

## Quantitative and perceived visual changes of the nasolabial fold following orthodontic retraction of lip protrusion

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### ABSTRACT

**Objectives:** The objectives of this study were to evaluate the quantitative and perceived visual changes of the nasolabial fold (NLF) after maximum retraction in adults and to determine its contributing factors.

**Materials and Methods:** A total of 39 adult women's cone-beam computed tomography images were collected retrospectively and divided into the retraction group (age  $26.9 \pm 8.80$ ) that underwent maximum retraction following 4 premolar extraction and the control group (age  $24.6 \pm 5.36$ ) with minor changes of the incisors. Three-dimensional morphologic changes of hard and soft tissue including NLF were measured by pre- and posttreatment cone-beam computed tomography. In addition, perceived visual change of the NLF was monitored using the modified Global Aesthetic Improvement Scale. The influence of age, initial severity of NLF, and initial soft tissue thickness was evaluated.

**Results:** Anterior retraction induced significant changes of the facial soft tissue including the lips, perioral, and the NLF when compared with the controls ( $P < .01$ ). Perceived visual changes of the NLF was noted only in women younger than age 30 ( $P < .05$ ), with the odds ratio (95% confidence interval) of 2.44 (1.3461–4.4226), indicating greater possibility for improvement of NLF esthetics in young women of the retraction group when compared with the controls.

**Conclusions:** Orthodontic retraction induced quantitative and perceived visual changes of the NLF. For adult women younger than age 30, the appearance of the NLF improved after maximum retraction despite the greater posterior change of the NLF. (*Angle Orthod.* 2018;88:465–473.)

**KEY WORDS:** Nasolabial fold; Soft tissue; Orthodontic retraction; Lip protrusion; CBCT; Global Aesthetic Improvement Scale

### INTRODUCTION

The improvement of facial esthetics as well as occlusion has long been one of the most important

treatment objectives in adult orthodontics. Especially for malocclusions diagnosed as bimaxillary or bialveolar protrusion, premolar extraction followed by maximum retraction of the anterior teeth is commonly accepted as a necessary treatment modality regardless of the relatively ideal occlusion per se because orthodontic retraction induces the dramatic improvement of the overall facial esthetics.<sup>1</sup>

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Following orthodontic retraction, evident soft tissue changes are induced in the midsagittal perioral regions, but considerable amounts of changes are also extended to the parasagittal regions of the middle and lower one-third of the face such as the nasolabial folds (NLFs).<sup>2,3</sup> NLFs originate from sagging of the skin, prominence of the buccal fat pad, and muscle function and changes in the underlying bone structure in conjunction with the anatomical and histological features. Together with the changes in the lips, morphological or volumetric changes in the NLFs are considered as the earliest and distinctive signs of facial aging but, for the young population, a thick cheek fat pad may relatively cause the NLFs to exhibit a concave appearance as well.<sup>4</sup>

Given that orthodontic retraction induces overall dimensional changes of the perioral soft tissue, the morphological and esthetic changes of the NLFs are also suspected. However, both objective and subjective information regarding these changes in the NLFs are limited in the literature. Thus, the objectives of this study were to quantify the morphologic and perceived changes of the NLFs after maximum retraction in adults and to determine the contributing factors that may influence the changes of the NLFs.

## MATERIALS AND METHODS

### Participants

This study was approved by the institutional review board of Gangnam Severance Hospital, Yonsei University. The patients consisted of 39 women ( $\geq 18$  years) treated in the Department of Orthodontics, Gangnam Severance Hospital, Yonsei University. The participants who had pre- and posttreatment cone-beam computed tomography (CBCT) images were collected retrospectively and divided into a retraction group ( $n = 22$ , age range 18–45) and the control group ( $n = 17$ , age range 18–36). The inclusion criteria for the retraction group were the following: skeletal class I to class II, diagnosed as bimaxillary dentoalveolar protrusion, treated following extraction of four premolars, finished with more than 4 mm of anterior-posterior change of the upper and lower incisor tip when superimposed on the anterior cranial base.<sup>5</sup> Inclusion criteria for the control group were the following: skeletal class I to class II, within the normal range of lips relative to Ricketts' E-line, treated nonextraction, finished with less than 1.5 mm of anterior-posterior change of the upper and lower incisor tip. Patients with facial asymmetry ( $>2$  mm of Me' deviation) and deformity were excluded (Table 1).

### Data Acquisition

CBCT scans were taken using a Pax Zenith 3D (Vatech, Seoul, Korea) by an experienced radiological technologist. The patients were instructed to stand straight in maximum intercuspal position with light contact of the lips and face relaxed. A scan captured 632 slices, with exposure parameters of 105 kV and 5.4 mAs, acquired for 24 seconds, with a voxel size of 0.3 mm and a field of view of  $24 \times 19$  cm encompassing the face, jaws, and entire cranial base. The obtained DICOM data were reconstructed into three-dimensional (3D) images using OnDemand 3D software (Cybermed Co., Seoul, Korea). The pre- and post-treatment CBCT data were superimposed by automatic voxel-by-voxel registration on stable structures of the anterior cranial base using the OnDemand 3D fusion module.<sup>5</sup>

### Coordinate System and Landmarks

On the superimposed 3D CBCT images, the horizontal reference plane was established parallel to the Frankfort plane, passing through nasion (N). The midsagittal vertical reference plane was set according to the plane perpendicular to the Frankfort plane and passing through the N and basion.<sup>6</sup> The coronal vertical reference plane was set perpendicular to the horizontal and midsagittal vertical planes, passing through N. A Cartesian coordinate system was used with N as the origin of coordinate system (0, 0, and 0) throughout the x-y, x-z, and y-z planes to represent the axial, coronal, and sagittal planes, respectively. Positive coordinate values were indicated by values to the left, posterior, and superior to the origin.

