The contemporary practice of dentistry must include management of the dentition and soft tissues to create an esthetic smile by means of 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. Investigators conducting studies in restorative dentistry and orthodontics historically have identified esthetic issues and demonstrated that dental professionals and laypeople can identify smile characteristics that both enhance and detract from a smile.

Researchers in some studies have applied computer-based methods to alter dental morphology and this computerized alteration appears to be an effective method of exploring esthetics owing to its consistency of variable manipulation and controlled presentation. Kokich and colleagues to our knowledge, were the first to use computer-based image modification in...
Attempting to quantify smile characteristic acceptability by using images of female lips and teeth. They found that orthodontists, general dentists and laypeople were able to detect discrepancies in smile characteristics at differing levels and that, for many variables, laypeople were less discriminating than were practitioners.

However, excessive cropping, skin tone differences, lipstick application and tooth shape can affect the perception of smile characteristics. Other authors have advocated the inclusion of more facial features, such as a full-face view, to demonstrate the interaction between all smile-related tissues. Furthermore, presentation of large incremental differences between images (for example, differences of 1 millimeter or more) 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 techniques.

A number of variables have been suggested to influence the attractiveness of a smile. Rosenstiel and colleagues suggested that the ideal width-to-height ratio for the maxillary anterior teeth is between 70 and 80 percent. The ideal smile arc should mimic the curvature of the lower lip from central incisor to canine. Buccal corridor minimization is a critical smile feature. Increased torque in posterior teeth is a way to improve the esthetics of narrow smiles. Excessive gingival display does not appear to be well-tolerated by raters. The highly variable permanent maxillary lateral incisor can be a challenging tooth to manage orthodontically and restoratively. Maxillary midline deviations can upset the balance of an otherwise esthetic smile. A maxillary-to-mandibular midline discrepancy alters anterior esthetics and indicates how posterior teeth will occlude. Overbite generally is characterized as ideal when its value is between zero and 2 mm. The vertical position of the lateral incisor affects the continuity of the smile arc. Kokich and colleagues found an occlusal plane cant to be an overwhelmingly displeasing smile characteristic to health professionals and laypeople. The location, shape and contour of the gingiva in the maxillary anterior region affect smile esthetics. Clearly, there are numerous characteristics that make up a smile, but these must be disaggregated and systematically evaluated to determine their effect.

Bearing these considerations in mind, we undertook a study to identify definitively the ideal and acceptable range of several smile characteristics through presentation of a standardized sex-ambiguous circumoral view including the lower face (a context that provided facial cues to symmetry) using raters from three regions of the United States. Most importantly, the raters were able to manipulate smile characteristics 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, METHODS AND SUBJECTS
This study and its procedures were approved by the institutional review board of The Ohio State University, Columbus.

Model selection and image manipulation. We examined the digital archive of the The Ohio State University College of Dentistry’s Division of Orthodontics for initial images following the protocol described by Parekh and colleagues. We used Adobe Photoshop CS2 (Adobe Systems, San Jose, Calif.) to crop the facial images to show only the lips, nasal tip and mentolabial fold to reduce distractions. To create a “hollow” lip set, we erased the teeth and periodontium from the lower face. We used a single intraoral frontal photograph of an ideally treated dentition for all smile-characteristic manipulation and inserted it inside the lip set after alteration. While conducting the survey, we projected these facial images on the computer screen at a size comparable to that of a face at typical conversational distance and standardized the resolution at 1,024 × 768 pixels.

Survey. We designed the survey to encompass a range of values for many smile characteristics. To make the raters’ time requirement reasonable, we constructed two surveys; the same raters did not answer both surveys.

