

# Smile line assessment comparing quantitative measurement and visual estimation

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**Introduction:** Esthetic analysis of dynamic functions such as spontaneous smiling is feasible by using digital videography and computer measurement for lip line height and tooth display. Because quantitative measurements are time-consuming, digital videography and semiquantitative (visual) estimation according to a standard categorization are more practical for regular diagnostics. Our objective in this study was to compare 2 semiquantitative methods with quantitative measurements for reliability and agreement. **Methods:** The faces of 122 male participants were individually registered by using digital videography. Spontaneous and posed smiles were captured. On the records, maxillary lip line heights and tooth display were digitally measured on each tooth and also visually estimated according to 3-grade and 4-grade scales. Two raters were involved. An error analysis was performed. Reliability was established with kappa statistics. **Results:** Interexaminer and intraexaminer reliability values were high, with median kappa values from 0.79 to 0.88. Agreement of the 3-grade scale estimation with quantitative measurement showed higher median kappa values (0.76) than the 4-grade scale estimation (0.66). Differentiating high and gummy smile lines (4-grade scale) resulted in greater inaccuracies. The estimation of a high, average, or low smile line for each tooth showed high reliability close to quantitative measurements. **Conclusions:** Smile line analysis can be performed reliably with a 3-grade scale (visual) semiquantitative estimation. For a more comprehensive diagnosis, additional measuring is proposed, especially in patients with disproportional gingival display. (*Am J Orthod Dentofacial Orthop* 2011;139:174-80)

Orofacial esthetics refers to dynamic facial expressions, such as smiling and speaking. The movements of the lips are the controlling factor for tooth and gingival display. According to the principles of visual perception, a harmonic and symmetric composition of teeth, visible gingiva, buccal corridors, and lips is a requirement for an esthetic and pleasing smile.<sup>1</sup> This “smile composition” is framed by the lips; in this way, the arrangement of the teeth and the visible gingiva is dictated by the outline of the lips and the height of the smile line. The outline of the lips affects visual constructs such as the buccal corridors and the smile arc.<sup>2</sup>

A smile line that displays the entire length of the teeth and some gingival tissue is associated with youth. In contrast, a smile line with only a portion of the teeth results in a less youthful smile.<sup>3</sup> Moreover, it was found recently that size and visibility of teeth, and upper lip position were critical factors in the self-perception of smile attractiveness.<sup>4</sup> Participants, smiling with their teeth entirely displayed including some gingival display, perceived their smile line as the most esthetic. Therefore, from a dental esthetic and patient point of view, the height and course of the smile line are important aspects of orthodontic diagnosis, treatment planning, and adequate long-term results.<sup>5</sup>

Static analysis of the smile with the photographic methods available in the past inevitably led to a posed smile as the starting point for an orthodontic diagnosis, since this was supposed to be the most reproducible smile.<sup>6,7</sup> This is, however, contrary to normal life, where smiles are not displayed in static but in dynamic situations. This drawback of photography has been overcome by contemporary videographic and computer technologies. Analysis of orofacial esthetics during spontaneous smiling and speaking is now feasible because the optimal record can be selected from a video registration.<sup>3,8-10</sup> The use of digital

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videography to capture an authentic spontaneous smile combined with digital measurements has been tested lately, and it appeared to be reliable, reproducible, and valid for use in clinical practice.<sup>9</sup> Moreover, it was found that a posed smile showed reduced smile line heights, tooth display, and smile width, compared with a spontaneous smile.<sup>11</sup> Spontaneous smiling records were therefore recommended for diagnostic purposes.

