ORIGINAL ARTICLE

Hard- and soft-tissue contributions to the esthetics of the posed smile in growing patients seeking orthodontic treatment

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Introduction: The purpose of this investigation was to broaden the understanding of how various skeletal, dental, and soft-tissue relationships are related to the esthetics of the smile in patients with malocclusions before orthodontic treatment. **Methods:** Images of the posed smile were captured from digital video clips of 60 growing patients (33 girls, 27 boys) seeking orthodontic treatment; they were judged by panels of laypersons and orthodontists. Discriminant analysis identified determinants of the "pleasing smile" from the results of a visual analog scale. Quantitative measurements of the soft and hard tissues were made by using the smile images, cephalometric radiographs, and study models. The esthetics of the smile were correlated with specific skeletal, dental, and soft-tissue structures in the anteroposterior, vertical, and transverse dimensions (Pearson test on nontopographic correlations). **Results:** The esthetic smile judgments of orthodontists agreed with those of laypersons (r >0.93). The vertical thicknesses of the lips were the most significant component of a pleasant smile, for both the orthodontists (upper lip) and laypersons (lower lip) (discriminant power: 75%). The vertical thickness of the upper lip had a significant positive correlation with the position of the maxillary incisor. **Conclusions:** Vertical lip thickness proved to be the most influential variable in smile esthetics. The significant relationship of incisor protrusion with the vertical thickness of the vermilion border of the upper lip must be considered when planning orthodontic treatment. (Am J Orthod Dentofacial Orthop 2008;133:491-9)

A smile is the sum of many attributes, both positive and negative. The upper and lower lips frame the display zone of the smile, bordering the dentition, the gingival scaffold, and the space in the oral cavity. Lip shape,[1,2] smile style,[3-5] smile index,[6-8] incisogingival display,[5,9-16] golden proportion,[17-19] smile arc,[6,8,9,15,18,20-23] and buccal corridor width[8,15,18,20,21,24-26] all have been associated with smile esthetics in past studies. Historically, smile analysis has been treated as a separate entity from cephalometrics and cast analysis in orthodontic diagnosis and treatment planning. Specific hard- and soft-tissue features of the smile have been studied extensively in the literature but without examination of the relationship between their etiology and smile esthetics.

The purpose of this investigation was to broaden the understanding of how specific hard- and soft-tissue relationships are related to the esthetics of the smile in patients with various degrees and types of malocclusion before orthodontic treatment. The associations between many smile features deemed important to esthetics and the position of the maxillary skeletal and dental structures in the anteroposterior, vertical, and transverse dimensions were examined. Quantitative measurements of vertical lip thickness, smile index, incisogingival display, and buccal corridor width were made by using images of the posed smile taken from video clips of the oral aperture and adjacent tissues. In addition, the judgments of both laypersons and orthodontists on these same images provided subjective indications of what constitutes a pleasing smile. This subjective analysis is an effort to verify and expand on previous investigations of smile attractiveness and provide esthetic values for this sample of orthodontic patients before treatment.

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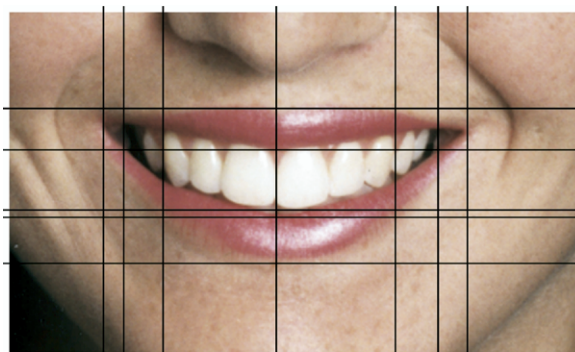
MATERIAL AND METHODS

The sample for this correlation study consisted of video clips of the dynamic oral aperture and adjacent tissues (including parts of the nose and chin), lateral cephalograms, and study models. All data were acquired during routine record-taking appointments for the purpose of diagnosis for orthodontic treatment.[6-8,27] Pretreatment video clips of 1242 consecutive patients over a 3-year period were screened initially for all inclusion criteria.[28]

To be included in the study, patients were required to meet the following criteria: age between 10 and 15 years at the record taking; North American white descent; no history of orthodontic treatment; no significant skeletal asymmetry, or anterior or posterior crossbite; no known missing or malformed teeth causing a tooth-size discrepancy; and visible erupting or erupted maxillary permanent canines and first premolars.

