*Original Article*

# An Evaluation of Dynamic Lip-Tooth Characteristics During Speech and Smile in Adolescents

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**Abstract:** This retrospective study was conducted to measure lip-tooth characteristics of adolescents. Pretreatment video clips of 1242 consecutive patients were screened for Class-I skeletal and dental patterns. After all inclusion criteria were applied, the final sample consisted of 50 patients (27 boys, 23 girls) with a mean age of 12.5 years. The raw digital video stream of each patient was edited to select a single image frame representing the patient saying the syllable ''chee'' and a second single image representing the patient's posed social smile and saved as part of a 12-frame image sequence. Each animation image was analyzed using a SmileMesh™ computer application to measure the smile index (the ratio of the intercommissure width divided by the interlabial gap), intercommissure width (mm), interlabial gap (mm), percent incisor below the intercommissure line, and maximum incisor exposure (mm). The data were analyzed using SAS (version 8.1). All recorded differences in linear measures had to be ≥2 mm. The results suggest that anterior tooth display at speech and smile should be recorded independently but evaluated as part of a dynamic range. Asking patients to say ''cheese'' and then smile is no longer a valid method to elicit the parameters of anterior tooth display. When planning the vertical positions of incisors during orthodontic treatment, the orthodontist should view the dynamics of anterior tooth display as a continuum delineated by the time points of rest, speech, posed social smile, and a Duchenne smile. (*Angle Orthod* 2004;74: 43–50.)

**Key Words:** Smile; Anterior tooth display; Adolescents; Speech; Digital video

## INTRODUCTION

The clinical examination and diagnostic exercise in orthodontic treatment planning have largely focused on the dental and skeletal hard tissue elements involved in a given patient's facial appearance. A reemergence of the soft tissue paradigm[1] in orthodontics has shifted diagnostic thinking to focus on soft tissue–hard tissue interrelationships and how they contribute to the overall facial esthetic makeup of the patient. In particular, the anterior tooth display during dynamic facial animation has entered clinical evaluation.[2–7] Presently, there is little data in the literature regarding lip-tooth characteristics during different facial animations.

The major difficulty in studying lip-tooth characteristics during facial animation has been our inability to accurately capture a reliable and repeatable image at one time point and across multiple time points. Rigsbee[4] found that the posed social smile was repeatable photographically in comparison with the Duchenne (enjoyment) smile. Ackerman et al[6] found questionable repeatability in posed social smiles in children and that there may exist a maturational sequence in developing a repeatable smile in adolescents. Zachrisson[5] presented a photographic methodology in which the patient was asked to smile and then say the word ''cheese'' to obtain an ideal lip-tooth presentation at smile. Ackerman and Ackerman[8] reported a technique using digital video clips for capturing speech and smile. They noted that digital video records roughly 15–30 frames per second and that it was possible to select matching images at different time points from these multiple frame galleries to effectively compare the ''same'' posed social smile.

Hulsey[2] published the first orthodontic study to quantify lip-tooth characteristics at smile. By placing a grid over the cropped smile photograph, he measured a sample of orthodontically treated patients and compared them with a sample of untreated orthodontic patients with normal occlusion. The treated group had significantly poorer smile scores, as judged by a lay and professional panel, when looking at maxillary incisor–maxillary lip relationships. Hulsey[2] concluded that a key component present in an esthetic smile was a consonance between the arcs formed between the

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**TABLE 1.** Inclusion Criteria

| Parameter | Inclusion Criteria |
|---|---|
| Age | 11–14 years of age |
| Sex | Male/female |
| Race | Whites only |
| Skeletal pattern | Class I (judged by facial proportion and cephalometric WITS appraisal) |
| Molar relationship | Angle Class I |
| Overbite | ≥50% |
| Overjet | Less than two mm |
| Soft tissue vertical proportionality | Equal facial thirds judged clinically |
| Chief complaint | Anterior dental alignment only (crowding or spacing) |

