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Original Article

The relationship between dentofacial morphology and smile characteristics in lateral and oblique views

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KEYWORDS
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Abstract *Background/purpose:* The purposes of this study were to develop smile measurements for lateral and oblique view photographs to help in orthodontic analysis and treatment planning, to quantitatively evaluate the relationship between smile esthetics and different types of malocclusion using lateral and oblique view photographs, to identify the cephalometric factors affecting smile measurements.
Materials and methods: Patients who came to orthodontic department of a university hospital from 2014 to 2017 and met the inclusion criteria were included and divided into three groups according to Angle's classification. Thirteen variables were measured for cephalometric analysis. Twenty-one variables were developed and measured on pretreatment photographs for lateral and oblique smile analysis. ANOVA and Scheffe post hoc test were used to compare cephalometric and smile variables among three groups. Multiple linear regression analysis was performed to identify cephalometric factors affecting smile measurements.
Results: Three-hundred and ninety patients (287 females, 103 males) with mean age of 24.5 ± 7.6 years reached the criteria. All cephalometric variables differed significantly among three groups. Except for maxillary teeth exposure number, visible maxillary width, and lip thickness ratio, all smile variables differed significantly. Smile characteristics had significant correlation with some cephalometric measurements.
Conclusion: Smile patterns on the lateral and oblique view photographs can be affected by different types of malocclusion. Therefore, we suggest to include lateral and oblique smile view photographs in the data collection for orthodontic treatment planning.

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Introduction

In the past, greater emphasis of orthodontic treatment has traditionally been placed on occlusal relationships. Afterward, the importance of facial esthetics and the enhancement of dentofacial characteristics has grown due to increasing public interest in the esthetics of looking younger and healthier.[1] Studies regarding smile esthetics have been published increasingly in orthodontics. Hulsey was the first one to quantify the lip–teeth relationship when smiling.[2] The ideal smile arc was then defined by Sarver.[3] The goals of orthodontic treatment should include facial and dental esthetics.[4] This is important for orthodontists as a smile is not just a key to expressing emotion, but is also an essential component of an esthetic face.[5] In response, as patients have placed greater importance on smile esthetics in recent years, orthodontists must first define the essential components of an esthetic smile, and its role in affecting dentofacial harmony,[6] and subsequently provide treatment plans that can deliver facial and dental esthetics results in an efficient manner.

Even though, there is plenty of research regarding smile esthetics, but most studies have been conducted using frontal view photographs.[7–13] This does not necessarily represent a realistic view of how a smile is perceived in society, as the human smile is expressed on a three-dimensional structure that is not easily analyzed with a single two-dimensional image. Therefore, the lateral and oblique view photos can be considered standard tools that orthodontists should utilize during diagnosis and treatment planning. Sarver also suggested that frontal at rest, frontal smile and profile at rest images do not contain an adequate information for smile analysis. Profile smile and oblique smile view photos should be also included in data collection for orthodontic planning.[3,14]

Some papers have proposed the usage of profile and oblique views, but are unable to provide further analysis due to a lack of measurement data and most of the studies conducted using subjective evaluation method.[15–17] Moreover, analyses used in orthodontic treatment planning typically consist of skeletal, dental, and soft tissue analyses. While there is currently no allocation for smile analysis in such a design, this study will attempt to expand the effectiveness of a potential smile analysis system, by providing lateral and oblique view smile measurements that would be applied in the orthodontic diagnosis and treatment planning.

The purposes of this study were to develop smile measurements for lateral and oblique view photographs to help in orthodontic analysis and treatment planning, to quantitatively evaluate the relationship between smile esthetics and different types of malocclusion using lateral and oblique view photographs, to identify the cephalometric factors affecting smile measurements.

Materials and methods

The participants were patients who came to the orthodontic department of a university hospital from year 2014–2017. All participants in this study reviewed and signed a consent form created in accordance with the rules and regulations of the university hospital. The participants should reach the following criteria. First, they should be at least 18 years of age at the time when the patient received the data collection. Second, the patients had never received orthodontic treatment before. Third, the patients should have a permanent dentition without missing teeth (except the third molars). Fourth, there was an intact set of diagnostic pretreatment records, including panoramic radiographs, cephalometric radiographs, study models, and intraoral and extraoral photographs. Fifth, there were both lateral and oblique smile view photographs taken with the patient's eyes open and head in natural position.

