Journal of Dental Sciences 20 (2025) 2143–2153

Available online at www.sciencedirect.com

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journal homepage: www.e-jds.com

Original Article

# Effects of horizontal dimensional malocclusion on changes in smile measurements in frontal, oblique, and lateral views

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Received 30 May 2025; Final revision received 6 July 2025
Available online 23 July 2025

**KEYWORDS**
Smile aesthetics;
Horizontal malocclusion;
Soft tissue variable changes

**Abstract** *Background/purpose:* Horizontal skeletal discrepancies can influence smile esthetics, but their impact on smile dynamics from different photographic perspectives remains underexplored. This study aimed to evaluate how horizontal malocclusion affects soft tissue changes in frontal, oblique, and lateral smile views.
*Materials and methods:* This retrospective study analyzed pre-treatment facial photographs of 200 patients. Subjects were divided into subgroups based on ANB angle and overjet values. Smile characteristics were measured from frontal, oblique, and lateral views at rest and during smiling. Variables were expressed as ratios relative to subnasale-menton distance. Statistical comparisons were made using ANOVA, Scheffé post hoc tests, and multiple regression analysis.
*Results:* Significant differences in smile measurements were more prominent in the oblique and lateral views than in the frontal view. Among ANB groups, greater discrepancies were noted in lower facial landmarks such as menton and pogonion. Oblique views were most sensitive in detecting differences in smile change, particularly among subjects with Class III malocclusion.
*Conclusion:* Horizontal dimensional malocclusion significantly affects soft tissue smile dynamics, particularly in the oblique view. Multiview smile analysis enhances diagnostic accuracy and should be considered in orthodontic assessment and treatment planning.

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https://doi.org/10.1016/j.jds.2025.07.005

## Introduction

The purpose of modern orthodontics is to not only establish ideal tooth alignment, interdigitation, and occlusal function but also ensure optimal smile aesthetics. Notably, a favorable occlusal relationship does not necessarily imply optimal smile aesthetics.[1] An attractive smile involves the lip-to-teeth relationship rather than tooth alignment alone. Since the early 2000s, the concept of "smile arc" has been widely applied by orthodontists, and a more specific definition of the ideal lip-to-teeth relationship has been established. Consequently, the ideal lip-to-teeth relationship has been a key focus in orthodontic treatment.[2–5] Therefore, the factors influencing smiles have increasingly been considered in orthodontic diagnosis and treatment planning.[6–10]

Research has evaluated static and dynamic smiles in terms of 3 dimensions and the factors influencing the frontal smile, including overbite, incisal display, mandibular plane angle, and buccal corridor.[11] However, little attention has been given to smile aesthetics in oblique and lateral views.[12] In addition, few studies have explored factors in the horizontal dimension, such as overjet (OJ) and A-nasion-B (ANB) angle, that influence smile aesthetics as well.[13,14]

In consideration of these gaps in the literature, the current study analyzed differences in the movements of facial landmarks and changes in soft tissue variables from rest to smile in patients with different horizontal dimensional malocclusions in the frontal, oblique, and lateral views.

## Materials and methods

### Patients

This retrospective cohort study was approved by the Institutional Review Board of Taipei Medical University Hospital (approval number: N201803029). The sample comprised 200 patients randomly recruited from the orthodontic department of Taipei Medical University Hospital from 2019 to 2021. The average age of the patients was 24.3 $\pm$ 1.8 years old. Patients who had complete pretreatment data, including frontal, oblique, and lateral resting and smiling photos; study models; panoramic X-rays; and lateral cephalometric X-rays were included. Patients with obvious facial asymmetry, congenital defects, and acquired defects or facial changes because of facial trauma or plastic surgery were excluded from this study.

The patients were divided into 2 groups on the basis of the cephalometric variables of the ANB angle (examined through Steiner analysis[15]) in the horizontal skeletal dimension and OJ in the horizontal dental dimension. The ANB and OJ groups were further divided into 3 subgroups each. The ANB subgroups were divided on the basis of ANB angle as follows: Group 1: $<0^\circ$, Group 2: $0^\circ \leq x \leq 4^\circ$, and Group 3: $>4^\circ$. The OJ subgroups were as follows: Group 1: $<0$ mm, Group 2: $0 \leq x \leq 4$ mm, and Group 3: $>4$ mm.

### Data collection

All pretreatment photographs were taken by the same operator by using a digital camera (Canon 400D, Melville, NY, USA) with a shutter speed of 1/160, F 7.1, and ISO 200. Participants sat 1.5 m away from the camera with a natural head position and with their eyes looking straight forward. For the pretreatment images, a total of 6 extra-oral photographs were obtained. Photographs of the lips at the rest position and in the smile position were taken from the frontal view, oblique view (taken from right side of the face with the nose tip tangent to the border of the left cheek), and lateral view (taken perpendicular to the right side of the face).

The resolution of all 6 photographs was set at 300 pixels/inch by using Photoshop (Adobe Inc., San Jose, CA, USA). For each participant, lip-at-rest and smile images were superimposed and adjusted to the same size. For superimposition in the frontal view, the interpupillary line was used as the reference line, whereas the ear-to-eye line was used for superimposition in oblique and lateral views.[16]

## Methods

This study analyzed smile variables and their changes in the frontal, oblique, and lateral views. A total of 21 smile variables were defined, which were composed of 11 landmark measurements and 10 linear measurements. The definitions of all variables are provided in the Appendix and are demonstrated in Fig. 1. (Please refer to Appendix for definitions of all smile measurements.)

