ESTHETICS AND SMILE CHARACTERISTICS FROM THE LAYPERSON’S PERSPECTIVE: A COMPUTER BASED SURVEY STUDY, PART I

A Thesis
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ABSTRACT

The paradigm shift from occlusion to esthetics emphasizes the interplay between dental structures and the surrounding soft tissue envelope. The objective of this study was to quantify the ideal and maximum acceptable deviation for nine smile characteristics by using digital manipulation of hard and soft tissue smile components. Intraoral photographs were manipulated using Adobe® Photoshop® CS2 to alter buccal corridor, smile arc, gingival display, crown torque in maxillary canines and the posterior buccal segments. Smiles were placed in a gender neutral face showing nasal tip to mentolabial fold. Quask™ Form Artist was used to generate the survey, which was administered in Columbus, OH (n=43); Seattle, WA (n=41) and Boston, MA (n=40). An interactive interface allowed raters to move a slider to answer questions. Rater reliability was assessed for each variable.

We found that, in general, raters were reliable (K = 0.5-0.8). Survey location was not significant except for the finding that the West coast accepted a broader smile (1.5 mm buccal corridor) than the Midwest and East coasts where the buccal corridor was found to be too minimal at 6 mm.
Rater preference for ideal and the threshold of acceptability is outlined below.

1. **SMILE ARC**: Cusp tips of the maxillary 2nd molars were 7.2mm above the incisal edges of the maxillary central incisors.

2. **SMILE ARC UNACCEPTABLE**: >7.9mm and <2.6mm above the incisal edges.

3. **BUCCAL CORRIDOR IDEAL**: 5.8 mm each side (16%).

4. **BUCCAL CORRIDOR UNACCEPTABLE**: >9.4 mm (26%) and <2.9 mm (8%) of dark space.

5. **GINGIVAL DISPLAY IDEAL**: 2.1mm (-2.1mm gingival display) central incisor coverage by upper lip.

6. **GINGIVAL DISPLAY UNACCEPTABLE**: >3.6mm of gingival display and 4mm of incisal coverage.

7. **CANINE TORQUE, IDEAL CORRIDOR**: -1 degree considered ideal with acceptable range of +10 to -7 degrees.

8. **CANINE TORQUE, LARGE CORRIDOR**: -4 degrees considered ideal with acceptable range of +8 to -10 degrees.

9. **POSTERIOR TORQUE, IDEAL CORRIDOR**: +4 degrees considered ideal with acceptable range of +5 to -7 degrees.

10. **POSTERIOR TORQUE, LARGE CORRIDOR**: +6 degrees considered ideal with acceptable range of +5 to -8 degrees.

We concluded that, overall, the preference of raters in different locations was not clinically significant and that raters displayed a wide range of acceptability for canine and posterior tooth crown torque in both narrow and broad smiles. This is a reliable method for determining individual smile characteristic preferences. Due to the wide range of...
acceptability for the ideal and threshold values for most variables, clinicians must be aware of individual preferences for each specific patient and should probably avoid sensitization of patients to smile characteristic deviations that fall within the acceptable range. The findings of this study can be used by clinicians as both a guideline toward ideal orthodontic finishes and acceptable compromise.
Dedicated to my grandparents, Alan and Thelma Ker, for their inspiration to think, show resolve, and their encouragement to be involved with important things and good people.
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CHAPTER 1

INTRODUCTION

An emerging attribute of the contemporary orthodontic practice is the ability to manage characteristics of the dentition and soft tissue to create an esthetic smile either by tooth movement, soft tissue modification, restorative procedures, or some combination of these techniques. The development of an esthetic smile, although subjective, should be based upon as much objective evidence as possible. Until recently, however, the refereed literature had not clarified the importance of smile characteristics according to dental professionals or laymen. Just one century ago, the central tenet of Angle, was that ideal dental and facial esthetics would emerge simply from an optimal dental occlusion integrating all permanent teeth. Subsequent studies in restorative dentistry and orthodontics demonstrated that dental professionals and laymen are aware of individual smile characteristics and certain outcomes had negative consequences on the overall appeal of a smile. A prominent example is flattening of the smile arc, which may be more unattractive than originally thought.

Unfortunately, without comprehensive studies of smile esthetics, practitioners are forced to make clinical decisions that are not evidence based or governed by established satisfaction data from laypeople. As the dental profession and lay people pay more attention to smile esthetics (dental and facial), orthodontists may no longer declare success by simply aligning the teeth and providing a good occlusion. Dentists are
obligated to understand harmony, proportion, and balance when planning treatment\textsuperscript{13}. Morley described a specific aspect of facial esthetics called ‘macroesthetics,’ which outlines the esthetic principles that apply when the relationship between groupings of teeth are considered\textsuperscript{14}. He recognized the importance of the relationship between teeth and the surrounding soft tissue in smile design. The shift in paradigm from occlusion to esthetics was also described by Sarver and Ackerman\textsuperscript{15} who emphasize the interplay between the dental structures and their surrounding soft tissue envelope. Sarver and Ackerman\textsuperscript{15} acknowledge three requirements for the assessment of dentofacial esthetics:

1. 3-dimensional evaluation of the face and smile both dynamically, from the clinical exam, and statically, from the photographic survey of the patient.
2. A measure of lip to tooth relationship at rest and during facial animation with emphasis on the clinical appearance over the cephalometric measurement.
3. An analysis of the current interaction between the dentoskeleton and the facial soft tissues in the frontal and lateral planes.

Furthermore, they stress that this process can be enhanced through the use of computer simulation and patient participation. The authors have piloted some of the studies.

Some studies have applied similar methodology to our study in altering dental morphology\textsuperscript{2,15-17}. Studies of this nature have been limited in the past due to the inability to standardize a realistic model in which discrete variables can be altered. Digital imaging has met this challenge by enabling image manipulation that is reliable and quantifiable on a continuous scale, for all practical purposes. Further, clinically relevant changes can be introduced to enhance the application to meaningful patient care. The
purpose of the proposed study is to adequately quantify both the ideal and maximum acceptable deviation from ideal for nine prominent smile characteristics as judged by laypeople using digital technology to manipulate hard and soft tissue components of the smile.

COMPREHENSIVE LITERATURE REVIEW AND STATEMENT OF THE PROBLEM

Dentofacial attractiveness is readily apparent and evaluated on several levels. Studies have demonstrated a strong interaction between dentofacial attractiveness and psychosocial well being\textsuperscript{18-22}. Shaw\textsuperscript{23}, for example, demonstrated that peers preferred to have children with more esthetic smiles as friends when shown pictures of a variety of faces with malocclusions. Others have also found that attractive people are seen as more popular\textsuperscript{24-27}, intelligent\textsuperscript{28}, sociable\textsuperscript{29,30}, and have greater potential as mates\textsuperscript{31,32}, when compared to less attractive people. Yet, despite centuries of study and our awareness of the importance of the smile, ideal and acceptable values of many smile characteristics remain speculative.

The study of dentofacial esthetics originated with the search for expression of proportionality in the face and dentition. Peck and Peck\textsuperscript{33} reviewed how erudite individuals of early Greek, Chinese, and Egyptian civilizations interpreted facial esthetics through analysis of proportions in their art. During the Renaissance, the smile was not studied as much as the face. Leonardo da Vinci used mathematics to measure harmony in
facial and body proportion in many of his works. Early European philosophers espoused the term “Golden Section” to emphasize that things molded in the proportion of 1.618:1 would be most visually stimulating. Alternatively, Japanese Buddhist culture preferred the square root of 2 as a mathematical explanation for harmony in natural form. Interestingly, both concepts are derived from the famous mathematical progression of Fibonacci.

Both concepts were applied in assessments of dental esthetics. Ricketts developed a method of facial analysis with the golden proportion (section) as a foundation for proportionality of vertical thirds of the face while Nakajima used the √2.

Unfortunately, these mathematical constructs have not been reliably applied in evaluating facial and dental esthetics. Preston questioned the idea that the golden proportion defined optimum esthetics in anterior teeth and found the ratio did not match actual measurements. Ong et al. also demonstrated that raters do not follow the golden proportion (.62) when evaluating central to lateral incisor widths as they chose a ratio of .8 to be most ideal. In an era of evidenced based dentistry, practitioners must be wary of using unsubstantiated methods in diagnosis and treatment planning.

Recently, increasing attention has been directed at esthetics in the scientific literature. In 1970, only five publications regarding physical attractiveness were published per year whereas now the number approaches 200. Early studies in dental esthetics focused on the size, shape, and proportions of teeth while later studies increased in complexity to emphasize the importance of symmetry, the neighboring periodontal architecture and the relationship of teeth to the extraoral soft tissues.
Today, the primary goal of orthodontics is summarized as the guidance of dental and facial development with the end result being a balanced profile and smile\textsuperscript{15}. A recent study used the aesthetic component of the Index Of Treatment Need (IOTN) to show that dental esthetics appear to contribute approximately 30\% to facial esthetics\textsuperscript{47}. However, orthodontists traditionally evaluate growth and development from a lateral perspective, which is reflected by cephalometric analyses used to measure facial proportions. A standardized frontal smile analysis is not part of the diagnosis and treatment planning process due to unavailability of norms or standards for measurement. Orthodontists are left to conclude that when balance is achieved from a lateral perspective, balance follows from the frontal perspective. This is a non sequitur as Mackley\textsuperscript{48} found profile photographs to be an unreliable predictor of smile esthetics and laypersons nearly always from the frontal perspective\textsuperscript{49}.