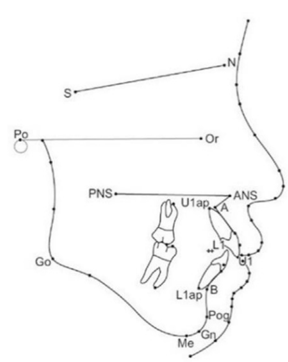
The participants who reached the inclusion criteria were then divided into the following three groups according to Angle's classification; group 1 (Angle Class I malocclusion), group 2 (Angle Class II malocclusion), and group 3 (Angle Class III malocclusion).

Cephalometric analysis

All pretreatment lateral cephalograms were traced using Viewbox software® (version 3.1.1.14; dHAL, Kifissia, Greece) by one examiner (P.C.C). Fig. 1 illustrates 13 cephalometric measurements. To verify the reliability of the measurements, 60 lateral cephalograms (20 from each group) were randomly selected from previously evaluated radiographs, and were retraced and redigitized by the same examiner after three or four weeks. Method errors were calculated using the Dahlberg's formula.[18]

Smile analysis

The pretreatment smiling photographs were taken using the digital camera (Av mode with F4.5, ISO 1600 and flash of canon EOS 550D Melville, NY, USA).



Skeletal	SNA (°) SNB (°) ANB (°) SN-GoGn (°) FMA (°)
Dental	U1-NA (°) U1-NA (mm) L1-NB (°) L1-NB (mm) U1-L1 (°) IMPA (°)
Facial Proportion	UFH/LFH (%) PFH/AFH (%)

Figure 1 Cephalometric landmarks and skeletal, dental, and soft tissue variables. SNA: Sella-Nasion-Point A angle, SNB: Sella-Nasion-Point B angle, ANB: Point A-Nasion-Point B angle, SN-GoGn: mandibular plane angle to the anterior cranial base, FMA: Frankfort horizontal plane to mandibular plane angle, U1-NA (°): upper incisor inclination to Nasion-Point A; U1-NA (mm): distance from upper incisor to NA line, L1-NB(°), lower incisor inclination to Nasion-Point B, L1-NB (mm): distance from lower incisor to NB line, U1-L1: angle between upper and lower incisor inclination, IMPA: lower incisor–mandibular plane angle, UFH/LFH: the proportion of upper facial height to lower facial height, PFH/AFH: the proportion of posterior facial height to anterior facial height.

The distance between the patient and the camera was 150 cm for every patient. The patients were also informed to say "cheese" while the photographs were taking and the head would be placed in the esthetic position as recommend by Bass (a natural head position adjusted by clinician to assure that the face did not tilt up or down).[19,20] For both lateral and oblique views, the patient's Frankfort horizontal plane should be parallel to the floor and the right ear should be seen clearly.[21] Eyes should be opened and looking straight.[22] The point focus should be at the patient's nose. For the lateral view photograph, the patient would be asked to bodily turn 90° to the left. The shot should be taken directly at 90° to the right side of patient's face.[22] The contralateral eyebrow should not be visible.[23] For the oblique view photograph, the patient would be asked to turn from the profile photograph position slightly to their right (about 45° or $^3/_4$ of the way) and the nose tip should be superimposed with the border of left cheek.[22,23] The smile variables consisted of three types of measurements (angular, ratio, and numerical measurements) (see Figs. 2 and 3).

When the alar-tragus line is five degrees downward, the Frankfurt plane will be parallel to the floor. A vertical line was drawn perpendicular to the horizontal plane and used as the vertical reference plane (Fig. 4).

All linear variables will be evaluated as a ratio The reproducibility of the evaluation process was evaluated by the same investigator, who remeasured 60 randomly selected images (20 from each group) after a 1-month interval using a Student's t -test for paired samples. The absence of a significant difference ($p < 0.05$) between the two sets of measurements indicated agreement between them.