In the first part of this study, the differences in various facial landmarks and linear measurements during smiling across different horizontal dimensional malocclusions were determined. The subnasale was set as the starting point. The line connecting the subnasale and nasion was set as the Y-axis. Another line that was perpendicular to the Y-axis and passed through the subnasale was set as the X-axis. For each landmark, the vector values were plotted on the X- and Y-axes from the starting point. To reduce the error caused by the magnification of each photo, we applied the method described in Cheng in 2021.[16] All landmarks and linear measurements were divided by the value of the subnasale—nasion distance, which is a stable measurement. Finally, the ratios of the landmarks and linear measurements were calculated and compared.

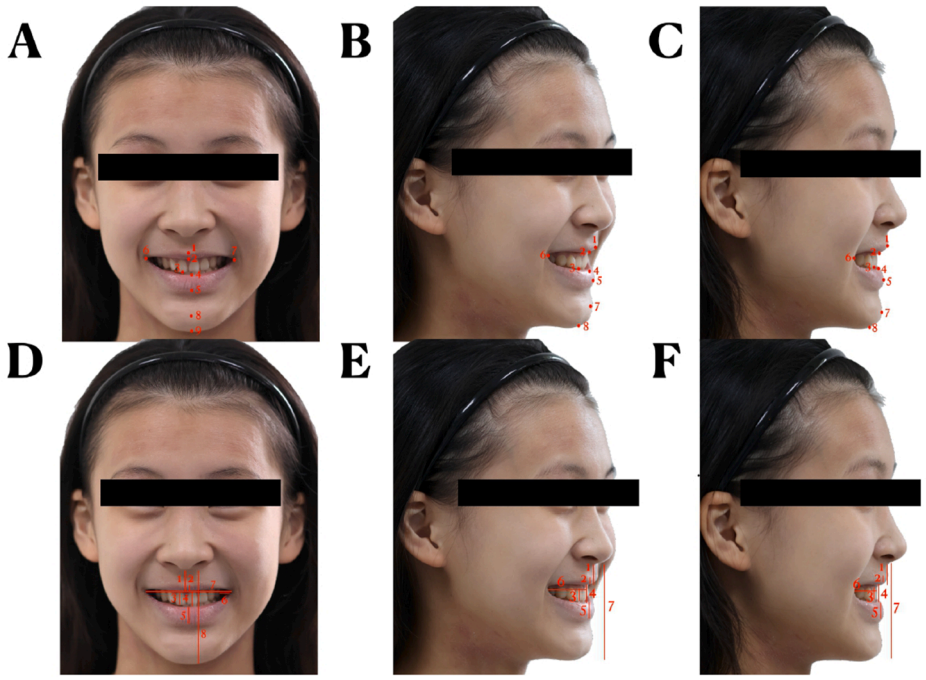


**Figure 1** Smile measurements (A): Landmarks in frontal view: 1. Labial superioris (Ls), 2. Upper stomion, 3. Incisal edge of #11 (FDI), 4. Lower stomion, 5. Labial inferioris (Li), 6. Right chelion, 7. Left chelion, 8. Pogonion, and 9. Menton. (B): Landmarks in oblique view: 1. Labial superioris (Ls), 2. Upper stomion, 3. Incisal edge of #11 (FDI), 4. Lower stomion, 5. Labial inferioris (Li), 6. Right chelion, 7. Pogonion, and 8. Menton. (C): Landmarks in lateral view: 1. Labial superioris (Ls), 2. Upper stomion, 3. Incisal edge of #11 (FDI), 4. Lower stomion, 5. Labial inferioris (Li), 6. Right chelion, 7. Pogonion, and 8. Menton. (D): Linear measurements in frontal view: 1. Upper lip length, 2. Upper lip thickness, 3. Maxillary incisor display, 4. Interlabial gap, 5. Lower lip thickness, 6. Buccal corridor, 7. Mouth width, and 8. LAFH. (E): Linear measurements in oblique view: 1. Upper lip length, 2. Upper lip thickness, 3. Maxillary incisor display, 4. Interlabial gap, 5. Lower lip thickness, 6. Mouth width, and 7. LAFH(lower anterior facial height). (F): Linear measurements in lateral view 1. Upper lip length, 2. Upper lip thickness, 3. Maxillary incisor display, 4. Interlabial gap, 5. Lower lip thickness, 6. Mouth width, and 7. LAFH(lower anterior facial height).

In the second part of this study, the change in each landmark from the lip-at-rest position to the smile position across different horizontal dimensional malocclusions was examined. For each landmark, the vector values were plotted on the X- and Y-axes, as mentioned earlier in the text. After the change in the distance of each landmark from the rest position to the smile position was measured, all values were divided by values at the lip-at-rest position. Moreover, the differences in linear measurements before and after smiling were divided by the linear measurements at the lip-at-rest position. Finally, the change in landmarks and linear measurements were calculated and compared in terms of ratios.

## Statistical analysis

Statistical analyses were performed using SAS software (version 9.4; SAS Institute, Cary, NC, USA). The effective sample size was calculated by using G-power test.[17] The power was set to 80 % and the significance level (alpha) to 0.05.