Landmarks were defined as shown in Table 2.<sup>7,8</sup> Landmark positioning and measurements were performed on 3D volume rendering soft tissue surface images. Subsequent adjustment on multiplanar reconstructed two-dimensional cross-sectional images was performed.

To measure quantitative changes of NLF areas, four landmarks both on the deepest point of the left and the right sides were defined along NLFs at the pretreatment subnasale level (NLF1) and 15-mm vertically downward from the pretreatment subnasale level (NLF2). Considering the vertical positional change of subnasale between pre- and posttreatment, NLF1 and NLF2 on the posttreatment image were calibrated on the x-z plane to the same vertical level of pretreatment in the superimposed image (Figure 1).

### Clinical Assessments of the NLFs

The initial condition of the NLF was categorized by the modified Wrinkle Severity Rating Scale (WSRS), a

**Table 1.** Initial Characteristics of the Participants<sup>a</sup>

| Characteristics            | Control Group, n = 17; Mean ± SD | Retraction Group, n = 22; Mean ± SD | P Value         |
|----------------------------|----------------------------------|-------------------------------------|-----------------|
| Age, years                 | 24.6 ± 5.36                      | 26.9 ± 8.80                         | NS <sup>b</sup> |
| ANB, °                     | 2.6 ± 1.82                       | 3.5 ± 1.73                          | NS              |
| U1 to A-Pog, mm            | 6.8 ± 2.13                       | 12.3 ± 1.80                         | <.001           |
| L1 to A-Pog, mm            | 4.5 ± 2.33                       | 7.9 ± 1.86                          | <.001           |
| U1 to SN, °                | 103.4 ± 7.86                     | 111.3 ± 5.60                        | .001            |
| IMPA, °                    | 91.1 ± 10.40                     | 96.4 ± 7.19                         | NS              |
| Upper lip to E-line, mm    | -1.9 ± 1.94                      | 0.8 ± 1.47                          | <.001           |
| Lower lip to E-line, mm    | -0.3 ± 2.08                      | 2.8 ± 1.69                          | <.001           |
| Treatment duration, months | 23.6 ± 7.79                      | 32.0 ± 6.50                         | .001            |

<sup>a</sup> ANB indicates A-point-Nasion-B-point angle; U1, upper incisal tip; A-Pog, A-point to pogonion line; L1, lower incisal tip; SN, sella-nasion line; IMPA, lower incisor mandibular plane angle; E-line, Ricketts' E-line; SD, standard deviation; NS, nonsignificant.

<sup>b</sup> NS indicates *P* > .05.

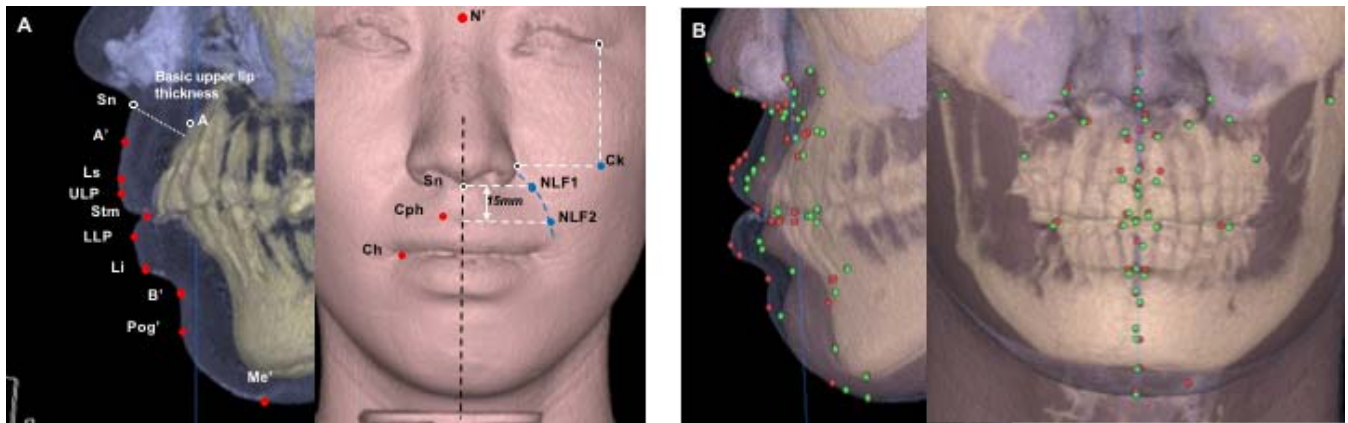
specific validated scale for quantifying facial folds<sup>9</sup> using initial CBCT soft tissue images by one investigator. The scoring of fold severity was based on visual assessment of the length and apparent depth of the

NLF without reference to baseline. Modified WSRS uses the following three-point scale: 1 = absent, no visible NLF; 2 = mild, shallow but visible NLF with a slight indentation with minor facial feature; 3 =

