face are more important to people than the smile when evaluating facial esthetics, so the range of acceptable smile variables might be wider when a full face perspective is employed. This also would mimic views encountered in normal conversation in contrast to the lower face view. This wider perspective could dilute the attention to details of the smile. Indeed, that appears to be the case as shown by Flores-Mir et al.[23], in which the esthetic impact of the anterior dental occlusion was less in the full face view compared to the dental or circumoral views. This study also demonstrated significant variation by patient, which was most likely their facial appearance.

Havens et al.[8] showed that photos of a malocclusion with a full face view were more attractive than the same malocclusion shown as a circumoral view. Their theory was that the perspective of the face helped camouflage the unattractive oral area. Conversely, when Rodrigues et al.[24] showed people a series of photographs with changes in smile arc, maxillary lateral incisor tip, midline diastema, and midline deviation, the perspective made no difference on their rankings.

Shaw et al.[25] argued that overall facial attractiveness was more important than dental esthetics in overall esthetics.   It is possible that the attractiveness of the face alters the importance of the smile characteristics and that the background attractiveness of the face must be accounted for and controlled so that this variable does not inadvertently bias results.

Certainly perspective has yielded contrasting results and should be further investigated for smile esthetics.

The specific aim of this research was to quantify smile variables from a layperson point of view with full face images of models of average attractiveness. These data then can be compared to the same variables viewed from the lower face perspective to determine the effect of perspective and further validate existing smile esthetics data.

Hypotheses:

Ho1: Rater gender will not significantly affect ratings of ideal and acceptable values of smile characteristics including buccal corridor, smile arc, maxillary anterior gingival height discrepancy, maxillary gingival display, incisal edge discrepancy, cant, overbite, central incisor gingival margin discrepancy, maxillary midline to face and to mandibular midline.

Ho2: There will be no significant differences between full face perspective and lower face[6] perspective in ideal and acceptable values of smile characteristics, including buccal corridor, smile arc, maxillary anterior gingival height discrepancy, maxillary gingival display, incisal edge discrepancy, cant, overbite, central incisor gingival margin discrepancy, maxillary midline to face, and maxillary to mandibular midline.

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Chapter 2

Materials and Methods

The overall objective of this computer-based survey was to digitally modify one smile so that raters could evaluate the ideal and the acceptable range of several important smile characteristics, measured in the context of male and female full face perspective images. The faces had been previously rated by peers to be of average attractiveness, which was important to avoid any uncontrolled influence due to the background attractiveness of the model. The design was approved by the University IRB.

Raters were recruited by displaying a poster in a central campus recreation facility. Those who were interested approached the investigators for more information - no raters were solicited. The raters were first provided with a script to briefly explain the study and to have any questions answered. Participants were required to understand English and be familiar with the use of a mouse to control a computer. A waiver of written informed consent was granted by the IRB. The participants voluntarily consented to participation by completing the study. Provision of demographic data (age, gender, ethnic status and socioeconomic status) was voluntary. No participant was allowed to be a dental professional of any type.

Photographs of faces of consenting young adults were digitally dissected, mirrored, and sized for the survey using Adobe® Photoshop® CS3 Version 10 (Adobe, San Jose, Calif). These photographs came from a database of facial images previously rated by peers to be of average attractiveness. One female and one male face were chosen.

A similar method was used to generate a set of symmetric and esthetic teeth placed within the lip profile of the full face images. An intraoral photograph of a finished orthodontic case was cut in half, mirrored, and reassembled to form a smile that was sized to fit the mouth using Adobe® Photoshop® CS2 (Adobe, San Jose, Calif). For each variable measured, sequential layers of the same smile were altered using templates of teeth digitally separated from the initial image. An overlay grid with a millimeter scale accurate to 1/5th mm was used and the high resolution layers of the teeth were altered at 5x or 6x magnification. Once a series of modification values was established that appeared to represent the range of visually realistic smiles, the tooth images were stored as sequences that showed gradual and incremental change in one variable, suitable for combination with any of the facial images to create a finished stimulus model for rating. See Ker et al.'s study for more detail [1]. The following were the 10 variables that were studied:

•Smile arc[1] - The smile arc, which is defined as the curvature formed by an imaginary line tangent to the incisal edges of the teeth, was modified in varying degrees of curvature in relationship to the lower lip. The range of modification may be from no curvature to an accentuated curvature. Since the degree of curvature in relationship to the lower lip is difficult to quantify, the degree of curvature will be progressively increased or decreased. Frush and Fisher[2] identified a more curved "smile line" as more youthful in appearance than a flat one. Tjan et al.[3] examined 454 random photographs of dental and dental hygiene students, and found that 85% had a smile arc parallel to the lower lip.

Sarver[4] defined the ideal smile arc as consonant with, or parallel to, the lower lip. Parekh et al.[5, 6] found that laypersons prefer parallel or even increased smile arcs much more than flat smile arcs, and that they strongly dislike flat smile arcs. Ker et al.[1] also found a parallel smile arc to be ideal, and defined limits to the acceptable range.

•Buccal corridor fill[1] – Buccal corridor (BC) is defined by the amount of dark space displayed between the facial surfaces of the posterior teeth and the corner of the mouth and was presented as a series of images representing the spectrum of corridors from 6% to 25.5%. Images showed variations of about 0.25 mm for this study. Ker et al.[1] found an acceptable range of 8%-22%, with an ideal value of 16%. Parekh et al.[5, 6] did not find an ideal value, but did find that raters preferred normal or narrow BC to broad corridors, and that even the less esthetic broad corridors were still acceptable 70% of the time. Moore et al.[7] showed a range of 2%-28% corridor in their study, and found that raters consistently favored the narrow corridors. Martin et al.[8] showed buccal corridors ranging from 0-16%, and found that both orthodontists and laypersons favored smaller corridors. Roden-Johnson et al., [9] on the other hand, found no effect of BC on esthetics in any of three rater groups: orthodontists, dentists, and laymen. There was no mention of how much buccal corridor was examined in this study, however.