The mean values and standard deviations of the smile variables (landmarks and linear measurements) were calculated. Analysis of variance (ANOVA) was used to investigate the differences in smile variables and their changes in the frontal, oblique, and lateral views between the ANB and OJ groups. If significant differences were identified in ANOVA, the differences in landmark and linear measurements between the 2 groups were compared using the Scheffe test. Multiple linear regression analysis was conducted to analyze landmark and linear measurements during smiling in the frontal, oblique, and lateral views.

To ensure the reliability of the measurements, photographs and lateral cephalometric X-rays of 5 % of the participants were randomly selected for re-examination after 2 weeks of the initial measurements. The intraclass correlation coefficient was 0.9, indicating high reliability of the measurements.

## Results

Table 1 presents the distribution of the demographics of the ANB and OJ groups. Participants were mainly aged from 10 to 40 years. The total sample size of 200 in our study is relatively large, providing sufficient power for statistical analysis.

## Comparison of smile measurements

Tables 2 and 3 provide the results of analyses of smile variables for the ANB and OJ groups, respectively. In ANOVA, significant differences were noted in the landmarks

**Table 1** Patient groupings (N = 200).

| Variable | Range | Numbers |
|---|---|---|
| ANB (°) | ≤0 | 53 |
| | 0–4 | 79 |
| | ≥4 | 68 |
| Overjet (mm) | ≤0 | 37 |
| | 0–4 | 60 |
| | ≥4 | 103 |
| Age (y) | 10–20 | 77 |
| | 20–30 | 84 |
| | 30–40 | 35 |
| | >40 | 4 |

of the pogonion and menton and in the linear measurements of lower anterior facial height (LAFH) among the ANB groups. The Scheffe test revealed significant differences only between group 1 and group 3.

ANOVA revealed significant differences in the labrale inferioris, lower stomion, upper incisal display, and buccal corridor in the frontal view among the OJ groups but not in the pogonion and menton. Significant differences were noted in the chelion R't, U1 incisal edge, LAFH, and interlabial gap in the oblique view among the OJ groups. Significant differences were observed in the chelion R't, pogonion, menton, and U1 incisal edge in the lateral view among the OJ groups. According to the Scheffe test, significant differences were more prominent between group 1 and group 3.

### Comparison of changes in smile measurements

Tables 4 and 5 present the results of analysis of changes in smile measurements for the ANB and OJ groups, respectively. According to the results of ANOVA, significant differences were observed only in the labrale inferioris and menton in the frontal view among the ANB groups. Significant differences were identified in most variables, including the labrale superioris, labrale inferioris, lower stomion, upper lip length, and lower lip thickness, in the oblique view among the ANB groups. In addition, significant differences were noted in the menton (Y-axis) and LAFH in the lateral view among the ANB groups but not in the labrale inferioris and lower stomion. The Scheffe test indicated that the significant differences were the largest between group 1 and group 3.

According to the ANOVA results, significant differences existed in the labrale inferioris, lower stomion, and menton in all views among the OJ groups. Significant differences were also noted in most variables in the oblique view, including the labrale superius, upper stomion, and lower lip thickness. The Scheffe test revealed that the significant differences were the largest between group 1 and group 3.

### Factors affecting smile measurements

In Table 6, only the labrale inferioris and upper lip length were correlated with OJ and ANB in the frontal view, respectively. More smile variables were correlated with ANB and OJ in oblique and lateral views, and the regression coefficients were mostly moderate. The labrale superioris, upper stomion, and upper lip length in the oblique and lateral views were significantly correlated with ANB and OJ. Moreover, the chelion R't, pogonion (X-axis), and menton (X-axis) were negatively correlated with OJ.

## Discussion

Based on the result of G power test on previous study,[17] the sample size of 21 in each group was ideal, with the actual power above 0.8. In the current study, the sample size was enough to show the power of statistical analysis (Table 1).

In the analysis of smile variables in this study, the largest significant differences in smile variables were those in the oblique view, followed by in the lateral and frontal views. Significant differences were observed in 3 of 9 variables in the frontal view, 4 of 8 variables in the oblique view, and 6 of 8 variables in the lateral view among the ANB groups. In addition, significant differences were noted in 6 of 9 variables in the frontal view, 4 of 8 variables in the lateral view, and all variables in the oblique view among the OJ groups. A similar trend was observed in the analysis of changes in smile measurements. Significant differences were observed in 3 of 8 variables in the frontal view and in 5 of 7 variables in both the oblique and the lateral view among the ANB groups. Significant differences were noted in 4 of 8 variables in the frontal view, 3 of 7 variables in the lateral view, and all variables in the oblique view among the OJ groups.

During smiling, changes in soft tissue landmarks in the anteroposterior dimension could not be detected in the frontal view, whereas the oblique and lateral views clearly revealed these changes. However, the changes in many landmarks are not purely anteroposterior but may lie at angles between the anteroposterior and lateral directions. Therefore, compared with the lateral view, the oblique view revealed more noticeable changes in soft tissue landmarks.