**Table 2.** Definitions of Landmarks

| Landmark                               | Abbreviation      | Definition                                                                                                                               |
|----------------------------------------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Skeletal</b>                        |                   |                                                                                                                                          |
| A-point                                | A                 | The point of maximum concavity in the midline of the alveolar process of the maxilla                                                     |
| B-point                                | B                 | The point of maximum concavity in the midline of the alveolar process of the mandible                                                    |
| Pogonion                               | Pog               | The most anterior midpoint of the chin on the outline of the mandibular symphysis                                                        |
| Menton                                 | Me                | The most inferior midpoint of the chin on the outline of the mandibular symphysis                                                        |
| <b>Dental</b>                          |                   |                                                                                                                                          |
| Upper incisor incisal tip <sup>a</sup> | Isi <sup>a</sup>  | The midpoint of the tip of the crown of each upper central incisor                                                                       |
| Upper incisor root apex <sup>a</sup>   | Isa <sup>a</sup>  | The tip of the root apex of each upper central incisor                                                                                   |
| Lower incisor incisal tip <sup>a</sup> | Ili <sup>a</sup>  | The midpoint of the tip of the crown of each lower central incisor                                                                       |
| Lower incisor root apex <sup>a</sup>   | Iia <sup>a</sup>  | The tip of the root apex of each lower central incisor                                                                                   |
| <b>Midfacial soft tissue</b>           |                   |                                                                                                                                          |
| Cheek point <sup>a</sup>               | Ck <sup>a</sup>   | The point at intersection of vertical projection from pretreatment exocanthion and horizontal projection from pretreatment alarcurvature |
| Soft tissue nasion                     | N'                | The midpoint on the soft tissue contour of the base of the nasal root at the level of the frontonasal suture                             |
| <b>Perioral soft tissue</b>            |                   |                                                                                                                                          |
| Subnasale                              | Sn                | The midpoint on the nasolabial soft tissue contour between the columella crest and the upper lip                                         |
| Soft tissue A-point                    | A'                | The most anterior concave point between subnasale and the anterior point of the upper lip                                                |
| Soft tissue B-point                    | B'                | The most posterior midpoint on the labiomental soft tissue contour that defines the border between the lower lip and the chin            |
| Soft tissue pogonion                   | Pog'              | The most anterior midpoint of the chin                                                                                                   |
| Soft tissue menton                     | Me'               | The most inferior midpoint on the soft tissue contour of the chin, located at vertical projection from menton on the soft tissue         |
| <b>Lip</b>                             |                   |                                                                                                                                          |
| Christa philitri <sup>a</sup>          | Cph <sup>a</sup>  | The point at each crossing of the vermilion line and the elevated margin of the philtrum                                                 |
| Labiale superius                       | Ls                | The most anterior midpoint of the vermilion line of the upper lip                                                                        |
| Upper lip point                        | ULP               | The most anterior midpoint of upper lip                                                                                                  |
| Stomion superius                       | STMs              | The midpoint of the lower border of the upper lip                                                                                        |
| Stomion Inferius                       | STMi              | The midpoint of the upper border of the lower lip                                                                                        |
| Lower lip point                        | LLP               | The most anterior midpoint of lower lip                                                                                                  |
| Labiale inferius                       | Li                | The most anterior midpoint of the vermilion line of the lower lip                                                                        |
| Cheilion <sup>a</sup>                  | Ch <sup>a</sup>   | The point located at each labial commissure at the most lateral intersection of upper and lower lip                                      |
| <b>Nasolabial folds</b>                |                   |                                                                                                                                          |
| Nasolabial fold 1 <sup>a</sup>         | NLF1 <sup>a</sup> | The deepest point on nasolabial fold at the horizontal level of initial subnasale                                                        |
| Nasolabial fold 2 <sup>a</sup>         | NLF2 <sup>a</sup> | The deepest point on nasolabial fold at horizontal level of 15mm below initial subnasale                                                 |

<sup>a</sup> Left and right landmarks used.



**Figure 1.** Three-dimensional cephalometric landmarks and measurements. (A) Three-dimensional facial soft tissue landmarks. Basic upper lip thickness is defined as the linear distance from 3 mm below A-point to subnasale. (B) Comparison of landmarks on the superimposed cone-beam computed tomography images. Dark grey, pretreatment; white, posttreatment.

moderate, moderately deep NLF with clear facial feature visible at normal.

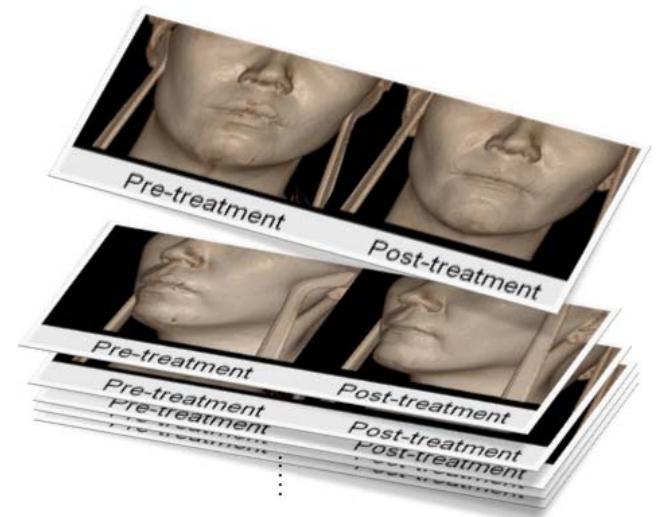
Clinical visual change of the NLF was evaluated using the modified Global Aesthetic Improvement Scale (GAIS), a reproducible grading system based on the visual subjective assessment of the length and apparent depth of the fold<sup>10</sup> by six experienced specialists: two dermatologists, one plastic surgeon, and three orthodontists with > 7 years of clinical experience. For the evaluation template, a pair of pre- and posttreatment reconstructed soft tissue surface CBCT images were presented on one slide, representing either frontal or three-quarter views from the left side (Figure 2). The modified GAIS uses the following three-point scale: 1 = improved, obvious improvement in appearance from the initial condition; 0 = no change, the appearance is essentially the same as the initial condition; -1 = worsened, the appearance is worse than the initial condition. The templates along with additional 20 duplicated sets were presented to evaluate intraobserver consistency. Assessments were conducted independently and the investigators were not informed of the treatment regimen. GAIS scores drawn by six specialists were averaged per participant for the statistical evaluation.