In spite of the digitized methods, performing smile line measurements is, however, relatively time-consuming and therefore less feasible for regular diagnostic use in clinical practice. Next to the quantitative measurements, a qualitative<sup>12,13</sup> and a semiquantitative approach<sup>14,15</sup> to determine the height of the smile line are proposed in the dental literature. In the qualitative approach, the clinician observes the smile line and makes a judgment about its height. A disadvantage of the qualitative analysis is that it lacks standardization and objective criteria. With a semiquantitative approach, the lip line height and tooth display are visually and rationally estimated with a scale. Lip line height and tooth display can, for instance, be classified as a high, average, or low smile line. The semiquantitative approach is a more formal and more objective method than the qualitative approach, and still it has the advantage that it is easy and quick to use. With the focus on daily patient care, the combination of digital videography and visual estimation of lip line height and tooth display on the images could be an efficient way of dynamic soft-tissue analysis.

Since semiquantitative estimations of lip line heights and tooth display are easier to perform and efficient, and do not require dedicated computer software, the question is whether this approach is justified for use in clinical practice. Therefore, the objectives of this study were to test the reliability and validity of semiquantitative estimation of the smile line and to make a comparison with quantitative measurements.

## MATERIAL AND METHODS

Of 1069 military men on an air force base, 122 were randomly selected from 3 age cohorts (20-25, 35-40, and 50-55 years). Inclusion criteria were full maxillary and mandibular dental arches up to and including the first molars and white ethnicity. The research proposal was approved by the ethical committee of the Academic Centre of Dentistry Amsterdam, The Netherlands. Informed consent was obtained from the participants according to the guidelines of that institution.

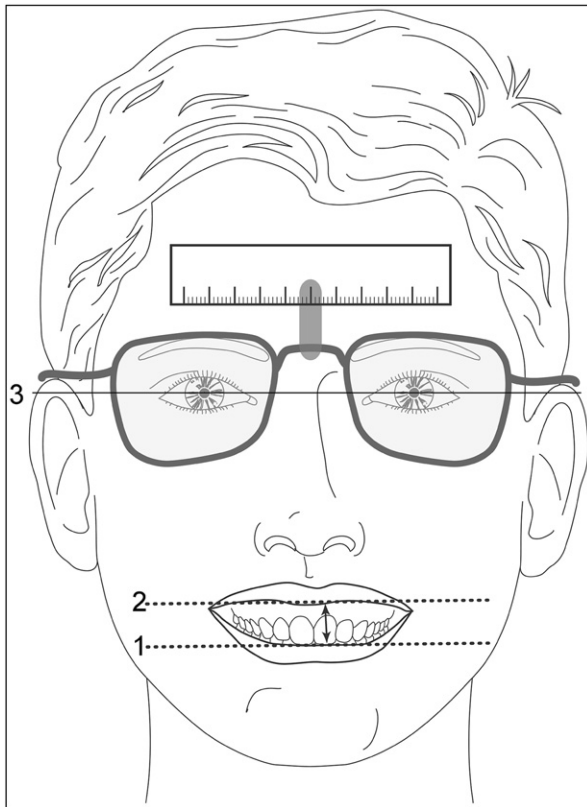
Of each participant, a video recording was made of a spontaneous smile of joy, a posed social smile, and full dentition with the aid of cheek retractors. The full

dentition was measured to obtain the actual lengths of the tooth crowns. The video recordings were made in a setup consisting of a chair with a digital video camera (XM 1 [3 CCD], Canon, Tokyo, Japan), a television set, and 2 spotlights mounted in front of the chair. The television screen was placed at eye level. When the visual axis was horizontal, the subjects kept their heads mainly in a natural head position.<sup>16,17</sup> The video camera was adjusted to the subject's mouth level and continuously registered the face. To prompt spontaneous smiling, the subjects watched television fragments of practical jokes, which had been assessed by a panel as the funniest from a film of 50 practical jokes. The subjects were unaware of the exact aim of the study. While watching television, the subjects wore glasses with a clipped-on reference standard to enable calibration in a digital measurement program. In this way, a maximum spontaneous smile was recorded with minimal intrusion of the subject. After the video registration, the digital recordings were transferred to a computer. Then, the dynamics of smiling could be observed image by image. The video images of smiling with maximum visibility of teeth and gingivae, referred to as the records, were selected.