For analysis of smile measurements, the results presented in Table 2 indicate that as the ANB angle decreased, the values of the pogonion and menton increased on the X- and Y-axes. A potential reason for this finding is that patients with a skeletal class III relationship exhibit more forward and longer mandibles; thus, they have larger horizontal and vertical vector values for the pogonion and menton and larger values for LAFH in terms of linear measurements.[18] In the frontal view, patients with ANB <0° have a smaller maxillary incisor display. This observation might be related to the dentoalveolar compensation of skeletal discrepancy in the anteroposterior dimension and potentially negative OJ in class III malocclusion; in these individuals, the maxillary incisors may be more proclined, resulting in a smaller maxillary incisor display.[19,20] In the lateral view, the measured value of the right chelion decreased as the ANB angle decreased. This indicates that during smiling, the protruded mandible in patients with a skeletal class III relationship may restrict the soft tissue chelion and the lips to a more anterior position.[19]

According to the results in Table 3, the measured values of the labrale inferioris and lower stomion decreased as OJ increased in the frontal smiling view. This finding indicates

**Table 2** Comparison of smile characteristics among A-nasion-B (ANB) groups. (Gr 1: ≤0°, Gr 2: 0°–4°, Gr 3: ≥4°).

| Frontal view | Gr 1: (n = 53) | | Gr 2: (n = 79) | | Gr 3: (n = 68) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | *P* value | Diff. | *P* value | Diff. | *P* value | Diff. | P value |
| Pogonion | 1.683 | 0.121 | 1.641 | 0.101 | 1.629 | 0.093 | 0.015* | 0.042 | 0.078 | 0.012 | 0.787 | 0.054 | 0.020* |
| Menton | 1.916 | 0.127 | 1.868 | 0.113 | 1.847 | 0.103 | 0.004* | 0.048 | 0.059 | 0.021 | 0.548 | 0.069 | 0.005** |
| Upper incisal display | 9.356 | 4.404 | 10.799 | 3.828 | 11.194 | 3.841 | 0.035* | −1.443 | 0.129 | −0.395 | 0.837 | −1.837 | 0.045* |
| **Oblique view** | Gr 1: (n = 53) | | Gr 2: (n = 79) | | Gr 3: (n = 68) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
| | Mean | SD | Mean | SD | Mean | SD | P Value | Diff. | *P* Value | Diff. | *P* Value | Diff. | *P* Value |
| Pogonion (X-axis) | 17.406 | 14.480 | 5.877 | 12.631 | 1.662 | 10.637 | 0.000*** | 11.529 | 0.000*** | 4.215 | 0.129 | 15.744 | 0.000*** |
| Menton (X-axis) | −21.461 | 15.719 | −32.180 | 13.855 | −34.906 | 12.352 | 0.000*** | 10.719 | 0.000*** | 2.726 | 0.496 | 13.444 | 0.000*** |
| Menton (Y-axis) | 255.126 | 16.128 | 249.018 | 13.567 | 243.966 | 13.563 | 0.000*** | 6.109 | 0.057 | 5.051 | 0.105 | 11.160 | 0.000*** |
| LAFH | 155.126 | 16.128 | 149.018 | 13.567 | 143.966 | 13.563 | 0.000*** | 6.109 | 0.057 | 5.051 | 0.105 | 11.160 | 0.000*** |
| **Lateral view** | Gr 1: (n = 53) | | Gr 2: (n = 79) | | Gr 3: (n = 68) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
| | Mean | SD | Mean | SD | Mean | SD | *P* Value | Diff. | *P* Value | Diff. | *P* Value | Diff. | *P* Value |
| Chelion right | −28.204 | 13.886 | −33.201 | 11.933 | −35.054 | 10.353 | 0.007** | 4.997 | 0.066 | 1.853 | 0.647 | 6.850 | 0.009** |
| Pogonion (X-axis) | 14.907 | 17.989 | 0.350 | 10.040 | −5.986 | 9.475 | 0.000*** | 14.557 | 0.000*** | 6.337 | 0.010* | 20.894 | 0.000*** |
| Pogonion (Y-axis) | 228.990 | 19.190 | 223.966 | 12.592 | 220.599 | 11.995 | 0.007** | 5.024 | 0.150 | 3.367 | 0.373 | 8.391 | 0.007** |
| Menton (X-axis) | −15.889 | 18.943 | −28.988 | 11.281 | −34.917 | 9.912 | 0.000*** | 13.099 | 0.000*** | 5.929 | 0.029* | 19.028 | 0.000*** |
| Menton (Y-axis) | 258.588 | 20.860 | 251.845 | 12.908 | 248.212 | 12.969 | 0.001** | 6.743 | 0.051 | 3.633 | 0.365 | 10.376 | 0.001** |
| LAFH | 158.588 | 20.860 | 151.845 | 12.908 | 148.212 | 12.969 | 0.001** | 6.743 | 0.051 | 3.633 | 0.365 | 10.376 | 0.001** |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.
LAFH: lower anterior facial height.

**Table 3** Comparison of smile characteristics among overjet (OJ) groups. (Gr 1: OJ $\leq$ 0 mm, Gr 2: 0–4 mm, Gr 3: $\geq$4 mm).