We used FormArtist Professional (Quask, Campbell, Calif.), a survey administration software allowing questions to be linked to images in both surveys. We used the images in this study to display continuously modifiable smiles across a predefined physiological range (Figure A, available as supplemental data to the online version of this article [found at “http://jada.ada.org”]). The changes made during the initial image manipulation in Photoshop produced a visually continuous scale of possible choices when the slider bar coupled with the image was manipulated (Figure B, available as supplemental data to the online ver-
The study was provided to 300 participants older than 18 years who did not work in the dental profession. We used voluntary-response questions to gather demographic data, including sex, ethnicity and sociodemographic status. Any previous professional dental affiliation disqualified respondents from participation. Raters evaluated 28 (survey 1) or 26 (survey 2) image-based questions. Each question was presented randomly with one of two statements:

- “Please move the slider to select the image you find to be most ideal”;
- “Please move the slider to select the first image that you find unattractive.”

Raters completed the surveys in Boston; Columbus, Ohio; and Seattle. They used identically configured laptop computers, and all responses were anonymous.

Survey 1 content. Below, we describe the image manipulation for all Survey 1 variables. Table 1 presents a summary of the range of possible values and how each variable was measured.

- Smile arc: We used the method described by Parekh and colleagues\(^1\) to create a series of template parabolas and then used Math GV Version 3.1 (freeware; Greg VanMullem, Bakersfield, Calif.) to generate a nearly continuous set of possible smile arcs.
- Buccal corridor: We manipulated buccal corridor spaces, 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: We approached gingival display by modifying the skeletal position of the dental arches in 0.1825-mm increments.
- Canine and posterior crown torque: We “torqued” individual tooth cutouts of the canine or all posterior teeth (first premolar through second molar) positively or negatively through their center of rotation in a smile with an ideal (2 percent bilaterally\(^2\)) or wide buccal corridor. We chose this method because the visibility of the posterior teeth may be different in broad and narrow smiles.

Survey 2 content. For all Survey 2 variables, Table 1 presents a summary of the image manipulation, as well as the range of possible values and how each variable was measured.

- Maxillary midline to face: We defined the ideal maxillary midline for the model and moved the maxillary dentition to the left in 0.1825-mm increments while morphing the posterior dentition to maintain even buccal corridors.
- Maxillary to mandibular midline: With the maxillary dentition static, we moved the mandibular midline to the left in 0.1825-mm increments while maintaining normal posterior overjet.
- Overbite: We altered the amount of overlap of the anterior dentition by moving the mandibular anterior dentition vertically in 0.1825-mm increments. We maintained normal posterior tooth contacts.
- Maxillary central incisor gingival height discrepancy: We created asymmetric gingival levels between the maxillary central incisors by moving the gingiva of the maxillary left central incisor incisally in 0.1825-mm increments.
- Maxillary lateral incisor gingival height discrepancy: An overlay gingival layer allowed apical or incisal movement of the gingival zenith of the maxillary lateral incisors in 0.1825-mm increments.
- Maxillary central to lateral incisal step: We moved the lateral incisors in vertical 0.1825-mm increments apically or incisally.
- Maxillary central incisor crown width-to-height ratio: We altered crown width-to-height ratios of the maxillary central, lateral and canine teeth by moving an overlay gingival layer apically in 0.1825-mm increments. We derived the width-to-height ratio by dividing the maxillary central crown width by its corresponding height.
- Maxillary central-to-lateral incisal ratio: We manipulated the widths of the maxillary lateral incisors to be wider or narrower in 0.1825-mm increments by means of digitally dissected tooth cutouts. We positioned the posterior dentition mesially as needed to maintain tooth contacts.
- Occlusal cant: We canted the entire dentition in one-quarter degree increments in a clockwise direction.

Statistical analysis. We assessed raters’ reliability for each variable by means of the weighted \(\kappa\) statistic and using statistical software (SAS, Version 3.1, SAS Institute, Cary, N.C.). We analyzed differences in attractiveness ratings by means of descriptive statistics, including median and 95 percent confidence intervals. To investigate for regional differences, we conducted multiple Mann-Whitney-Wilcoxon tests with a Bonferroni-Holm correction. We used the signed rank test 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. We set the level of significance at $\alpha = .05$ for all analyses.