Angle\textsuperscript{10} and Sarver and Ackerman\textsuperscript{15} emphasize that a variety of faces can be alluring. What, on the other hand, makes the interaction between the dental hard tissues, soft tissues, and perioral tissues esthetic? Even though Morley\textsuperscript{14} has suggested that it is the interplay of all characteristics of the anterior dentition that makes a smile attractive or unattractive, a hierarchy of smile characteristics seems to exist\textsuperscript{38}. That implies that smile esthetics must be disaggregated to clarify the relative importance of individual characteristics to the whole.
Treatment planning in orthodontics cannot be predicated upon simple alignment of the teeth because it ignores the interaction between the hard and soft tissues. However, characterization of the interaction between treatment protocol and esthetic outcome proves difficult before the desirability of a particular smile characteristic is definitively quantified.

Work on these characteristics has progressed for some time with investigators approaching the problem from different perspectives. The principles relevant to the creation of an ideal smile stem from the desire to fabricate a more natural looking denture. In 1914, Williams investigated whether tooth shape (rectangular, triangular, or ovoid) should be dictated by facial shape in denture patients. He concluded that tooth shape should reflect the shape of the patient’s head when viewed upside down. Frush and Fisher advanced the literature in trying to harmonize teeth with the patient’s gender, personality and age. This study was the foundation for the prosthodontic ethos that round, soft teeth suit women and square, robust teeth suit men. Focusing on dental esthetics is not a new idea, even though early studies have roots in pseudo-science.

Many authors have emphasized the importance of evaluating the position of the maxillary incisors inside the labial arcade of the smile. Development of a harmonious relationship between the central incisors and between central and lateral incisors was considered a hallmark of esthetic dental therapy. Brisman used adumbrations of the four maxillary incisors to establish that the width to length proportion of anterior teeth ideally falls between 66 and 80%. Lombardi and Levin followed with the proposal that the proportion of visibility of a central and lateral incisor and of a lateral incisor and canine followed the golden proportion. That is to say, on
frontal view, 100% visibility of a central incisor is optimally paired with 62% visibility of a lateral incisor. As mentioned above, Preston refuted this hypothesis. A web based study\textsuperscript{17} showed that dentists preferred a width to height ratio of 0.75-0.78 for the maxillary incisors. Recently, Wolfart and colleagues\textsuperscript{4} found the ideal width to length ratio of anterior teeth fell between 75 and 85%. However, the inclusion of medical students in their lay sample may have biased the outcome due to their increased knowledge of corporeal proportions. Additionally, their method of image modification did not limit the alteration to the teeth of interest. The limitations of previous studies and the variability in outcome warrant further investigation into preferences of tooth proportionality by lay people.

Tooth to lip interaction is a prominent aspect of smile esthetics requiring better quantification. Sarver\textsuperscript{12} wrote that, in a repeatable posed smile\textsuperscript{54}, the ideal smile arc is one that mimics the curvature of the lower lip from central incisor to canine. Hulsey\textsuperscript{11} first addressed the smile arc in 1970 when he found that orthodontically treated patients displayed flatter incisal planes than untreated patients when measured at the central incisor. Tjan and colleagues found that, naturally, 85% of people have a smile arc that follows the curvature of the lower lip. Conversely, a straight (14%) or reverse (1%) smile arc is seen only rarely\textsuperscript{55}. More recently, Ackerman et al\textsuperscript{56} found that 32% of his patients displayed flattening of the smile arc but other research\textsuperscript{3} concluded that flattening of the smile arc after orthodontic treatment was still consonant to the lower lip with a head posture common to normal conversation. Whether orthodontic treatment flattens the smile arc or not, Parekh et al\textsuperscript{1} definitively showed that when the smile arc was flat, smiles were more negatively rated by males and females across the board.
Another smile characteristic characterized by the interaction of the teeth and lips is the buccal corridor. As originally described by Frush and Fisher\(^{40}\), the buccal corridor was defined as the dark space between the lateral aspect of the maxillary posterior teeth and the commissure of the mouth. Historically, having the appropriate amount of negative (or dark) space between teeth and the corner of the mouth was a denture esthetics concept -- too much negative space resulted in large empty spaces at the corner of the mouth, while too little looked artificial. A recent study by Yang\(^{57}\) indicates that the buccal corridor is a multifactorial outcome of vertical face height, upper incisor exposure, and overall tooth mass. Archform, dental expansion, soft tissue animation, and the transverse dimension of the smile also contribute to buccal corridor size. Regardless of what factors determine the buccal corridor size, it is unclear if it is really an important smile characteristic to laypersons.

Previous studies on the esthetic importance of the buccal corridor used varying definitions and methods of measurement\(^{11, 46, 58}\), which limits the collective power of these studies. Hulsey\(^{11}\) found that buccal corridors did not contribute positively or negatively to smile esthetics, but he used the distal of the canine as the inner boundary of the corridor which probably misrepresents the actual size of the buccal corridor. Roden-Johnson\(^{8}\) used digitally altered photos of orthodontically treated and untreated controls to conclude that buccal corridor did not affect smile esthetics but their study was limited because the ideal and maximum allowable corridor sizes were determined by the investigators, not the raters. That problem was eliminated by Moore et al.\(^{6}\) who used five different categories of buccal corridor width in paired, dual-image combinations. Raters demonstrated some image preference and it was determined that minimal buccal
corridors (2%) were preferred by men and women when evaluated in view of the full face. This is a vastly smaller corridor than the 19.2% proposed to be average by Ritter.

Increased emphasis on non-extraction orthodontics and consequently, maxillary expansion, has increased the apparent relevance of buccal corridor space to esthetic dentistry. Some orthodontists currently incorporating extensive arch broadening to accommodate crowded teeth may affect the corridor size. Others support non-extraction treatment on the belief that premolar extraction increases dark space between the corner of the mouth and the posterior teeth. There is ample evidence that this is not the case, however. Numerous authors have found that premolar extraction does not result in narrower dental arches, nor does it negatively affect the perception of smile esthetics. Given this, the more relevant issue may be whether non-extraction with buccal expansion actually affects smile esthetics negatively.

Biological and anatomical limitations do not permit overexpansion of the dental arches so alternative strategies to minimize the buccal corridor size (reduce dark space at the corner of the mouth) have been proposed. Zachrisson’s recommendations for canine uprighting and increasing buccal crown torque in the maxillary premolars and molars to increase posterior tooth display and minimize negative buccal corridor space have not been substantiated through research. Additionally, it is not clear if such torque applications would be more valuable in narrow arches as might be suggested by Moore’s findings that raters preferred a 2% buccal corridor.

Another interaction between the dentition and the facial soft tissues is the amount of gingival display shown with a posed smile. Peck and Peck and Tjan and colleagues independently observed gender differences in gingival display with females displaying a
high (gummy) smile line twice as often as males. Additionally, Vig and Brundo\textsuperscript{67} demonstrated sexual dimorphism in anterior tooth display with males showing more lower incisor and females showing more upper incisor on smile. This implies women are more likely to have a high smile line. Kokich\textsuperscript{2} found that most dentists and lay people did not object to gingival display of 4 mm in a posed female photograph, although the 2 mm increment used to detect the threshold of unattractiveness appeared quite large. His more recent study\textsuperscript{68} used 0.5 mm increments and showed lay people detected 3 mm of gingival display. This is a strong indication that smaller increments are required to establish threshold levels of esthetic acceptability. Excessive gingival display is also a byproduct of an abnormal crown width to height ratio; the implications of altered crown dimension have not been fully clarified.

Kokich\textsuperscript{2} was the first to use computer based image modification in an attempt to quantify the acceptability of certain smile characteristics. It appears that he used life size smile images of the lips and teeth. Kokich only displayed female faces to reduce confounding variables. This method is supported because other authors\textsuperscript{1,6,69} have found no difference in esthetic ratings in male or female faces. He found that orthodontists, general dentists, and lay people were able to detect discrepancies in smile characteristics at differing levels and that, for many variables, the lay people were less discriminating than the practitioners. A summary of his findings is below.
His study represented progress and opened new vistas for investigators, but was limited by excessive cropping of the lips and differences in skin tone, lipstick, tooth shape, and other distracters. Other authors\textsuperscript{6,9} have advocated the inclusion of more facial features to allow the interaction between all smile related soft tissues and the dentition. Standardized images also reduce confounding variables. Kokich also used incremental adjustments of each variable for the raters to judge. This method of variable alteration might obscure the true threshold for variable awareness, depending upon the increment. It may be possible to refine and confirm the results of this study using more advanced digital imaging methods.