| Frontal view | Gr 1: (n = 37) | | Gr 2: (n = 60) | | Gr 3: (n = 103) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | *P* value | Diff. | *P* value | Diff. | *P* value | Diff. | *P* value |
| Labrale inferioris | 144.000 | 11.584 | 140.245 | 9.003 | 138.503 | 8.831 | 0.011* | 3.755 | 0.166 | 1.743 | 0.525 | 5.498 | 0.011* |
| Lower stomion | 126.594 | 10.157 | 123.059 | 7.949 | 120.028 | 13.543 | 0.010* | 3.535 | 0.343 | 3.031 | 0.272 | 6.566 | 0.013* |
| Pogonion | 1.720 | 0.124 | 1.651 | 0.096 | 1.620 | 0.092 | 0.000*** | 0.070 | 0.004** | 0.031 | 0.171 | 0.100 | 0.000*** |
| Menton | 1.956 | 0.136 | 1.875 | 0.101 | 1.843 | 0.103 | 0.000*** | 0.081 | 0.002** | 0.031 | 0.211 | 0.113 | 0.000*** |
| Buccal corridor | 12.023 | 5.584 | 10.119 | 12.266 | 14.457 | 8.805 | 0.019* | 1.903 | 0.634 | −4.337 | 0.021* | −2.434 | 0.414 |
| Maxillary incisal display | 9.053 | 4.943 | 10.578 | 3.677 | 11.073 | 3.783 | 0.032* | −1.525 | 0.191 | −0.495 | 0.747 | −2.020 | 0.033* |
| **Oblique view** | Gr 1: (n = 37) | | Gr 2: (n = 60) | | Gr 3: (n = 103) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
| | Mean | SD | Mean | SD | Mean | SD | *P* Value | Diff. | *P* Value | Diff. | *P* Value | Diff. | *P* Value |
| Chelion right | −59.116 | 14.311 | −65.949 | 10.605 | −67.891 | 12.059 | 0.001* | 6.833 | 0.028* | 1.942 | 0.614 | 8.775 | 0.001** |
| Pogonion (X-axis) | 18.966 | 15.129 | 7.708 | 12.610 | 3.258 | 11.846 | 0.000*** | 11.258 | 0.000*** | 4.450 | 0.101 | 15.708 | 0.000*** |
| Menton (X-axis) | −19.121 | 14.438 | −30.672 | 14.970 | −34.033 | 12.953 | 0.000*** | 11.551 | 0.000*** | 3.361 | 0.330 | 14.912 | 0.000*** |
| Menton (Y-axis) | 254.469 | 15.291 | 249.968 | 14.309 | 246.314 | 14.524 | 0.013* | 4.500 | 0.339 | 3.654 | 0.307 | 8.154 | 0.016* |
| U1 incisal edge | 147.269 | 25.871 | 154.167 | 6.646 | 155.598 | 9.835 | 0.007** | −6.898 | 0.056 | −1.431 | 0.811 | −8.329 | 0.007** |
| Maxillary incisal display | 8.692 | 26.379 | 13.813 | 5.358 | 15.043 | 8.792 | 0.045* | −5.121 | 0.184 | −1.230 | 0.850 | −6.351 | 0.046* |
| LAFH | 154.469 | 15.291 | 149.968 | 14.309 | 146.314 | 14.524 | 0.013* | 4.500 | 0.339 | 3.654 | 0.307 | 8.154 | 0.016* |
| Interlabial gap | 24.551 | 9.613 | 22.640 | 7.931 | 20.665 | 6.670 | 0.024* | 1.911 | 0.492 | 1.975 | 0.286 | 3.886 | 0.032* |
| **Lateral view** | Gr 1: (n = 37) | | Gr 2: (n = 60) | | Gr 3: (n = 103) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
| | Mean | SD | Mean | SD | Mean | SD | *P* Value | Diff. | *P* Value | Diff. | *P* Value | Diff. | *P* Value |
| Chelion right | −25.247 | 13.775 | −32.781 | 11.408 | −34.956 | 11.156 | 0.000*** | 7.534 | 0.010* | 2.174 | 0.524 | 9.708 | 0.000*** |
| Pogonion (X-axis) | 16.303 | 18.892 | 1.684 | 12.480 | −2.850 | 10.869 | 0.000*** | 14.619 | 0.000*** | 4.534 | 0.108 | 19.152 | 0.000*** |
| Menton (X-axis) | −13.494 | 19.714 | −28.432 | 14.341 | −32.052 | 10.223 | 0.000*** | 14.938 | 0.000*** | 3.620 | 0.267 | 18.558 | 0.000*** |
| U1 incisal edge | 147.154 | 27.017 | 154.168 | 6.844 | 156.662 | 12.300 | 0.005** | −7.014 | 0.085 | −2.494 | 0.594 | −9.508 | 0.005** |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.
LAFH: lower anterior facial height.