### RESULTS

**Raters’ demographics.** Not all respondents completed the survey; our final total was 243
(81 percent), with approximately one-third of the respondents being from each location (Boston; Columbus, Ohio; and Seattle). The final rater group was composed of 66 percent female raters; the median educational level for all raters was a bachelor’s degree or higher, and the median annual income was $100,000 to $150,000. Two hundred (82 percent) of the 243 respondents were white, and the other 43 (18 percent) reported they were Asian, African-American, Hispanic or of other ethnicities.

Reliability. Table 2 presents weighted $\kappa$ statistics.

Regional effects on raters’ preferences. We sorted raters’ responses according to their region of residence in the United States. Results of multiple Mann-Whitney-Wilcoxon tests comparing West with East, West with Midwest and Midwest with East indicated that the only significant finding was the preference for broader smiles (buccal corridor of 1.75 mm versus 6.00 mm) by raters in the Western group when compared with the Midwestern and Eastern groups ($P = .025$).

Effect of buccal corridor size on torque preference. There was no difference in raters’ perception and preference of buccal crown torque in canines only or in posterior teeth related to the size of the buccal corridors (Table A, available as supplemental data to the online version of this article [found at “http://jada.ada.org”]).

Defining ideal and acceptable smile characteristics. The numeric value and the associated image for each variable selected by the raters as ideal and the threshold of acceptability are reported for each smile characteristic by using medians. These summary statistics and images for the ideal smile characteristics are displayed in Figures 1 through 10 and in Figures C, D, E, F, G and H (available as supplemental data to the online version of this article [found at “http://jada.ada.org”]).

### Table 2

Weighted $\kappa$ values.

<table>
<thead>
<tr>
<th>SMILE CHARACTERISTIC RATED</th>
<th>$\kappa$ VALUE</th>
<th>LOWER CONFIDENCE BOUNDARY (95%)</th>
<th>UPPER CONFIDENCE BOUNDARY (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smile Arc</td>
<td>0.79</td>
<td>0.74</td>
<td>0.83</td>
</tr>
<tr>
<td>Buccal Corridor</td>
<td>0.81</td>
<td>0.76</td>
<td>0.85</td>
</tr>
<tr>
<td>Gingival Display</td>
<td>0.87</td>
<td>0.84</td>
<td>0.90</td>
</tr>
<tr>
<td>Canine Torque</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broad smile</td>
<td>0.71</td>
<td>0.65</td>
<td>0.78</td>
</tr>
<tr>
<td>Narrow smile</td>
<td>0.70</td>
<td>0.64</td>
<td>0.76</td>
</tr>
<tr>
<td>Posterior Crown Torque</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broad smile</td>
<td>0.72</td>
<td>0.67</td>
<td>0.78</td>
</tr>
<tr>
<td>Narrow smile</td>
<td>0.74</td>
<td>0.68</td>
<td>0.80</td>
</tr>
<tr>
<td>Maxillary Midline to Face</td>
<td>0.71</td>
<td>0.57</td>
<td>0.85</td>
</tr>
<tr>
<td>Maxillary to Mandibular Midline</td>
<td>0.56</td>
<td>0.40</td>
<td>0.72</td>
</tr>
<tr>
<td>Overbite</td>
<td>0.88</td>
<td>0.83</td>
<td>0.93</td>
</tr>
<tr>
<td>Maxillary Central Incisor Gingival Height Discrepancy</td>
<td>0.70</td>
<td>0.55</td>
<td>0.85</td>
</tr>
<tr>
<td>Maxillary Lateral Incisor Gingival Height Discrepancy</td>
<td>0.81</td>
<td>0.77</td>
<td>0.86</td>
</tr>
<tr>
<td>Maxillary Central to Lateral Incisal Step</td>
<td>0.47</td>
<td>0.34</td>
<td>0.60</td>
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<tr>
<td>Maxillary Central Incisor Crown Width-to-Height Ratio</td>
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<td>0.13</td>
<td>0.55</td>
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<tr>
<td>Maxillary Lateral-to-Central Incisal Ratio</td>
<td>0.73</td>
<td>0.67</td>
<td>0.79</td>
</tr>
<tr>
<td>Occlusal Cant</td>
<td>0.76</td>
<td>0.65</td>
<td>0.88</td>
</tr>
</tbody>
</table>

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 effects, an important facial state for investigation.