The patient sample was reduced further based on the following exclusionary criteria: poor video clip quality (out of focus, not viewable), incomplete records (lack of corresponding lateral cephalogram and study models), and ectopic canine position (not visible on smile). The final sample of subjects in this study was 60 (33 girls, 27 boys). Their average ages at the time of records were 12 years 5 months $\pm$ 12 months for the girls and 12 years 9 months $\pm$ 14 months for the boys.

A digital video camera was used to record anterior tooth display while the subjects were speaking and smiling. To standardize the technique, a fixed patient-camera distance, a cephalometric head holder, and natural head position were used. The same digital video camera and lighting source were used to capture all data. Before recording the video clip, each patient was asked to rehearse the following phase, "Chelsea eats cheesecake on the Chesapeake."[7,8] Once comfortable, the patient was asked to repeat the phrase into the digital video camera and then to smile, showing his or her teeth. Subsequently, the raw digital video stream was downloaded to a computer and compressed.

The digital video clips were imported into a commercially available video editing program (Adobe Premiere, version 6.0, Adobe, San Jose, Calif), allowing for individual frames to be viewed. The frame that best represented the patient's natural unstrained social smile was selected. This frame, identified as the "held smile," was described as 1 of 15 or more frames showing an identical smile. The chosen frame was imported into Photoshop (version 7.0, Adobe) to eliminate any rotations due to head positioning. In addition, the image was cropped to eliminate most of the nose, cheeks, and chin to minimize the influence of background facial

Fig 1. A printout from the SmileMesh computer application.

attractiveness.[13,24,29,30] By eliminating most of the background, criteria not under orthodontic control are less likely to become a factor in the rating of the smile.[24]

An updated version of the SmileMesh computer application (TDG Computing, Philadelphia, Pa) was used. It consisted of an adjustable grid with 7 vertical lines and 5 horizontal lines superimposed on an image.[6,7,28] These grid lines can be moved with the cursor to be placed on defined hard- and soft-tissue landmarks and are used to measure 15 attributes of the smile as illustrated in Figure 1. The 60 selected smile images were analyzed with the SmileMesh software.

The height and width of the patient's maxillary right central incisor was entered into the SmileMesh program before making the measurements, allowing a computer algorithm to calibrate the measurements to actual life size.[7,8] The resulting measurements were both ratios and linear values. Due to the inherent error in this measurement process, which is similar to that in radiographic cephalometric analysis, the ratios are of greater value than the linear measurements.[7,8]

The following attributes of the smile were measured in millimeters by using the grid lines.

1. Maximum incisor exposure: the amount of vertical display of the maxillary right central incisor.
2. Upper lip drape: the amount of vertical coverage of the maxillary right central incisor by the upper lip (or amount of gingival display if the value is negative).
3. Lower lip to maxillary incisor: vertical distance from the deepest midline point on the superior margin of the lower lip to the maxillary right central incisor edge.
4. Interlabial gap: the distance between the most inferior portion of the tubercle of the upper lip and the deepest midline point on the superior margin of the lower lip.
5. Maxillary intercanine width: the distance from the distal aspect of the right canine to the distal aspect of the left canine.
6. Width of all visible maxillary teeth: the distance from the distal aspect of the most posterior visible tooth on the right to the most posterior visible tooth on the left side of the maxilla.
7. Smile width: the distance from outer commissure to outer commissure on smile.
8. Smile index: smile width/interlabial gap.
9. Right and left buccal corridors: the horizontal distance from the distal aspect of the canine to the respective outer commissure.
10. Right and left posterior corridors: the horizontal distance from the distal aspect of the most posterior tooth visible on smile to the respective outer commissure.
11. Buccal corridor ratio: intercanine width/smile width.
12. Posterior corridor ratio: visible maxillary teeth width/smile width.
13. Upper vertical lip thickness: the vertical distance from the most superior peak of the lip to the most inferior portion of the tubercle of the upper lip.
14. Lower vertical lip thickness: the vertical distance from the deepest midline point on the superior margin of the lower lip to the most inferior portion of the lower lip.
15. Smile arc (consonant, flat, reverse): the curvature of the maxillary incisal edges and canines relative to the curvature of the lower lip on smile.