•Maxillary gingival display[1] – Gingival display, or a “gummy smile,” is defined as the amount of gingival show above the zenith of the crown and below the central nadir of the upper lip. The range of modification presented a dentition moving upward or downward in approximately 0.25 mm increments ranging from 1 mm of gingival display to almost 7 mm of tooth coverage (-7) for the female model, and almost 2 mm gingival display to 6 mm tooth coverage (-6) for the male model. The variation between models was due to difficulties in sizing and coordinating the images for different faces. Tjan et al.'s[3] descriptive study found that the majority of faces analyzed had the upper lip at the gingival margin of the upper central incisors, which would be no gingival display. Peck and Peck's[10] descriptive study of 88 patients found a mean gingival display of 0.7 mm for females, and -0.8 mm for males. Kokich et al.[11] altered gingival display in 2 mm increments from -2 to 6 mm gingival display, and found that orthodontists did not rate the attractiveness lower until 2 mm gingival was displayed, and laypersons until 4 mm was displayed. A second Kokich et al.[12] study showed both orthodontists and laypersons to be sensitive to the increased gingival show at 3 mm display. Hunt et al.[13] varied the gingival display from -2 to 4 mm, and found the ideal to be 0 mm display. Ker et al.[1] found an ideal of about -2 mm, with the acceptable range from -3.65 to 4 mm.

•Maxillary midline to face[1] – The ideal maxillary midline to face is when the maxillary midline is coincident with the philtrum. The maxillary midline was moved to the left of the face in approximately 0.25 mm increments. The right and left buccal corridors were maintained throughout the movement of the dentition. The ideal is defined for this variable. Johnston et al.[14] varied the midline by 1,2,4,6, and 8 mm in both directions, and found that 2 mm midline deviation was sufficient for more than 50% of people to rate the image as less attractive. Kokich et al.[11] tested from 0 to 4 mm deviation in 1 mm increments, and found that while orthodontists rated the image as less attractive at 4 mm, laypersons never detected a difference in attractiveness. Ker et al. found the acceptability limit to be almost 3 mm of deviation. Rodrigues et al.[15] showed an image with a 3 mm midline shift that was ranked the same by raters as the ideal image.

•Maxillary to mandibular midline discrepancy[1] – While maintaining the maxillary midline, the mandibular dentition was moved to the left in approximately 0.25 mm increments. The right and left buccal corridors were maintained throughout the movement of the mandibular dentition. The ideal is defined for this variable. Ker et al.[1] found the acceptability limit to be 2 mm discrepancy.

•Overbite[1] – The overbite, defined by Ker et al.[1] as the projection of the upper front teeth over the lower in the normal occlusal position of the jaws, was modified by incrementally altering the mandibular layer of the photograph image in the vertical dimension. The vertical movement of the mandibular layer produced an increased or decreased overbite. The layer was moved incrementally in approximately 0.25 mm increments. Ker et al.[1] found an ideal overbite of 2 mm, with the acceptable range from 0.37 to 5.66 mm.

•Central incisor gingival margin discrepancy[1] – A common problem in orthodontic finishing is gingival margin discrepancies between contra lateral incisors. In this study the gingival margin of the left maxillary central incisor was altered in approximately 0.25 mm increments. The incisal edges were maintained at their original height. The ideal is defined for this variable. Kokich et al.[12] tested this variable with 0 to 2 mm discrepancy, and found that it took a 1.5-2 mm gingival discrepancy before laypersons' ratings were affected. Ker et al.[1] also found 2 mm to be the acceptable limit.

•Maxillary anterior gingival height discrepancy from central to lateral incisor zenith[1] – This variable represents the relationship in the height of the gingival zenith of the six maxillary anterior teeth. The range of modification was based upon symmetrical alteration of the gingival zenith of the middle teeth on each side, the lateral incisors.

Variations from increased height through decreased height were presented in approximately 0.25 mm increments. Kokich et al.[11] did not show detection of variation in this variable when varied from 1 mm incisal to the central incisor gingival to 3 mm incisal to it. Ker et al.[1] found an ideal of 0.38 mm incisal to the central gingival, but with an acceptable range from almost 3 mm incisal to just over 1 mm apical.

•Incisal edge discrepancy[1] – This variable evaluated the difference between the incisal edges of the central and lateral incisors and was assessed by moving the entire lateral incisor tooth up or down in approximately 0.125 mm increments. Bukhary et al.[16] altered the lateral incisor length in 0.5 mm increments from 0.5 mm shorter than the central incisor to 2.5 mm shorter, and found that the most popular lateral incisor length was 1-1.5mm shorter than the central. King et al.[17] varied the images from 1.4mm longer than the central incisor to 2.2mm shorter, and found the ideal to be 0.6mm shorter than the central, with the acceptable range 0.3 to 1 mm shorter. Ker et al.[1] varied the length from about 0 to 4 mm shorter than the central, and found the ideal to be 1.4 mm shorter, with an upper acceptable limit of 2.9 mm shorter.

•Cant[1] – The divergence of the occlusal plane from the horizontal axis, as seen in the smiling patient, was altered by gradually rotating the plane through a point between the central incisors. The rotation of the plane occurred in 0.25° increments. The ideal is defined for this variable. Kokich et al.[11] found the limit for laypersons to be 3 mm of incisal plane rotation, which translates to 2.5-3.5 degrees of cant depending on the width of the smile. Ker et al.[1] found the acceptability limit to be 4° cant.

Dependent Variables

•Esthetic attractiveness of each variable – The perception of esthetics was based on raters' answer to the question "Please adjust the slider below to the ideal image." Smile characteristics could be adjusted by positioning a slider to a rater determined ideal position. The slider was not anchored so the rater could find any of the images to be the most esthetically pleasing. Each image was assigned a known value based upon the deviation from the original image.

•Acceptability – In separate images the raters were then asked to select the position of the slider moving up or to the right from the middle position until the smile became unacceptable. Finally, the rater was asked to select the position of the slider moving down or to the left from the middle position until the smile became unacceptably unattractive. By completing this exercise they defined the limits of acceptability. Each image was assigned a known value based upon the deviation from the original image.

Data were collected on a standalone laptop via a customized program running within the MATLAB® (The Mathworks™, Natick, Mass) software suite. This program randomly displayed a single face image with teeth and allowed the participant to use the mouse to adjust an on screen slider according to displayed instructions, e.g. "Please adjust the slider below to the ideal image" or "Move the slider until the smile is no longer acceptable." The slider motion triggered changes in the tooth image displayed, allowing the participant to adjust through the full sequence of tooth images for one variable at a time. Every image for each variable had a number assigned to it that was identified by the program as the choice and saved as data by image number. The images numbers were translated to values that represented the modification value of that smile characteristic. This allowed the participants' choices to be summarized so that a median ideal and confidence interval for each variable could be established.

6 of the variables ("large") had three questions associated with them: choose the ideal image, upper limit, and lower limit. These were: buccal corridor fill, smile arc, maxillary anterior gingival height discrepancy, maxillary gingival display, incisal edge discrepancy, and overbite. The other 4 had only 1 question: deviation from 0, because the ideal was defined as no deviation. These were: central incisor gingival margin discrepancy, maxillary midline to face, maxillary to mandibular midline discrepancy, and cant.

