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Three-dimensional Facial Soft Tissue Changes after Bimaxillary Orthognathic Surgery in Patients with Cleft Lip and Palate

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-ABSTRACT-

Three-dimensional Facial Soft Tissue Changes after Bimaxillary Orthognathic Surgery in Patients with Cleft Lip and Palate

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Objective: To investigate three-dimensional changes in facial soft tissue including nose, upper and lower lips, and chin after bimaxillary orthognathic surgery (BOGS) in patients with cleft lip and palate.

Material and Methods: The samples consisted of 34 Korean young adult patients with skeletal Class III malocclusion who underwent BOGS for maxillary advancement/posterior impaction and mandibular setback. They were divided into cleft-Class III (C-CIII) group (n=18) and noncleft-Class III (NC-CIII) group (n=16). Three-dimensional computed tomography images were taken one month before (T1) and three months after (T2) surgery. After 34 hard/soft tissue landmarks were automatically identified using software, the amount and direction of change in landmarks and the amount of change in 16 soft tissue variables during T1-T2 were calculated. Then, statistical analysis was performed.

Results: Compared to NC-CIII group, C-CIII group showed more posteriorly-positioned hard/soft tissue landmarks, larger alar width, alar base width and philtrum width, and more obtuse nasal tip angle at both T1 and T2 stages. C-CIII group exhibited higher soft-to-hard tissue movement ratios at the bottom of the nose (ΔSn/ΔANS, 1.08 vs. 0.81) and the upper part of the upper lip (UL, ΔPoint A'/ΔPoint A, 1.08 vs. 0.91), but a lower ratio at the lower part of the UL (ΔLs'/ΔIs, 0.72 vs. 1.01) than NC-CIII group. The number of hard-soft tissue landmarks with high correlation (>0.90) was smaller in C-CIII group than in NC-CIII group (2 vs. 6).

Conclusion: Post-surgical scar tissues and contracted and abnormally attached muscles in the nose and upper lip might elicit different responses in the nasolabial soft tissues to BOGS between C-CIII and NC-CIII patients.

Keywords: 3D analysis; facial soft tissue changes; bimaxillary orthognathic surgery; cleft lip and palate

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서울대학교 대학원 치의과학과 치과교정학 전공

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서 지 희

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I. INTRODUCTION

Cleft patients often exhibit skeletal Class III malocclusion due to maxillary hypoplasia, which was induced by post-surgical scar tissues following cheiloplasty and palatoplasty.[1-3] Although a facemask therapy with tooth- or bone-borne anchorage has been applied to treat maxillary hypoplasia in adolescent patients with unilateral (UCLP) and bilateral cleft lip and palate (BCLP),[4,5] a wide range of patients (20% to 76.5%) were in the need for orthognathic surgery (OGS) or distraction osteogenesis (DO) to correct their sagittal skeletal discrepancy.[6,7]

Numerous studies have attempted to evaluate the facial soft tissue changes following OGS or DO and determine the correlations and ratios of soft-to-hard tissue changes in cleft lip and palate (CL/P) patients.[8-19] However, the facial soft tissues of CL/P patients differ from those of noncleft normal patients morphologically and behaviorally owing to the cleft-related deformity itself and scar tissues in the lip, nose, and alveolus.[20,21]

Three-dimensional (3D) imaging modalities, such as laser surface scanning and stereophotogrammetry, have been used to quantitatively assess the 3D facial soft tissue changes in CL/P patients after surgical interventions.[22] However, to analyze the hard and soft tissues simultaneously, these modalities require an additional step of integrating the surface scanning data with the corresponding soft tissue images in computed tomography (CT) or cone-beam CT data. If those data sets are obtained with different head postures and/or on different timetables, these 3D methodologies may be susceptible to errors in interpreting postoperative alterations of the hard and soft tissues. Therefore, it is prudent to use a single imaging modality for simultaneous evaluation of the hard and soft tissues.