### Statistical Analysis

The positioning of landmarks was repeated for 10 randomly selected CBCTs by the same operator at 2-week intervals. Averaged intraclass correlation coefficients were > 0.94 and the Dahlberg's method errors were < 1 mm (range of 0.20–0.94). The intraclass correlation coefficient for intraobserver reliability of the WSRS was 0.96. Weighted kappa coefficients of GAIS ranged from 0.36 to 0.71 (mean 0.65, 95% confidence

interval 0.53–0.78). The sample size was calculated with a power of 80%.<sup>11</sup>

The differences between pre- and posttreatment were analyzed by a paired *t*-test, and the comparisons between the groups were performed using independent 2-sample *t*-tests with a false discovery rate method. To determine age effect, independent *t*-tests with the false discovery rate method and chi-square tests were used. To identify correlations among quantitative changes of NLFs, Pearson's correlation was analyzed. Generalized estimating equations were used to compare distribution of the GAIS score, and odds ratio was calculated. All of the measurements were statistically calculated using SAS version 9.3(SAS Institute, Cary, N.C.).



**Figure 2.** Pre- and posttreatment image templates used for the modified Global Aesthetic Improvement Scale.

## RESULTS

### Three-Dimensional Changes in the NLFs Following Anterior Retraction

The retraction group showed statistically significant changes in the sagittal plane axis for the dental ( $P < .01$ ), perioral and lip soft tissue landmarks ( $P < .05$ ). NLF1 and NLF2 indicated significant posterior movement in the retraction group by  $0.8 \pm 0.66$  and  $1.2 \pm 0.78$  mm, respectively, which was significantly different when compared with the control group ( $P < .001$ ).

Vertical changes (axial axis) were more prominent in the retraction group for landmarks representing medial soft tissue in the perioral (soft tissue A point) and lip areas (christa philtri (Cph), labialis superius (Ls), upper lip point (ULP), and labialis inferius (Li)) than parasagittal soft tissue such as cheilion (Ch), which showed no significant vertical changes in both groups ( $P < .05$ ). The upper lip vermilion border (Ls and Cph) and ULP moved downward, while the Li moved upward only in the retraction group and not in the control group ( $P < .01$ ; Table 3).

### Clinical Factors Associated With the Quantitative Changes of the NLFs

Intrinsic factors, such as age,<sup>12</sup> initial soft tissue thickness,<sup>13</sup> initial severity of NLFs (WRSR),<sup>14</sup> or changes of the surrounding fat pad<sup>4</sup> may directly or indirectly influence the overall changes of the NLFs. Accordingly, the influences of these candidate factors along with the quantitative changes of NLFs were evaluated. Given that morphologic profile change occurs in spurts from the second to the third decades especially in women,<sup>15</sup> the participants were subcategorized according to age subgroups of younger than age 30 ( $< 30$  years) and equal or older than age 30 ( $\leq 30$  years).

The initial basic upper lip thickness was significantly greater in the retraction group when compared with the control group ( $P < .05$ ), but the distribution pattern of initial WRSR score was comparable between subgroups. Following the posterior movement of the anterior teeth and the lips, significant posterior movement of the cheek (Ck), NLF1, and NLF2 was noted in the subgroup of patients younger than age 30 when compared with the corresponding control group ( $P < .05$ ). However, no significant changes were noted in the Ck, NLF1, and NLF 2 for subgroup of patients aged equal to or older than the age of 30 when compared with the corresponding controls (Table 4).

For the subgroup of patients younger than age 30, the anterior-posterior quantitative changes along Y axis ( $\Delta y$ ) of NLFs (NLF1  $\Delta y$  and NLF2  $\Delta y$ ) showed moderate to high positive correlation with hard (upper

incisor incisal tip (I<sub>si</sub>  $\Delta y$ ) and lower incisor incisal tip (I<sub>li</sub>  $\Delta y$ ) and soft tissue (ULP  $\Delta y$ , lower lip point (LLP  $\Delta y$ ), Ch  $\Delta y$  and Ck  $\Delta y$ ) changes following retraction ( $P < .001$ ,  $r = 0.59-0.79$ ). However, for the subgroup of patients equal to or older than age 30, NLF1  $\Delta y$  or NLF2  $\Delta y$  showed limited correlation only with lip soft tissue (ULP  $\Delta y$ , LLP  $\Delta y$  and Ch  $\Delta y$ ;  $r = 0.66-0.71$ ,  $P < .05$ , data not shown).

### Clinical Visual Changes of NLFs After Orthodontic Treatment—GAIS

The majority of GAIS scores were within no-change criteria (GAIS 0), followed by improved (GAIS 1) and worsened (GAIS -1) criteria, but a higher averaged GAIS score was noted in the retraction group of patients younger than age 30 when compared with the corresponding control group ( $P < .05$ ). Accordingly, a significant difference in each score category distribution was found only between the retraction group of women younger than age 30 and the corresponding control group ( $P < .01$ ). For the subgroups of patients younger than age 30, the odds ratio (95% CI) was 2.44 (1.3461–4.4226), indicating that the possibility for improvement of GAIS score in the retraction group was 2.44 times greater than the control group. For women equal to or older than age 30, no statistically significant difference was noted for GAIS between the retraction and control groups (Table 5, Figure 3).