Because of the software, the program was used twice on each image; the buccal corridor widths/ratio and posterior corridor widths/ratio could not be obtained simultaneously. In addition to the information obtained from the SmileMesh computer application, the presence or absence of visible mandibular teeth was noted.[24]

The lateral cephalograms were hand traced with no attempt to standardize the magnification because all cephalograms were taken on the same machine. The films initially were traced by 1 investigator (L.M.), and landmark location was verified by a second (J.M.). Twelve landmarks (porion, orbitale, sella [S], nasion [Na], anterior nasal spine [ANS], Point A [Pt A], Point B [Pt B], pogonion [Pog], gonion, menton [Me], maxillary central incisor [U1], and mandibular central incisor) were identified, and 10 measurements (SNA angle, Pt A-NaPerpendicular [Perp], SNB angle, Pog-NaPerp, U1-SN, U1-Pt A Vertical [Vert], IMPA, FMIA, ANS-Me, and Na-Me) were derived for conventional cephalometric analysis.

By using a digital dental caliper—Dentagauge 2 (Erkinedental, Marina Del Rey, Calif)—the following maxillary cast measurements were made directly on the study models.

1. Buccal intercanine width: measured from the surface that would give the greatest buccal dimension, regardless of rotations.
2. Lingual intercanine width: measured from the surface that would give the smallest lingual dimension, regardless of rotations.
3. Intercanine width at cusp tip: measured from the center of the cusp tip, regardless of wear.
4. Buccal intermolar width: measured from the surface that would give the greatest buccal dimension, regardless of rotations.
5. Lingual intermolar width: measured from the surface that would give the smallest lingual dimension, regardless of rotations.
6. Height of maxillary right central incisor: measured from the most cervical aspect of the gingival margin to the incisal edge.
7. Width of maxillary right central incisor: measured at the widest mesiodistal portion of the clinical crown.

After these measurements, the maxillary and mandibular casts were photocopied individually, surrounded by 4-mm rulers that were 10 cm in length to verify magnification. The photocopies of the maxillary casts were used to make arch-depth measurements with a millimeter ruler. For this study, arch depth was defined as the distance from the line connecting the mesial contact point of the right and left first molars to the facial surface of the maxillary right central incisor.

The attractiveness of each smile was studied by using the held-smile frame from the video clips, as described above. The influence of variations in facial appearance was minimized by using computer-imaging techniques.[29,31] Facial blemishes were removed from the smiling photographs, and severely discolored teeth were whitened to match the adjacent teeth digitally with Adobe Photoshop version 7.0. Limiting the subjects to

Patient: 12345
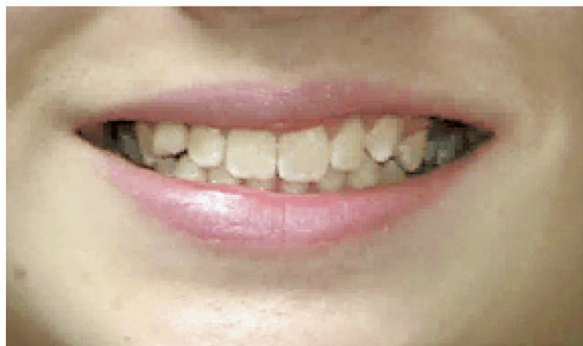
Insructions: Please mark the location along the line below that indicates how pleasing you find this smile.

Least	Most
Pleasing	Pleasing
Smile	Smile

Fig 2. Each frame was identified by patient number and printed on half of an 8 × 10-in sheet of white paper, centered above the 100-mm line that served as a VAS.

those of North American white descent was another effort to minimize variations in facial appearance.[32]

After detailing was completed, the frames were standardized in width, at 4 inches. Each frame was identified by patient number and printed on half of an 8 × 10-in sheet of white paper with a high quality color printer (Photosmart 7550 series; Hewlett Packard, Palo Alto, Calif). Each smile frame was centered above the 100-mm line that served as a visual analog scale (VAS). An example of a smile with the VAS is shown in Figure 2.