Among the studies on the facial soft tissue changes in CL/P patients mentioned above, only two studies[16,17] used a 3D imaging modality. However, it was 3D photography, neither CT nor CBCT. Moreover, only one study included a noncleft control group to compare the facial soft tissue changes with CL/P patients.[15] However, that study had some limitations, such as a 2D lateral cephalometric analysis and confinement of research scope to the changes in the lower lip.[15] Accurate assessment of the 3D facial soft tissue changes in CL/P patients can provide clinicians with trustworthy guidelines to determine the amount and direction of surgical movement of the maxilla and mandible for better esthetic outcomes.

To the best knowledge of authors, no study to date has compared the facial soft tissue changes by bimaxillary orthognathic surgery (BOGS) between cleft-Class III (C-CIII) and noncleft-Class III (NC-CIII) patients using 3D analysis. Therefore, this retrospective study was intended to compare the amounts, directions, correlations, and ratios of changes in the facial hard and soft tissue landmarks and the amount of change in the soft tissue variables after BOGS between C-CIII and NC-CIII patients using artificial intelligence-assisted landmark autodigitization on 3D-CTs.

II. REVIEW OF LITERATURE

1. Maxillary hypoplasia in cleft patients

It is quite common that cleft patients presented skeletal Class III malocclusion, which mainly originated from maxillary hypoplasia and relative mandibular prognathism. The hypoplastic maxilla in cleft patients is known to be highly attributed to inherent growth deficiencies in the zygomatico-maxillary complex and scar tissues following primary repairs in the lip and palate.[1-3]

Maxillary protraction via facemask with dental or skeletal anchorage has been widely used as first-line treatment for the maxillary hypoplasia of adolescent cleft patients.[4,5] However, 20% to 76.5% of cleft patients, in spite of agreeable orthopedic effects of the facemask therapy, is reported to be in the need of orthognathic surgery (OGS) or distraction osteogenesis (DO) for the purpose of correcting their sagittal skeletal discrepancy.[6,7]

2. Previous studies on postoperative facial soft tissue changes in cleft patients

The prediction of postoperative facial profile is a challenging task of paramount importance for the successful surgico-orthodontic treatment. Numerous studies have evaluated the post-surgical changes in the nasolabial complex and to determine the correlations between the surgical movement of the hard tissues and the resultant changes in the overlying soft tissues in cleft patients.[8-19] However, since the facial soft tissues of cleft patients, in addition to high individual variability, differ from those of noncleft normal patients morphologically and behaviorally due to the cleft-related deformity itself and scar tissues in the lip, nose, and alveolus,[20,21] the conclusions drawn from the data based on noncleft controls were not applicable to cleft patients.

It is obvious that the orthognathic surgery can correct the skeletodental deformities and brings the cephalometric measurements to be close to normal. However, from anesthetic point of view, people perceive the post-surgical changes on the soft tissue envelope, not on the underlying bones. Both hard and soft tissue structures in the face should be evaluated for the thorough description of facial morphology of individual patient. Thus, the number of publications on 3D analysis of facial hard and soft tissues in cleft patients is steadily rising.[22]

(1) Studies using 2D lateral cephalograms

al-Waheidi el al.[8] pointed out that the upper incisal tip was the most significant variable to predict the post-surgical position of upper lip, but it failed to account for more than 50% of changes in the soft tissue landmarks. Although the initial upper lip thickness (ULT) was the second significant determinant, cleft patients did not encounter initial ULT-dependent lip compression in the postoperative follow-up period. They suggested that the ratios of soft-to-hard tissue changes increased progressively from top to bottom.

According to the study of Heliövaara et al.[9], UCLP patients experienced significant horizontal changes in the upper lip (Sn-Y, Cm-Y, A'-Y) and vertical changes in the lower face (Ls'-X, Li'-X, B'-X, Pog'-X) after maxillary advancement with Le Fort 1 osteotomy and mandibular setback. One year post-operative follow-up revealed lesser changes in the upper lip than the lower lip (upper lip vs. lower lip: horizontally 80% vs. 100%; vertically 40% vs. >100%).