The records of spontaneous and posed smiles were measured with the help of the Digora program for dental radiography (Orion Corporation Soredex, Helsinki, Finland). For each record, the measurement program was recalibrated with the filmed reference standard.

Tooth length was measured on the full dentition record to obtain the clinical crown length. Teeth and gingival display were measured on the spontaneous and posed smiling records. In the maxilla, a central incisor, a lateral incisor, a canine, a first premolar, a second premolar, and a first molar were measured on the right and left sides alternately to exclude possible interferences of asymmetries. The most incisal point of each tooth and the lip edge were marked with a digital horizontal line, parallel to the interpupil line (Fig 1). The vertical distance between these lines was measured (Fig 1). Tooth display during smiling was calculated as a percentage of the clinical crown length as measured on the full dentition record. In case of a high lip line, gingival display above the cervical margin was expressed in millimeters. Sometimes, the upper and lower lips covered both the gingival margin and the incisal point. In that case, lip line height was denoted as not measurable. If a tooth was not visible, lip line height was coded as missing.

An extensive reliability study and a more detailed description were reported earlier (Table 1).<sup>9</sup> The reliability was expressed by means of the generalizability coefficient, which is comparable with the intraclass correlation. The generalizability coefficient allows a reliability



**Fig 1.** Digital videographic method: measurement of maxillary central incisor. *Line 1*, Most incisal point; *line 2*, lip edge; *line 3*, interpupillary line.

estimate when several sources of error are present: in this case, teeth and ratings. The data obtained with the digital videographic measurement method were used in this study as the gold standard.

For the semiquantitative estimation, the lip line heights on the spontaneous and posed smiling records were visually classified according to a scale. Two classification concepts were used: a 3-grade scale, which has been used before, and a 4-grade scale.<sup>14,15</sup>

According to the 3-grade scale, a lip line height that showed less than 75% of the tooth was visually classified as a low smile line. A lip line height that showed 75% to 100% of the tooth and less than 1 mm of gingival display was visually classified as an average smile line. A lip line height that showed the total cervico-incisal length of a tooth and a continuous band of gingiva (minimum, 1 mm) was visually classified as a high smile line.

In the 4-grade scale, a gummy smile line was added as the fourth category. Based on the results of perception studies in which smile line heights displaying more than 4 mm of gingiva were perceived as less attractive, a lip line height that showed more than

**Table I.** Digital videographic measurement: generalizability coefficients (GC) and standard errors of measurement in millimeters (SEM) for spontaneous smiling

	Maxilla		
	Anterior teeth GC, SEM	Premolars GC, SEM	First molar GC, SEM
Interexaminer agreement	0.98, 0.4	0.98, 0.5	0.91, 1.1
Intraexaminer agreement	0.99, 0.3	1.0, 0.2	0.99, 0.3

4 mm of gingiva was classified as a gummy smile line (Fig 2).<sup>4,18</sup> The other 3 categories were identical to the categories of the 3-grade scale.

To determine the intraexaminer reliability for the 3-grade and 4-grade scales' semiquantitative estimations, all records were assessed twice by an examiner (P.G.) with a time interval of 2 weeks. To determine the interexaminer reliability, all records were assessed by a second examiner.