In this study, we surveyed laypeople, because they are the primary consumers of orthodontic services, instead of practitioners, who are providers of care. The possibility of regional differences among the East, West and Midwest had not been considered in previous research, to our knowledge and, ultimately, we found that lay raters in different locations were not significantly different in their assessment of individual smile characteristics. The penetration of mass media and popular culture may be responsible for this finding. The one difference, that raters on the West Coast accepted a broader smile, probably is not clinically significant, given the magnitude of the difference.
It still is unclear how laypeople evaluate smile esthetics. There are many potential distracters and interactions among 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 raters’ preferences across numerous smile characteristics.

The observation that orthodontic treatment flattens 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 1). Parekh and colleagues found flat smile arcs to be extremely objectionable, but it appears that there are increments flatter than ideal that are acceptable. We found that the addition of more upward curvature beyond what follows the lower lip did not rate well. Clearly, there is a wide and clinically significant difference between the upper and lower thresholds, but, generally, smiles should follow the curvature of the lower lip.

To enable the smile to follow the curvature of the lower lip, clinicians customarily increase the overbite. Our findings (Figure 2) suggest that lay raters are tolerant of a deeper bite, which enables the creation of a congruent smile arc. In addition, it is common orthodontic practice to incorporate a modest step between maxillary central and lateral incisors despite the absence of evidence that this is a desirable technique. Our findings (Figure 3) support a lateral step up beyond the recommended value (0.5 mm), which allows establishment of a smile arc without excursive interferences. These three aspects of the smile—smile arc, overbite and lateral step—all can work harmoniously and contribute to a more esthetic smile. 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 percent to 19 percent. Our ideal buccal corridor size (Figure 4) was 16 percent, and our acceptability range was 8 to 22 percent. It appears that raters prefer the appearance of a buccal corridor approaching the 19 percent preferred by untreated patients in the study by Ritter and colleagues. Facial perspective or inclusion of more than the circumoral area, however, may make a difference.

Buccal corridor ratings indicate that visibility of the buccal segments may have an esthetic effect. Crown torque in the posterior segments may be visible, but claims that increased torque improves the esthetics of a narrow smile have not been substantiated. In our study, laypeople tolerated nearly every image presented to them and unexpectedly preferred negative torque in narrow smiles (Figures C, D, E and F, available as supplemental data to the online version of this article [found at “http://jada.ada.org”]). Therefore, torque of canine and posterior teeth probably...
should be controlled primarily for purposes of functional occlusion.

Gingival display has been investigated extensively. Kokich and colleagues first reported that 4.0 mm of gingival display represented the threshold of acceptability but more recently used smaller increments and found it to be 3.0 mm. Our data (Figure 5) indicate the ideal value for gingival display to be 2.1 mm incisor coverage and the acceptable range essentially ± 4 mm. Vertical lip changes occur with aging and may make maintenance of gingival display difficult, but finishing orthodontic treatment within the acceptability range should be possible.

The location, shape and contour of the maxillary anterior gingiva are important smile characteristics, 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 because of uneven wear of one central incisor combined with active incisor eruption. In recent years, investigators have found that laypeople did not detect asymmetric crown length unless one crown was 1.5 to 2.0 mm shorter than the other. Our study results corroborated that 2.0 mm is the limit of acceptability for this variable (Figure 6); however, one-third of the raters did not find the discrepancy unacceptable until the heights had a difference of 4.0 mm.