**Table 4** Comparison of smile changes among A-Nasion-B (ANB) groups (Gr 1: ≤0°, Gr 2: 0°–4°, Gr 3: ≥4°).

| Frontal view | Gr 1: (n = 53) | | Gr 2: (n = 79) | | Gr 3: (n = 68) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | *P* value | Diff. | *P* value | Diff. | *P* value | Diff. | *P* value |
| Labrale inferioris | 6.669 | 4.191 | 4.206 | 3.373 | 4.193 | 3.474 | 0.000*** | 2.463 | 0.001** | 0.013 | 1.000 | 2.476 | 0.001** |
| Menton | 1.017 | 1.144 | 1.509 | 1.139 | 1.876 | 1.622 | 0.002** | −0.492 | 0.115 | −0.367 | 0.249 | −0.858 | 0.002** |
| **Oblique view** | Gr 1: (n = 53) | | Gr 2: (n = 79) | | Gr 3: (n = 68) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
| | Mean | SD | Mean | SD | Mean | SD | *P* Value | Diff. | *P* Value | Diff. | *P* Value | Diff. | *P* Value |
| Labrale superioris | −5.229 | 3.443 | −3.718 | 3.218 | −4.184 | 3.606 | 0.045* | −1.510 | 0.047* | 0.466 | 0.712 | −1.044 | 0.251 |
| Labrale inferioris | 6.427 | 3.957 | 4.245 | 3.687 | 3.678 | 3.371 | 0.000*** | 2.182 | 0.004** | 0.567 | 0.645 | 2.749 | 0.000*** |
| Lower stomion | 8.059 | 4.088 | 6.677 | 3.902 | 5.723 | 3.669 | 0.005** | 1.381 | 0.136 | 0.954 | 0.332 | 2.336 | 0.005** |
| Upper lip length | −18.487 | 13.462 | −12.374 | 12.428 | −14.553 | 12.798 | 0.029* | −6.113 | 0.029* | 2.179 | 0.591 | −3.934 | 0.249 |
| Lower lip thickness | −2.939 | 14.843 | −9.774 | 10.464 | −8.759 | 10.654 | 0.004** | 6.835 | 0.006** | −1.015 | 0.874 | 5.820 | 0.029* |
| **Lateral view** | Gr 1: ANB (n = 53) | | Gr 2: ANB (n = 79) | | Gr 3: ANB (n = 68) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
| | Mean | SD | Mean | SD | Mean | SD | *P* Value | Diff. | *P* Value | Diff. | *P* Value | Diff. | *P* Value |
| Labrale inferioris | 6.829 | 4.402 | 5.502 | 3.558 | 5.068 | 3.169 | 0.029* | 1.327 | 0.130 | 0.434 | 0.776 | 1.761 | 0.035* |
| Lower stomion | 9.094 | 5.293 | 7.719 | 4.094 | 6.855 | 3.630 | 0.019* | 1.375 | 0.201 | 0.864 | 0.480 | 2.239 | 0.019* |
| Menton (X-axis) | −21.661 | 100.095 | 2.019 | 30.537 | −0.218 | 21.009 | 0.043* | −23.680 | 0.063 | 2.237 | 0.972 | −21.444 | 0.118 |
| Menton (Y-axis) | 1.745 | 2.130 | 2.756 | 1.995 | 2.768 | 1.896 | 0.007** | −1.011 | 0.019* | −0.012 | 0.999 | −1.024 | 0.022* |
| LAFH | 3.657 | 3.853 | 5.233 | 3.496 | 5.336 | 3.463 | 0.020* | −1.576 | 0.049* | −0.102 | 0.985 | −1.678 | 0.040* |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.
LAFH: lower anterior facial height.

**Table 5** Comparison of smile changes among overjet (OJ) groups. (Gr 1: OJ $\leq$ 0 mm, Gr 2: 0–4 mm, Gr 3: $\geq$4 mm).

| Frontal view | Gr 1: (n = 37) | | Gr 2: (n = 60) | | Gr 3: (n = 103) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | *P* value | Diff. | *P* value | Diff. | *P* value | Diff. | *P* value |
| Labrale inferioris | 6.832 | 4.175 | 5.555 | 3.502 | 3.736 | 3.421 | 0.000*** | 1.277 | 0.238 | 1.819 | 0.009** | 3.096 | 0.000*** |
| Lower stomion | 8.370 | 4.634 | 6.863 | 3.616 | 4.522 | 10.055 | 0.021* | 1.508 | 0.650 | 2.341 | 0.181 | 3.849 | 0.037* |
| Menton | 1.037 | 1.253 | 1.361 | 1.151 | 1.754 | 1.459 | 0.013* | −0.324 | 0.512 | −0.393 | 0.197 | −0.717 | 0.022 |
| Upper lip length | −20.951 | 9.627 | −17.301 | 9.439 | −16.690 | 8.407 | 0.045* | −3.650 | 0.152 | −0.612 | 0.915 | −4.261 | 0.048* |
| **Oblique view** | Gr 1: (n = 37) | | Gr 2: (n = 60) | | Gr 3: (n = 103) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
| | Mean | SD | Mean | SD | Mean | SD | *P* Value | Diff. | *P* Value | Diff. | *P* Value | Diff. | *P* Value |
| Labrale superius | −5.309 | 3.512 | −4.797 | 3.605 | −3.603 | 3.216 | 0.013* | −0.512 | 0.771 | −1.194 | 0.098 | −1.706 | 0.034* |
| Labrale inferioris | 6.893 | 4.249 | 5.419 | 3.595 | 3.359 | 3.246 | 0.000*** | 1.474 | 0.142 | 2.060 | 0.002** | 3.534 | 0.000*** |
| Upper stomion | −7.205 | 3.688 | −5.876 | 3.702 | −5.162 | 2.968 | 0.007** | −1.329 | 0.166 | −0.714 | 0.422 | −2.043 | 0.007** |
| Lower stomion | 8.666 | 4.400 | 7.401 | 3.829 | 5.622 | 3.524 | 0.000*** | 1.265 | 0.282 | 1.779 | 0.017* | 3.044 | 0.000*** |
| Menton (X-axis) | −28.049 | 123.876 | 2.919 | 38.325 | 3.163 | 35.093 | 0.025* | −30.967 | 0.062 | −0.244 | 1.000 | −31.211 | 0.035 |
| Menton (Y-axis) | 1.087 | 2.194 | 2.154 | 2.306 | 1.973 | 1.985 | 0.044* | −1.067 | 0.058 | 0.181 | 0.871 | −0.886 | 0.096 |
| Lower lip thickness | −3.094 | 14.358 | −6.087 | 12.729 | −10.134 | 10.236 | 0.005** | 2.993 | 0.483 | 4.048 | 0.112 | 7.040 | 0.009** |
| **Lateral view** | Gr 1: (n = 37) | | Gr 2: (n = 60) | | Gr 3: (n = 103) | | ANOVA | Scheffe test (Gr1 vs Gr2) | | Scheffe test (Gr2 vs Gr3) | | Scheffe test (Gr1 vs Gr3) | |
| | Mean | SD | Mean | SD | Mean | SD | *P* Value | Diff. | *P* Value | Diff. | *P* Value | Diff. | *P* Value |
| Labrale inferioris | 7.817 | 4.363 | 6.099 | 3.772 | 4.720 | 3.078 | 0.000*** | 1.718 | 0.072 | 1.379 | 0.060 | 3.097 | 0.000*** |
| Lower stomion | 10.213 | 5.467 | 7.955 | 4.287 | 6.823 | 3.599 | 0.000*** | 2.257 | 0.039* | 1.133 | 0.255 | 3.390 | 0.000*** |
| Menton (X-axis) | −27.812 | 111.786 | 0.815 | 44.876 | −0.226 | 22.393 | 0.025* | −28.627 | 0.053 | 1.041 | 0.993 | −27.586 | 0.039* |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