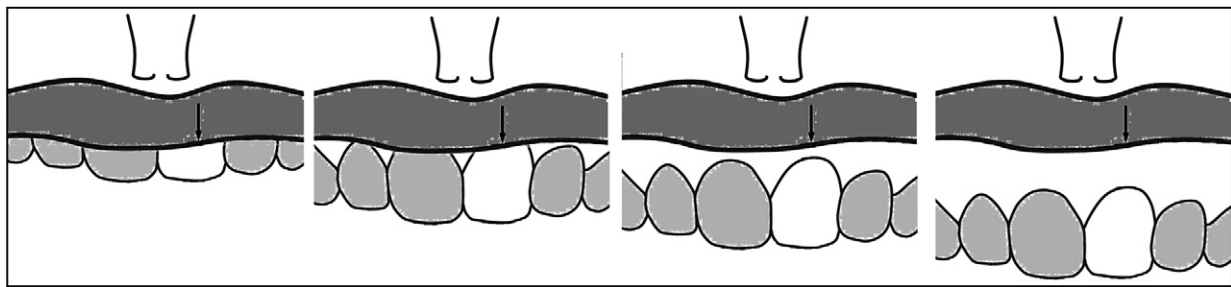
### Statistical analysis

The measured tooth display and lip line heights were recoded into the above-described ordinal values of the semiquantitative estimation: low, average, high, and gummy smile line categories. Cohen kappa statistics were used to establish both interexaminer and intraexaminer reliability values and the accuracy of the semiquantitative estimation of smile line height in relation to the quantitative measurements. All of these analyses were performed for each tooth. According to the conventions, kappa statistics of 0.40, 0.60, and 0.80 were considered moderate, substantial, and almost perfect, respectively.<sup>19</sup>

An error analysis was performed for further investigation of sources, which might lead to differences (errors) between semiquantitative estimations and quantitative measurements. The errors were correlated with the actual tooth length and the smile line height relative to the gingival margin. The significance level of  $P < 0.05$  was chosen. This meant that, with a sample size of 122, correlations of .25 can be detected with a power of .80.

### RESULTS

Table II shows the interexaminer and intraexaminer agreement values for the 2 concepts of semiquantitative estimation for both spontaneous and posed smiles. No substantial differences were noted between the values of interexaminer and intraexaminer reliability. The median values of the 3-grade scale estimation were considered almost perfect.<sup>19</sup> For the 4-grade scale estimation,



**Fig 2.** Four categories of smile line height: (left to right) low, average, high, and gummy.

**Table II.** Kappa statistics (K) and percentages (%) of interexaminer and intraexaminer agreement for semiquantitative estimation of lip line heights of the maxillary teeth during spontaneous and posed smiling

	Central incisor K, %	Lateral incisor K, %	Canine K, %	First premolar K, %	Second premolar K, %	First molar K, %	Median K, %
<b>Interexaminer agreement</b>							
Spontaneous smiling							
3-grade scale estimation	0.89, 94	0.84, 91	0.85, 91	0.88, 95	0.75, 92	0.93, 97	0.87, 93
4-grade scale estimation	0.83, 91	0.81, 88	0.83, 89	0.79, 86	0.73, 83	0.77, 84	0.81, 87
Posed smiling							
3-grade scale estimation	0.88, 93	0.85, 91	0.74, 84	0.89, 95	0.88, 95	0.90, 95	0.88, 94
4-grade scale estimation	0.87, 92	0.83, 90	0.70, 81	0.78, 85	0.80, 86	0.89, 93	0.82, 88
<b>Intraexaminer agreement</b>							
Spontaneous smiling							
3-grade scale estimation	0.95, 94	0.77, 87	0.86, 92	0.84, 93	0.73, 91	0.91, 96	0.85, 93
4-grade scale estimation	0.92, 96	0.73, 82	0.82, 88	0.76, 84	0.75, 84	0.81, 87	0.79, 86
Posed smiling							
3-grade scale estimation	0.86, 92	0.87, 92	0.79, 87	0.84, 91	0.92, 96	0.82, 90	0.85, 92
4-grade scale estimation	0.85, 91	0.86, 91	0.73, 82	0.73, 81	0.89, 92	0.72, 79	0.79, 87

in which the gummy smile line was included, the kappa values were slightly lower and were considered substantial to almost perfect.

Table III shows the kappa statistics and percentages of agreement between semiquantitative estimations and quantitative measurements of tooth display and lip line height. The anterior-tooth kappa values varied between substantial and almost perfect, for both spontaneous and posed smiling. The posterior-tooth kappa values for spontaneous smiling varied between moderate and substantial. Kappa values for posed smiling varied between substantial and almost perfect.