## DISCUSSION

Maximum retraction induces quantitative and perceived visual changes of the NLFs. Quantitatively, NLFs moved posteriorly along with the perioral soft tissue following anterior retraction, and the amount of change positively correlated with the amount of change of surrounding tissue, especially in young women younger than age 30. The posterior movement of the deepest area of the NLFs may imply deepening of the folds that may cause unfavorable effects in facial appearance. Contrary to preconceived concerns, posterior changes in the NLFs did not worsen but, rather, improved the appearance of NLFs in young women.

Anatomically, the medial side of NLFs is tightly associated with the muscle fibers and fixed to the maxilla by ligaments, whereas the lateral side of the NLFs contains a relatively large amount of subcutaneous fat that is very mobile and readily undergoes obesity- and age-related changes of adipose tissue or a decrease of dermal elasticity.<sup>12,14</sup> Clinically, changes in the NLFs are classified into skin sagging type, manifested as a deep furrow that disappears in supine position; bone retrusion type, manifested as a concave depression due to the retrusion of bone around the

**Table 3.** Three-Dimensional Hard and Soft Tissue Changes, mm

| Landmark <sup>a</sup>        | Control Group, n = 17 |                       |                 |                       |                 |                       |
|------------------------------|-----------------------|-----------------------|-----------------|-----------------------|-----------------|-----------------------|
|                              | $\Delta x$            |                       | $\Delta y$      |                       | $\Delta z$      |                       |
|                              | Mean $\pm$ SD         | P Value <sup>b*</sup> | Mean $\pm$ SD   | P Value <sup>b*</sup> | Mean $\pm$ SD   | P Value <sup>b*</sup> |
| <b>Skeletal</b>              |                       |                       |                 |                       |                 |                       |
| A                            | 0.0 $\pm$ 0.10        | NS                    | 0.0 $\pm$ 0.27  | NS                    | 0.5 $\pm$ 0.95  | NS                    |
| B                            | -0.2 $\pm$ 0.69       | NS                    | 0.0 $\pm$ 0.67  | NS                    | -0.6 $\pm$ 1.14 | NS                    |
| Pog                          | 0.0 $\pm$ 0.25        | NS                    | 0.3 $\pm$ 0.68  | NS                    | -0.1 $\pm$ 0.80 | NS                    |
| Me                           | 0.0 $\pm$ 0.01        | NS                    | 0.2 $\pm$ 0.76  | NS                    | 0.2 $\pm$ 0.86  | NS                    |
| <b>Dental</b>                |                       |                       |                 |                       |                 |                       |
| Isi                          | 0.1 $\pm$ 0.68        | NS                    | 0.1 $\pm$ 0.88  | NS                    | 0.4 $\pm$ 0.20  | NS                    |
| Isa                          | -0.2 $\pm$ 0.49       | NS                    | 0.0 $\pm$ 1.03  | NS                    | 0.4 $\pm$ 0.03  | NS                    |
| lii                          | -0.3 $\pm$ 0.67       | NS                    | -0.5 $\pm$ 0.92 | NS                    | -0.3 $\pm$ 1.24 | NS                    |
| lia                          | -0.1 $\pm$ 0.59       | NS                    | -0.3 $\pm$ 0.95 | NS                    | -1.1 $\pm$ 0.91 | NS                    |
| <b>Midfacial soft tissue</b> |                       |                       |                 |                       |                 |                       |
| Ck                           | 0.0 $\pm$ 0.20        | NS                    | 0.3 $\pm$ 1.09  | NS                    | 0.0 $\pm$ 0.20  | NS                    |
| N'                           | 0.0 $\pm$ 0.12        | NS                    | 0.2 $\pm$ 0.60  | NS                    | 0.0 $\pm$ 0.23  | NS                    |
| <b>Perioral soft tissue</b>  |                       |                       |                 |                       |                 |                       |
| Sn                           | 0.0 $\pm$ 0.35        | NS                    | 0.0 $\pm$ 0.62  | NS                    | 0.1 $\pm$ 0.68  | NS                    |
| A'                           | 0.0 $\pm$ 0.44        | NS                    | 0.1 $\pm$ 0.81  | NS                    | 0.1 $\pm$ 0.60  | NS                    |
| B'                           | 0.0 $\pm$ 0.09        | NS                    | 0.7 $\pm$ 3.4   | NS                    | -0.3 $\pm$ 1.51 | NS                    |
| Pog'                         | 0.0 $\pm$ 0.53        | NS                    | 0.0 $\pm$ 1.16  | NS                    | 0.6 $\pm$ 2.36  | NS                    |
| Me'                          | -0.1 $\pm$ 0.32       | NS                    | 0.0 $\pm$ 1.17  | NS                    | 0.0 $\pm$ 1.23  | NS                    |
| <b>Lip</b>                   |                       |                       |                 |                       |                 |                       |
| Cph                          | 0.2 $\pm$ 0.92        | NS                    | 0.0 $\pm$ 0.93  | NS                    | 0.2 $\pm$ 0.62  | NS                    |
| Ls                           | 0.1 $\pm$ 0.63        | NS                    | 0.2 $\pm$ 0.91  | NS                    | 0.1 $\pm$ 0.72  | NS                    |
| ULP                          | 0.0 $\pm$ 0.91        | NS                    | 0.2 $\pm$ 0.83  | NS                    | 0.2 $\pm$ 0.58  | NS                    |
| STMs                         | -0.1 $\pm$ 0.22       | NS                    | 0.5 $\pm$ 0.95  | NS                    | -0.1 $\pm$ 0.87 | NS                    |
| STMi                         | -0.1 $\pm$ 0.75       | NS                    | 0.3 $\pm$ 1.34  | NS                    | -0.1 $\pm$ 0.75 | NS                    |
| LLP                          | -0.1 $\pm$ 0.79       | NS                    | 0.0 $\pm$ 1.06  | NS                    | -0.2 $\pm$ 0.81 | NS                    |
| Li                           | -0.1 $\pm$ 0.63       | NS                    | -0.2 $\pm$ 1.06 | NS                    | 0.1 $\pm$ 0.76  | NS                    |
| Ch                           | 0.1 $\pm$ 0.48        | NS                    | 0.1 $\pm$ 1.35  | NS                    | 0.1 $\pm$ 0.42  | NS                    |
| <b>Nasolabial folds</b>      |                       |                       |                 |                       |                 |                       |
| NLF1                         | 0.1 $\pm$ 0.39        | NS                    | 0.1 $\pm$ 0.63  | NS                    | 0.1 $\pm$ 0.42  | NS                    |
| NLF2                         | -0.3 $\pm$ 0.55       | NS                    | 0.3 $\pm$ 0.78  | NS                    | 0.1 $\pm$ 0.29  | NS                    |