The survey questions for this study were combined with a separate study that used faces of varying attractiveness. Thus there were 4 faces of varying attractiveness that were used in addition to the two average faces. With 6 faces per variable, that equaled 18 questions for each "large" variable and 6 questions for each "small" variable. Each question was asked twice to assess rater reliability, ultimately equaling 36 questions per large variable and 12 per small variable, or 264 total questions. To make the length of the survey manageable they were divided into six separate surveys of either 48 or 36 questions each. Each variable was viewed completely by one group of raters. Surveys 1-4 included two variables only and asked all the questions for those two variables. Surveys 5 and 6 included only one large variable each and asked all the questions for that variable. It took most participants 10-15 minutes to complete one of these surveys.

A power analysis was performed in order to determine our necessary sample size. Of the dependent variables in this study, overbite was shown by Ker et al.[1] to have the highest variance. Consequently, overbite was used to determine the sample size. With a non-directional alpha risk of 0.05 and assuming a standard deviation of 3.5[1] a sample size of 87 subjects was needed in order to detect a difference of ± 1.5 mm with a power of 0.86. Ten percent was added to this sample size in case nonparametric analysis would be needed. As a result, the final sample size per variable was 96 subjects. With a sample size of 96 for each variable, multiplied by 6 surveys, we needed a total of 576 participants.

Data were backed up after each session in which surveys were administered. These data were stored in a secure database and if removed from the server were stored and processed only on password protected computers. Any hard copies of the data were locked in cabinetry within the academic Division. Subjects were only cataloged by series number; no personally identifying information (such as name, address, or SSN) was collected since no identifiers were available. There were no links between subject and data.

Statistical analysis

Reliability for each of the ten dependent variables was evaluated using the Fleiss-Cohen weighted kappa statistic and corresponding 95% confidence interval.

Within study differences

The first comparison we made was to assess any differences between male and female raters when rating full face male and female models of average attractiveness. This was done nonparametrically with the randomization test due to skewing of the data. As no differences were found between the male and female raters, we combined their ratings for further statistical analysis.

Between-study differences

For each of the ten dependent variables, differences between the present study and the Ker et al.[1] study were assessed using a randomization test. P-values were adjusted using the step-down Bonferroni-Holm method.

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Chapter 3

Manuscript:

Smile Esthetics from the Patients' Perspective

Abstract

Computer-based smile esthetic surveys based on emoticon (slider) technology allow control of variables and the possibility of obtaining continuous data. However, differences in the perception of smiles using different facial perspectives have not been resolved. **Objectives**: To quantify the ideal values and the range of acceptability for specific smile variables judged by laypersons from a full face perspective for comparison to lower face data. **Methods**: Ninety-six laypersons judged each smile variable that was digitally embedded in mirrored and symmetric male or female full faces, which had previously been determined by peers to be of average attractiveness. Smile arc, buccal corridor fill, maxillary gingival display, maxillary midline to face, maxillary to mandibular midline discrepancy, overbite, central incisor gingival margin discrepancy, maxillary anterior gingival height discrepancy, incisal edge discrepancy and cant were manipulated by the raters using emoticon technology that allowed the variable to morph and appear continuous on a computer monitor. Medians for each smile variable were compiled and Fleiss-Cohen weighted kappa statistic was used to measure reliability. Multiple randomization tests with adjusted p-values were used to compare these data with those for lower face views. **Results**: Reliability ranged from 0.25 for ideal overbite to 0.60 for upper midline to face, except in the case of the buccal corridor limits, which each

had an ICC near 0. There were no statistically significant differences between ratings for the male and female raters. The following variables showed statistically significant differences when compared with the lower face view: ideal smile arc, all 3 buccal corridor measures, gingival display up and down, U to L midline, minimum overbite, lateral gingiva up and down, maximum and ideal lateral step, and occlusal cant. In all but 5 cases (ideal smile arc, ideal buccal corridor, maximum gingival display, upper to lower midline and occlusal cant), these differences were not considered to be clinically meaningful due to the small magnitude of the differences (less than 1 mm) and therefore similar to the lower face perspective. While the smile arc numbers differed from those found with the lower face perspective due to a model with different lip curvature, the principle of tracking the curve of the lower lip was consistent for both perspectives. For the full face view, raters preferred less maximum gingival display than the lower face rater by several millimeters. Full face raters favored less buccal corridor than lower face raters, and allowed more upper to lower midline discrepancy. The full face raters allowed less cant of the occlusal plane than the lower face raters. **Conclusion**: Reliability was fair to moderate with the exception of the buccal corridor limits. Most variables showed no clinically meaningful differences from the lower face view. The acceptable range is quite large for most variables. Detailed knowledge of the ideal values of the various variables is important and can be incorporated into orthodontic treatment to produce an optimal esthetic smile.

Introduction

Smile esthetics has become a central concern for patients and orthodontists because this is one of the primary reasons patients seek orthodontic treatment,[1] and orthodontists are now using this as a focus for treatment planning. Investigation of the variables that contribute to esthetic smiles began in a controlled manner with Kokich et al.'s[2] innovative study. Using altered photographs with only the lips and teeth visible to fabricate five variations of each of eight variables, they asked participants to rate the attractiveness of the altered images on a visual analog scale (VAS). They found that laypersons, dentists, and orthodontists detected changes in smile characteristics at different threshold levels, and that laypersons were the most forgiving. This study began to define values for the smile variables. One drawback to Kokich et al.'s[2] study was the large increments they used to alter the images -- in some cases 2 mm between images. This made detection of small differences impossible, and also left open the possibility that the true value for the variable was between the choices offered.

Johnston et al.[3] also showed a difference between orthodontist and layperson ratings. These differences highlight the importance of focusing on what the patients want regarding orthodontic treatment, since they ultimately must be satisfied as long as their goals are within a clinically acceptable range.

Study of smile variables was advanced by using more sophisticated digital image manipulation and computer based methodologies. Parekh et al.[4, 5] studied smile arc and buccal corridor, with raters viewing a series of incremental photographs with different combinations of ideal, decreased, and increased smile arcs and buccal corridors and made judgments regarding the ideal and the range of acceptable options for each variable. In the pilot study for this work, Parekh et al.[4] used a creative technology called "emoticons." This was a method of linking a slider to an oral image so that moving the slider altered selected portions of the image. The raters (all orthodontists) were asked to move the slider to choose the image representative of the ideal smile.