In Figure 3, the quantitative and semiquantitative percentages of tooth display and lip line height in the sample are shown according to the 4-grade scale. For both spontaneous and posed smiling, the gummy smile line category was mostly overestimated in the semiquantitative judgment, especially for the second premolar. The analyses of differences between semiquantitative and quantitative ratings in the 4-grade scale showed significant correlations for rating errors associated with

smile line height of spontaneous smiling (central incisor:  $r = 0.20, P = 0.026$ ; second premolar:  $r = -0.26, P = 0.007$ ). No correlations were found for the 3-grade scale analyses of differences.

**DISCUSSION**

When examining the whole range of lip-tooth relationships in a smile, simply observing a patient's smile without any quantification is not an adequate starting point for an evidence-based decision regarding orthodontic therapy. Therefore, a record is required for a dynamic smile analysis. By using records of spontaneous smiling next to posed smiling, diagnostics can be improved so that they approach the daily perceptions of patients by their social environment.<sup>11</sup> In this study, records were analyzed by measurements as well as by visual and rational estimations. Visual estimation and perception can be less accurate than measuring and susceptible to interference. A reason for this is the cooperation of different parts of the brain in which retinal stimuli are associated with recognition, the visual

**Table III.** Kappa statistics (K) and percentages (%) of agreement between semiquantitative estimation and quantitative measurement of the lip line heights of the maxillary teeth during spontaneous and posed smiling

	Central incisor K, %	Lateral incisor K, %	Canine K, %	First premolar K, %	Second premolar K, %	First molar K, %	Median K, %
Spontaneous smiling							
3-grade scale estimation	0.81, 90	0.76, 87	0.75, 85	0.71, 84	0.58, 85	0.77, 90	0.76, 86
4-grade scale estimation	0.77, 87	0.70, 80	0.72, 81	0.58, 71	0.55, 70	0.62, 73	0.66, 78
Posed smiling							
3-grade scale estimation	0.86, 91	0.72, 83	0.73, 83	0.75, 86	0.89, 95	0.77, 88	0.76, 87
4-grade scale estimation	0.84, 90	0.66, 78	0.67, 78	0.60, 71	0.71, 80	0.61, 71	0.67, 78

processing. Interference by visual processing can be a visual illusion: eg, if 2 teeth are the same length, the wider tooth seems shorter; or if 2 teeth are the same size, the whiter one appears larger.<sup>1</sup> By perceptual grouping, another interference of visual processing, the observation of single objects is less accurate, because perception of the whole is prior to that of its parts.<sup>20</sup> This makes visual perception not suitable for all types of estimation. For example, visual estimation of tooth-size discrepancies in dental arches was found to have low sensitivity and specificity.<sup>21</sup> However, a study into detection and activity assessment of primary coronal caries lesions showed high accuracy of visual estimation combined with probing.<sup>22</sup> The starting point for this study was to develop an efficient and practical method for smile line determination combined with videography. Therefore, the reliability of the semiquantitative approach for smile line determination was tested on videographic records.