<sup>a</sup>  $\Delta x$ , changes along X axis;  $\Delta y$ , changes along Y axis;  $\Delta z$ , changes along Z axis; A, A-point; B, B-point; Pog, pogonion; Me, menton; Isi, upper incisor incisal tip; Isa, upper incisor root apex; lii, lower incisor incisal tip; lia, lower incisor root apex; Ck, cheek; N', soft tissue nasion; Sn, subnasale; A', soft tissue A-point; B', soft tissue B-point; Pog', soft tissue pogonion; Me', soft tissue menton; Cph, christa philtri; Ls, labialis superius; ULP, upper lip point; STMs, stomion superius; STMi, stomion inferius; LLP, lower lip point; Li, labialis inferius; Ch, cheilion; NLF, nasolabial fold; SD, standard deviation.

<sup>b</sup> NS indicates  $P > .05$ .

\*  $P$  value, paired  $t$ -test.

†  $P$  value, independent 2-sample  $t$ -test with false discovery rate method between the control group and the retraction group.

pyriform aperture; muscular type, manifested as a deep furrow in both upright and supine position due to the high tension resulting from muscle contraction; and cheek fat pad type, manifested as a broad concave depression due to the relatively thick soft tissue mass on the lateral side of the NLFs.<sup>4</sup>

Given that skin elasticity and soft tissue thickness decreases with redistribution of subcutaneous adipose tissue with aging,<sup>12,16</sup> it was initially hypothesized that greater perceived changes may be noted in the older age group. The overall changes of the upper lips relative to incisor movement was 46% (14%–92%), similar to a previous report,<sup>2</sup> with women older than age 30 exhibiting greater lip changes than the younger subgroup (53% vs 38%), as expected. However, the current participants were composed of relatively young adults, where skin sagging type is reportedly rare to

start with,<sup>4</sup> and changes of bony structure similar to the bone retrusion type were not noted. Thus, unlike the conventional physiologic changes of the NLFs due to major volumetric changes and sagging of the lateral side of the fold, the majority of our patients with notable NLF initially may be classified as the cheek fat type. Along with the active reorientation of both the soft and hard tissue on the medial side of the NLFs (ie, the perioral region) induced by orthodontic retraction that overwhelmed the quantitative posterior changes of the NLFs per se, the combination of posterior change of the cheek region that was especially noted in the young women younger than age 30 may have also contributed to the overall esthetic improvement of the NLF. Soft tissue, especially the cheek fat pad, is also influenced by changes in body weight. Due to the retrospective nature of this study, only the sole effect of