Ker et al.[6] also used emoticons to study smile variables and were the first to use emoticon sliders for a full survey with lay raters. This technology allowed the raters to manipulate the variables themselves through a seamless range of possibilities, and to choose the ideal and the acceptable limits instead of merely making judgments on preselected images. The slider also was a change from the traditional use of VAS to quantify esthetic judgments. VAS is well established and reliable. It is an absolute rating of the variable, and it is anchored to concrete concepts to make it valid. The slider allowed raters to view a large series of photographs quickly and choose the ideal easily. This was an efficient design that presented a wider range of possible choices in a shorter period of time and allowed a more precise selection.

Ker et al.[6] also used the lower face perspective so they could compare their data to Parekh et al.'s[4, 5] oral image data while expanding the number of variables investigated. Ker et al.[6] looked at the following variables: buccal corridor fill, smile arc, maxillary anterior gingival height discrepancy, maxillary gingival display, incisal edge discrepancy, overbite, central incisor gingival margin discrepancy, canine torque in broad and narrow smiles, posterior crown torque in narrow and broad smiles, maxillary central incisor crown width to height ratio, maxillary lateral to central incisal ratio, maxillary midline to face, maxillary to mandibular midline discrepancy, and cant. Their study refined or defined the ideal for each of these variables and also a range within which the raters still considered the images to be acceptable. It is important to note the difference between ideal and acceptable. An acceptable range of values would be quite useful to clinicians in evaluating the smiles of their patients, especially understanding that we cannot always achieve the ideal.

There are few studies of smile characteristics using a full face perspective. The full face perspective mimics views encountered in normal conversation in contrast to the lower face or oral views. This wider perspective could dilute the attention to details of the smile. Indeed, that appears to be the case as shown by Flores-Mir et al.,[7] in which the esthetic impact of the anterior dental occlusion was less in the full face view compared to the dental or lower face views. This study also demonstrated significant variation by patient, which was most likely due to the model's facial appearance.

Havens et al.[8] showed that photos of a malocclusion with a full face view were more attractive than the same malocclusion shown as a circumoral view. Their theory was that the perspective of the face helped camouflage the unattractive oral area. Conversely, when Rodrigues et al.[9] showed people a series of photos with changes in smile arc, maxillary lateral incisor tip, midline diastema, and midline deviation, the perspective made no difference on their rankings.

Parekh et al.'s[4, 5] oral view data appeared similar to Moore et al.'s[10] full face perspective data for buccal corridors, but were different from Ker et al.'s[6] lower facial view. Certainly perspective has yielded contrasting results.

Shaw et al.[11] argued that overall facial attractiveness was more important than dental esthetics in overall esthetics. It is possible that the attractiveness of the face alters the importance of the smile characteristics and that the background attractiveness of the face must be accounted for and controlled so that this variable does not inadvertently bias results.

The purpose of this study was to quantify smile variables from a layperson point of view with full face images of models of average attractiveness. These data were compared to the same variables viewed from the lower face perspective to determine the effect of perspective and further validate existing smile esthetics data.

Method

The general method of this computer-based survey was to digitally modify one smile so that raters could evaluate the ideal and the acceptable range of several important smile characteristics, measured in the context of male and female full face perspective images. The design was approved by the Institutional Review Board.

Raters were recruited by displaying a poster in a central campus facility. Those who were interested approached the investigators for more information -- no raters were solicited. The raters were first provided with a script that briefly explained the study. Inclusion criteria required that participants be conversant in English and familiar with the use of a mouse to control a computer. The participants consented to participation by completing the study and provided optional demographic data (age and gender). All dental professionals and dentistry/dental hygiene students were excluded.

Photographs of faces of consented young adults were digitally bisected, mirrored, and sized for the survey using a photo editing program, Adobe® Photoshop® CS3 Version 10 (Adobe, San Jose, Calif). These photographs were acquired from a database of facial images previously rated by peers to be of average attractiveness. Faces of average attractiveness were used to avoid any uncontrolled influence due to the background attractiveness of the model. One female and one male face were selected.

A similar method was used to generate a set of symmetrical and esthetic teeth placed within the lip profile of the full face images. An intraoral photograph of a completed orthodontic case was bisected, mirrored, and reassembled to form a smile that was sized to fit the mouth using Adobe® Photoshop® CS2 (Adobe, San Jose, Calif). For each variable measured, sequential layers of the same smile were altered using templates of teeth digitally separated from the initial image. Once a series of modification values was established that appeared to represent the range of visually realistic smiles, the tooth images were stored as sequences that showed small incremental change in one variable, suitable for combination with any of the facial images to create a finished stimulus model for rating[6]. The following were the 10 variables that were studied:

•Smile arc[6] - The smile arc, which is defined as the curvature formed by an imaginary line tangent to the incisal edges of the teeth, was modified in varying degrees of curvature in relationship to the lower lip. The range of modification was from no curvature to an accentuated curvature. The degree of curvature was in relationship to the lower lip so quantification differed for each model.

•Buccal corridor fill[6] – The buccal corridor is defined by the amount of dark space displayed between the facial surfaces of the posterior teeth and the corner of the mouth and was presented as a series of images representing the spectrum of corridors from 6% to 25.5%.

•Maxillary gingival display or gummy smile[6] – Gingival display is defined as the amount of gingival show above the central incisor crowns and below the center of the upper lip. The range of modification presented a dentition moving upward or downward in 0.25 mm increments ranging from 1 mm of gingival display to almost 7 mm of tooth coverage (-7) for the female model, and approximately 2 mm of gingival display to 6 mm tooth coverage (-6) for the male model. The variation between models was due to difficulties in sizing and coordinating the images for different faces.

•Maxillary midline to face[6] – The ideal maxillary midline to face is when the maxillary midline is coincident with the philtrum and the facial midline. The maxillary midline was moved to the left of the face in approximately 0.25 mm increments. The right and left buccal corridors were maintained throughout the movement of the dentition.

•Maxillary to mandibular midline [6] – While maintaining the maxillary midline, the mandibular dentition was moved to the left in approximately 0.25 mm increments. The right and left buccal corridors were maintained throughout the movement of the mandibular dentition By definition, the ideal was considered to be 0 for this variable.

•Overbite[6] – The overbite, defined as the vertical overlap of the incisors,[12] was modified by incrementally altering the mandibular layer of the photograph image in the vertical dimension. The vertical movement of the mandibular layer produced an increased or decreased overbite. The layer was moved incrementally in 0.25 mm increments.