Yun el al.[14] reported that cleft patients showed a significant increase in the nasolabial angle and decreases in upper lip-to-Rickett's E-line distance and lower-to-upper lip length ratio after bimaxillary orthognathic surgery. The ratios of soft tissue-to-bone change in the maxilla (A-A′) were lesser than those in the mandible (B-B′) (horizontal: 55% vs. 93%; vertical: 8% vs. 89%).

Park et al.[15] found that although orthognathic surgery did not cause significant differences in SNA, SNB, and ANB between cleft and noncleft patients, the lower lips of cleft patients had trouble to adapt to the surgical correction of mandibular setback procedures and protruded even further, ensued by the disharmony between upper and lower lips and persistent lip deformity.

Since these studies mentioned above used 2D lateral cephalograms to evaluate the postoperative soft tissue changes, they might be incapable of overcoming intrinsic limitations of 2D analysis. Two-dimensional lateral cephalograms cannot accurately depict 3D anisotropic behaviors of a 3D subject.

(2) Studies using 3D photogrammetric analysis

Davidson et al.[16] conducted a 3D photogrammetric analysis and reported that Le Fort l advancement in cleft patients produced an increase in the inter-alar width, decrease in the columellar length, no change in the nasal length and inter-nostril width, and no change or decrease in the nasal tip projection. Meanwhile, it was found that noncleft patients demonstrated an increase in the inter-alar width, inter-nostril width, and nasolabial angle, no change in the nasal length and columellar length, and no change or increase in the nasal tip projection. However, this methodology is susceptible to errors in interpreting the relations between the surgical movement of the hard tissues and the resultant changes in the overlying soft tissues, since it requires a supplementary step of integrating its surface scanning data with the corresponding soft tissue images in CT or CBCT to address the hard and soft tissues concurrently.

Susarla el al.[17] stated that cleft patients exhibited larger ratios of soft tissue-to-bone change, since their pre-operative positions of maxilla and mandible were more retruded than normal individuals. This retrospective study provided a precise 3D volumetric assessment of midfacial soft tissues. However, since 3D photogrammetric data could not afford to visualize the underlying hard tissues, post-surgical changes in the soft and hard tissues were carried out individually by means of 3D photography and lateral cephalograms, respectively.

(3) Comparison of facial soft tissue changes between orthognathic surgery and DO

Among the studies on the postoperative facial soft tissues changes of cleft patients, six studies endeavored to compare the effects of orthognathic surgery and DO.[10-13,18,19] Two studies investigated the effects of one-piece versus two-piece osteotomy in the maxilla on the soft tissue changes.[16,17]

Harada et al.[10] illustrated that landmarks in the midface (Cm, Sn, Ls', ANS, UI) showed significantly larger horizontal changes in the DO group than the orthognathic surgery group, but did not exhibit significant differences in the vertical changes between orthognathic surgery and DO groups. In the sagittal movement ratios for soft-to-hard tissue, Ls/U1 was higher in the orthognathic surgery group, Sn/ANS, Ls'/ANS, Ls'/U1 and Ls'/ANS, higher in the DO group, and Cm/ ANS, almost equal between the two groups. The lower facial height decreased in the orthognathic surgery group (Sn-Bo, St-Bo). Increases in the sub-nasal length (Sn-St) and the nasolabial angle were more prominent in the DO group. Therefore, they concluded that DO would more effectively improve the soft tissue profiles of cleft patients who have severe midfacial retrusion.

Daimaruya el al.[11] summarized in their study on Japanese UCLP patients that the DO group showed significantly higher forward movement ratios of soft -to-hard tissue (Prn/A, Sn/A, Ls'/A, Ls'/U1) than the orthognathic surgery group, without differences in the nasolabial angle and facial height between the two groups.