### Statement of the Problem

More clarification as to what is ideal and acceptable in smile esthetics is necessary so that unique esthetic preferences can be incorporated for each patient\textsuperscript{19,70}. This study will attempt to identify the ideal and acceptable range of several smile
characteristics through digital image manipulation. The presentation of a standardized gender ambiguous circumoral area including the lower face will allow the smile to be seen in a more natural context. Smaller increments that appear to be nearly continuous will be incorporated. Most importantly, smile characteristics can be physically manipulated by the raters so they can appreciate the realm of possibilities before they choose what they find most appealing or at the threshold of acceptability. The definitive preferences of lay people for ideal and acceptable deviations of smile characteristics will be demonstrated.

**Specific Aims**

1. To develop and administer a computerized survey to allow lay raters to evaluate and manipulate several smile characteristics along the spectrum of their possible manifestations.

2. To determine that rater response is reliable by repeating every question twice throughout the survey.

3. To assess for regional differences by administering the survey in Seattle, WA, Columbus, OH, and Boston, MA.

4. To determine if lay raters prefer different torque quantities when evaluating buccal crown torque in bilateral canines or bilateral posterior segments (1\textsuperscript{st} premolar through 2\textsuperscript{nd} molar) in a narrow and a broad smile.
Population and samples

The perception of esthetics on digitally altered smiles will be studied using a population of lay people. The sample will be drawn from those population subtypes located within the United States. All participants of the study will be a minimum of 18 years of age. Studies have shown no difference in rater evaluation of smile characteristics and age\textsuperscript{71}. However, gender, ethnicity and socio-demographic status (SDS) will be identified as they may play a role in perception. Participants possessing a professional or related dental background will be excluded from the sample. Individual participants will represent an experimental unit. The true population sampled will be defined through analysis of the demographic questions administered with the survey.

Variables

Independent Variables

- SMILE ARC - The smile arc, which is defined as the curvature formed by an imaginary line tangent to the incisal edges of the teeth, will be modified by 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. The curvatures that correspond with these smile arcs were established in a pilot study\textsuperscript{1} of orthodontists with greater than five years of experience and they represent a series of parabolic curves. Ultimately, the outcomes for this variable will be determined by measuring the vertical distance from a tangent line through the incisal edges of
the maxillary central incisors to the cusp tips of the maxillary canines and maxillary $2^{nd}$ molars. The smile arc will range from flat, 0 mm through 5 mm at the canines and 9 mm at the $2^{nd}$ molars.

- **BUCCAL CORRIDOR** – 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 will be presented as a series of images representing the spectrum of corridors from essentially none to large. The amounts that correspond with a minimal, moderate, and large buccal corridor have been established by a pilot study\textsuperscript{1} of orthodontists with greater than five years of experience and by Moore et al\textsuperscript{6}. Images will show variations of 0.1825 mm for this study and the range of corridor size is 0 mm up through 12 mm.

- **MAXILLARY GINGIVAL DISPLAY** – Gingival display, or a “gummy smile,” is defined as the amount of gingival show above the zenith of the maxillary central incisor crown and below the central nadir of the upper lip. The range of modification will be from ±6 mm of gingival display demonstrated by moving the entire dentition upward or downward in 0.1825 mm increments.

- **CANINE AND POSTERIOR TOOTH CROWN TORQUE** – Also referred to as “buccal crown torque,” this variable represents the amount that these maxillary posterior teeth lean toward the cheek or toward the tongue from gingival margin to cusp tip. The range of modification will be ±10 degrees in 1 degree increments. This variable will be presented such that the bilateral canines or bilateral $1^{st}$ premolar through $2^{nd}$ molar are adjusted on both narrow and broad (2% buccal corridor) smiles.
• SURVEY LOCATION – The survey will be administered in Seattle, WA, Columbus, OH, and Boston, MA to assess for regional differences.

• CORRIDOR SIZE FOR CROWN TORQUE – The canine and posterior tooth crown torque variables will be assessed in both an ideal and narrow corridor to investigate whether rater preference for crown torque quantity changes with alteration of overall smile width.

**Dependent Variables**

• Esthetic perception of each variable – The perception of esthetics will be based on raters’ response to the statement “Please move the slider to select the image you find to be MOST IDEAL.” Smile characteristics can be adjusted by positioning a slider, termed an emoticon, in a rater determined ideal position. The emoticon will be not be anchored so the rater may find any of the images to be the most esthetically pleasing. Each image is assigned a known value.

• Acceptability – The same slide will be refreshed and the raters will then be asked to respond to the statement “Please move the slider to select the first image that you find UNATTRACTIVE.” to select the position of the slider moving up or to the right from the ideal position until the smile becomes unacceptably unattractive. Finally, the rater will be asked to select the position of the slider moving down or to the left from the ideal position until the smile becomes unacceptably unattractive in the other direction, for instance the maximum and minimum gingival display. By completing this exercise they will have defined the ideal and the limits of acceptability. Each image is assigned a known value.
Null Hypotheses

$H_01$: There will be no difference in the perception of ideal and acceptable values of posterior buccal crown angulation (torque) or canine buccal crown angulation (torque) in narrow and broad smiles when evaluating digitally manipulated images of the smile and circumoral area.

$H_02$: Location of survey administration will not influence the perception of ideal and acceptable values of esthetic and smile characteristics including buccal corridor, smile arc, maxillary gingival display, posterior buccal crown angulation, or canine buccal crown angulation.

$H_03$: Raters will not be reliable in their perception of ideal or maximum deviation from ideal for the smile characteristics investigated herein.
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CHAPTER 2

MATERIALS AND METHODS

This research project attempts to present the general population with the chance to view a comprehensive set of possibilities for numerous smile characteristics so that accurate selection of the most ideal and maximum acceptable deviations of each characteristic can be defined. Digital “continuous” motion pictures of the possible values of female smile characteristics (smile arc, buccal corridor, gingival display on smile, and canine and posterior tooth crown torque) were presented for lay raters to evaluate. This method provides for a comprehensive and unbiased opportunity to make the selections based on esthetic considerations.

Human Subjects Approval

Applications for Institutional Review Board (IRB) exemption, HIPAA waiver, and Waiver of Written Informed Consent were made and granted by the IRB.

Model Selection

A university digital archive was scanned for one intraoral center photograph of an ideally treated orthodontic case, and extraoral photographs of both a male and female patient that displayed esthetic lips. Initial image selection and manipulation follows the protocol of Parekh, et. al\(^1\). The high resolution extraoral photographs from one male and
one female patient had different oral apertures so they were matched using the liquefy feature of Photoshop® CS2. Alteration of image opacity allowed overlay and compression of the male image into the female image so that the combined image would represent no identifiable patient.

**Initial Image Manipulation**

As in Parekh, et. al\(^1\), original JPEG images were opened in Adobe Photoshop® CS2 and saved as a Photoshop® Document (PSD). This allowed for subsequent changes and saved images to have similar resolution and quality. The intraoral center photograph was cropped to display only the right half of the mouth, and then mirrored for symmetry. The images of the face were cropped to show only the lips, nasal tip, and mentolabial fold with minimal other surrounding tissue. No other facial features were evident in order to reduce distractions.

Using the imaging program, the teeth and periodontium were erased from the male and female lower face picture to create a “hollow” lip set. Previous research is conflicting on the influence of male or female face on the perception of smile characteristics. Parekh\(^1\) showed no difference while Geron\(^2\) reiterated the issue of sexual dimorphism in maxillary anterior tooth display. Therefore, this study blended one female and one male lower face to produce a sexually ambiguous subject for raters to evaluate. The faces were blended using the liquefy feature in Adobe Photoshop® CS2 to make the oral apertures congruent and then overlaying the male lower face at one-third opacity onto the female lip profile. The male and female lower faces were then merged into a composite image.

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Smiles and lower faces were projected at the same size on the computer screen when completing the survey as they would at typical conversational distance. The resolution was standardized on all computers used during this study at 1024 x 768 pixels. The teeth and lips were proportioned and sized to meet these viewing dimensions. This was done through use of a digital measurement grid overlayed on the smile so that the central incisor width and height could be matched to the appropriate size for conversational distance. The lower face was then proportionally downsized from the original raw image to match the smile arc and buccal corridor quantity established as ideal by previous research\(^1, 3, 4\).

**SURVEY 1**

Survey 1 focused on the following characteristics: smile arc, buccal corridor width, gingival display, canine crown torque, and posterior tooth crown torque. The last two variables were compared on a wide and narrow smile (small and large buccal corridors, respectively) because the visibility of the posterior teeth may be different in broad and narrow smiles. Survey two included occlusal cant, maxillary and mandibular midline deviation, peg laterals, lateral to central incisal edge discrepancy, and crown height to width ratio alterations.

**Smile Arc**

The method of Parekh, et. al\(^1\) was used to create a series of parabolas to use as a template to generate a nearly continuous set of possible smile arcs with Math GV™ FREEWARE Version 3.1. The function \(f(x) = ax^2\), with “a” representing a coefficient
ranging from 0.01-0.21, a series of 21 parabolas of increasing curvature were plotted. This plot was saved as a JPEG, imported into Adobe Photoshop® CS2, and sized to fit the number 7 parabola to the lower lip curvature.