•Central incisor gingival margin discrepancy[6] – A common problem in orthodontic finishing is gingival margin discrepancies between the central incisors. In this study the gingival margin of the left maxillary central incisor was altered in 0.25 mm increments. The incisal edges were maintained at their original height. By definition, the ideal was considered to be 0 for this variable.

•Maxillary anterior gingival height discrepancy from central to lateral incisor[6] – This variable represents the relationship in the height of the gingival zenith of the six maxillary anterior teeth. The range of modification was based upon symmetrical alteration of the gingival zenith of the middle teeth on each side, the lateral incisors. Variations from increased height through decreased height were presented in 0.25 mm increments.

•Incisal edge discrepancy or lateral step[6] – This variable evaluated the difference between the incisal edges of the central and lateral incisors and was assessed by moving both lateral incisor teeth up or down together in 0.125 mm increments.

•Cant [6] – The divergence of the occlusal plane from the horizontal axis, as seen when smiling, was altered by gradually rotating the plane through a point between the central incisors. The rotation of the plane occurred in 0.25° increments. By definition, the ideal was considered to be 0 for this variable.

Dependent Variables

•Esthetic attractiveness of each variable – The perception of esthetics was based on raters' answer to the question "Please adjust the slider below to the ideal image." Smile characteristics could be adjusted by positioning a slider to a rater-determined ideal position. Each image was assigned a known value based upon the deviation from the original image.

•Acceptability – In separate images the raters were then asked to select the position of the slider moving up or to the right from the middle position until the smile became unacceptable.   Finally, the rater was asked to select the position of the slider moving down or to the left from the middle position until the smile became unacceptably unattractive. By completing this exercise they defined the limits of acceptability. Each image was assigned a known value based upon the deviation from the original image.

Data were collected on a standalone laptop computer via a customized program running within MATLAB® (The Mathworks™, Natick, Mass), a numerical computing environment and programming language software. The program randomly displayed a single face image with teeth and allowed the participant to use the mouse to adjust an on-screen slider according to displayed instructions, in order to choose the ideal image or the acceptable limit. The slider motion triggered changes in the tooth image displayed, allowing the participant to adjust through the full sequence of tooth images for one variable at a time. Every image for each variable had a number assigned to it that was identified by the program as the choice and saved as data by image number. The image numbers were translated to values that represented the modification value of that smile characteristic.

Of the 10 variables, 6 had 3 questions associated with them: choose the ideal image, upper limit and lower limit. These were: buccal corridor fill, smile arc, maxillary anterior gingival height discrepancy, maxillary gingival display, incisal edge discrepancy and overbite. The other 4 had only 1 question: deviation from 0, because the ideal was defined as no deviation. These were: central incisor gingival margin discrepancy, maxillary midline to face, maxillary to mandibular midline discrepancy and cant.

Each question was asked twice to assess rater reliability. To make the length of the survey manageable the variables were divided into six separate surveys. Each variable was viewed completely by 1 group of raters. Surveys 1-4 included two variables only and asked all the questions for those two variables. Surveys 5 and 6 included only one variable. It took most participants 10-15 minutes to complete one of these surveys. Participants received a $10 gift card for their participation.

Statistical Analysis

A power analysis was performed in order to determine the sample size. Of the dependent variables in this study, overbite was reported by Ker et al.[6] to have the highest variance, so it was used to determine the sample size. With a non-directional alpha risk of 0.05 and assuming a standard deviation of 3.5,[6] a sample size of 87 subjects was needed in order to detect a difference of ± 1.5 mm with a power of 0.86. Ten percent was added to this sample size in case nonparametric analysis would be needed. As a result, the final sample size per variable was 96 subjects. With a sample size of 96 for each variable and 6 surveys, a total of 576 participants were required.

Median data were compiled and a Fleiss-Cohen weighted kappa statistic (K_W) was used to confirm reliability. Multiple randomization tests with p-values adjusted using the step-down Bonferroni method of Holm were used to compare the data with that published by Ker et al.[6].

Results

The raters were 51% male and 49% female. Their ages ranged from 18-72, with a mean age of 25.

The K_W for our 10 variables ranged from 0.25 for ideal overbite to 0.60 for upper midline to face, except in the case of the buccal corridor acceptable limits, which both had a K_W close to 0. (Table 1)

There were no statistically significant differences between ratings for the male and female raters ($p>0.13$).

The following variables showed statistically significant differences when compared to the lower face view: ideal and maximum smile arcs, all 3 buccal corridor measures, maximum and minimum acceptable gingival display, acceptable upper midline to face, upper to lower midline deviation, minimum overbite, maximum and minimum acceptable lateral to central incisor gingival discrepancy, maximum and ideal lateral incisal step, and occlusal cant (Table 2). In all but 5 cases (ideal smile arc, ideal buccal corridor, maximum gingival display, upper to lower midline and occlusal cant), these differences were not considered to be clinically meaningful due to the small magnitude of the differences (either less than approximately 1 mm as measured or converted from percentage or degrees) and therefore similar to the lower face perspective.

Discussion

Reliability was fair to moderate for all measure except the buccal corridor limits. There are several possible explanations for this. First, the variability among the items being rated (between subjects) was low and therefore emphasized the contribution of the within subject (between time periods) variability, thereby lowering the value of the kappa statistic. There may have been a training effect with raters and they may have refined their answers or just changed their minds, as all variables were rated twice. Another possibility is that the perspective of the face made the raters less sensitive to small changes in the variables.

The complete lack of reliability for the buccal corridor limits in the full face perspective was unexpected. Ker et al.[6] had reliability ranging from 0.44 to 0.55 for buccal corridor. It is possible that in a full face view raters lost their ability to evaluate the extremes for this variable. Moore et al.[10] did not report reliability in their paper, and no other studies have reported buccal corridor data in a full face perspective.

No differences were found between male and female raters. This is consistent with Ker et al.'s[6] findings, as well as Martin et al.[13], Dunn et al.[14], and Moore et al.[10]. With no differences between male and female raters, the data were combined for comparison to Ker et al.'s[6] data.

Ker et al.[6] used a gender ambiguous image for their survey and therefore could make no model gender comparisons. Because the data were compared to Ker et al.'s,[6] no model gender comparisons were made.

The perspective of the image did not make a clinically significant difference for most variables. This is in part due to the arbitrary decision that approximately 1 mm or less difference between full face and lower face ratings were clinically insignificant. Although arbitrary, due to the power of the sample differences of 0.2 mm were detectable, which was unreasonably precise to be clinically relevant.