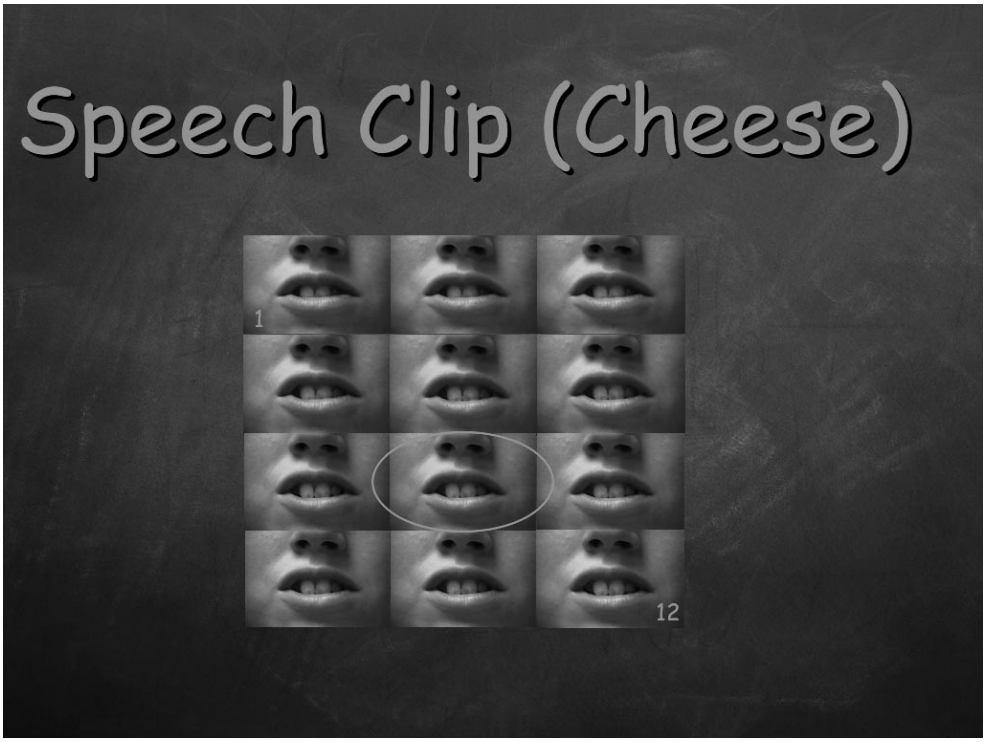


**FIGURE 1.** The ''chee'' articulation clip.

incisal edges of the maxillary anterior teeth and the curvature of the lower lip. Ackerman et al[6] conducted a similar study using a computerized multimedia program to measure similar smile characteristics. The treated group in their study had less esthetic smile measures than the untreated group, as measured by the smile arc.[6] They reported that the smile arc was flattened in 37% of the treated patients as compared with only 5% in the untreated group.

Weedon et al[9] examined seven facial movements (smile, grimace, cheek puff, lip purse, eye opening, eye closure, and mouth opening) in a sample of 50 adults with normal dentoskeletal patterns. On average, males exhibited a greater amount of maximum facial movement than females. In addition, they found a very small but statistically significant effect on facial movement when measured in one dimension, ie, the commissures of the maxillary lip moved to a more superior and posterior position in males compared with females.

The goal of this retrospective study was to measure differences in lip-tooth characteristics of adolescent patients during speech and while smiling. A tested methodology both for eliciting anterior tooth display and quantifying lip-tooth relationships was used.[6,10] Quantitative differences in lip-tooth relationships during facial animations are examined and analyzed relative to our current guidelines for animated facial capture and the resulting planning of treatment for maximizing smile esthetics.