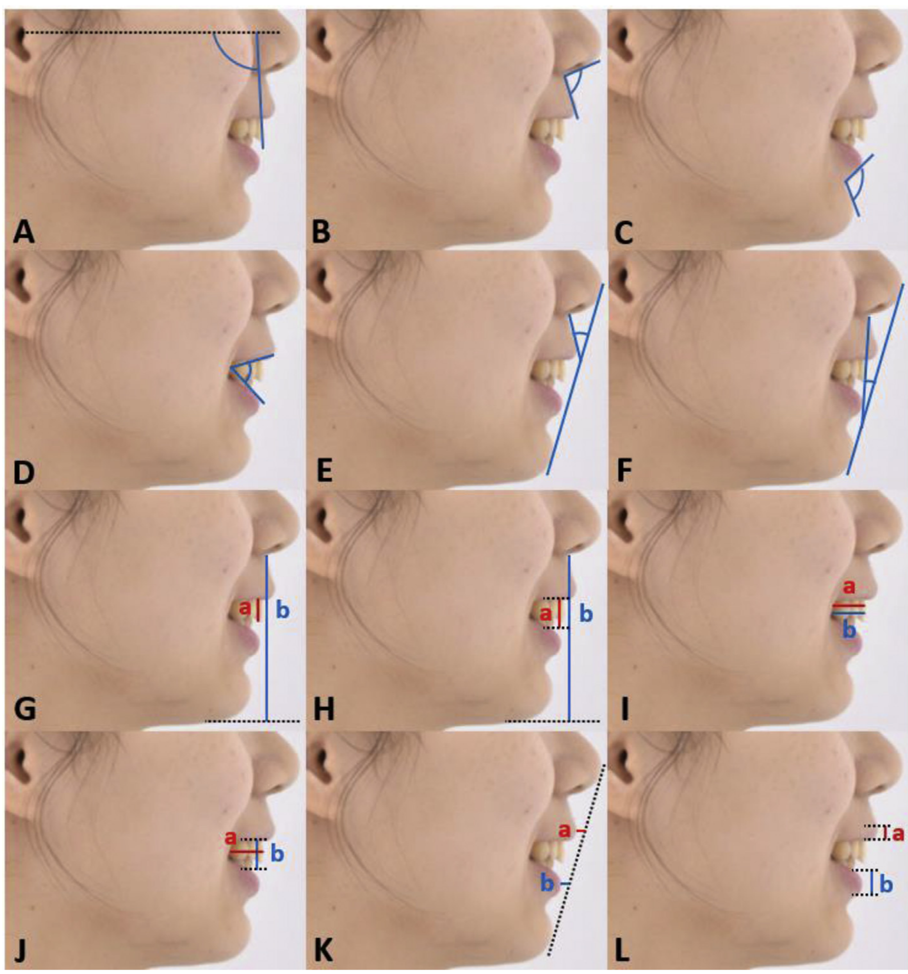


Figure 2 Smile measurements for lateral smiling-view photographs. *Angular measurements;* maxillary incisor angle (A): angle of tooth 11 to horizontal plane, nasolabial angle(B): Columella (Cm)-Subnasale (Sn)-Ls* angle, labio-mental angle (C): lower lip-labiomental fold-soft tissue Pogonion (Pog'), commissure angle (D): lower border of upper lip-commissure point*-upper border of lower lip, upper lip to E-line angle (E): Sn-Ls* line and E-line angle, lower lip to E-line angle(F): Sn—Li* line and E-line angle. *Linear measurements(a/b %);* incisal display ratio (G): maximum exposure of tooth 11/LFH*, interlabial gap ratio (H): Vertical distance between upper and lower lip/LFH*, visible maxillary teeth width (I): horizontal distance between most posterior point of visible tooth and labial surface of tooth 11(FDI)/anterior teeth width, lateral smile index(J): Visible maxillary teeth width/IGH*, lip to E-line ratio (K): ratio between horizontal distance from Ls to E-line, and from Li to E-line, lip thickness ratio(L): upper lip thickness/lower lip thickness. *Ls = Labrale Superius, Li= Labius Inferiorus, commissure point = the most posterior point of oral commissure, LFH = lower facial height, IGH= Interlabial gap height.