Kokich and colleagues noted that gingival discrepancies between the maxillary central and lateral incisors were not obvious to laypeople. Our study results confirmed the broad range of acceptability for this variable and demonstrated it was acceptable even when the lateral gingival margin was superior to the central gingival.
Kokich and colleagues also found that laypeople needed a 2.0-mm deviation of the ideal crown length to classify the central incisors as noticeably less esthetic. In their research, Kokich and colleagues defined the ideal central incisor crown width-to-height ratio at approximately 0.77, and the 2.00-mm deviation resulted in a width-to-height ratio of approximately 0.90. In a study in which they reviewed anatomic crown width-to-length ratios, Magne and colleagues found that unworn central incisors had a ratio of 0.78. Results of other studies have shown similar values. Our findings confirmed these values (Figure G, available as supplemental data to the online version of this article [found at “http://jada.ada.org”]).

Proportional size of the maxillary lateral incisor is an interesting variable because of the tooth’s variability in size. Its most frequent anomaly is a peg shape, in which the tooth’s width is grossly decreased in comparison with the height. Kokich and colleagues found that the threshold for acceptability was 4.0 mm narrower than the ideal width of the lateral incisor. At the ideal, the lateral incisor’s width was 78 percent of the central incisor’s width, whereas at the threshold it was 45 percent. Our findings were similar: 72 percent for the ideal and a threshold value of 53 percent (Figure H, available as supplemental data to the online version of this article [found at “http://jada.ada.org”]). We found that lateral incisors can be as wide as 76 percent of the central incisor before becoming unacceptable.

The maxillary dental midline often is compared with the facial midline using the center of the philtrum and soft-tissue nasion. Some authors have demonstrated that maxillary midline discrepancies of more than 2.0 mm were likely to be noticed by laypeople, whereas others found that laypeople could not perceive a 4.0-mm deviation. Our findings established the maximum acceptable value to be 2.9 mm (Figure 8), although one-third of our respondents accepted a deviation of 4.3 mm.

Maxillary and mandibular midlines are noncoincident in three-fourths of the population, and small deviations do not cause any detriment to smile esthetics. The contribution of the mandibular midline to esthetics may be diminished owing to the narrow width and uniform size of mandibular incisors. We found that mandibular midline deviation was acceptable until it exceeded 2.1 mm (Figure 9) and one-third of the respondents accepted the maximal deviation of 2.9 mm. This demonstrates that many respondents found this deviation to be acceptable when more than one-half of the mandibular incisor deviated from the maxillary midline. This finding adequately accommodates patients who have a missing or extracted lower incisor.

Asymmetry, even among esthetically pleasing faces, is a typical finding. An occlusal cant is a form of asymmetry that is apparent when a person smiles but is not perceived on intraoral images or study casts. Kokich and colleagues found that laypeople did not detect this type of asymmetry until it reached 3.0 mm (equivalent to 4 degrees). Results of other studies have showed that deviations in cant are not noticeable unless they exceed 2 degrees, 3 degrees or 4 degrees.
We found that our lay raters accepted cants of as much as 4 degrees (Figure 10), but one-third of the respondents accepted cants at the maximum deviation of 6 degrees.

CONCLUSIONS

The method of using computer-based slider technology to allow raters to select images that are both ideal and at the threshold of acceptability provided a means of accurately and reliably identifying the ideal value for many smile characteristics. Some values deviated from previous findings, and others were confirmed and more precisely defined by this method. Because substantial variability is reported in the existing literature on this topic, variability remains the issue, making comparison of results cumbersome. We investigated other smile characteristics—torque preference, overbite, maxillary-to-mandibular-midline deviation, lateral incisal step and lateral gingival margin height—for the first time, to our knowledge. The sum of our findings provides an outline for clinicians to use to assemble patient-centered orthodontic, restorative and periodontal treatment in a more comprehensive manner than has been possible to date.

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

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