## MATERIALS AND METHODS

A series of pretreatment video clips of 1242 consecutive patients from a private orthodontic practice was available

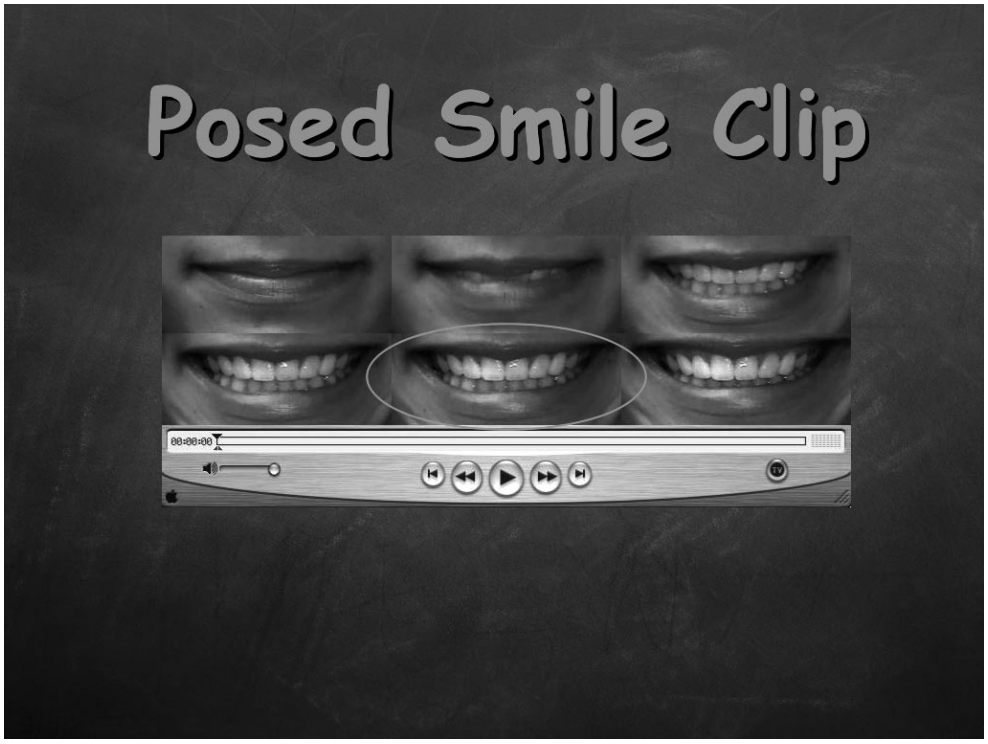


**FIGURE 2.** Posed social smile clip.

for analysis. All video clips were recorded with a standard capture protocol.[10] The initial inclusion criteria were Class I dental and skeletal patterns, and this resulted in the availability of 306 video clips. When these clips were reviewed to establish that the video capture protocol was actually applied and that the clip was in focus and viewable, the preliminary sample was reduced to 244 video clips.

Inclusion criteria for the study included age, sex, race, skeletal pattern, dental pattern (molar relationship, overbite-overjet), soft tissue facial vertical proportionality, and the patient's chief orthodontic complaint and were applied to the preliminary sample (Table 1). A sample of 62 patients was obtained after applying all the inclusion criteria. After randomization, the final sample consisted of 50 patients (27 boys, 23 girls) with a mean age of 12.5 years (range 10.6–14.6 years).

### Video editing

The subjects' digital video streams were imported to the video editing software iMovie™ Apple Computer, Inc. 1 Infinite Loop Cupertino, CA 95014 and prepared for editing. The raw digital video stream for each subject was edited to select a cropped single image frame representing the subject saying the syllable ''chee'' from the word cheese and a second cropped single image frame representing the subject's posed social smile. The video clip was then edited into two separate miniclips (''chee'' and posed social smile), which were on average one second or less in duration. These two files were saved as exportable Quicktime™ movies.

The ''chee'' clips and posed social smile clips were opened in the software application Quicktime™ Apple Computer, Inc. 1 Infinite Loop Cupertino, CA 95014 Viewer. This software enables the operator to save a movie as an image sequence and then export roughly 12–15 frames per second. Each frame was saved as a sequential jpeg identical in size and resolution. The study clips were saved as 12 single images for each facial animation. The eighth frame during the ''chee'' articulation was selected as the standard image of the speech animation ''chee'' (Figure 1). This was the most representative image depicting lip-tooth relationships on uttering the ''chee'' sound. The 10th frame was arbitrarily selected for the posed social smile animation image (Figure 2). A qualitative assessment was also made as to whether this 10th image was representative of the posed social smile.