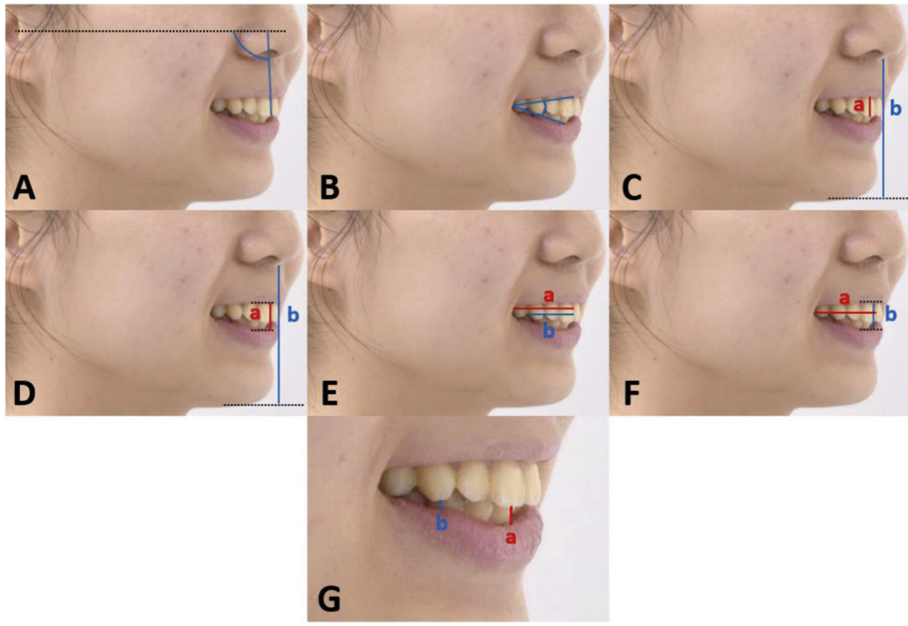


Figure 3 Smile measurements for oblique smiling-view photographs. *Angular measurements;* maxillary incisor angle (A): angle of tooth 11 to horizontal plane, commissure angle (B): lower border of upper lip-commissure point-upper border of lower lip. *Linear measurements (a/b %);* incisal display ratio (C): maximum exposure of tooth 11/LFH*, interlabial gap ratio (D): Vertical distance between upper and lower lip/LFH*, visible maxillary teeth width (E): horizontal distance between most posterior point of visible tooth and labial surface of tooth 11(FDI)/anterior teeth width, oblique smile index(F): Visible maxillary teeth width/IGH*, smile arc ratio (G): ratio of vertical distances between incisal edge or cusp tip to upper border of lower lip of upper right teeth. *commissure point = the most posterior point of oral commissure, LFH = lower facial height, IGH = interlabial gap height.

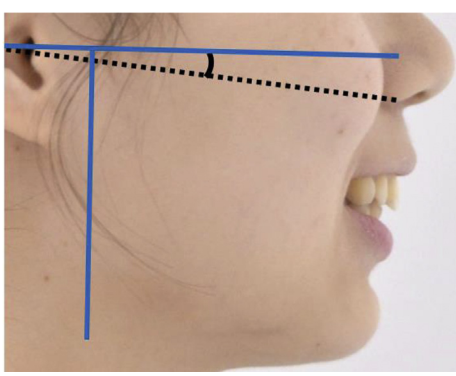


Figure 4 Horizontal and vertical reference planes of the smile measurements used in this study.

Statistical analysis

Statistical analyses were performed using SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA). Analysis of variance (ANOVA) was used to compare the pretreatment cephalometric, lateral smile and oblique smile variables among the three groups. A post hoc test was performed using Scheffe's method The level of significance was set at *p*-value < 0.05. Multiple linear regression analysis was performed to identify the cephalometric factors affecting smile measurements in three groups by using the smile variables as the dependent variables and the cephalometric measurements as the independent variables.

Results

There were 390 patients (287 females and 103 males) who reached the criteria and were included in this study. Their ages ranged from 18 to 48 years, with a mean age of 24.5 ± 7.6 years. The participants were divided by Angle's classification into three groups: group 1 (Angle Class I malocclusion, N = 148 [93 females]), group 2 (Angle Class II malocclusion, N = 102 [92 females]), and group 3 (Angle Class III malocclusion, N = 140 [102 females]).