Past research has shown that people look other places first and longer than the teeth when viewing a smiling face[2, 15]. It seems logical that the esthetic effect of the smile would be diluted when presented in a full face, so it is somewhat surprising to see few clinically significant differences in the full face smile study compared to lower face view[6]. One potential distraction was the attractiveness of the face. This variable was managed by selecting models of average attractiveness and standardizing it throughout the survey.

A possible reason that so few differences were found was the nature of our survey. Allowing raters to manipulate the variables themselves drew their attention to those variables. This could have caused the smile to be the focus of the rating to the exclusion of the background facial features. Global rating of faces may combat this problem and provide different results, but would then resort to incremental and less precise evaluations of the variables.

Although the dental variables evaluated by the raters were identical for the full face and comparison lower face perspective, those images did not have identical surrounding facial context, with only a change in perspectives. Ker et al. [6] used a gender ambiguous model and the full face models were gender specific.

Of all the statistically significant differences we found, only 5 were deemed to be clinically significant by our definition: ideal smile arc, ideal buccal corridor, maximum gingival display, upper to lower midline, and cant.

The critical feature of the ideal smile arc is that it parallels the curvature of the lower lip[6, 16, 17]. While the ideal smile arc from our study has a different parabolic curve than Ker et al.'s[6] reported ideal, the principle holds true and it did track the curvature of the lower lip for both models. The difference in which curve paralleled the lip most accurately is due to the different lip contour of our models. So while the numbers were different, this study supports the principle of the ideal smile arc matching the lower lip. This concept and data supporting the ideal smile arc are well established in the literature[4-6, 16-18] and agrees with these findings. There were no differences for the range of acceptability for this variable.

All three buccal corridor measures were statistically different from Ker et al.'s,[6] however, only the ideal had reasonable reliability. The 4% buccal corridor difference compared to Ker etal.[6] equates to a 2-3 mm difference in the combined width of the buccal corridors, depending on the width of the smile. So, the full face raters favored a smaller buccal corridor than the lower face raters. The belief that smaller corridors are favored over larger corridors, as shown by Parekh et al.,[4, 5] Moore et al.[10], and Martin et al.[13] was upheld by this study. It is not reasonable to make judgments about the limits of the buccal corridors from this study due to the reliability.

The upper limit for gingival display is much lower than any previously published study that purported to examine ranges of acceptability or thresholds. This upper limit for gingival display was more than 4 mm lower than Ker et al.'s[6], even though our ideal and lower limit matched very closely. The current raters did not favor any gingival display at the central incisors, while Ker et al.'s[6] allowed 3.65 mm of gingival display. Kokich et al.[2, 19] found either 4 mm or 3 mm to be the upper acceptable limit. Even though a large range of options were not provided for this variable due to the height of the oral aperture of our two models, the raters did not use the limits of the available range. It is possible that differences in the lip contour of these models contributed to this lack of tolerance for gingival display. These models showed similar gingiva laterally to Ker et al.'s[6], but less in the central incisor area. This may point to the fact that gingival display is not confined to just the central incisor area, but more of a global evaluation of the maxillary arch. The ideal of 2 mm tooth coverage was the same as Ker et al.,[6] and not effectively different than averages reported by Tjan et al.[16] and Peck and Peck,[20] and the ideal reported by Hunt et al.[21]. The lower limit of 4.5 mm was very similar to Ker et al.'s.[6]

The allowable discrepancy between upper and lower midlines was found to be 3.6 mm. This is about 1.6 mm more than Ker et al.'s[6] 2 mm difference. In this case the belief that full face raters would allow more leeway was upheld. The lower midline can be off by approximately half of a lower incisor width with no esthetic ramifications. This demonstrates that lower incisor extraction, for example, would be well tolerated esthetically by laypersons.

The maximum acceptable cant of the occlusion was 2.75°. Given smile widths from 50-70 mm, the vertical measure of the cant could be from 2.4-3.4 mm. This is quite similar to what Kokich et al.[2] found at 3 mm of allowable cant. Ker et al.'s[6] 4° limit for cant translates to 3.5-4.9 mm of vertical discrepancy. So the vertical difference in millimeters between this study and Ker et al.'s[6] ranges from 1.1-1.5 mm depending on the width of the smile. This result seems counterintuitive, as we expected raters to allow more leeway when viewing full faces. It is possible that seeing the whole face made raters more sensitive to the horizontal axis of the image, and to smiles that deviated from it. In either case, laypersons will tolerate quite a bit of canting of the occlusion before rating the image less attractive.

The limit of acceptability for the maxillary midline deviation from the facial midline was found to be 3.15 mm. While Johnston et al.[3] found the limit to be 2 mm, this finding is the same as Rodrigues et al.[9] and Ker et al.[6]. Kokich et al.[2] found even more leeway at 4 mm using 1 mm increments. Substantial midline discrepancy can exist before it becomes unattractive.

The ideal overbite was found to be 2.25 mm, with a minimum of 0.94 mm and a maximum of 5.4 mm. This matches Ker et al.'s[6] findings very closely. The minimum is statistically different from Ker et al.'s[6] 0.37 mm, but is not clinically significant. While orthodontists usually level the curve of Spee for practical, mechanical reasons to enable retraction and space closure, leaving more overbite than the 2 mm ideal is well accepted by laypersons and there is a great range. More overbite is preferable esthetically than limited overbite or an open bite.

The 2.1mm acceptability limit for the gingival discrepancy between central incisors is the same as both Kokich et al.[19] and Ker et al.[6] found. Laypersons' tolerance for up to 2mm difference is consistent.

The ideal central to lateral gingival margin discrepancy of -0.38mm (i.e., the lateral incisor gingival margin was incisal to the central incisor gingival margin) is the same as Ker et al.'s[6] -0.38 mm. In Kokich et al.'s[2] study, laypersons did not detect differences in any version of this variable, which they varied from 1-3 mm incisal to the canine gingival margin. The acceptability limits were statistically different from Ker et al.'s,[6] but at less than 1mm cannot be considered clinically significant. This provided substantial latitude from -1.88 to 0.38 mm as the acceptable range. This leeway works well with lateral incisal step; for example, intruding lateral incisors to increase the lateral step and provide an ideal smile arc would be well tolerated esthetically at the gingival level.