### Image analysis

Each facial animation image in the two categories was imported into the SmileMesh™ TDG Computing Philadelphia, PA computer application. The measurement protocol using the SmileMesh™ measured selected lip-tooth variables involved in anterior tooth display.[6] A calibrated measuring grid consisting of seven vertical lines and six horizontal lines was superimposed on the facial animation image and was adjusted to the appropriate lip-tooth landmarks

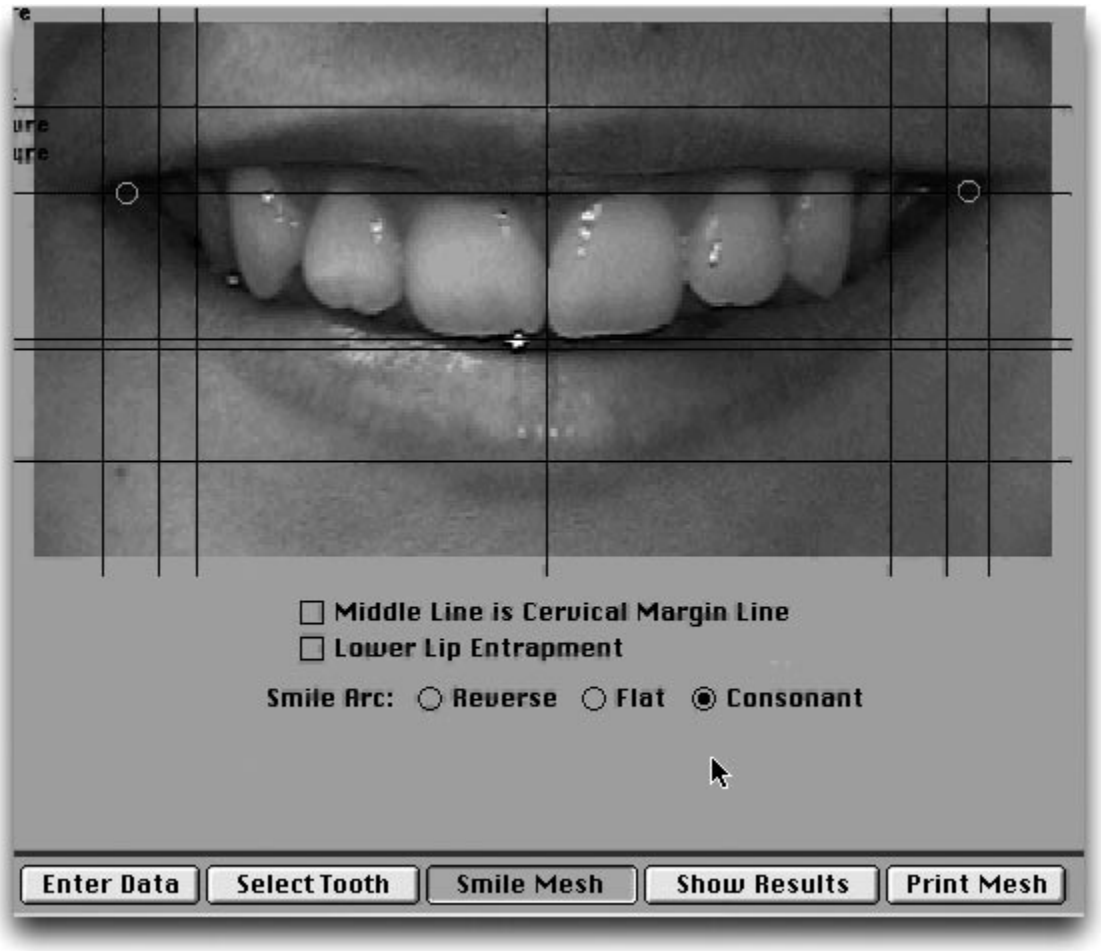


**FIGURE 3.** The smile mesh.

**TABLE 2.** Boys and Girls Combined (Mean ± SD)

| Parameter | Posed Smile | Speech: Saying "Cheese" | Difference | Paired *t*-Test *P* Value |
|---|---|---|---|---|
| Maximum incisor exposure | 6.47 ± 1.56 | 5.77 ± 1.79 | 0.70 ± 1.31 | .0004 |
| Interlabial gap | 8.41 ± 2.10 | 8.45 ± 2.19 | −0.04 ± 2.06 | .8940 |
| Smile width | 49.39 ± 5.28 | 39.01 ± 4.91 | 10.37 ± 4.70 | <.0001 |
| Smile index | 6.15 ± 1.31 | 4.88 ± 1.21 | 1.28 ± 1.33 | <.0001 |
| Percent tooth below intercommissure | 92.13 ± 25.93 | 45.63 ± 33.25 | 46.51 ± 30.30 | <.0001 |