Chua et al.[12] described that the DO procedure ensured greater changes in pronasale, subnasale, labrale superius, and nasal projection, compared to the orthognathic surgery, but there was no significant difference in the nasolabial angle between DO and orthognathic surgery. They found that the correlation of hard-to-soft tissue movements was much stronger anteroposteriorly than vertically in both groups.

Rachmiel el al.[13] asserted that DO had advantages over orthognathic surgery in cases of moderate-to-severe maxillary hypoplasia or in growing patients due to greater maxillary movement, more skeletal stability, and more favorable soft tissue changes. They added that one stage orthognathic surgery was preferable for patients with mild maxillary hypoplasia or after completion of pubertal growth.

Kanzaki et al.[18] analyzed the lateral cephalograms of 23 Japanese cleft patients who had undergone maxillary advancement, and found out that the soft tissue advancement in the midface (Prn, Sn, Ls') was significantly larger in the patients treated with anterior maxillary distraction osteogenesis (AMDO) and maxillary distraction osteogenesis (DO) with rigid external distraction system (RED) than those with orthognathic surgery. They stated that DO was feasible to improve the postoperative stability by releasing tension of soft tissues effectively.

Kloukos et al.[19], in their retrospective study on 47 cleft patients in Hong Kong, reported that DO showed greater maxillary advancement (A point) and less horizontal relapse, resulting in more satisfactory results than Le Fort I orthognathic surgery.

(4) Soft tissue changes in the nose and upper lip

Davidson et al.[16] reported that cleft patients, contrary to normal population, manifested tendencies of increase in the inter-alar width and decrease in the columellar length, while there was no change in the nasal length and inter-nostril width and no change or decrease in the nasal tip projection after maxillary advancement surgery. In addition, the nasolabial angle showed greatest variation in cleft patients owing to post-surgical scarring and pre-existing 3D anatomical malposition.

al-Waheidi el al.[8] announced that upper lip elongation occurred in cleft patients in spite of their inherent shorter upper lips. The initial upper lip thickness and post-surgical lip thickness reduction were similar between cleft and noncleft patients. The ratios of soft-to-hard tissue change increased progressively for points that are more inferiorly located on the upper soft tissue profile.

Yun el al.[14] ascribed smaller soft tissue changes in the maxilla than in the mandible to the physical and environmental properties of the soft tissues around the maxilla. Since the soft tissues in the maxilla are more closely interconnected to the nose, cheek, and the surrounding area, scar tissues from previous palatoplasties can restrain the postoperative changes in the maxilla.

Heliövaara et al.[9] insisted that V-Y plasty executed concomitantly during orthognathic surgery did not completely eliminate the need for secondary lip/nose correction, even though it could minimize vertical shortening of the upper lip, increase its anteroposterior thickness (Pr-Ls'), and finally improve upper lip aesthetics (smile line/incisal display). In addition, simultaneous rhinoplasty had no significant effect on soft tissue changes.

Davidson et al.[16] proposed the interplay between scar tissues from primary lip/nose repair and adjacent tissues undermined during LeFort I osteotomy would contribute to different responses of cleft patients to the surgery. Since midface advancement alone could not guarantee desired changes in the nasal aesthetics, cleft patients would need definitive septorhinoplasty.

(5) Soft tissue changes in the lower lip

Park et al.[15] contended that the lower lip is to blame for persistent facial deformity in cleft patients because the muscles surrounding the lower lip were maladjusted to the surgically acquired new conditions. They explained the soft tissue imbalance responsible for lip disharmony in cleft patients resulted from (1) discontinuity of muscles around the upper lip (orbicularis oris), (2) upper lip tightening due to scar tissue, and (3) poor muscle power around the mouth (buccinators, mentalis). Therefore, lower lip inversion or Abbe flap for hypertrophied, anteriorly rotated lower lip in cleft patients is recommended after mandibular setback surgery.