**Table 3.** Extended

|             |                     | Retraction Group, n = 22 |                     |             |                     | Comparison      |                 |                 |
|-------------|---------------------|--------------------------|---------------------|-------------|---------------------|-----------------|-----------------|-----------------|
| $\Delta x$  | <i>P</i>            | $\Delta y$               | <i>P</i>            | $\Delta z$  | <i>P</i>            | <i>P</i> Value† | <i>P</i> Value† | <i>P</i> Value† |
| Mean ± SD   | Value <sup>b*</sup> | Mean ± SD                | Value <sup>b*</sup> | Mean ± SD   | Value <sup>b*</sup> | $\Delta x$      | $\Delta y$      | $\Delta z$      |
| -0.1 ± 0.47 | NS                  | -0.1 ± 0.66              | NS                  | 1.0 ± 1.25  | .003                | NS              | NS              | NS              |
| 0.1 ± 0.32  | NS                  | -0.5 ± 1.33              | NS                  | -0.7 ± 3.10 | NS                  | NS              | NS              | NS              |
| 0.0 ± 0.32  | NS                  | -0.1 ± 1.31              | NS                  | 0.0 ± 1.28  | NS                  | NS              | NS              | NS              |
| 0.3 ± 0.88  | NS                  | -0.2 ± 1.43              | NS                  | 0.1 ± 0.80  | NS                  | NS              | NS              | NS              |
| -0.5 ± 0.76 | NS                  | -6.4 ± 0.57              | <.001               | 0.4 ± 0.89  | NS                  | .039            | <.001           | NS              |
| -0.6 ± 1.31 | NS                  | -2.2 ± 1.41              | <.001               | -0.4 ± 2.71 | NS                  | NS              | <.001           | NS              |
| -0.4 ± 1.95 | NS                  | -5.4 ± 1.73              | <.001               | -0.5 ± 1.31 | NS                  | NS              | <.001           | NS              |
| -0.2 ± 1.10 | NS                  | -2.5 ± 1.02              | <.001               | -0.2 ± 1.34 | NS                  | NS              | <.001           | NS              |
| 0.0 ± 0.25  | NS                  | -0.4 ± 1.11              | NS                  | 0.0 ± 0.19  | NS                  | NS              | NS              | NS              |
| 0.0 ± 0.02  | NS                  | 0.0 ± 0.66               | NS                  | 0.0 ± 0.27  | NS                  | NS              | NS              | NS              |
| -0.1 ± 0.40 | NS                  | -0.6 ± 0.71              | .010                | 0.8 ± 0.66  | .001                | NS              | NS              | .038            |
| -0.2 ± 0.85 | NS                  | -2.4 ± 0.94              | <.001               | 1.4 ± 0.94  | <.001               | NS              | <.001           | <.001           |
| 0.1 ± 0.69  | NS                  | -2.4 ± 1.82              | <.001               | -1.7 ± 1.75 | .003                | NS              | .018            | NS              |
| -0.3 ± 1.12 | NS                  | -1.0 ± 1.77              | NS                  | 1.1 ± 3.32  | NS                  | NS              | NS              | NS              |
| 0.7 ± 3.81  | NS                  | 0.0 ± 1.44               | NS                  | 0.1 ± 0.90  | NS                  | NS              | NS              | NS              |
| -0.1 ± 0.79 | NS                  | -2.4 ± 0.94              | <.001               | 1.9 ± 0.85  | <.001               | NS              | <.001           | <.001           |
| -0.2 ± 0.56 | NS                  | -2.7 ± 1.20              | <.001               | 1.9 ± 1.09  | <.001               | NS              | <.002           | <.001           |
| -0.1 ± 0.70 | NS                  | -2.7 ± 1.22              | <.001               | 1.7 ± 1.17  | <.001               | NS              | <.003           | <.001           |
| -0.3 ± 0.87 | NS                  | -3.8 ± 1.37              | <.001               | 0.5 ± 0.96  | NS                  | NS              | <.004           | NS              |
| -0.3 ± 0.71 | NS                  | -3.8 ± 1.59              | <.001               | 0.3 ± 0.87  | NS                  | NS              | <.005           | NS              |
| -0.1 ± 0.61 | NS                  | -4.3 ± 1.41              | <.001               | -0.3 ± 1.59 | NS                  | NS              | <.006           | NS              |
| 0.1 ± 0.48  | NS                  | -3.9 ± 1.29              | <.001               | -1.3 ± 1.61 | .024                | NS              | <.007           | .021            |
| 0.0 ± 0.93  | NS                  | -4.1 ± 1.71              | <.001               | 0.5 ± 1.48  | NS                  | NS              | <.008           | NS              |
| 0.1 ± 0.55  | NS                  | -0.8 ± 0.66              | <.001               | 0.2 ± 0.26  | NS                  | NS              | <.009           | NS              |
| 0.0 ± 0.42  | NS                  | -1.2 ± 0.78              | <.001               | 0.0 ± 0.23  | NS                  | NS              | <.010           | NS              |

**Table 4.** Initial Condition of the Nasolabial Fold (WSRS) and Soft Tissue Changes According to Age<sup>a</sup>

| Soft Tissue Parameters      | <30 Years, n = 28                |                                     |                             | >30 Years, n = 11               |                                    |                             |
|-----------------------------|----------------------------------|-------------------------------------|-----------------------------|---------------------------------|------------------------------------|-----------------------------|
|                             | Control Group, n = 13; Mean ± SD | Retraction Group, n = 15; Mean ± SD | <i>P</i> Value <sup>b</sup> | Control Group, n = 4; Mean ± SD | Retraction Group, n = 7; Mean ± SD | <i>P</i> Value <sup>b</sup> |
| Initial upper lip thickness | 13.4 ± 1.54                      | 16.4 ± 0.82                         | <.001*                      | 12.1 ± 1.01                     | 13.9 ± 1.08                        | .033*                       |
| WSRS score <sup>c</sup>     |                                  |                                     |                             |                                 |                                    |                             |
| 1                           | 53.8% (7)                        | 46.7% (7)                           | NS†                         | 25.0% (1)                       | 0.0% (0)                           | NS†                         |
| 2                           | 46.2% (6)                        | 40.0% (6)                           |                             | 75% (3)                         | 71.4% (5)                          |                             |
| 3                           | 0.0% (0)                         | 13.3% (2)                           |                             | 0.0% (0)                        | 28.6% (2)                          |                             |
| Total                       | 100% (13)                        | 100% (15)                           |                             | 100% (4)                        | 100% (7)                           |                             |
| Isi $\Delta y$              | -0.1 ± 0.85                      | -6.4 ± 1.67                         | <.001*                      | 0.9 ± 0.38                      | -6.5 ± 1.46                        | <.001*                      |
| lii $\Delta y$              | -0.6 ± 0.81                      | -5.6 ± 1.61                         | <.001*                      | -0.2 ± 1.32                     | -5.0 ± 2.04                        | .004*                       |
| ULP $\Delta y$              | 0.7 ± 0.55                       | -2.4 ± 1.25                         | <.001*                      | 0.7 ± 0.41                      | -3.4 ± 0.89                        | <.001*                      |
| LLP $\Delta y$              | 0.8 ± 0.68                       | -4.4 ± 1.44                         | <.001*                      | 0.9 ± 0.51                      | -4.2 ± 1.44                        | <.001*                      |
| Ch $\Delta y$               | 0.0 ± 1.49                       | -3.8 ± 1.80                         | <.001*                      | 0.5 ± 0.71                      | -4.7 ± 1.43                        | <.001*                      |
| Ck $\Delta y$               | 0.4 ± 0.13                       | -0.6 ± 1.17                         | .030*                       | -0.1 ± 0.99                     | 0.3 ± 0.65                         | NS*                         |
| NLF1 $\Delta y$             | 0.1 ± 0.69                       | -0.9 ± 0.68                         | <.001*                      | 0.1 ± 0.43                      | -0.5 ± 0.52                        | NS*                         |
| NLF2 $\Delta y$             | 0.4 ± 0.83                       | -1.4 ± 0.81                         | <.001*                      | 0.0 ± 6.22                      | -0.7 ± 0.54                        | NS*                         |