**TABLE 3.** Boys only (Mean ± SD)

| Parameter | Posed Smile | Speech: Saying "Cheese" | Difference | Paired *t*-Test *P* Value |
|---|---|---|---|---|
| Maximum incisor exposure | 6.56 ± 1.49 | 5.59 ± 1.90 | 0.96 ± 1.43 | .0018 |
| Interlabial gap | 8.66 ± 2.11 | 8.35 ± 2.28 | 0.31 ± 1.83 | .3935 |
| Smile width | 50.33 ± 6.04 | 38.99 ± 4.48 | 11.34 ± 4.71 | <.0001 |
| Smile index | 6.04 ± 1.14 | 4.96 ± 1.30 | 1.08 ± 1.21 | <.0001 |
| Percent tooth below intercommissure | 91.50 ± 29.62 | 41.96 ± 38.22 | 49.54 ± 30.54 | <.0001 |

**TABLE 4.** Girls only (Mean ± SD)

| Parameter | Posed Smile | Speech: Saying "Cheese" | Difference | Paired *t*-Test *P* Value |
|---|---|---|---|---|
| Maximum incisor exposure | 6.37 ± 1.67 | 5.97 ± 1.68 | 0.40 ± 1.11 | .0983 |
| Interlabial gap | 8.11 ± 2.10 | 8.56 ± 2.14 | −0.44 ± 2.27 | .3592 |
| Smile width | 48.28 ± 4.06 | 39.04 ± 5.48 | 9.24 ± 4.54 | <.0001 |
| Smile index | 6.29 ± 1.49 | 4.78 ± 1.11 | 1.51 ± 1.45 | <.0001 |
| Percent tooth below intercommissure | 92.88 ± 21.45 | 49.93 ± 26.44 | 42.95 ± 30.30 | <.0001 |