**Table 6** Multiple linear regression analysis of changes in smile variables in different views in A-Nasion-B (ANB) and overjet (OJ) groups.

| | Frontal | | | *P* value | Oblique | | | *P* value | Lateral | | | *P* value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ANB | | OJ | | ANB | | OJ | | ANB | | OJ | |
| | Coefficient | *P* Value | Coefficient | | Coefficient | *P* Value | Coefficient | | Coefficient | *P* Value | Coefficient | |
| Landmark | | | | | | | | | | | | |
| Labrale superius | −0.027 | 0.871 | −0.092 | 0.453 | −0.338 | 0.044* | 0.301 | 0.015* | −0.391 | 0.020* | 0.254 | 0.041* |
| Labrale inferioris | 0.061 | 0.698 | −0.235 | 0.043* | −0.134 | 0.420 | 0.052 | 0.673 | −0.138 | 0.402 | 0.055 | 0.654 |
| Upper stomion | −0.078 | 0.638 | −0.124 | 0.310 | −0.443 | 0.009** | 0.250 | 0.045* | −0.475 | 0.005** | 0.262 | 0.035* |
| Lower stomion | 0.102 | 0.530 | −0.155 | 0.198 | −0.130 | 0.432 | 0.094 | 0.444 | −0.099 | 0.553 | 0.065 | 0.600 |
| Chelion R't | −0.046 | 0.788 | −0.008 | 0.950 | −0.003 | 0.983 | −0.459 | 0.000*** | −0.055 | 0.724 | −0.386 | 0.001** |
| Chelion L't | 0.020 | 0.907 | 0.114 | 0.370 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| U1 incisal edge | 0.047 | 0.771 | −0.082 | 0.494 | −0.097 | 0.567 | 0.220 | 0.080 | −0.037 | 0.826 | 0.095 | 0.449 |
| Pogonion | −0.119 | 0.451 | −0.223 | 0.057 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Pogonion (X-axis) | N/A | N/A | N/A | N/A | −0.043 | 0.757 | −0.353 | 0.001** | −0.205 | 0.092 | −0.327 | 0.000*** |
| Pogonion (Y-axis) | N/A | N/A | N/A | N/A | −0.256 | 0.124 | 0.033 | 0.790 | −0.287 | 0.085 | 0.074 | 0.548 |
| Menton | −0.208 | 0.188 | −0.187 | 0.110 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Menton (X-axis) | N/A | N/A | N/A | N/A | 0.004 | 0.980 | −0.344 | 0.002** | 0.003 | 0.984 | −0.395 | 0.000*** |
| Menton (Y-axis) | N/A | N/A | N/A | N/A | −0.391 | 0.016* | 0.126 | 0.292 | −0.419 | 0.010* | 0.147 | 0.220 |
| Linear | | | | | | | | | | | | |
| Upper lip length | −0.354 | 0.034* | 0.211 | 0.087 | −0.338 | 0.044* | 0.301 | 0.015* | −0.475 | 0.005** | 0.262 | 0.035* |
| Upper lip thickness | −0.142 | 0.403 | −0.098 | 0.438 | −0.286 | 0.092 | 0.007 | 0.956 | −0.220 | 0.200 | 0.085 | 0.506 |
| Lower lip thickness | −0.079 | 0.645 | −0.056 | 0.657 | −0.075 | 0.656 | −0.089 | 0.477 | −0.179 | 0.281 | 0.003 | 0.981 |
| Mouth width | 0.041 | 0.809 | 0.055 | 0.666 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Buccal corridor | 0.103 | 0.545 | −0.018 | 0.887 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Maxillary incisor display | 0.237 | 0.154 | 0.084 | 0.491 | 0.110 | 0.517 | 0.110 | 0.382 | 0.219 | 0.199 | −0.044 | 0.726 |
| LAFH | N/A | N/A | N/A | N/A | −0.391 | 0.016* | 0.126 | 0.292 | −0.419 | 0.010* | 0.147 | 0.220 |
| Interlabial gap | 0.187 | 0.258 | −0.089 | 0.465 | 0.211 | 0.189 | −0.095 | 0.422 | 0.317 | 0.054 | −0.164 | 0.176 |

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.
LAFH: lower anterior facial height.

that the lower lip was positioned higher as OJ increased. This may be because of the posteriorly positioned mandibular incisors resulting in the formation of an obtuse labiomental fold. The values of the pogonion and menton also decreased as OJ increased. This is typical in patients with a skeletal class II relationship and large OJ.