Cephalometric analysis

The errors of the measurements in cephalometric analysis and smile analysis were calculated to test the reliability of the measuring method. In cephalometric analysis, there were mean differences of 0.79° in the angular measurements and 0.71 mm in the linear measurements. In smile analysis, there is no significant difference between the first and the second measurement results.

Table 1 demonstrates the statistical comparison of the cephalometric measurements using ANOVA for the three groups. The results showed that all cephalometric variables differed significantly among three groups. All variables except U1-NA (mm) differed significantly between group 1 and group 2. All variables except and L1-NB (mm) differed significantly between group 1 and group 3. And SNA (°), SNB (°), ANB (°), L1-NB (°), L1-NB (mm), U1-L1 (°), IMPA (°) differed significantly between group 2 and group 3.

Table 1 Comparison of the cephalometric measurements between different types of Angle's classification using ANOVA.

	Group 1 (Mean ± SD) (N = 148)	Group 2 (Mean ± SD) (N = 102)	Group 3 (Mean ± SD) (N = 140)	P-value
Skeletal				
SNA (°)	$82.93 \pm 3.21^{a,b}$	85.53 ± 2.01^{b}	80.41 ± 2.97	<0.001***
SNB (°)	$80.46 \pm 2.51^{a,b}$	77.57 ± 3.04^{b}	85.16 ± 3.43	<0.001***
ANB (°)	$2.47 \pm 2.46^{a,b}$	7.96 ± 2.94^{b}	-4.75 ± 3.09	<0.001***
SN-GoGn (°)	$31.80 \pm 4.23^{a,b}$	38.03 ± 3.61	35.05 ± 4.48	<0.001***
FMA (°)	$25.43 \pm 3.05^{a,b}$	30.81 ± 4.53	29.28 ± 3.48	<0.001***
Dental				
U1-NA (°)	$25.52 \pm 5.90^{a,b}$	28.82 ± 4.49	27.74 ± 3.90	<0.01**
U1-NA (mm)	7.50 ± 2.01^{b}	8.13 ± 1.93	8.22 ± 1.56	<0.05*
L1-NB (°)	$28.02 \pm 3.73^{a,b}$	35.51 ± 4.04^{b}	23.60 ± 3.81	<0.001***
L1-NB (mm)	7.31 ± 1.99^{a}	9.13 ± 2.05^{b}	6.96 ± 1.55	<0.001***
U1-L1 (°)	$126.96 \pm 5.69^{a,b}$	118.29 ± 5.85^{b}	123.24 ± 4.94	<0.001***
IMPA (°)	$95.33 \pm 4.71^{a,b}$	100.84 ± 4.78^{b}	87.66 ± 4.90	<0.001***
Soft tissue				
UFH/LFH	$45/55 \pm 1.61^{a,b}$	$44/56 \pm 1.31$	$44/56 \pm 1.43$	<0.01**
PFH/AFH	$63.64 \pm 3.21^{a,b}$	60.39 ± 3.05	60.54 ± 2.84	<0.001***

Group 1 = Angle class I, Group 2 = Angle class II, Group 3 = Angle class III, UFH = Upper facial height, LFH = Lower facial height, PFH = Posterior facial height, AFH = Anterior facial height.
*p ≦ 0.05, **p ≦ 0.01, ***p ≦ 0.001, n.s.: not statistically significant.
[a] Statistically significant with Group 2.
[b] Statistically significant with Group 3.

Smile analysis

In smile analysis, there was no significant difference between the first and the second measurement results. All variables except L1-NB (mm) differed significantly between group 1 and group 3. In addition, SNA (°), SNB (°), ANB (°), L1-NB (°), L1-NB (mm), U1-L1 (°), IMPA (°) differed significantly between group 2 and group 3. Regardless of these three variables, significant differences in maxillary incisor angle, nasolabial angle, commissure angle, upper lip to E-line angle, lower lip to E-line angle, interlabial gap ratio, and lip to E-line ratio were found between group 1 and group 2. There were also significant differences in maxillary incisor angle, nasolabial angle, labio-mental angle, commissure angle, incisal display ratio, and lateral smile index between group 1 and group 3. Significant differences in maxillary incisor angle, incisal display ratio, and interlabial gap ratio were observed between group 2 and group 3 (Table 2).