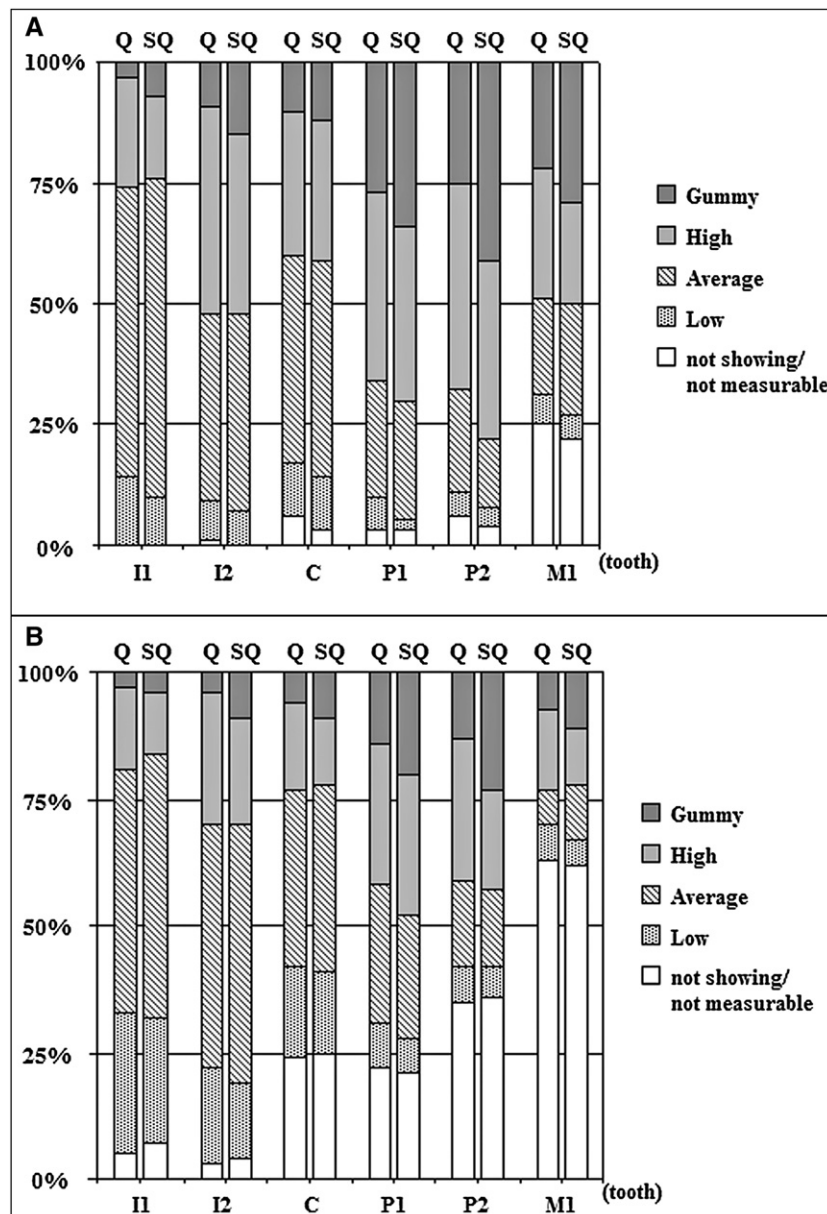
The 3-grade scale semiquantitative estimation is a commonly used approach in orthodontics and esthetic dentistry for the estimation of the smile line in the total anterior maxillary region. To prevent interfering factors of perceptual grouping as a result of visual processing in this study, the classification was used on the tooth level. When the smile line is estimated on each tooth, a rater must observe more carefully. Because the maxillary posterior region must also be considered part of the esthetic zone, the smile line was estimated up to the first molar.<sup>5,15,23</sup> A drawback of the 3-grade scale is that no difference is made between high and gummy smile lines. Gummy smiles can be considered a serious esthetic problem.<sup>24</sup> Smiles entirely displaying the teeth including more than 4 mm of gingiva were judged negatively, and disproportional gingival display was correlated with personality characteristics such as lower self-esteem and neuroticism.<sup>4,18</sup> Therefore, in this study, a fourth category was added to the semiquantitative classification to distinguish gummy smile lines exceeding 4 mm of gingival display.

The sample was restricted to Dutch military men. At first, this sample seems to be a limitation of this study.

It can result among others in a restriction of range for age and sex. However, since our aim was to test the reliability of smile line assessment as a method, confounding of the results by age or sex was not expected. Furthermore, this sample was randomly selected from 3 age cohorts. It is likely that all smile line categories were represented.