The determination of the subjective esthetic value of each smile was accomplished by using the VAS. This rating scale was designed for minimal constraints and the most freedom to express a personal response style.[33-35] The VAS was 100 mm long bordered by opposite words.[36] "Pleasing," used to subjectively rate the smile, is defined as "giving pleasure or enjoyment; agreeable."[37] Raters used their own esthetic values to rank the patients' smiles from "least pleasing" to "most pleasing."[38]

An esthetic score was obtained by measuring the distance in millimeters from the least-pleasing (zero) end of the scale to the hash mark.[32] This method was used to assign numerical scores to subjective judgments of smile esthetics. The locations of the marks were measured to the nearest 0.5 mm.[33]

A VAS was used to obtain subjective opinions on smile esthetics from 30 orthodontists and 30 laypersons. All were of white ancestry. For this study, an orthodontist was defined as a specialist who had completed advanced training in an orthodontic residency program, and a layperson was defined as someone with no formal education in dentistry or dental hygiene.[24] Twenty male orthodontists and 10 female orthodontists participated, with a mean of more than 15 years in orthodontic practice. The layperson panel was included 15 men and 15 women; 10 men and 9 women had undergone orthodontic treatment. The study by Moore et al[26] on smile esthetics previously showed that there are no significant differences in the esthetic judgments of men and women.

Both the orthodontic and layperson panel members worked independently and had no time restrictions.[24] Questions were answered verbally, and the judges were told that they did not have to use the extremes of the line if they did not think it was warranted. No specific criteria were suggested for rating the smiles.[35] Each judge received all 60 images simultaneously, randomly ordered, and rated the smiles from least pleasing to most pleasing.

Statistical analysis

Statistical analysis was performed with a software program (SPSS version 12.0, for Windows, SPSS, Chicago, Ill). Descriptive statistics for cephalometric, cast, and smile measurements were calculated. An exploratory Shapiro Wilks test was performed on all variables to test for normality. Normal distribution of the data was found for all variables and allowed for parametric statistics. A Pearson correlation study was performed between all cephalometric, cast, and objective smile analysis parameters. The evaluation of significant correlations took into account the discrimination between topographic and nontopographic correlations. Topographic correlations occur between measurements that share at least 1 landmark, or at least 1 line, or part of an angle, or part of a structure; their statistical significance might show an anatomic or geometric relationship rather than a true biological one.[39] Therefore, in this study, significant nontopographic correlations were considered only for clinical interpretation of the results.

Discriminant analysis with stepwise variable selection was used for the subjective analysis of pleasant vs unpleasant smiles for both laypersons and orthodontists. The variables eligible for discriminant analysis were those pertaining to smile analysis with the exception of redundant parameters. All variables that were bilateral were reduced to unilateral variables with

Table I. Cephalometric, cast, and smile measurements (n = 60)

Craniofacial measurements	Mean	SD
Cephalometric measurements		
SNA (°)	80.7	4.0
PtA-NaPerp (mm)	–0.3	3.2
SNB (°)	77.8	4.1
Pog-NaPerp (mm)	–4.5	7.0
U1-SN (°)	105.6	7.1
U1-Pt A Vert (mm)	6.6	2.1
FMIA (°)	59.7	7.5
IMPA (°)	95.0	7.4
Na-Me (mm)	123.6	7.8
ANS-Me (mm)	69.9	6.0
Cast measurements		
Upper right 1 width (mm)	8.8	0.6
Upper right 1 height (mm)	9.2	0.8
Arch depth (mm)	29.1	2.1
Lingual maxillary 3-3 (mm)	24.9	2.1
Cusp tip maxillary 3-3 (mm)	33.9	2.2
Buccal maxillary 3-3 (mm)	37.9	2.1
Lingual maxillary 6-6 (mm)	31.6	2.1
Buccal maxillary 6-6 (mm)	54.8	2.2
Smile measurements		
Incisor exposure (mm)	7.6	1.6
Gingival display (mm)	–1.0	2.6
Lower lip to incisor (mm)	2.2	2.1
Interlabial gap (mm)	10.4	3.7
Width 3-3 (mm)	38.7	2.8
Width of visible teeth (mm)	46.0	4.8
Intercommissure width (mm)	61.1	5.4
Smile index (mm)	6.5	2.1
Left buccal corridor (mm)	11.2	2.4
Right buccal corridor (mm)	11.2	2.5
Buccal corridor ratio (mm)	0.6	0.0
Left posterior corridor (mm)	7.7	2.6
Right posterior corridor (mm)	7.4	2.4
Posterior corridor ratio (mm)	0.8	0.1
Upper vertical lip thickness (mm)	7.3	1.7
Lower vertical lip thickness (mm)	9.4	2.1

1, Central incisor; *3,* canine; *6,* first molar.