The statistical comparison for oblique smile measurements are shown in Table 3. The results of ANOVA indicated that except for visible maxillary teeth width and maxillary teeth exposure number, all six variables showed significant differences among three groups. Regardless of these two variables, maxillary incisor angle and interlabial gap ratio differed significantly between group 1 and group 2, while all variables showed significant difference between group 1 and group 3. Significant differences between group 2 and group 3 were observed in maxillary incisor angle, incisal display ratio, and interlabial gap ratio.

Correlation between cephalometric and smile measurements

There was no significant correlation of the data in group 3. For oblique smile, the multiple linear regression showed that visible maxillary teeth width was positively correlated with SNA and SNB in group 1. However, there were no significant correlations of these data in group 2 and 3 (Table 4).

Discussion

For the cephalometric analysis, significant differences were found among three groups for all cephalometric variables. This finding showed that the dental relationship for all three groups (Angle Class I, II, and III) was coincident with the skeletal relationship (Skeletal Class I, II, and III). And it may be implied that, in this study, Angle Class I, Class II and Class III groups could also represent Class I, Class II, and Class III jaw patterns respectively. Regarding to the post-hoc result, U1-NA (mm) was the only variable that did not have significant different between group 1 and group 2, and L1-NB (mm) was the only variable that did not differ significantly between group 1 and group 3. This might be because there were many Class I with bimaxillary dentoalveolar protrusion cases in group 1. Those patients had large U1-NA (mm) which was similar to those in group 2 and also had large L1-NB (mm) which was similar to those in group 3. Thus, U1-NA (mm) in both group 1 and group 2 did not show dramatic difference, while L1-NB (mm) in group 1 and group 3 did not differ significantly.

For the smile analysis, most of the smile variables in all lateral and oblique view photographs had significant differences among three groups. In Angle Class I malocclusion group, it was found that patients in this group had the highest smile index and the most consonant smile arc. While in Angle Class II malocclusion group, the patients had the highest interlabial gap ratio in both lateral and oblique smile views. They also had the largest labio-mental angle, the most protrusive upper lip and high upper incisal display.

Table 2 Comparison of the lateral smile measurements between different types of Angle's classification using ANOVA.

	Group 1 (Mean ± SD) (N = 148)	Group 2 (Mean ± SD) (N = 102)	Group 3 (Mean ± SD) (N = 140)	P-value
Maxillary incisor angle	111.20 ± 5.90[a,b]	123.16 ± 4.76[b]	96.6 ± 5.93	<0.001***
Nasolabial angle	95.5 ± 7.26[a,b]	85.76 ± 7.40	90.50 ± 8.22	<0.001***
Labio-mental angle	127.10 ± 7.49[b]	128.2 ± 6.62[b]	116.5 ± 8.97	<0.001***
Commissure angle	35.90 ± 4.49[a,b]	41.08 ± 5.80[b]	31.97 ± 4.79	<0.001***
U-lip to E-line angle	31.90 ± 6.28[a]	41.08 ± 9.75[b]	31.47 ± 7.82	<0.001***
L-lip to E-line angle	15.27 ± 3.17[a]	14.16 ± 2.81[b]	16.77 ± 3.15	<0.01**
Incisal display ratio	0.11 ± 0.02[b]	0.11 ± 0.03[b]	0.08 ± 0.04	<0.001***
Interlabial gap ratio	0.14 ± 0.03[a]	0.18 ± 0.05[b]	0.15 ± 0.05	<0.01**
Visible maxillary teeth width	1.08 ± 0.14	1.15 ± 0.18[b]	1.02 ± 0.24	n.s.
Lateral smile index	1.53 ± 0.41[b]	1.51 ± 0.39[b]	1.17 ± 0.44	<0.01**
Lip to E-line ratio	2.42 ± 1.69[a]	0.75 ± 1.48[b]	3.14 ± 2.29	<0.001***
Lip thickness ratio	0.69 ± 0.16	0.74 ± 0.18	0.69 ± 0.11	n.s.
Maxillary teeth exposure number	2.82 ± 0.59	2.86 ± 0.45	2.55 ± 0.44	n.s.

Group 1 = Angle class I, Group 2 = Angle class II, Group 3 = Angle class III, U-lip = Upper lip, L-lip = Lower lip.
*p ≦ 0.05, **p ≦ 0.01, ***p ≦ 0.001, n.s.: not statistically significant.
[a] Statistically significant with Group 2.
[b] Statistically significant with Group 3.