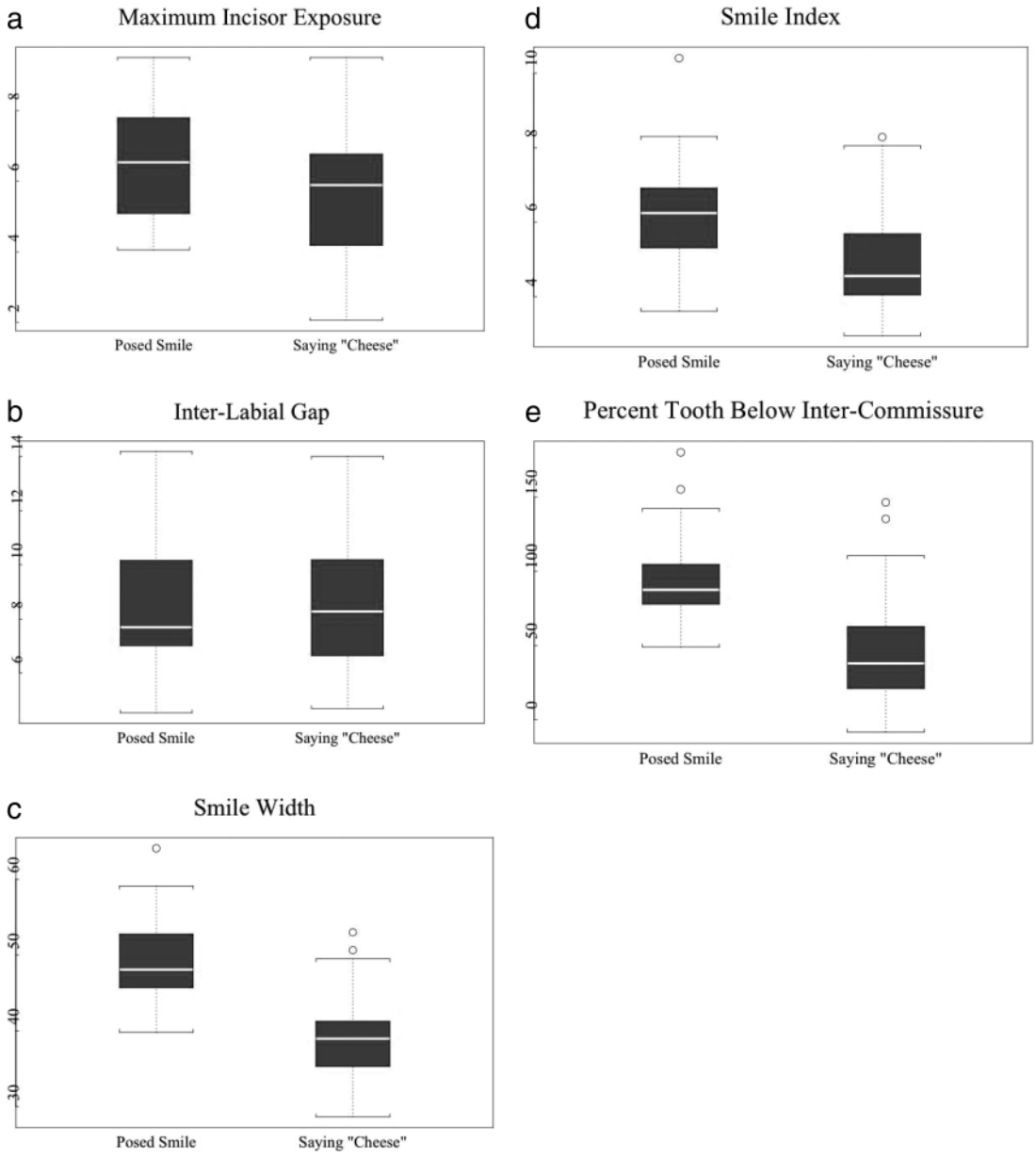


**FIGURE 4a–e.** Box and whisker plots graphically represent the difference between speech and posed social smile values in the complete sample.

(Figure 3). The measured variables included smile index (the ratio of the intercommissure width divided by the interlabial gap), intercommissure width (mm), interlabial gap (mm), percent incisor below the intercommissure line, and maximum incisor exposure (mm). The derived data were exported from SmileMesh™ into Microsoft Excel™ Microsoft Corporation Redmond, WA 98052 for data analysis.

The speech smile measurements were compared with the posed smile measurements using paired *t*-tests. This method of analysis assumes that the data are symmetrically distributed around the mean and that the standard error of each sample is approximately the same. The data were examined for significant violations of this assumption. The data were also stratified by sex to see whether the differences between the speech smile and the posed social smile were the same in both boys and girls. Additionally, two-sample *t*-tests were used to test for differences between boys and girls on each of the speech and posed smile measurements. All analyses were performed using SAS version 8.1 (SAS Institute, Cary, NC) and Splus version 6.0 (MathSoft, Inc, Seattle, Wash). The intraclass correlation coefficients for the reliability and replicability of landmark identification were previously reported by Ackerman et al.[6]

## RESULTS

Table 2 shows the means and standard deviations (SD) for each of the measurements during the ''chee'' articulation and the posed social smile, as well as the mean difference between the two for boys and girls combined. All differences in linear measures had to be at least two mm to be clinically noticeable. The difference in percent incisor below the intercommissure line needed to be at least 20% for clinical significance. This was because the average height of the maxillary central incisor crown is 10.5 mm,[11] ie, the amount of maxillary tooth showing a difference would have to be equivalent to two mm or more.