Table II. Discriminant analysis with stepwise variable selection for orthodontists and laypersons

Step	Tolerance	F-to-remove*	Wilks lambda
Orthodontic raters			
1. Lower lip to incisor	1.000	12.221	
2. Lower lip to incisor	0.999	11.332	.905
Upper lip thickness	0.999	5.393	.826
Layperson raters			
1. Upper lip thickness	1.000	11.343	
2. Upper lip thickness	0.700	16.671	1.000
Lower lip thickness	0.700	4.642	.836

*F > 4.

Table III. Classification power of stepwise discriminant analysis for orthodontists and laypersons (steps defined in Table II)

	Step 1	Step 2	Total
Orthodontic raters*			
Number			
Unpleasant	23	11	34
Pleasant	5	21	26
Percentage			
Unpleasant	67.6	32.4	100
Pleasant	19.2	80.8	100
Layperson raters†			
Number			
Unpleasant	36	12	48
Pleasant	3	9	12
Percentage			
Unpleasant	75.0	25.0	100
Pleasant	25.0	75.0	100

*73.3% of the subjects were classified correctly.
†75.0% of the subjects were classified correctly.

RESULTS

Descriptive statistics for all the cephalometric, dental cast, and smile measurements are given in Table I.

The esthetic smile judgments of the orthodontists were correlated positively with those of the laypersons (r = 0.93). Upper vertical lip thickness was correlated positively with smile esthetics as judged by the 2 panels. Both laypersons and orthodontists used the thickness of the upper lip as 1 of 2 variables that accounted mostly for discrimination between pleasant and unpleasant smiles. The classification power of discriminant analysis was about 75% (Tables II and III).

Lower vertical lip thickness was correlated positively with smile esthetics as judged by the laypersons. They used the thickness of the lower lip as the second of the 2 variables that accounted mostly for discrimination between pleasant and unpleasant smiles. The distance from the central incisor to the lower lip

random selection, and ratios of other variables were eliminated. The stepwise analysis was used to predict the characteristics that alone, or in combination, best predicted smile attractiveness.[30] For the discriminant analysis, unpleasant smiles were defined as those with mean numerical scores of 0 to 50. Pleasant smiles defined as those with mean numerical scores of 51 to 100, as measured from the VAS. The classification power of the discrimination was calculated and expressed for the identified variables.

The measurements on the lateral cephalograms, dental casts, and smile images were repeated 1 month later. The measurement error, assessed with paired *t* tests, was insignificant.

correlated positively with smile esthetics as judged by the orthodontists. They used the distance from the deepest midline point on the superior margin of the lower lip to the incisal edge of the maxillary right central incisor as 1 of 2 variables that accounted mostly for discrimination between pleasant and unpleasant smiles.

No significant correlations were found between smile arc, amount of incisogingival display, size (or ratio value) of buccal corridors and posterior corridor width, mandibular tooth display, and esthetics of the smile.

The thickness of the upper lip was correlated positively (r = 0.287; P <.05) with the position of the maxillary incisor relative to the maxilla, as measured from the facial surface of the maxillary incisor to the line perpendicular to Frankfort horizontal through Point A. Upper vertical lip thickness also had a positive correlation (r = 0.340; P <.01) to the skeletal vertical dimension, as measured from nasion to menton and a strong positive correlation (r = 0.392; P <.01) from anterior nasal spine to menton. Lower vertical lip thickness was correlated (P <.05) to lower anterior facial height.

Arch depth was correlated positively with incisor exposure (r = 0.285; P <.05), upper vertical lip thickness (r = 0.283; P <.05), and buccal corridor ratio (r = 0.412; P <.01), and negatively with width of the right buccal corridor (r = −0.271; P <.05) and lip drape (r = 0.461; P <.01).

Neither the amount of vertical tooth display nor the amount of upper lip drape was correlated with the skeletal vertical dimension, as measured from nasion to menton and from anterior nasal spine to menton. No correlation was found between the size of the buccal or posterior corridors and the position of the maxilla relative to the cranial base. No correlations were found between the widths of the right and left buccal or posterior corridors and the intermolar and intercanine widths of the maxillary arch as measured from the dental casts.