The ideal incisal edge discrepancy or step between lateral and central incisors was found to be 1.2mm and the upper limit to be 1.95mm. The lower limit was not reported here because Ker et al.[6] did not look for a lower limit. Again, these numbers are statistically different from Ker et al.'s, [6] but not clinically significant. These values are in line with those of Bukhary et al.[22] and King et al.[23]. While orthodontists typically set the lateral incisor brackets 0.5mm incisal to the centrals, laypersons' preference for a bigger lateral step is clear. Again, this works well with the central to lateral gingival height variation to create an esthetic smile.

After viewing the details of the variables, several concepts emerge. It appears that all but one of the variables (upper to lower midline) that did demonstrate statistical and clinical significance did so in the context of the face. That is, they required the face as a background to make the judgments as opposed to more of a dental context (upper to lower midlines). In the majority of these cases the raters allowed less range of acceptability (maximum gingival display and occlusal cant) or a smaller ideal (buccal corridor). Certainly, all aspects of these variables did not show this effect,

In most cases the perspective made little clinical significance. The range of acceptability remains large for most variables and several of these variables work together to produce an esthetic smile with a smile arc coincident with the lower lip. A slightly increased overbite, a central to lateral incisal step and the central to lateral gingival step can all partner to produce an ideal smile. It should be possible for most practitioners to work in the latitude described by these variables and with sensible occlusal concepts to produce an acceptable and attractive smile.

Conclusions

The acceptable range is quite large for most smile characteristics.

The perspective (i.e. full face versus lower face) made little difference in ratings of smile esthetic variables.

Clinically significant differences that did exist, appear to have the face as a context.

Reliability was fair to moderate for all measures except the buccal corridor limits, which had poor reliability.

Rater gender is not critical to evaluation of smile esthetics.

Many of the esthetic variables complement each other so that achieving an esthetic smile is clinically possible.

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Chapter 4

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Legend

Table 1. Reliability

Table 2. Full face vs Circumoral differences

Figure 1. A, Ideal smile arc; B, Maximum smile arc and C, Minimum smile arc

Figure 2. A, Ideal buccal corridor; B, Minimum BC and C, Maximum BC

Figure 3. A, Ideal gingival display; B, Maximum GD and C, Minimum GD

Figure 4. A, Ideal overbite; B, Minimum overbite and C, Maximum overbite

Figure 5. U midline to face maximum deviation

Figure 6. U to L midline deviation

Figure 7. Maximum central gingival deviation

Figure 8. A, Ideal lateral gingival height; B, Lower limit LG and C, Upper limit LG

Figure 9. Ideal lateral step

Figure 10. Lateral step down

Figure 11. Maximum cant

MEASURE	K_W[1]	$LCB_{.95}$	$UCB_{.95}$	Interpretation[2]
SA Ideal	0.34	0.25	0.43	Fair
SA Down	0.31	0.22	0.41	Fair
SA Up	0.30	0.20	0.40	Fair
BC Ideal	0.36	0.26	0.45	Fair
BC Min	0.09	0.06	0.14	Slight
BC Max	0.03	-0.02	0.09	Slight
GD Ideal	0.49	0.41	0.56	Moderate
GD Down	0.58	0.52	0.64	Moderate
GD Up	0.46	0.38	0.55	Moderate
U Mid/Face	0.60	0.53	0.67	Moderate
U/L Midline	0.48	0.40	0.57	Moderate
OB Ideal	0.25	0.13	0.38	Fair
OB Down	0.34	0.25	0.43	Fair
OB Up	0.45	0.37	0.54	Moderate
Cent Ging	0.58	0.51	0.66	Moderate
LG Ideal	0.35	0.25	0.44	Fair
LG Down	0.48	0.40	0.55	Moderate
LG Up	0.38	0.29	0.47	Fair
LS Ideal	0.30	0.21	0.39	Fair
LS Up	0.44	0.37	0.52	Moderate
Cant	0.53	0.45	0.61	Moderate

[1]Fleiss-Cohen weighted kappa statistic

[2]Landis and Koch{{68 Landis,J.R. 1977}}

Table 1: Reliability

Full face view

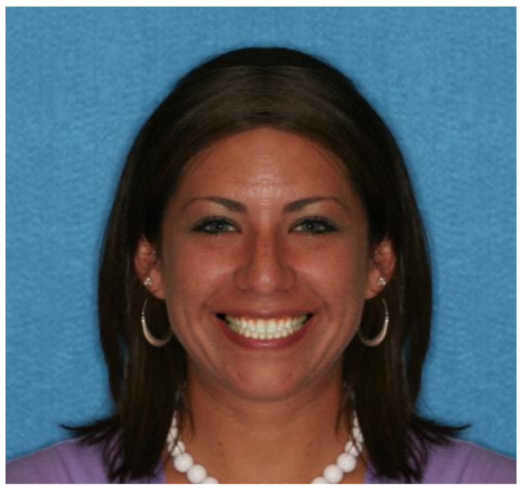
Variable	N	Median	Quartile Range	L 95% CL for Median	U 95% CL for Median	Min	Max	Δ	P (adj)[2]
SA Ideal	187	**-2.00**	2.0	-2.50	-2.00	-6.0	4.0	-3.50	**<.0001**
SA Down	182	**-4.00**	2.5	-4.50	-4.00	-6.0	3.0	1.00	**0.26**
SA Up	184	**1.50**	2.0	1.00	2.00	-6.0	4.0	-1.00	**0.00**
BC Ideal	177	**0.13**	0.05	0.12	0.13	0.06	0.25	-0.04	**<.0001**
BC Min	180	**0.17**	0.10	0.16	0.19	0.06	0.27	0.09	**<.0001**
BC Max	175	**0.17**	0.10	0.16	0.18	0.07	0.27	-0.05	**<.0001**
GD Ideal	184	**2.33**	1.20	2.25	2.40	-1.05	5.55	0.14	**1.0000**
GD Down	179	**0.75**	1.73	0.30	0.75	-1.88	3.00	4.40	**<.0001**
GD Up	178	**4.50**	1.95	4.50	4.95	2.25	6.75	0.49	**<.0001**
U Mid/Face	185	**3.15**	1.80	3.00	3.60	1.05	5.70	0.23	**0.01**
U/L Midline	157	**3.60**	1.35	3.45	3.75	1.05	5.70	1.59	**<.0001**
OB Ideal	179	**2.25**	1.20	2.25	2.40	0.0	6.15	0.24	**1.0000**
OB Down	182	**0.94**	2.40	0.75	1.50	0.0	4.95	0.57	**<.0001**
OB Up	173	**5.40**	1.65	5.40	6.00	4.95	8.85	-0.26	**0.88**
Cent Ging	180	**2.10**	1.05	1.80	2.25	0.0	3.00	0.09	**0.29**
LG Ideal	185	**-0.38**	0.75	-0.75	-0.38	-2.63	0.75	0.01	**0.07**
LG Down	179	**-1.88**	0.75	-2.25	-1.88	-2.63	-1.13	1.03	**<.0001**
LG Up	183	**0.38**	0.75	0.38	0.38	-1.13	0.75	-0.77	**<.0001**
LS Ideal	188	**1.20**	0.75	1.13	1.20	0.38	2.40	-0.20	**<.0001**
LS Up	186	**1.95**	0.60	1.88	1.95	1.50	2.40	-0.95	**<.0001**
Cant	172	**2.75**	2.25	2.50	3.25	0.00	6.00	-1.50	**<.0001**