The mirrored intraoral center image was then morphed using the liquefy 3D transform function in Photoshop™ by making the cusp tips of the maxillary and mandibular teeth fit the curves. To prevent distortion in the teeth, the central incisors were covered with a digital “mesh” that prevented the liquefy feature from modifying their size, shape, or position. The liquefy feature was then used to make the cusp tips of the lateral incisors through second molars match the series of parabolas generated in the method described above. After each transformation, the new smile arc was saved as a new layer in Photoshop™ labeled by the amount of vertical change in the canine and second molar from a line tangent to the incisal edges of the central incisors. The range of possibilities was 0 through 5 mm at the canine and 0 through 9 mm at the 2nd molar. Lastly, the lower face image was overlayed over each individual smile arc for placement into the survey emoticon.

**Buccal Corridor**

The buccal corridor spaces were manipulated starting with composite smile number 7 because this matches the current, accepted definition of an ideal smile arc; where maxillary incisal edges are parallel to the curvature of the lower lip. Instead of using an airbrush as in previous research, the amount of black space between the commisure of the lips and the most buccal tooth in the smile was increased or decreased by moving each individual tooth. The arch breadth was altered so that the number of
teeth visible was not changed but rather the amount of each posterior tooth visible was modified. This was done using individual cutouts of each posterior tooth with an overlay measurement grid. A digital mesh was overlayed over the mesial of right canine to mesial of left canine to prevent any changes in their size, shape, or position. The individual tooth cutouts were moved in or out to emphasize or minimize, respectively, the dark space at the lateral aspects of the smile in one-quarter millimeter increments. Sixty-five possible corridors in total were made at one-quarter millimeter increments for a range of 0 mm dark space to 12 mm dark space bilaterally. This quantity closely represents the physiologically possible variations of the buccal corridor space.

Conversion of millimetric values to a percentage of overall smile width was done post-hoc by dividing the millimetric measurement of the dark space by the overall millimetric width of the smile from commisure to commisure. All lips and morphs of the teeth were stored as layers in Photoshop™ which allowed them to be overlayed upon each other. Lastly, the lower face image was overlayed over each individual buccal corridor for placement into the survey emoticon.

**Gingival Display**

Lay rater assessment of gingival display on smile was approached by modifying the skeletal position of the dental arches. Inside the lip profile, the intraoral center photograph was manipulated upward and downward in one-quarter millimeter increments using a digital measurement grid to represent the range of possible positions of the maxilla and mandible and the effect of their position on gingival display during a full smile. The lower face image and morphs of the teeth (ranging from +6 mm display to -6
mm display) were stored as layers in Photoshop™ which allowed them to be combined into a composite image. Lastly, the lower face image was overlayed over each individual gingival display for placement into the survey emoticon.

**Buccal Crown Torque**

Addition or subtraction of crown torque in posterior teeth is hypothesized to aid in balancing the relationship between the commissure of the lips and the buccal tooth surfaces. Therefore, individual tooth cutouts of the posterior teeth (canine through second molar) of an intraoral center smile image with an ideal buccal corridor (2% bilaterally\(^3\)) and with a wide buccal corridor were made. A rotation icon was placed on each individual tooth to replicate the center of resistance of the tooth (near two-thirds the length of the root from the cementoenamel junction for canines or the molar furcation). Then, the teeth (either canines individually or all teeth distal to the canines) were “torqued” using the rotation feature in Photoshop™. Canines were torqued positively (labial crown torque) to 10 degrees and negatively (lingual crown torque) to -10 degrees. Similarly, the posterior teeth were torqued positively to 10 degrees and negatively to -10 degrees. The lower face image and morphs of the crown torque images were stored as layers in Photoshop™ which allowed them to be combined into a composite image. The lower face image was then overlayed over each individual torque value for placement into the survey emoticon.
The survey was designed to encompass the ideal and maximally deviant values for many smile characteristics studied previously\textsuperscript{1,5,6}. Two surveys were necessary as one survey including all variables would require more time to complete than the average orthodontic adjustment in private practice.

Survey 1 and 2 were created using Quask Form Artist\textsuperscript{TM} Professional Edition. Form Artist\textsuperscript{TM} is a survey administration software allowing questions to be linked to emoticons. Emoticons are a series of discrete pictures that represent answers to survey questions. An example of an emoticon is the “smiley face to frown with tears” pain scale found in many doctor’s offices.

Emoticons were used in this study as a proxy for the display of fluid, continuously modifiable smiles over a pre-defined range. They were created by measuring the pixel width of the lower face image and multiplying that number of pixels by the number of morphed intraoral center pictures for each variable. This provided the appropriate size for the “comic strip” or “motion picture” designed emoticon. The morphed intraoral center image was coupled with the lower face image (as described above) and laid out in sequential order along the “comic strip.” The comic strip was then compressed and saved as a Quask supported .gif image. Code was written in the emoticon notepad executable file telling the survey software what value each lower face-intraoral center image represented when selected by a rater.
Each emoticon was then joined to a slider bar which allowed the image to change as the slider was moved left/right or up/down. Due to the minute changes made during the initial image manipulation in Photoshop™, movement of the slider produced what appeared to be a continuous scale of possible smile choices even though changes were occurring in discrete 1 degree or .25 mm amounts.

The emoticons were then laid out in survey pages in Form Artist™ following several introductory slides. The survey began by detailing the purpose of the study, instructions, examples, and demographic questions used to typify the rater sample. Respondents were asked to voluntarily provide U.S. geographical region of residence, ethnic background, level of education completed, and dental affiliation. Any previous dental affiliation disqualified respondents from participation and terminated the survey.

Upon completion of the introduction, respondents were launched into a series of 28 (survey 1) or 26 (survey 2) emoticon questions. Each emoticon question was presented with one of two statements: 1) “Please move the slider to select the image you find to be **MOST IDEAL**” or 2) “Please move the slider to select the first image that you find **UNATTRACTIVE**.”

The first question was designed to clarify the ideal value for a given smile characteristic. The second question was designed to elucidate how far in each possible direction from the median value a smile characteristic can deviate before becoming unattractive. For this research design and, where possible, previously defined mean ideal values³,⁵-¹² were utilized as the starting point when the emoticon was activated by the respondent. Any movement from this start point would theoretically be toward a less esthetic alternative. Raters were asked to move in either direction from the previously
defined ideal, where applicable. Thus, the maximum tolerable deviation in either
direction of ideal for the smile characteristics could be defined. The survey software
presented the emoticons in random order for each rater to minimize bias.

**Sample**

Survey administration was completed in orthodontic offices in Seattle, WA, Columbus, OH, and Boston, MA by asking 300 parents and patients over the age of 18 to participate anonymously. For the estimated 10-15 minutes of participation time, respondents received a ten dollar gift card. All surveys were presented on laptop computers with resolution set to 1024 x 768 so the aspect ratio was similar between all four computers. Wired optical mice were available at each computer. After survey administration was completed, rater responses were coded to a random number which linked all of the responses to a single rater. These data were then exported so the responses to each survey could be compiled for statistical analysis.

**Statistical Analysis**

Rater reliability was assessed for each variable as each emoticon question was presented twice inside each survey (1 and 2) using the weighted Kappa statistic. Differences in attractiveness ratings were analyzed using descriptive statistics including median and 95% confidence intervals. Due to non-normally distributed data, multiple Mann-Whitney-Wilcoxon tests with Bonferroni correction of Holm were conducted to investigate whether raters indicated different preferences for the smile characteristics by region. To evaluate the possibility that raters prefer different amounts of crown torque in
canines and posterior teeth when the size of the buccal corridor varies, the signed rank test was used. Due to the number of comparisons for the regional differences, a Bonferroni correction was instituted and adjusted p-values are reported. The level of significance was set at a p value of <0.05 for all analyses.

For an experiment-wise, non-directional alpha risk of 0.05 and assuming a common standard deviation of 17.42\textsuperscript{13} a sample size of 100 subjects per rater group was necessary to achieve a power of 0.85 to demonstrate a difference of 1 mm or 1 degree on the slider scale.
LIST OF REFERENCES


CHAPTER 3

MANUSCRIPT:

Esthetics and Smile Characteristics from the Layperson’s Perspective: A Computer Based Survey Study

ABSTRACT

The paradigm shift from occlusion to esthetics emphasizes the interplay between dental structures and the surrounding soft tissue envelope. The objective of this study was to quantify the ideal and maximum acceptable deviation for nine smile characteristics by using digital manipulation of hard and soft tissue smile components. Intraoral photographs were manipulated using Adobe® Photoshop® CS2 to alter buccal corridor, smile arc, gingival display, crown torque in maxillary canines and the posterior buccal segments, maxillary midline to face, maxillary to mandibular midline, overbite, crown width to height ratio, central gingival height discrepancy, lateral incisor step, lateral incisor size, and maxillary cant. Smiles were placed in a lower face showing nasal tip to mentolabial fold. Quask™ Form Artist was used to generate the survey, which was administered in Columbus, OH (n=81); Seattle, WA (n=84) and Boston, MA (n=78). An interactive interface allowed raters to move a slider to answer questions. Rater reliability was assessed for each variable.
We found that, in general, raters were reliable (K = 0.5-0.8). Survey location was not significant except for the finding that the West coast accepted a broader smile (1.5 mm buccal corridor) than the Midwest and East coasts where the buccal corridor was found to be too minimal at 6 mm.