In the posed smile, the subjects showed a greater maximum incisor exposure, smile width, smile index, and percent tooth below intercommissure as compared with during speech ($P < .01$). All these values were statistically significant except maximum incisor exposure.

There was no significant difference in the interlabial gap between speech and the posed social smile. This was true even when the boys and girls were viewed separately (Tables 3 and 4). However, when the difference in maximum incisor exposure between speech and the posed social smile was viewed by sex, the difference was only marginally significant for girls ($P = .0983$). None of the posed smile or speech measurements differed significantly between boys and girls ($P > .10$). Box and whisker plots graphically demonstrate the separation between differences in speech and the posed social smile in the entire sample (Figure 4a through e).

Scatter plots depicting the change in percent incisor below the intercommissure line vs change in interlabial gap and change in smile width were constructed (Figures 5 and 6). All the change measurements represent the posed social smile minus the ''chee'' articulation. The lines added on the graphs are the least-squares regression lines. For the change in percent incisor below the intercommissure line vs change in interlabial gap, the Pearson correlation coefficient was $r = 0.09$ ($P = .5497$). Thus, the correlation coefficient was not statistically significantly different from zero (ie, no association between change in percent incisor below the intercommissure line and change in interlabial gap).

For the change in percent incisor below the intercommissure line vs change in smile width, the Pearson correlation was $r = 0.37$ ($P = .0081$). Therefore, as the smile

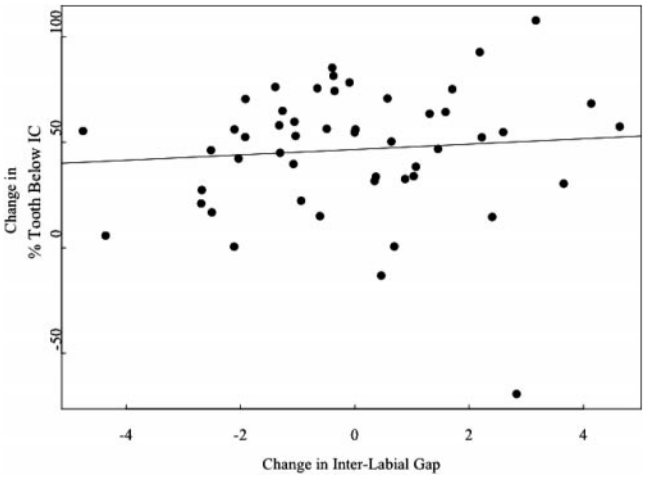


**FIGURE 5.** Change in percent incisor below the intercommissure line vs change in interlabial gap. The Pearson correlation was $r = 0.09$ ($P = .5497$).

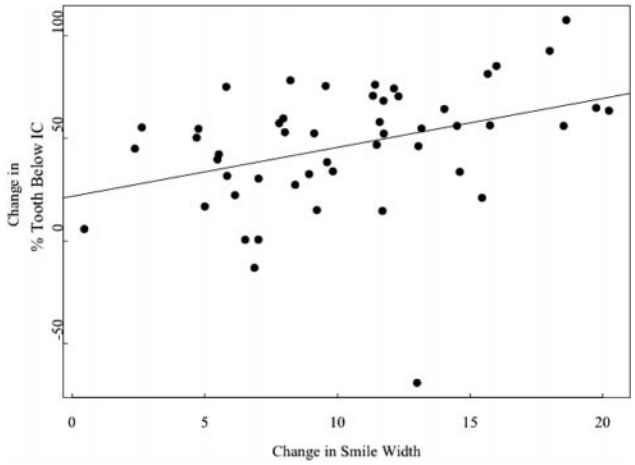


**FIGURE 6.** Change in percent incisor below the intercommissure line vs change in smile width. The Pearson correlation was $r = 0.37$ ($P = .0081$).