Lower face view

Variable	N	Median	Quartile Range	L 95% CL for Median	U 95% CL for Median	Min	Max
SA Ideal	119	**1.50**	2.5	1.000	2.000	-6.0	4.0
SA Down	119	**-5.00**	3.0	-6.000	-4.000	-6.0	4.5
SA Up	119	**2.50**	3.0	2.500	3.500	-1.0	4.0
BC Ideal	119	**0.16**	0.1	0.146	0.171	0.0	0.3
BC Min	119	**0.08**	0.1	0.055	0.106	0.0	0.2
BC Max	119	**0.22**	0.1	0.204	0.250	0.1	0.3
GD Ideal	119	**2.19**	2.2	1.825	2.555	-0.9	5.8
GD Down	119	**-3.65**	3.3	-5.110	-2.920	-5.1	0.0
GD Up	119	**4.02**	4.0	3.468	4.928	0.0	5.8
U Mid/Face	123	**2.92**	2.6	2.555	3.650	0.0	4.4
U/L Midline	123	**2.01**	1.8	1.643	2.373	0.0	2.9
OB Ideal	123	**2.01**	0.9	1.825	2.008	0.0	9.5
OB Down	123	**0.37**	0.9	0.000	0.548	0.0	1.5
OB Up	123	**5.66**	4.7	5.110	6.388	1.5	9.5
Cent Ging	123	**2.01**	1.5	1.825	2.373	0.0	2.9
LG Ideal	123	**-0.38**	0.3	-0.384	-0.307	-1.1	1.1
LG Down	123	**-2.90**	3.2	-3.870	-2.258	-4.5	0.0
LG Up	123	**1.15**	0.5	1.059	1.236	0.0	1.2
LS Ideal	123	**1.40**	0.7	1.400	1.633	0.0	3.7
LS Up	123	**2.90**	1.2	2.694	3.316	0.0	3.3
Cant	123	**4.00**	3.5	3.250	5.000	0.0	6.0

Table 2: Full face view v circumoral view{{8 Ker,A.J. 2008}}

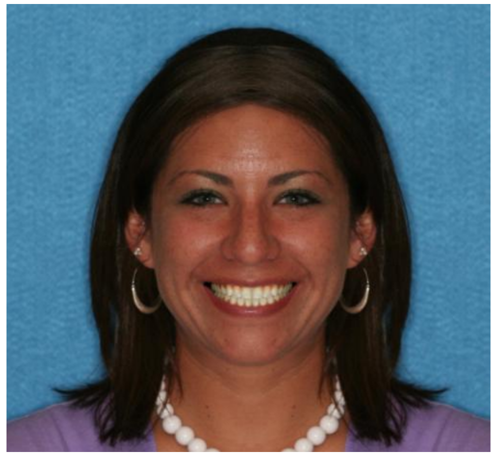
A



B

C

Figure 1. A, Ideal smile arc; B, Maximum smile arc and C, Minimum smile arc



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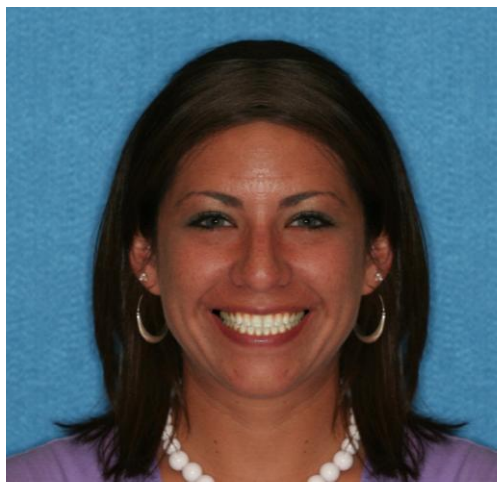

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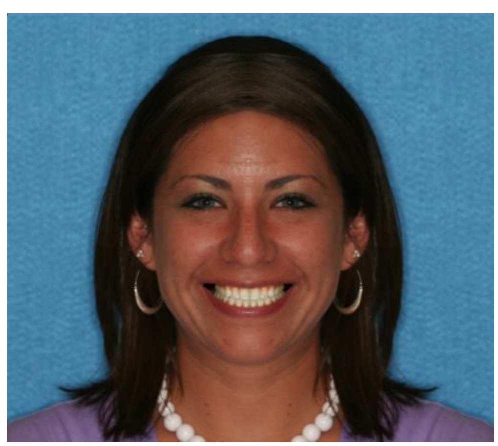


C

Figure 2. A, Ideal buccal corridor; B, Minimum BC and C, Maximum BC

A

B

C

Figure 3. A, Ideal gingival display; B, Maximum GD and C, Minimum GD

A

B

C

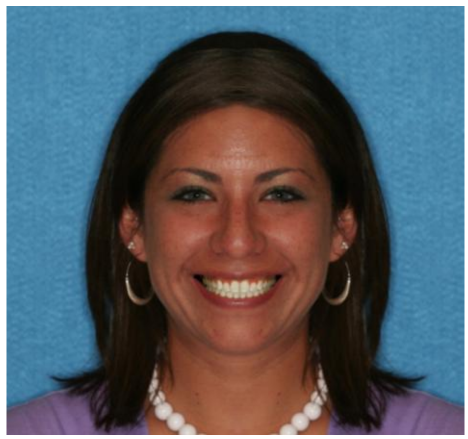
Figure 4. A, Ideal overbite; B, Minimum overbite and C, Maximum overbite

Figure 5. U midline to face maximum deviation

Figure 6. U to L midline deviation

Figure 7. Maximum central gingival deviation

A



B

C

Figure 8. A, Ideal lateral gingival height; B, Lower limit LG and C, Upper limit LG

Figure 9. Ideal lateral step

Figure 10. Lateral step down

Figure 11. Maximum cant