III. MATERIALS AND METHODS

The experimental group (C-CIII group) consisted of 18 Korean young adult patients with CL/P and skeletal Class III malocclusion [15 males and 3 females; mean age, 22.3 ± 3.6 years; 10 UCLP (5 right and 5 left side involvement) and 8 BCLP; Table 1]. The inclusion criteria for the C-CIII group were (1) diagnosis of complete UCLP or BCLP, (2) history of cheiloplasty, palatoplasty, and secondary alveolar bone grafting during childhood; (3) presence of skeletal Class lll malocclusion; (4) the same surgical orthodontic treatment protocol applied by a single orthodontist (BSH) at the Department of Orthodontics, Seoul National University Dental Hospital (SNUDH), Seoul, Republic of Korea; and (5) 3D-CT data obtained one month before (T1) and at least 3 months after surgery (T2) (Table 1). The exclusion criteria for the C-CIII group were as follows: (1) presence of syndromic clefts or other craniofacial anomalies; (2) history of the secondary revision surgery in the lip and nose before BOGS; and (3) presence of severe facial asymmetry (> 6 mm of soft tissue menton deviation from the facial midline). As the age-matched control group (NC-CIII group), 16 Korean young adult noncleft patients with skeletal Class III malocclusion (9 males and 7 females; mean age: 22.2 ± 2.5 years; Table 1) were chosen.

Both groups underwent BOGS via the Le Fort I osteotomy for maxillary advancement/posterior impaction and the bilateral sagittal split ramus osteotomy (BSSRO) for mandibular setback at SNUDH from 2015 to 2020. Alar cinch suture was performed as an adjunctive procedure in all the patients of both groups. This retrospective study was reviewed and approved by the institutional review board of the SNUDH (ERI20027).

1. Sample size determination

Power analysis was performed using the mean and standard deviation (SD) values of the labrale inferius from Park el al.' study[15] (Control group: 12.35 and 1.97; Experimental group: 6.03 and 6.53, respectively). The Sample Size Determination Program Ver. 2.0.1 (SNUDH, Registration number 2007-01-122-004453) suggested nine as the minimum sample size.

2. Data acquisition and construction of reference planes

3D-CTs (Sensation 10, Siemens, München, Germany; axial slice thickness, 1.0 mm) were taken with centric relation and lips in repose at the T1 and T2 stages. Each data set was imported into the ON3D program (3DONS, Seoul, Korea).

The three reference planes were set up using the 3DONS (Figure 1): (1) As the coronal reference plane (y-axis), the naso-fronto-zygomatic (NFZ) plane was constructed using the nasion (N) point and the right and left fronto-zygomatic points. (2) As the horizontal reference plane (x-axis), the right Frankfort horizontal (R-FH) plane was established using the right porion (Po) point and the orbitale (Or) point, perpendicular to the NFZ plane. (3) The mid-sagittal plane (z-axis) was constructed using the N point, perpendicular to the NFZ and

R-FH planes.[23] The N point was registered as the origin (0, 0, 0) of the Cartesian coordinate system.

3. Hard and soft tissue landmarks

A total of 34 landmarks (10 midline hard tissue landmarks, and 12 midline and 12 bilateral soft tissue landmarks) were automatically identified on each CT image with the function of "automatic digitization of the landmarks" in the 3DONS (Figure 2). Then, those were validated meticulously and adjusted manually by a single operator (SJH).

As the 3D-coordinate values of a landmark (x, y, z) specified its spatial location relative to the N point, the amount and direction of change in a certain landmark position during T1-T2 could be calculated (Table 2). A positive (+) sign indicated left, posterior, and superior to the N point, while a negative (−) sign meant the opposite. Accordingly, the changes in the x, y, and z axes denoted the transverse, anteroposterior, and vertical movement, respectively. The correlation coefficients and ratios of soft-to-hard tissue landmark movements were evaluated in each axis.