Table 3 Comparison of the oblique smile measurements between different types of Angle's classification using ANOVA.

	Group 1 (Mean ± SD) (N = 148)	Group 2 (Mean ± SD) (N = 102)	Group 3 (Mean ± SD) (N = 140)	P-value
Maxillary incisor angle	115.13 ± 6.0[a,b]	127.00 ± 4.57[b]	100.77 ± 5.67	<0.001***
Commissure angle	19.87 ± 6.33[b]	22.32 ± 6.10	24.83 ± 8.59	<0.05*
Incisal display ratio	0.13 ± 0.03[b]	0.15 ± 0.03[b]	0.09 ± 0.04	<0.001***
Interlabial gap ratio	0.15 ± 0.03[a,b]	0.18 ± 0.04[b]	0.12 ± 0.03	<0.001***
Visible maxillary teeth width	1.37 ± 0.20	1.44 ± 0.19	1.37 ± 0.26	n.s.
Oblique smile index	3.33 ± 0.86[b]	2.89 ± 0.80	2.48 ± 0.74	<0.01**
Smile arc ratio	1.23 ± 1.15[b]	1.80 ± 1.35	2.19 ± 1.43	<0.05*
Maxillary teeth exposure number	4.75 ± 0.82	5.10 ± 0.68	4.53 ± 1.22	n.s.

Group 1 = Angle class I, Group 2 = Angle class II, Group 3 = Angle class III.
*p ≦ 0.05, **p ≦ 0.01, ***p ≦ 0.001, n.s.: not statistically significant.
[a] Statistically significant with Group 2.
[b] Statistically significant with Group 3.

In Angle Class III malocclusion group, the patients had the smallest (obtused) labio-mental angle, the lowest smile index, and least consonant smile arc. This indicated that smile patterns from both views could be affected by Angle's classifications of malocclusion.

A consonant smile should be based on normal jaw relation. In Angle Class I group, the jaw relation tends to be normal. While in Angle Class III group, discrepancy develops more likely between both jaws. This explains the significant difference of the smile characteristics between Angle Class I and Class III malocclusion groups.

According to the results, it was found that visible maxillary teeth width and maxillary teeth exposure number was the two variables that had no significant difference on both views. This indicated that the maximum horizontal amount that could be seen while smiling might not be affected by Angle's classification of malocclusion. It might be because when smiling, the amount of the visible teeth in horizontal dimension in all three groups would be limited by the commissure of the lip which was controlled by perioral muscles.[24,25] Regardless of visible maxillary teeth width and maxillary teeth exposure number that mentioned above, on the lateral view, the lip thickness was also had no significant difference among three groups. This could be because while smiling, both upper and lower lips heights would become much smaller than lip height at rest for all three groups and make the differences of lip thickness ratios also became smaller among groups and thus, did not differed significantly.

According to the smile index, we included lateral smile index and oblique smile index in the analysis using the definition of smile index in frontal smile as a reference. The Angle Class I group has the highest smile index among three groups on both lateral and oblique views. Ackerman and Ackerman who developed a ratio called the smile index to visualize and quantify the frontal smile.[26] Concluded that

Table 4 Multiple linear regression of cephalometric measurements on lateral and on oblique smile variables.

	B	SE	P
Lateral smile variables			
(Group 1)			
Visible maxillary teeth width			
- SNA	0.02	0.01	<0.01**
- SNB	0.03	0.01	<0.05*
(Group 2)			
Maxillary incisal angle			
- SN-GoGn	−0.53	0.25	<0.05*
- FMA	−0.51	0.19	<0.01**
Upper lip to E-line angle			
- U1-NA(°)	0.97	0.40	<0.05*
Oblique smile variables			
(Group 1)			
Visible maxillary teeth width			
- SNA	0.04	0.01	<0.001***
- SNB	0.03	0.01	<0.05*

at the lower the smile index, the less youthful the smile appears. Brian et al. also stated that subjects with the "most unattractive" smiles had a significantly smaller smile index than did those with the "most attractive" smiles.[27] Therefore, according to our findings, Angle Class I group seemed to have more youthful and attractive smile than other groups.