<sup>a</sup> WSRS, Wrinkle Severity Rating Scale; Isi, upper incisor incisal tip;  $\Delta y$ , changes along Y axis; lii, lower incisor incisal tip; ULP, upper lip point; LLP, lower lip point; Ch, cheilion; NLF, nasolabial fold; SD, standard deviation.

<sup>b</sup> NS indicates *P* > .05.

<sup>c</sup> Data presented as % (n).

\* *P* value, independent 2-sample *t*-test with false discovery rate method.

† *P* value, chi-square test (Fisher exact test).

**Table 5.** GAIS Scores and Distribution According to Age<sup>a</sup>

| GAIS                    | <30 Years, n = 28                   |                                        |         | >30 Years, n = 11                  |                                       |                      |
|-------------------------|-------------------------------------|----------------------------------------|---------|------------------------------------|---------------------------------------|----------------------|
|                         | Control Group,<br>n = 13; Mean ± SD | Retraction Group,<br>n = 15; Mean ± SD | P Value | Control Group,<br>n = 4; Mean ± SD | Retraction Group,<br>n = 7; Mean ± SD | P Value <sup>b</sup> |
| Averaged GAIS score     | 0.2 ± 0.16                          | 0.4 ± 0.27                             | .022*   | 0.1 ± 0.28                         | 0.0 ± 0.48                            | NS*                  |
| GAIS score <sup>c</sup> |                                     |                                        |         |                                    |                                       |                      |
| 1                       | 22.4% (35)                          | 42.8% (77)                             | .003†   | 25.0% (12)                         | 33.3% (28)                            | NS†                  |
| 0                       | 68.6% (107)                         | 52.2% (94)                             |         | 62.5% (30)                         | 33.3% (28)                            |                      |
| -1                      | 9.00% (14)                          | 5% (9)                                 |         | 12.5% (6)                          | 33.3% (28)                            |                      |
| Total                   | 100% (156)                          | 100% (180)                             |         | 100% (48)                          | 100% (84)                             |                      |
| OR (95% CI)             | 2.44 (1.3461–4.4226)                |                                        |         | NS                                 |                                       |                      |

<sup>a</sup> GAIS, Global Aesthetic Improvement Scale; SD, standard deviation; OR, odds ratio; CI, confidence interval.

<sup>b</sup> NS indicates  $P > .05$ .

<sup>c</sup> Data presented as % (n).

\*  $P$  value, independent 2-sample  $t$ -test with false discovery rate method.

†  $P$  value, generalized estimating equations.

tooth movement on NLF was determined. Further investigations including changes in body mass would be beneficial.

Landmarks along the midline reportedly exhibited the most prominent posterior changes, and the changes gradually decreased to the outer area after anterior retraction.<sup>2</sup> Accordingly, similar but more prominent differences in midsagittal vs parasagittal soft tissue were noted in the vertical dimension. The facial aging process involves vertical changes of soft tissue: increase of prolabium, decrease of vermilion height midsagittally or descending mouth corners, or sagging cheeks parasagittally.<sup>17</sup> Among these changes, the earliest signs of aging appear in the parasagittal area surrounding the eye and the NLFs rather than the midsagittal area.<sup>18</sup> Although the vertical changes of the NLFs could not be detected based on landmark evaluation, it is noteworthy that major vertical soft tissue changes following retraction were limited in the midsagittal area unlike the physiologic nature of facial aging.

Due to the complicated structural features of NFL along with the limited nature of quantitative methods to

measure the changes in soft tissue, only a few studies have reported objective quantification of NLFs.<sup>19</sup> The use of CBCT images enabled efficient 3D hard and soft tissue quantification, and the 3D superimposition techniques using the cranial base allowed additional adjustment for precise soft tissue landmark positioning.<sup>5</sup> CBCT images were also applied as templates for subjective GAIS scoring. According to the pilot study, GAIS results were highly influenced by lighting conditions of the clinical photos, presented facial angles, facial make-up, and the examiner's field of expertise. The application of reconstructed CBCT facial images without color and texture was effective in avoiding the influence of these external features and also enabled the standardized presentation of frontal and three-quarter facial views.

## CONCLUSIONS

- Orthodontic retraction induced quantitative and perceived changes of the NLFs.
- For adult women younger than age 30, the appearance of the NLFs significantly improved after



**Figure 3.** Representative pre- and posttreatment images indicating the changes of the nasolabial folds using the modified Global Aesthetic Improvement Scale. (A) Age 19, posterior changes in the upper incisors along Y axis ( $Isi \Delta y$ ) was 8.1mm, majority scored “Global Aesthetic Improvement Scale 1, improved.” (B) Age 23,  $Isi \Delta y$  was 8.3mm, majority scored “Global Aesthetic Improvement Scale 0, no change.” (C) Age 41,  $Isi \Delta y$  was 6.8mm, majority scored “GAIS -1, worsened.”



maximum retraction despite the posterior change of the NLFs.

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