Rater preference for ideal and the threshold of acceptability is outlined below.

11. **SMILE ARC:** Considered ideal when the cusp tips of the maxillary 2nd molars were 7.2mm above the incisal edges of the maxillary central incisors. The acceptability range fell between 7.9 mm and 2.6 mm above the incisal edges.

12. **BUCCAL CORRIDOR:** 5.8 mm corridor on each side (16%) considered ideal. The acceptability range was between 9.4 mm (26%) and 2.9 mm (8%) of corridor.

13. **GINGIVAL DISPLAY:** 2.1mm (-2.1mm gingival display) central incisor coverage by upper lip considered ideal. Acceptable range between 3.6 mm of gumminess and 4 mm of incisal coverage.

14. **CANINE TORQUE, IDEAL CORRIDOR:** -1 degree considered ideal with an acceptable range of +10 to -7 degrees.

15. **CANINE TORQUE, LARGE CORRIDOR:** -4 degrees considered ideal with an acceptable range of +8 to -10 degrees.

16. **POSTERIOR TORQUE, IDEAL CORRIDOR:** +4 degrees considered ideal with an acceptable range of +5 to -7 degrees.

17. **POSTERIOR TORQUE, LARGE CORRIDOR:** +6 degrees considered ideal with an acceptable range of +5 to -8 degrees.

18. **MAXILLARY MIDLINE TO FACE:** Acceptable range up to 2.9 mm deviation.
19. **MAXILLARY TO MANDIBULAR MIDLINE:** Acceptable range up to 2.1 mm deviation.

20. **OVERTURN:** 2.0 mm considered ideal with acceptable range of 0.4 mm to 5.7 mm.

21. **CROWN WIDTH TO HEIGHT RATIO:** Central incisor had ideal ratio of 0.73:1.

22. **CENTRAL GINGIVAL HEIGHT DISCREPANCY:** Acceptable up to 2.0 mm deviation.

23. **LATERAL GINGIVAL HEIGHT DISCREPANCY:** -0.4 mm considered ideal with acceptable range of -2.9 mm to 1.2 mm.

24. **LATERAL INCISOR STEP:** 1.4 mm considered ideal with acceptable range up to 2.9 mm.

25. **LATERAL INCISOR SIZE:** 0.72:1 considered ideal ratio with acceptable range of 0.53:1 to 0.76:1.

26. **CANT:** Acceptable up to 4.0° deviation.

We concluded that the preference of raters in different locations was not clinically significant and that raters displayed a wide range of acceptability for canine and posterior tooth crown torque in both narrow and broad smiles. This is a reliable method for determining individual smile characteristic preferences. Due to the wide range of acceptability for the ideal and threshold values for most variables, clinicians must be aware of individual preferences for each specific patient and should probably avoid sensitization of patients to smile characteristic deviations that fall within the acceptable range. The findings of this study can be used by clinicians as both a guideline toward ideal orthodontic finishes and acceptable compromise.
INTRODUCTION

The contemporary practice of dentistry must include management of the dentition and soft tissue to create an esthetic smile by tooth movement, soft tissue modification, restorative procedures, or some combination of these techniques. The development of an esthetic smile should be based on as much objective evidence as possible. Until recently, however, the refereed literature had not clarified the importance of smile characteristics.

Studies in restorative dentistry and orthodontics demonstrated that dental professionals and laymen can identify smile characteristics that both enhance and detract from a smile.

Some studies have applied computer-based methodology to alter dental morphology and this appears to be an effective method to explore esthetics due to consistency of variable manipulation and controlled presentation.

Kokich Jr. was the first to use computer based image modification when he attempted to quantify smile characteristic acceptability using images of female lips and teeth. He found that orthodontists, general dentists, and lay people were able to detect discrepancies in smile characteristics and that, for many variables, lay people were less discriminating than the practitioners.

However, excessive cropping, skin tone differences, lipstick application, tooth shape, and other distracters can affect the perception of smile characteristics. Other authors have advocated the inclusion of more facial features to demonstrate the interaction between all smile related tissues. Further, large incremental adjustments (e.g. 1 mm) may have obscured the true threshold of acceptability. It may be possible to refine, confirm, and expand the results of previous studies using more advanced digital imaging methods and survey presentation techniques.
A number of variables have been suggested to influence the attractiveness of a smile. Rosenstiel\textsuperscript{11, 12} suggested that the ideal width to height ratio for the maxillary anterior teeth is between 70 and 80%. The ideal smile arc should mimic the curvature of the lower lip from central incisor to canine\textsuperscript{1, 14}. Buccal corridor minimization is a critical smile feature\textsuperscript{1, 6, 8, 15, 16}. Increased torque in posterior teeth is \textsuperscript{17, 18}a way to improve the esthetics of narrow smiles. Excessive gingival display does not appear to be well tolerated by raters\textsuperscript{2}. The highly variable permanent maxillary lateral incisor can be a challenging tooth to manage orthodontically and restoratively\textsuperscript{19}. Maxillary midline deviations can upset the balance of an otherwise esthetic smile\textsuperscript{20-22}. A maxillary to mandibular midline discrepancy alters anterior esthetics and indicates how posterior teeth will occlude\textsuperscript{23}. Overbite is generally characterized as ideal when the value is between 0-2 mm\textsuperscript{23}. The vertical position of the lateral incisor affects the continuity of the smile arc\textsuperscript{24}. Kokich\textsuperscript{2} found an occlusal plane cant to be an overwhelmingly displeasing smile characteristic to health professionals and lay people. The location, shape and contour of the gingiva in the maxillary anterior region can affect smile esthetics\textsuperscript{25}. Clearly, there are numerous characteristics that make up a smile, but these must be disaggregated and systematically evaluated to determine their impact.

The purpose of this study was to definitively identify the ideal and acceptable range of several smile characteristics through presentation of a standardized gender ambiguous circumoral view including the lower face (a context that provided facial cues to symmetry) using raters from three regions of the U.S. Most importantly, smile characteristics were manipulated by the raters on a visually continuous scale so they could appreciate the realm of possibilities before they chose what they found most appealing or at the threshold of acceptability.
MATERIALS AND METHODS

Model Selection and Image Manipulation

A university digital archive was examined for initial images following the protocol of Parekh, et. al. Adobe Photoshop® CS2 was used to crop the facial images to show only the lips, nasal tip, and mentolabial fold to reduce distractions. The teeth and periodontium were erased from the lower face to create a “hollow” lip set. An intraoral frontal photograph of an ideally treated dentition was used for all smile characteristic manipulation and was inserted inside the lip set after alteration.

These facial images were projected on the computer screen at a size comparable to typical conversational distance and resolution was standardized at 1024 x 768 pixels.

General Survey

The survey was designed to encompass a range of values for many smile characteristics. Two surveys were constructed to make the rater time requirement reasonable.

Survey 1 and 2 were created using Quask Form Artist™ Professional Edition, a survey administration software allowing questions to be linked to emoticons. Emoticons were used in this study to display continuously modifiable smiles over a pre-defined, physiological range (Fig 3.1). The changes made during the initial image manipulation in Photoshop™ produced a visually continuous scale of possible choices when the slider bar coupled to the emoticon was manipulated (Fig 3.2).
The study was completed by 300 participants over age 18 with no dental affiliation. Voluntary response demographic questions, including gender, ethnicity, and socio-demographic status were gathered. Any previous professional dental affiliation disqualified respondents from participation and terminated the survey.

Raters evaluated 28 (survey 1) or 26 (survey 2) emoticon questions. Each emoticon question was randomly presented with one of two statements: 1) “Please move the slider to select the image you find to be MOST IDEAL” or 2) “Please move the slider to select the first image that you find UNATTRACTIVE.”

The survey was administered in Seattle, WA, Columbus, OH, and Boston, MA. Surveys were administered on identically configured laptop computers and all responses were anonymous.

**Survey 1 Content**

For all Survey 1 variables, the image manipulation is described below while the range of possible values and how the variable was measured is summarized in Table 3.1.

**Smile Arc**

The method of Parekh, et. al\(^1\) was used to create a series of template parabolas to generate a nearly continuous set of possible smile arcs with Math GV™ FREEWARE Version 3.1.

**Buccal Corridor**

Buccal corridor spaces were manipulated in .1825 mm increments by altering the amount of black space between the lip commissure and the most buccal tooth in the smile by moving the posterior teeth medially or laterally.
Gingival Display

Gingival display on smile was approached by modifying the skeletal position of the dental arches in .1825 mm increments.