It has been suggested in many studies that, smile arc can be clearly seen in the oblique smiling view because it can provide evaluation of curvature of molars (when visible), premolars, and anterior teeth in relation to lower lip.[3,14] The maxillary occlusal plane should be consonant with the curvature of the lower lip on smile.[26] However, there had been no studies so far measuring the smile arc on oblique view photos among different types of Angle's classification. Therefore, in this study, we included the smile arc variable in the oblique smile measurement. In order to perform an objective evaluation, we measured as a ratio (a/b %). The value that was closed to one was likely to have more consonant smile arc. According to our results, we found that Angle Class I patients tended to have the most consonant smile arc, while angle class III patients had least consonant smile arc among three groups.

Regarding to the angular measurements, all variables (maxillary incisor angle, nasolabial angle, labio-mental angle, commissure angle, upper lip to E-line and lower lip to E-line angle) differed significantly among three groups. These variables could be measured only on profile and/or oblique views not on frontal view. This could support the statement of Sarver that profile smile and oblique smile photos should be included in data collection for orthodontic diagnosis and treatment planning.[3,14] Kerns et al. also suggested that orthodontists should consider both frontal and lateral views because the same smile from profile and frontal views were not similarly rated for esthetic pleasantness.[15]

According to the multiple linear regression analysis, the correlation between cephalometric and lateral smile measurements showed that in group 2, the angle of upper incisors at smile negatively affected by Sn-GoGn and FMA. This means that patients with hypodivergent pattern (low mandibular angle) tends to have proclined upper incisors during smiling, in another word, patients with hyperdivergent pattern (high mandibular angle) tends to have more retroclined upper incisors at smile.

Moreover, we also found that lip procumbency while smiling significantly influenced by upper incisor angle at rest (U1-NA angle) in group 2. It can be noticed that this correlation was found in group 2 only and the patients in this group had larger upper incisor angle (U1-NA angle) than those from group 1 and group 3. Thus, it can be implied that patients with proclined upper incisors at rest (U1-NA angle) tends to have more protrusive upper lip at smile. This dental and soft tissue correlation would not be applied in patients with normal or small incisor angle at rest.

In group 1, the correlation between cephalometric and lateral smile measurements showed the same result with the correlation between cephalometric and oblique smile measurements, which was that maximum teeth width was positively influenced by SNA and SNB. In our study, SNA and SNB (mean $\pm$ SD) in group 1 were 82.9 ± 3.2 and $80.46 \pm 2.5°$ respectively which also referred to the Skeletal class I pattern according to the Steiner's analysis.[28] Thus, it might be implied that, in Angle and skeletal class I patients, increased SNA and SNB (within norm values) could provide a horizontally wider smile in lateral and oblique view.

According to the photograph used in our study, the size in each photograph was not an actual size of the patient, therefore, we used the ratios (a/b%) in linear measurements in order to decrease the error and increase the reliability of the measurements. Regarding the two-dimentional photography method that we used for the smile evaluation in this study, the advantage of using a facial photograph for analysis is that the process is simple and economical and the number of participants can be easily increased. For further study, as three-dimentional photography can be captured for many views at one time, so, it can be used in order to understand the three-dimentional smile changes and can also be used to evaluate changes between resting and smiling position. This would be broadening our knowledge in the orthodontic field. For more comprehensive results in terms of smile esthetics, a future study should be conducted in which adolescent, male, and female subjects be analyzed separately. Facial and lip tone between young and older adult subjects will also be investigated.

For the clinical application, evaluating a smile by using a frontal view photo alone is not sufficient to obtain the complete information. Therefore, it is highly suggested to include lateral smiling and oblique smiling view photos in the data collection for the orthodontic diagnosis and treatment planning.

The findings of this study can be concluded as follows: First, smile pattern in lateral and oblique view photographs can be affected by different Angle's classifications of malocclusion. Second, maxillary teeth exposure number, visible maxillary width, and lip thickness ratio are the only three variables from total 21 smile variables that have no significant difference on lateral and oblique smiling view photographs among different types of malocclusions. Third, lateral and oblique smile characteristics have significant correlation with some of the cephalometric measurements.

Declaration of competing interest

The authors declare that they have no competing interests.

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