DISCUSSION

This study was undertaken to clarify the relationships between specific skeletal, dental, and soft-tissue structures and the configuration of the smile in patients with various degrees and types of malocclusion. These results apply to subjects before orthodontic treatment, when possible problems of alignment were part of the overall evaluation of smile characteristics. Knowledge of the correlations between hard- and soft-tissue anatomy and smile esthetics might add important clinical meaning to orthodontic diagnosis and treatment planning, even more so when our findings are compared with those of previous studies using similar methodologies, especially evaluating posttreatment samples or samples of untreated subjects with excellent occlusions and well-balanced faces.

With an emphasis on studying structures that influence esthetics, the posed smile was analyzed both subjectively and objectively. Smile images were judged by laypersons and orthodontists to give subjective results about a pleasing smile in growing patients seen at an orthodontic practice before treatment. Quantitative measurements were made by using images of the posed smile, focusing on features that previous investigations deemed important to esthetics.[1-26] Those measurements included vertical lip thickness, smile index, incisogingival display, and buccal corridor widths. The results of this objective smile analysis then were correlated with the hard-tissue dimensions derived from the casts and radiographs.

A pretreatment sample was selected for this study because it exemplified typical orthodontic patients requiring treatment. Growing patients between the ages of 10 and 15 years at the initial records are the "bread and butter" of average orthodontic practices in the United States. Because a pretreatment sample was used, these subjects varied greatly. The variety in the sample provided a range of smiles and dentofacial discrepancies that was ideal in correlating the hard-tissue structures to the resulting smile configurations.

The array of malocclusions in the pretreatment sample complicated the subjective smile analysis. Other studies used computer-altered images to look at the esthetic importance of 1 smile feature without the influence of other aspects of the malocclusion.[13,16,29,31,34,36] An untreated "normal" sample would have controlled for fewer esthetic extremes but would not have represented an orthodontic patient pool.

Esthetic correlations

There was high agreement in the judgments between laypersons and orthodontists (r = 0.93). Previous studies have disagreed on specific topic. Tedesco et al[40] found that laypersons were more sensitive to dentofacial impairments than those with orthodontic training. Johnson and Smith[24] and Kokich et al[13] found that dental professionals were more sensitive to minor dental disharmonies. Our findings may be a result of specialists considering their past experiences in treating various malocclusions when rating smile esthetics. In addition, the smiles were judged as an esthetic whole, and minor discrepancies in specific smile features were less of a decisive factor.

No correlation was found between gingival display and smile esthetics. Of the 60 patients, however, only 12 had gingival tissue apical to the cervical margin of the maxillary right central incisor. Although the acceptable range of gingival exposure varies by study, Kokich et al[13] showed that orthodontists found smiles most attractive when no gingiva was displayed and less attractive when 2 mm of gingiva was exposed; general dentists and laypersons were more tolerant in classifying gingival exposure as excessive once 4 mm of gingiva was displayed. Of the 12 subjects with gingival display in this study, 6 subjects had less than 2 mm of gingiva, and 1 had just 2.7 mm of gingiva. Only 5 subjects displayed more than 4 mm of gingiva.

According to Peck et al,[10,11] lip coverage of the maxillary incisors increases with age. Therefore, a high smile that shows 100% of the maxillary incisors and a contiguous band of gingiva is characteristic of a younger population.[23] It was hypothesized that, with our subjects' ages, less incisor display would be correlated with less pleasing smile esthetics, yet no correlation was found. The mean amount of incisor exposure for this sample was 7.7 ± 1.6 mm (range, 2.6-11.0 mm). No correlation was found between smile arc and esthetic judgment.

A review of the literature showed varied findings about how buccal corridor size affects smile esthetics.[18,20,21,26] For this study, buccal corridors were defined as the horizontal distance from the distal aspect of the canines to the corners of the lips when the patient smiles. It was hypothesized that less buccal corridor width would be correlated with a more pleasing smile. We found no correlations between smile esthetics and the size or ratio value of the buccal corridors. In addition, no correlation was found between the size or ratio value of the corridors distal to the most posterior teeth visible on smile.