Crown Torque

Individual tooth cutouts of the canine or all posterior teeth (1st premolar through second molar) were “torqued” positively or negatively through their center of rotation in a smile with an ideal (2% bilaterally\(^{15}\)) or wide buccal corridor. This method was chosen as the visibility of the posterior teeth may be different in broad and narrow smiles.

Survey 2 Content

For all Survey 2 variables the image manipulation and the range of possible values and how the variable was measured is summarized in Table 3.1.

Maxillary Midline to Face

The ideal maxillary midline was defined for the model and the maxillary dentition was moved to the left in .1825 mm increments while the posterior dentition was morphed to maintain even buccal corridors.

Maxillary to Mandibular Midline

With the maxillary dentition static, the mandibular midline was moved to the left in .1825 millimeter increments while normal posterior overjet was maintained.

Overbite

The amount of overlap of the anterior dentition was altered by moving the mandibular anterior dentition vertically in .1825 mm increments. Normal posterior tooth contacts were maintained.
Maxillary Central Incisor Crown Width to Height Ratio

Crown width to height ratios of the maxillary centrals, laterals, and canines were altered by moving an overlay gingival layer apically in .1825 millimeter increments. The width to height ratio was derived by dividing the maxillary central crown width by its corresponding height.

Maxillary Central Gingival Levels

Asymmetric gingival levels between the maxillary central incisors were created by moving the gingiva of the maxillary left central incisor incisally in .1825 millimeter increments.

Maxillary Lateral Gingival Levels

An overlay gingival layer allowed apical or incisal movement of the gingival zenith of the maxillary lateral incisors in .1825 millimeter increments.

Maxillary Central to Lateral Incisal Edge Discrepancy

The lateral incisors were moved in vertical, .1825 millimeter increments apically or incisally.

Maxillary Lateral Size Discrepancy

The widths of the maxillary lateral incisors were manipulated to be wider or narrower in .1825 millimeter increments using digitally dissected tooth cutouts. The posterior dentition was mesialized as needed to maintain tooth contacts.

Cant

The entire dentition was canted in one-quarter degree increments in a clockwise direction.
Statistical Analysis

Rater reliability was assessed for each variable using the weighted Kappa statistic. Differences in attractiveness ratings were analyzed using descriptive statistics including median and 95% confidence intervals. Multiple Mann-Whitney-Wilcoxon tests with Bonferroni correction of Holm were conducted to investigate for regional differences. The signed rank test was used to evaluate the possibility that raters prefer different amounts of crown torque in canines and posterior teeth when the size of the buccal corridor varies. The level of significance was set at $\alpha \leq 0.05$ for all analyses.

RESULTS

Rater Demographics

Because all individuals did not completely finish the survey, $N=243$ with 33% from each location – Boston, MA, Columbus, OH, and Seattle, WA. The final rater group was comprised of 66% female raters with a median education of Bachelors degree or higher and income of $100-150,000. 200 of 243 were Caucasian and the other 18% reported they were Asian, African American, Hispanic or other ethnicities.

Reliability

Weighted Kappa statistics are reported in Table 3.2.

Regional Effects on Rater Preference

Rater responses were sorted by region of residence in the United States. Multiple Mann-Whitney-Wilcoxon tests comparing west to east, west to central, and central to east
indicate that the only significant finding was the preference for broader smiles (1.75 mm vs. 6 mm buccal corridor) by raters in the western group when compared to the central and eastern groups (p = .0252).

**Effect of corridor size on torque preference**

There was no difference in rater perception and preference of buccal crown torque in canines only or posterior teeth (Table 3.3).

**Defining Ideal and Acceptable Smile Characteristics**

The ideal (image) and the threshold of acceptability (image) are reported for each smile characteristic using medians. The summary statistics for the ideal smile characteristics are displayed in Figures 3 through 16.

**DISCUSSION**

The posed smile is repeatable and displays esthetic characteristics not visible during speaking and in repose. This makes the smile, aside from its social and psychological impact, an important facial state for investigation.

In this study, dental professionals were excluded and only lay persons were surveyed because they are the primary consumer of orthodontic services. The possibility of regional differences (US: East (Boston, MA), West (Seattle, WA), and Midwest (Columbus, OH) had not been considered before and, ultimately, lay raters in different locations were not significantly different in assessment of individual smile characteristics. The display of esthetic images and messages in the widely distributed media may be responsible for this
finding. The one significant difference, that raters on the west coast were more tolerant of an extremely broad smile (1.5 mm buccal corridor bilaterally), is probably not clinically significant.

It is still unclear how lay persons evaluate smile esthetics. There are many potential distracters and interactions between different smile characteristics. Numerous facial or dental characteristics can be distracters that supersede interpretation of smile characteristic deviation. Standardization of image presentation in a realistic context should allow for true assessment of lay rater preferences across numerous smile characteristics.

The observation that orthodontists flatten the smile arc is less troubling given the findings of this study. Lay raters preferred a consonant smile but accepted a smile with minimal curvature as well (Figure 3.3). Parekh found flat smile arcs to be extremely objectionable but it appears that there are increments flatter than ideal that are acceptable. Interestingly, the addition of more upward curvature beyond what follows the lower lip did not rate well. There is a wide and clinically significant difference between the upper and lower threshold but, generally, smiles should follow the curvature of the lower lip.

In order for the smile to follow the curvature of the lower lip, it is usually customary to increase the overbite through artistic bends in the maxillary archwire during the finishing and detailing phase of an orthodontic treatment plan. Our findings (Figure 3.4) suggest that lay raters are tolerant of a deep bite, which enables the creation of a congruent smile arc. Additionally, it is common orthodontic practice to incorporate a modest step between maxillary central and lateral incisors despite no evidence that this is a desirable technique. Our findings (Figure 3.5) demonstrate that stepping up the maxillary lateral incisor with relation to the incisal edge of the maxillary central incisor
beyond the traditionally recommended value (0.5 mm) allows establishment of a smile are without excursive interferences. However, many raters preferred even incisal edges, emphasizing that individual preference should be assessed during finishing.

Previous reports of ideal buccal corridor size vary from 2%\(^6\) to 19%\(^29\). Our ideal corridor size (Figure 3.6) was 16% and our acceptability range (8-26%). It appears that raters prefer the appearance of a buccal corridor approaching the 19% reported from untreated patients. Facial perspective or inclusion of more than the circumoral area, however, may make a difference.

Buccal corridor ratings indicate that visualization of the buccal segments may have an esthetic impact. Crown torque in the posterior segments may be visible but claims that increased torque improves the esthetics of a narrow smile\(^{17,18}\) have not been substantiated. In our study, lay persons tolerated nearly every image presented to them and unexpectedly preferred negative torque in narrow smiles (Figures 3.7a through 3.8b). Torque of canines and posterior teeth should probably only be controlled for functional occlusion purposes.

Gingival display has been investigated extensively\(^2,13,27,29-36\). Kokich Jr.\(^2\) first reported 4 mm of gingival display represented the threshold of acceptability but recently\(^{13}\) used smaller increments found it to be 3 mm. Our data (Figure 3.9) found the ideal value for gingival display to be 2.1 mm incisor coverage and the acceptable range was essentially ±4. Vertical lip changes occur with aging\(^{37-41}\) and may make maintenance of gingival display difficult, but, finishing within the acceptability range should be possible.

The location, shape, and contour of the maxillary anterior gingiva are important smile characteristics\(^{25}\), especially in the context of a smile with some amount of gingival display. Crown length discrepancies are most common when one maxillary central
incisor is shorter than the contralateral incisor due to uneven wear of one central incisor combined with active incisor eruption. Recent investigators found that laypersons did not detect asymmetric crown-length unless one crown was 1.5-2.0 mm shorter than the other. Our study (Figure 3.10) verified that 2.0 mm is the limit of acceptability for this variable. It is interesting to note, however, that a third of the raters did not find the discrepancy to be unacceptable until the heights had a 4.0 mm difference.

Kokich et al noted that gingival discrepancies between the maxillary central and lateral incisors were not obvious to lay persons. Our study confirmed (Figure 3.11) the broad range of acceptability for this variable and demonstrated it was even acceptable when the lateral gingival margin was superior to the central gingival margin.

Kokich also found that lay people needed a 2-mm deviation of the ideal crown length in order to classify the central incisors as noticeably less esthetic. In his research, Kokich defined the ideal central incisor crown width to height ratio at approximately 0.77, and the 2-mm deviation resulted in a width to height ratio of approximately 0.90. In a study reviewing anatomic crown width/length ratios, Magne found that unworn central incisors had a ratio of 0.78. Other studies have shown similar values. Our findings (Figure 3.12) confirmed these values.

The proportional size of the maxillary lateral incisor is an interesting smile characteristic to investigate due to the high variability in size of this tooth. The most frequent anomaly is a “peg” shaped tooth, where the width is grossly decreased in comparison to the height. Kokich Jr. previously determined that the threshold for acceptability was 4.0 mm narrower than the ideal lateral incisor. At the ideal, the lateral incisor was 78% of central incisor width, while at the threshold it was 45%. Our findings
(Figure 3.13) were similar at 72% for ideal and a threshold value of 53%. Lateral incisors can be as wide as 76% of the central incisor before becoming unacceptable.