4. Soft tissue variables

Sixteen soft tissue variables comprised 6 nose-, 6 upper lip-, and 4 lower lip and chin-related ones (Figure 3). The amount of change in these variables during T1-T2 was calculated (Table 3).

5. Validation of landmark identification

Seventeen CT images were randomly selected from the C-CIII and NC-CIII groups and re-digitized by the same operator (SJH) at a 2-week interval. Since there were no significant differences in landmark locations between the first and second measurements in Wilcoxon signed rank test (all $P>0.05$), the first set of measurement was used for further analysis.

6. Statistical analysis

Mann-Whitney test, Wilcoxon signed-rank test, Chi-square test, Fisher's exact test, and bivariate correlation analysis were performed using SPSS (version 23.0; IBM, Armonk, NY, USA). A p-value of less than 0.05 was considered statistically significant.

IV. RESULTS

1. Demographic data of the subjects (Table 1)

Distribution of sex, the number of patients who underwent genioplasty concomitant with BOGS, and mean ages at the T1 and T2 stages did not differ between the two groups (all $P>0.05$).

2. Cephalometric characteristics of the two groups (Table 4)

The NC-CIII group exhibited a normally positioned maxilla, a protrusive mandible, normodivergent pattern, and retroclined mandibular incisors at the T1 stage. At the T2 stage, the NC-CIII group showed significant mandibular setback, correction of Class III relationship, increase in FMA, and linguoversion of the maxillary incisors.

The C-CIII group showed retrusive maxilla and mandible, normodivergent pattern, and normal mandibular incisor inclination at the T1 stage. The C-CIII group exhibited significant maxillary advancement, mandibular setback, correction of Class III relationship, and increase in FMA at the T2 stage.

3. Comparison of the midline hard tissue landmarks between the two groups (Table 5)

At the T1 stage, the C-CIII group presented a retrusive maxilla and a retrusive mandible; while the NC-CIII group had a normally positioned maxilla and a protrusive mandible (Point A-y, Point B-y, Pog-y, all P<0.01). At the T2 stage, the maxilla and mandible of the C-CIII group were relatively retruded even after BOGS, compared to the NC-CIII group (Point A-y, Point B-y, Pog-y, all P<0.01).

4. Comparison of the midline soft tissue landmarks between the two groups (Table 6)

The nose (Prn-y, Cm-y, Sn-y), upper lip (Point A'-y, Ls'-y, Stms-y), lower lip (Stmi-y, Li'-y, Point B′-y), and chin (Pog'-y) were more posteriorly located in the C-CIII group than in the NC-CIII group at both T1 and T2 stages, mirroring the relative retrusion of the maxilla and mandible in the C-CIII group. Interestingly, the columella (Cm-z) was found more inferiorly in the C-CIII group than in the NC-CIII group.

5. Comparison of the bilateral soft tissue landmarks between the two groups (Table 7)

Compared to the NC-CIII group, the C-CIII group displayed more posteriorly positioned alar curvature (ac-R-y, ac-L-y), crista philtrum (cph-R-y, cph-L-y), and cheilion (ch-R-y, ch-L-y) at both T1 and T2 stages.

6. Correlations of soft-to-hard tissue landmark movements in the two groups (Table 8)

In the transverse (x) axis, the C-CIII group presented moderate-to-high correlations of soft-to-hard tissue landmark movements in the upper lip, lower lip, and chin (range: 0.62 to 0.91), while the NC-CIII group showed high correlations only in the lower lip and chin (range: 0.87 to 0.97).

In the sagittal (y) axis, the correlations of the bottom of the nose, upper lip, lower lip, and chin with their corresponding hard tissue landmarks were moderate-to-high in the C-CIII group (range: 0.62 to 0.94) and high in the NC-CIII group (range: 0.86 to 0.99). Furthermore, the number of soft-to-hard tissue landmarks with high correlation (> 0.90) was smaller in the C-CIII group than in the NC-CIII group (2 vs. 6).