Vertical lip thickness was important in the determination of the attractiveness of the smile. According to discriminant analysis, both laypersons and orthodontists used the thickness of the upper lip, and laypersons used the thickness of the lower lip, as variables in determining the pleasantness of a smile. These results are not surprising. Much commercialism today on television, radio, and the internet is aimed at self-improvement, specifically society's interest in fuller lips. Plastic surgery and other cosmetic treatments are all the rage; many involve enhancement of the size of the lips. Yet little information about lip esthetics is found in the orthodontic literature, most of which concerns cleft repair and norms for the lips at rest. Only 1 study correlating lip thickness and smile esthetics was found; it stated that more prominent lips were preferred in American black patients than in white patients.[32]

According to Dunn et al,[30] laypersons find having a greater number of teeth displayed more attractive than fewer teeth. Yet, the increased display of mandibular teeth has been described as a characteristic of aging; as maxillary lip coverage increases, the amount of mandibular incisor display increases as well.[23] We found no correlation between visible mandibular teeth and smile esthetics. In addition, no correlation was found between smile index and smile esthetics.

Structural correlations

Incisogingival display, the vertical distance from the inferior border of the upper lip to the incisal edge of the maxillary central incisors, was not correlated with the skeletal vertical dimension. Neither the vertical display on smile of the maxillary right central incisor nor the amount of upper lip drape was correlated with the skeletal vertical dimension, as measured from nasion to menton and from anterior nasal spine to menton. These results agree with the literature, suggesting that vertical maxillary excess is only 1 etiology that contributes to a gummy smile, which occurs when excessive gingival tissue is exposed during smiling.[11,14]

Shadows in the corners of the mouth during smiling have been advocated in the past as a clinical manifestation of inadequate maxillary arch width.[41] In this study, no correlations were found between the widths of the right and left buccal corridors and the intermolar and intercanine widths of the maxillary arch, as measured from the dental casts. Furthermore, according to Sarver and Ackerman,[8] a patient with a retrusive maxilla can have large buccal corridors. Although the maxilla is of normal width, the buccal corridors might appear prominent because the wider portion of the dental arch is more posterior. We tested that concept and found no correlation between the size of the buccal corridors and the position of the maxilla relative to the cranial base.

The vertical thickness of the upper lip was correlated significantly with maxillary incisor protrusion relative to the maxilla. This finding agrees with the clinical observation that flared maxillary incisors have a tendency to roll the upper lip up and out, exposing more of the mucocutaneous lip and increasing the vertical height of the exposed vermilion border of the lip. In addition, vertical upper lip thickness was correlated positively to arch depth and also had a strong positive correlation to the skeletal vertical dimension. In contrast, the thickness of the lower lip was correlated only to lower anterior facial height. Reduction in incisor protrusion often is a goal of orthodontic treat-

ment. Incisors are often retracted after extractions to reduce overjet, thus improving the dental occlusion. Subjective smile analysis showed that both orthodontists and laypersons preferred thicker lips, and this study has shown that lip thickness is positively correlated to incisor protrusion. Therefore, the impact of incisor retraction on the soft tissues, especially the upper lip, can influence smile esthetics negatively and must be considered by orthodontists when planning treatment.

CONCLUSIONS

We found strong agreement between orthodontists and laypersons in their subjective evaluations of smile esthetics. In addition, specific variables were shown to influence smile esthetics in growing patients before orthodontic treatment. The vertical thickness of the upper lip was an esthetic determinant for orthodontists and laypersons, and the vertical thickness of the lower lip was an esthetic determinant for laypersons: fuller lips were associated with better smiles. The distance between the incisal edge of the maxillary central incisor and the lower lip was an additional esthetic factor for the orthodontists: the greater the distance, the better the smile.

In addition to these subjective esthetic findings, the vertical thickness of the upper lip was correlated positively with the position of the maxillary incisor: the more protrusive the incisor, the fuller the upper lip. The vertical thickness of the upper lip also was correlated positively with arch depth and anterior facial height, and the vertical thickness of the lower lip was correlated positively with lower anterior facial height. Vertical lip thickness was the most influential variable in smile esthetics. Although this soft-tissue variable is not completely under an orthodontist's control, the relationship of incisor protrusion with upper lip thickness must be considered when planning orthodontic treatment.

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