The maxillary dental midline is often compared to the facial midline using the center of the philtrum\(^{33, 46-48}\) and soft tissue nasion\(^{33, 48}\). Numerous authors\(^{49-52}\) have demonstrated that maxillary midline discrepancies >2 mm were likely to be noticed by laypeople, while others\(^{2, 43}\) found that laypeople could not perceive a 4 mm deviation. Our findings (Figure 3.14) established the maximum acceptable value to be 3.0 mm although one third of our respondents accepted a deviation of 4.3 mm.

Maxillary and mandibular midlines are non-coincident in three-fourths of the population\(^46\) and small deviations will not cause any detriment to smile esthetics\(^23\). The contribution of mandibular midline to esthetics may be diminished due to the narrow width and uniform size of mandibular incisors\(^53\). We found that (Figure 3.15) mandibular midline deviation was acceptable until it exceeded 2.1 mm and one third of the respondents accepted the maximal deviation of 2.9 mm. This demonstrates that many individuals found this deviation to be acceptable when over half\(^49\) the mandibular incisor deviated from the maxillary midline. This adequately accommodates patients with a missing or extracted lower incisor.

Asymmetry, even among esthetically pleasing faces, is a typical finding\(^54\). An occlusal cant is a form of asymmetry that is not apparent when evaluating intraoral photographs or trimmed study models. It can be noticeable when a person smiles because the smile can appear to be out of harmony with adjacent smile and facial characteristics\(^33\). Kokich Jr. found that lay people did not detect this type of asymmetry until it reached 3-mm (equivalent to 4\(^\circ\))\(^2\). Other studies have found they are not
noticeable unless they exceed $2^\circ, 3^\circ$ or $4^\circ$. We found (Figure 3.16) that lay people accepted cants until they reached $4^\circ$, but one-third of the respondents accepted cants at the maximum deviation of $6^\circ$.

This method provided a means to accurately and reliably identify the ideal value for many smile characteristics. Some values deviated from previous findings while others were confirmed. Yet, the issue with the existing literature on this topic remains variability, which makes comparison of results cumbersome. Other smile characteristics were investigated here for the first time (torque preference, overbite, maxillary to mandibular midline deviation, lateral incisor step, and lateral gingival margin height). The sum of the findings provides an outline for clinicians to assemble patient centered orthodontic, restorative and periodontal results.

Probably, the most important finding is the range of acceptability. Lay raters tolerated a wide range of variability for most characteristics and knowledge of what is ideal does not make it appropriate to ignore this range. It is probably sound for the clinician to use care in identifying the ideal to patients when that knowledge could sensitize them to unrealistic or unattainable goals. In their naiveté they are more inclusive than practitioners would think. Remembering that our values as clinicians should not be imposed except near the margins of acceptability is probably the best guide.

**Limitations and Future Directions**

Our study only provided rater preference in the context of the lower face including the mentolabial fold and the nasal tip. Other studies have displayed fewer facial features and found different results than those reported here. It is clear that the context in which the
smile is presented may make a difference to raters and this must be considered in future research of this type. Additionally, demographic sampling was not controlled. While age and gender have previously shown no effect on smile characteristic ratings, ethnicity and cultural background may make a difference. This could be considered in future investigations as well.

CONCLUSIONS

1. In the assessment of individual smile characteristics, the difference of raters for different locations was not clinically significant, although there was one statistically significant finding (wider smiles more tolerable to West versus Midwest and East).

2. There is no significant difference in the perception of ideal and acceptable values of posterior and canine torque in narrow and broad smiles.

3. This is a reliable method for determining individual smile characteristic preferences.

4. Due to the wide range of acceptability for ideal and the overall range of acceptability for most variables, clinicians must be aware of individual preferences for each specific patient.

5. The findings of this study can be used by clinicians as both a guideline toward ideal orthodontic finishes and acceptable compromises.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Range of Values</th>
<th>How Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Smile Arc</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At maxillary Canine</td>
<td>0 mm - 2.4 mm</td>
<td>Vertical distance from horizontal tangent from maxillary central incisors to cusp tip of maxillary canine or 2nd molar</td>
</tr>
<tr>
<td>At maxillary 2nd Molar</td>
<td>0 mm - 6.6 mm</td>
<td></td>
</tr>
<tr>
<td><strong>Buccal Corridor (bilateral total)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millimetric</td>
<td>0 - 10.2 mm</td>
<td>Horizontal distance from the facial of the most buccal posterior tooth to a vertical line through the commissure of the lips</td>
</tr>
<tr>
<td>Percentage</td>
<td>0 - 22%</td>
<td></td>
</tr>
<tr>
<td><strong>Gingival Display</strong></td>
<td>-5.1 mm to +5.8 mm</td>
<td>Vertical distance from the gingival zenith of the maxillary central incisors to the nadir of the upper lip above these teeth</td>
</tr>
<tr>
<td><strong>Canine Torque, Broad Smile</strong></td>
<td>-10 to +10 degrees</td>
<td>Amount of positive or negative torque in the bilateral maxillary canine teeth rotated through the center of rotation for each tooth</td>
</tr>
<tr>
<td><strong>Canine Torque, Narrow Smile</strong></td>
<td>-10 to +10 degrees</td>
<td>Amount of positive or negative torque in the bilateral maxillary canine teeth rotated through the center of rotation for each tooth</td>
</tr>
<tr>
<td><strong>Posterior Torque, Broad Smile</strong></td>
<td>-10 to +10 degrees</td>
<td>Amount of positive or negative torque in the bilateral maxillary posterior teeth (1st premolar through 2nd molar) rotated through the center of rotation for each tooth</td>
</tr>
<tr>
<td><strong>Posterior Torque, Narrow Smile</strong></td>
<td>-10 to +10 degrees</td>
<td>Amount of positive or negative torque in the bilateral maxillary posterior teeth (1st premolar through 2nd molar) rotated through the center of rotation for each tooth</td>
</tr>
<tr>
<td><strong>Maxillary Midline to Face</strong></td>
<td>0 mm - 4.4 mm</td>
<td>Horizontal distance from the middle of the embrasure between the maxillary central incisors onto a line determined to be the midline of the face</td>
</tr>
<tr>
<td><strong>Maxillary to Mandibular Midline</strong></td>
<td>0 mm - 2.9 mm</td>
<td>Horizontal distance between the middle of the embrasure of the maxillary central incisors to the middle of the embrasure between the mandibular central incisors</td>
</tr>
<tr>
<td><strong>Overbite</strong></td>
<td>0 mm - 9.5 mm</td>
<td>Vertical distance from the maxillary central incisal edge to the mandibular central incisal edge</td>
</tr>
</tbody>
</table>

Table 3.1 Variable Summary
Table 3.1 Continued

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range of Values</th>
<th>How Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crown Width to Height Ratio</td>
<td>0.61:1 - 1.2:1</td>
<td>Ratio between the maxillary central incisor crown width to the crown height</td>
</tr>
<tr>
<td>Central Gingival Height Discrepancy</td>
<td>0 mm - 2.9 mm</td>
<td>Vertical distance between the apex of the right maxillary central incisor gingival margin to the apex of the left maxillary central incisor gingival margin</td>
</tr>
<tr>
<td>Lateral Gingival Height Discrepancy</td>
<td>1.1 mm apical to central incisor - 3.8 mm incisal to central incisor</td>
<td>Vertical distance between the apex of the maxillary central incisor gingival margin to the apex of the maxillary lateral incisor gingival margin</td>
</tr>
<tr>
<td>Lateral Incisor Step</td>
<td>0 mm - 2.9 mm</td>
<td>Vertical distance between the maxillary central incisor edge to the maxillary lateral incisor edge</td>
</tr>
<tr>
<td>Lateral Incisor Size</td>
<td>0.53:1 - 0.76:1</td>
<td>Ratio between the width of the maxillary lateral incisor to the width of the maxillary central incisor</td>
</tr>
<tr>
<td>Cant</td>
<td>0 to 6 degrees</td>
<td>Amount of rotation in the maxillary and mandibular dentition from horizontal through the middle of the maxillary central incisors</td>
</tr>
<tr>
<td>Smile Characteristic Rated</td>
<td>Value</td>
<td>LCB (95%)</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------</td>
<td>-----------</td>
</tr>
<tr>
<td>Smile Arc</td>
<td>0.79</td>
<td>0.74</td>
</tr>
<tr>
<td>Buccal Corridor</td>
<td>0.81</td>
<td>0.76</td>
</tr>
<tr>
<td>Gingival Display</td>
<td>0.87</td>
<td>0.84</td>
</tr>
<tr>
<td>Canine Torque, Broad Smile</td>
<td>0.71</td>
<td>0.65</td>
</tr>
<tr>
<td>Canine Torque, Narrow Smile</td>
<td>0.70</td>
<td>0.64</td>
</tr>
<tr>
<td>Posterior Torque, Broad Smile</td>
<td>0.72</td>
<td>0.67</td>
</tr>
<tr>
<td>Posterior Torque, Narrow Smile</td>
<td>0.74</td>
<td>0.68</td>
</tr>
<tr>
<td>Maxillary Midline to Face</td>
<td>0.71</td>
<td>0.57</td>
</tr>
<tr>
<td>Maxillary to Mandibular Midline</td>
<td>0.56</td>
<td>0.40</td>
</tr>
<tr>
<td>Overbite</td>
<td>0.88</td>
<td>0.83</td>
</tr>
<tr>
<td>Crown Width to Height Ratio</td>
<td>0.34</td>
<td>0.13</td>
</tr>
<tr>
<td>Central Incisor Gingiva</td>
<td>0.70</td>
<td>0.55</td>
</tr>
<tr>
<td>Lateral Incisor Gingiva</td>
<td>0.81</td>
<td>0.77</td>
</tr>
<tr>
<td>Lateral Incisor Step</td>
<td>0.47</td>
<td>0.34</td>
</tr>
<tr>
<td>Lateral Incisor Size</td>
<td>0.73</td>
<td>0.67</td>
</tr>
<tr>
<td>Cant</td>
<td>0.76</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Table 3.2: Weighted Kappa for Reliability
### Torque Preference in Narrow vs Broad Smiles