Similar findings were obtained in oblique and lateral views. As OJ decreased, the values of the pogonion, menton, and LAFH increased. This result is highly correlated with the findings in the ANB groups. It is also consistent with the clinical observation of a higher prevalence of negative OJ in patients with a more severe skeletal class III tendency. Therefore, some degree of similarity in findings between ANB and OJ is reasonable.

About the analysis of changes in smile measurements, changes in the labrale inferioris exhibited the greatest differences in all the views in the ANB $<0^{\circ}$ group according to the results in Table 4. This finding indicates that patients with a skeletal class III relationship may exhibit greater downward movement of the lower lip during smiling. A more protrusive and longer chin may restrict the movement of the lower lip and the depressor labii inferioris muscle, resulting in a greater degree of muscle traction in the lower lip during smiling.[11] Furthermore, in the oblique and lateral views, changes in the menton (X-axis) were greater in the ANB $<0^{\circ}$ group. This might be because of the difference in muscle tension in the menton area. This difference is potentially caused by a more protruded chin in class III malocclusion and a retruded chin in class II malocclusion leading to variations in smile measurements.

The results presented in Table 5 indicate that the OJ $< 0$ group exhibited a significantly larger downward movement of the labrale inferioris and lower stomion and a significantly smaller downward movement of the menton (Y-axis) during smiling in all views. The muscle tension around the lower lip area may be smaller than that in the menton area, which may result in greater movement of landmarks around the lower lip area during smiling. In the oblique view, a larger upward movement of the labrale superioris and upper stomion and a greater discrepancy in the upper lip length during smiling were noted in the OJ $< 0$ group. We assume that slight muscle strain leads to the upper lip being in a lower position at rest. This causes greater upward movement of the upper lip and a reduction in the upper lip length during smiling. The findings of this study are consistent with those of Rafiqul Islam.[21]

To avoid intergroup bias caused by differences in the magnification of individual photos, all numerical values in this study were expressed in ratios, which may have reduced the intensity of actual changes in measurements. Future research should develop a standardized reference scale that can be used during photography to minimize errors caused by differences in magnification. In addition, in this study, the main age group was that of 10—30 years. Age differences can lead to variations in smile expression. Gender differences may influence smile characteristics as well. Previous studies have shown that females tend to exhibit a greater incisal display and lip curvature during smiling compared to males.[22] In future research, we aim to expand and average the sample distribution across different age groups and examine the influence of age and gender on smile variables. Notably, vertical dimensional factors can also affect smile expression. In consideration of this, the current study included vertical dimensional factors; the findings related to these factors will be published in another journal.

In conclusion, smile variables and changes in these variables are considerably influenced by horizontal skeletal and dental dimensions. The more extreme the initial measurement is, the more significant the change in smile measurements is. Moreover, more differences were noted in smile variables in the lower face (eg, labrale inferius, lower stomion, menton, and pogonion). The largest differences were noted for changes in smile measurements for the lower lip (eg, labrale inferius and lower stomion). This finding indicates that more movement of the lower face occurs during smiling. At last, more changes were revealed in measurements in the oblique and lateral views than in the frontal view. The influence of horizontal dimensional malocclusion on smile variables is more significant in the oblique and lateral views than in the frontal view. Therefore, the findings of this study demonstrate the importance of considering the oblique and lateral views in clinical practice.

## Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

## Acknowledgments

We wish to thank the many authors whose work was included in this article.

## Appendix

Definitions of landmark measurements for smile variables

| | |
|---|---|
| Nasion | The midpoint of the interpupillary line |
| Subnasale (Sn) | The most inferior point of the nose |
| Labial superioris (Ls) | The uppermost and most central point of the upper lip |
| Labial inferioris (Li) | The lowermost and most central point of the lower lip |
| Upper stomion | The inferior center point of the upper lip |
| Lower stomion | The superior center point of the lower lip |
| Chelion (Che) | Apex of the angle of the mouth on both sides |

(*continued*)

| Definitions of landmark measurements for smile variables | |
|---|---|
| U#11 edge | Central incisal edge of the upper right central incisor |
| Visible maxillary dentition | The most distal surface of visible teeth on both sides |
| Pogonion (Pog) | Prominence of the chin button |
| Menton (Me) | Most inferior point of the mandible symphysis |
| **Definition of linear measurements for smile variables** | |
| Nasal length | Nasion to subnasale (Sn) |
| Upper lip length | Subnasale to upper stomion |
| Upper lip thickness | Upper stomion to labial superioris (Ls) |
| Lower lip thickness | Lower stomion to labial inferioris (Li) |
| Mouth width | Frontal view: Right chelion to left chelion<br>Oblique and lateral view: Right chelion to labial surface of tooth #11(FDI) |
| Buccal corridor | Mouth width-visible maxillary dental width |
| Visible maxillary dental width | Side of the most posterior tooth surface that is visible on the other side |
| Maxillary incisor display | Center of the maxillary incisor edge to the lower edge of the upper lip |
| Interlabial gap | Center of the lower edge of the upper lip to the center of the upper edge of the lower lip |
| Lower anterior facial height (LAFH) | Subnasale to menton |

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