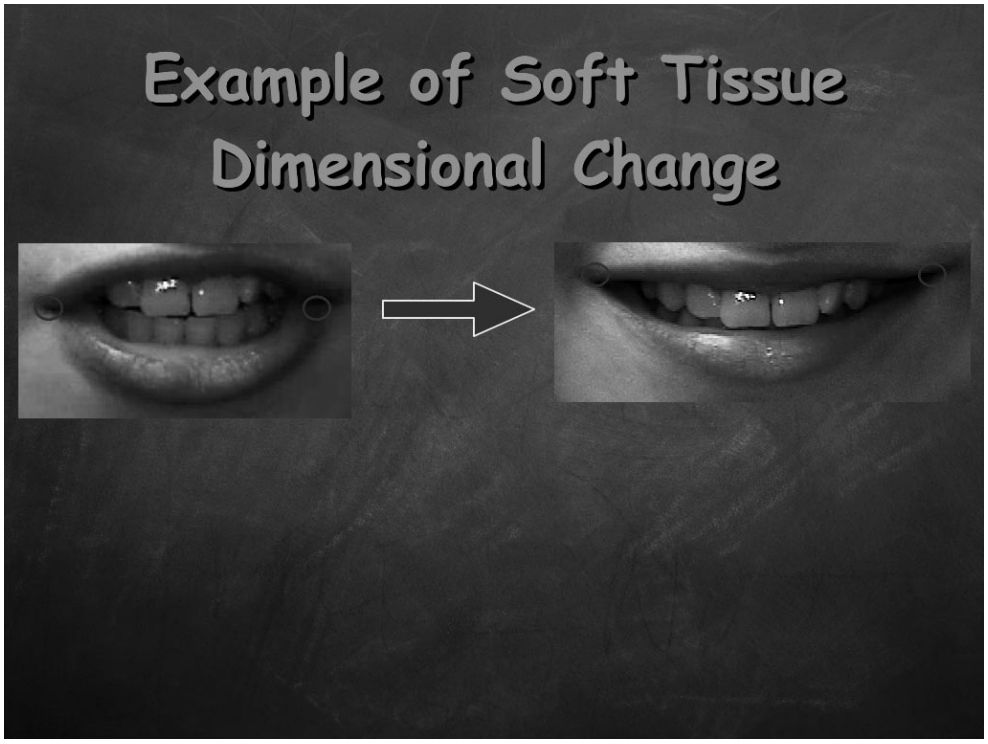


**FIGURE 7.** Example of soft tissue dimensional change.

width increases, the change in percent incisor below the intercommissure line also increases. Conversely, when going from the posed social smile to saying cheese, the larger the decrease in smile width, the larger the decrease in percent incisor below the intercommissure line.

## DISCUSSION

Clinically and statistically significant changes in anterior lip-tooth relationships were found between speech and smile. Figure 7 shows the soft tissue dimensional change occurring between saying ''chee'' and the posed social smile. The commissures of the lips move significantly more superiorly and laterally in the posed social smile. Hence, the spatial change at the commissures directly affects the amount of percent incisor below the intercommissure line, and the increase in smile width will proportionately increase smile index. Two dimensionally and morphologically different lip frameworks are present in the ''chee'' articulation and the posed social smile.

The use of digital video provides an accurate recording of the patient's speech, the posed social smile, and the Duchenne (enjoyment) smile. When compared with single frame capture method with digital photography, standardized digital videography provides the clinician a wider range of images for selecting the parameters of lip-tooth relationships during facial animation. Because there is variability in the posed social smile in adolescents with time, the single digital photograph is insufficient for the evaluation of treatment effects or maturational changes.

## CONCLUSION

The results of this study suggest that the lineaments of anterior tooth display at speech and the posed social smile should be recorded independently but evaluated as part of a dynamic range. Photographers asking patients to say ''cheese'' and then smile is no longer a valid method to elicit the parameters of anterior tooth display. When planning the vertical positions of incisors during orthodontic treatment, the orthodontist should view the dynamics of anterior tooth display as a continuum delineated by the time points of rest, speech, posed social smile, and Duchenne smile.

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