<table>
<thead>
<tr>
<th>Variable</th>
<th>Narrow Smile Median Value</th>
<th>Broad Smile Median Value</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Canine Torque</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideal</td>
<td>- 4 degrees</td>
<td>- 1 degree</td>
<td>3 degrees***</td>
</tr>
<tr>
<td>Maximum</td>
<td>+ 8 degrees</td>
<td>+ 10 degrees</td>
<td>2 degrees</td>
</tr>
<tr>
<td>Minimum</td>
<td>- 10 degrees</td>
<td>- 7 degrees</td>
<td>3 degrees***</td>
</tr>
<tr>
<td><strong>Posterior Torque</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ideal</td>
<td>+ 6 degrees</td>
<td>+ 4 degrees</td>
<td>2 degrees*</td>
</tr>
<tr>
<td>Maximum</td>
<td>+ 5 degrees</td>
<td>+ 5 degrees</td>
<td>ND</td>
</tr>
<tr>
<td>Minimum</td>
<td>- 8 degrees</td>
<td>- 7 degrees</td>
<td>1 degree</td>
</tr>
</tbody>
</table>

* p < .05
** p < .001
*** p < .0001

*Table 3.3: Signed Rank for Torque Difference*
Figure 3.1 Emoticon Example
Click on the picture to activate the slider.

Use the slider to select the picture you find MOST IDEAL.
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>7.9 mm at 7s, 4.4 mm at 3s</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>7.2 mm at 7s, 4 mm at 3s</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>2.6 mm at 7s, 2.1 mm at 3s</td>
</tr>
</tbody>
</table>

Figure 3.3: Smile Arc
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>5.7 mm</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>2.0 mm</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>0.4 mm</td>
</tr>
</tbody>
</table>

Figure 3.4: Overbite
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>2.9 mm</td>
</tr>
<tr>
<td>Ideal</td>
<td>1.4 mm</td>
</tr>
</tbody>
</table>

Figure 3.5: Lateral Step Up
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>2.9 mm (8%)</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>5.8 mm (16%)</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>9.4 mm (26%)</td>
</tr>
</tbody>
</table>

Figure 3.6: Buccal Corridor
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>+10 degrees</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>-1 degrees</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>-7 degrees</td>
</tr>
</tbody>
</table>

Figure 3.7a: Canine Torque in a Broad Smile
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>+8 degrees</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>-4 degrees</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>-10 degrees</td>
</tr>
</tbody>
</table>

Figure 3.7b: Canine Torque in a Narrow Corridor
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>+5 degrees</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>+4 degrees</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>-7 degrees</td>
</tr>
</tbody>
</table>

Figure 3.8a: Posterior Torque in a Broad Smile
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>+5 degrees</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>+6 degrees</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>-10 degrees</td>
</tr>
</tbody>
</table>

Figure 3.8b: Posterior Torque in a Narrow Smile
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>-3.6 mm</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>2.1 mm</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>4 mm</td>
</tr>
</tbody>
</table>

Figure 3.9: Gingival Display
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>2.0 mm</td>
</tr>
<tr>
<td>Ideal</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

Figure 3.10: Central Gingival Height Discrepancy
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td></td>
<td>1.2 mm</td>
</tr>
<tr>
<td>Ideal Value</td>
<td></td>
<td>-0.4 mm</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td></td>
<td>2.9 mm</td>
</tr>
</tbody>
</table>

Figure 3.11: Lateral Gingival Height Discrepancy
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ideal</strong></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td>.73</td>
<td>(Width/Height)</td>
</tr>
</tbody>
</table>

**Figure 3.12: Crown Width to Height Ratio**
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>0.76:1</td>
</tr>
<tr>
<td>Ideal Value</td>
<td>0.72:1</td>
</tr>
<tr>
<td>Minimum Tolerable Value</td>
<td>0.53:1</td>
</tr>
</tbody>
</table>

Figure 3.13: Lateral Incisor Size
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>2.9 mm</td>
</tr>
<tr>
<td>Ideal</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

Figure 3.14: Maxillary Midline to Face
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>2.1 mm</td>
</tr>
<tr>
<td>Ideal</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

Figure 3.15: Maxillary to Mandibular Midline
<table>
<thead>
<tr>
<th>Median Value</th>
<th>Depiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Tolerable Value</td>
<td>4 degrees</td>
</tr>
<tr>
<td>Ideal</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

Figure 3.16: Occlusal Cant
LIST OF REFERENCES


CHAPTER 4

GENERAL CONCLUSIONS

Clinical Applications & Impact on Orthodontics

Our findings have important clinical implications and probably can be used as a guide in both the diagnosis and treatment planning and finishing stages of orthodontic treatment. Knowing what a large group of potential patients find to be the most ideal representation of a given smile characteristic is quite important and could be used as a standard to guide dental professionals toward treatment success.

The advances in computer technology, particularly image manipulation and computer based survey presentation, allowed a new method to be developed to assess outcomes and the desirability of certain byproducts of orthodontic treatment. The method proved to be reliable and the survey was enjoyable for raters to complete.

Administration of the digital survey in Seattle, WA, Columbus, OH, and Boston, MA allowed us to investigate for regional differences. Outside of the finding that a very minimal buccal corridor was more acceptable to lay raters on the West coast than in the Midwest and East coasts, the results of this study may be generalized between regions. This finding is most likely related to intense media saturation with esthetic images.
Despite the influx of perfect looking faces and smiles in the airbrushed and ‘photoshopped’ media, it is uncommon that a patient will actually exhibit the ideal value for the entire collection of smile characteristics studied herein. Therefore, it is probably the large range of acceptability in the threshold deviation from ideal for the smile characteristics studied here that is most relevant to clinical dental practice and achieving esthetic results in our patients. Overstepping the boundary between informed consent and patient sensitization should be a chief concern of dental professionals and this study provided a clearer picture of where that line falls. In general, patients are much more accepting than most dental professionals may have originally imagined.

**Conclusions**

6. In the assessment of individual smile characteristics, the difference of raters for different locations was not clinically significant, although there was one statistically significant finding (wider smiles more tolerable to West versus Midwest and East).

7. There is no significant difference in the perception of ideal and acceptable values of posterior and canine torque in narrow and broad smiles.

8. This is a reliable method for determining individual smile characteristic preferences.

9. Due to the wide range of acceptability for ideal and the overall range of acceptability for most variables, clinicians must be aware of individual preferences for each specific patient.

10. The findings of this study can be used by clinicians as both a guideline toward ideal orthodontic finishes and acceptable compromises.
Future Studies

Continued research in this area could help to delineate patients’ perceptions of the interaction between prominent smile characteristics and the effect of the context in which they are viewed (circumoral, lower face, full face, full face from distance). Future studies may further delineate patient perception of smile characteristics in the following ways:

1. Previous studies focused on variations in smile characteristics in a tightly cropped, circumoral context. Our study included more of the lower face including the mentolabial fold and nasal tip. Future studies could include the entire face at varying distances to see how the perception of smile characteristics changes in a different context.

2. Demographic questions were posed in our study but sampling was not controlled so that demographic distinctions could be used as independent variables for analysis. While previous studies have downplayed the importance of age and gender, ethnic background and cultural norms may alter the outcomes of the study. This should be investigated.

3. Throughout the administration of the survey, many raters provided feedback that they found the survey very interesting and that they might like access to similar ‘smile design’ software prior to embarking upon extensive dental restoration or adult orthodontics. A comparison of the perceived satisfaction with a software generated outcome and the actual satisfaction with subsequent treatment would be very informative to dentists who are looking to improve the informed consent process without creating potentially unachievable or unrealistic expectations.
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