Although esthetic analysis is popular in contemporary orthodontics, relatively little research has been done regarding the reliability. Until now, no researchers have reported a reliability analysis of the semiquantitative estimation of the smile line. Basting et al<sup>25</sup> compared smile line height determination between the semiquantitative and quantitative approaches but focused only on the average smile line height. Table II shows substantial or almost perfect kappa statistics for semiquantitative estimation with little difference between the values of interexaminer and intraexaminer agreement. The 3-grade scale estimation showed the highest reproducibility with median kappa statistics considered almost perfect.

The agreement between the 3-grade scale estimation and the quantitative measurement method was substantial to almost perfect for both spontaneous and posed smiling except for moderate agreement of the second premolar during spontaneous smiling. For the second premolar, a discrepancy was noted between the relatively low kappa and the high percentage of agreement in the 3-category estimation. This was due to the high proportion of high smile lines in the study sample. In classifications with a high proportion of 1 category, high agreement percentages could be due to chance alone. The kappa coefficient corrects for this base rate agreement. By the addition of the extra grade scale of the gummy smile line, the agreement between the semiquantitative and the quantitative approaches also decreased. Especially in the premolar area during spontaneous smiling, the agreement was moderate. When combining both reproducibility and validity, the 3-grade scale estimation showed the highest reliability.



**Fig 3.** Percentages of the quantitative measurement (Q) and semiquantitative estimation (SQ) of tooth display and lip line height according to the 4-grade scale of the maxillary incisors, canine, premolars, and first molar: **A**, spontaneous smiling; **B**, posed smiling.

To learn from estimation errors, analyses of the differences between the semiquantitative and quantitative approaches were performed and correlated with possible interfering factors on visual processing such as actual tooth length and smile line height. The estimation errors were, however, relatively low, since the kappa statistics in Table III varied between moderate and almost perfect. The correlations with interfering factors were therefore not significant; they were weak and found only in the

4-grade scale estimation for smile line height. Relatively more estimation errors were made for central incisors with higher smile lines. For the second premolars, no estimation errors were made in the relatively large highest grade scale. The negative correlation seems mainly due to estimation errors as a result of overestimation of the grade scales below.

These results indicate that the 3-grade scale estimation is a reliable means for determination of the smile

line and thereby an instrument for clinical practice. Smile line discrepancies and the total smile line height can be efficiently determined in this way. Moreover, the 3-grade scale offers a good means of communication regarding smile line height with colleagues or patients, but it allows a certain degree of variability as proposed by Ker et al.<sup>26</sup> Although high gum lines can easily be detected without a scale, this study shows that the estimation of the height of the smile lines in teeth with more than 4 mm of gingival display is less accurate, and gingival display then seems to be overestimated.

In general, when a complete low smile line is determined, intrusion therapy in adolescents should be avoided. Reduced tooth display as a result of lip coverage during smiling, speaking, and even at rest is associated with aging. Intrusion therapy will lead to a premature aged oral appearance, and tooth display will be even more reduced by sagging of the lips in middle age. If an average smile line height is determined, orthodontic intrusion should also be avoided, including unwanted side effects of active therapy such as flattening of the smile arc.

In patients in whom a complete high smile line is determined, it should be kept in mind that smiles that include some gingival display are perceived as most esthetic.<sup>4</sup> However, when the balance between the amount of tooth and gingival display is lost, for instance, as a result of altered passive eruption, vertical maxillary excess, short upper lip, or increased lip elevation with smiling, additional digital measurement of lip line height and tooth display is proposed for orthodontic diagnosis and treatment planning.<sup>27,28</sup> The exact values can guide the decision for orthodontics or gingivectomy in milder cases and maxillary osteotomies in more severe cases.

## CONCLUSIONS

Smile line analysis can be performed reliably with a semiquantitative estimation by using a 3-grade scale. For a more comprehensive diagnosis, additional measuring is proposed for patients with disproportional gingival display.

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