In the vertical (z) axis, the C-CIII group showed moderate-to-high correlations only in the lower lip and chin (range: 0.50 to 0.92), whereas the NC-CIII group showed moderate-to-high correlations in the bottom of nose, upper lip, lower lip, and chin (range: 0.53 to 0.97).

7. Ratios of soft-to-hard tissue landmark movements in the two groups (Table 8)

In the transverse (x) axis, both groups showed fairly wide ranges of movement ratios (-0.85 to 0.91 in the C-CIII group and -1.77 to 0.59 in the NC-CIII group). The range of ratios in the vertical (z) axis was wide in the

C-CIII group (-4.59 to 1.26) but narrow in the NC-CIII group (0.74 to 1.05).

In the sagittal (y) axis, both groups showed confined ranges of ratios (0.72 to 1.08 in the C-CIII group and 0.81 to 1.06 in the NC-CIII group). The ratios of the C-CIII group were higher at ΔSn/ΔANS (1.08 vs. 0.81), ΔPoint A'/ΔPoint A (1.08 vs. 0.91), and ΔPog'/ΔPog (1.04 vs. 0.83), lower at ΔLs'/ΔIs (0.72 vs. 1.01), and similar at ΔLi'/ΔIi (0.94 vs. 0.99) and ΔPoint B'/ΔPoint B (1.04 vs. 1.06) in comparison with the NC-CIII group.

8. Comparison of the soft tissue variables between the two groups (Table 9)

At both T1 and T2 stages, the C-CIII group exhibited larger alar width ($P<0.05$; $P<0.01$), alar base width ($P<0.05$; $P<0.01$), and philtrum width ($P<0.01$; $P<0.001$), and more obtuse nasal tip angle ($P<0.05$; $P<0.05$) than the NC-CIII group. Further, the C-CIII group demonstrated a more acute lower lip prominence angle at the T1 stage ($P<0.05$) and shorter upper lip vermilion height at the T2 stage ($P<0.05$) than the NC-CIII group.

9. Superimposition of the facial soft tissue between the T1 and T2 stages (Figure 4)

The three reference planes (NFZ, R-FH, and mid-sagittal planes) and the N point were used for superimposition of the T1 and T2 images. Examples of the facial soft tissue changes in C-CIII and NC-CIII patients are presented in Figure 4 using a heat map, which indicates the distance from the T1 image to the T2 image.

V. DISCUSSION

1. Cephalometric characteristics of the two groups (Table 4)

Despite considerable maxillary advancement (ΔSNA, 2.4°, ΔA-N perpendicular, 2.3 mm), the C-CIII group still had a retrusive maxilla (SNA, 76.3°, A-N perpendicular, -2.2 mm) after BOGS, indicating that the amount of maxillary advancement was restricted in cleft patients in consideration for tension in scar tissues and post-surgical stability.

2. Comparison of the midline hard tissue landmarks in the two groups (Table 5)

Similar to cephalometric findings, the C-CIII group had more retruded maxilla and mandible at the T2 stage than the NC-CIII group (Point A-y, Point B-y, Pog-y, all $P<0.01$). It suggested that posterior impaction in conjunction with advancement in the maxilla could be effectively used to treat midface hypoplasia in cleft patients and reduce the risk of post-surgical instability from large maxillary advancement.

3. Comparison of the midline soft tissue landmarks in the two groups (Table 6)

The nose moved forward in both C-CIII and NC-CIII groups (ΔPrn-y: -0.8 mm and -1.2 mm, all $P<0.01$; ΔSn-y: -1.7 mm and -1.8 mm, all $P<0.01$).

However, the columella shifted inferiorly in the C-CIII group (ΔCm-z: -0.4 mm, $P<0.05$), although a tendency of its superior displacement was discovered in the NC-CIII group (ΔCm-z: 0.2 mm, $P>0.05$). This finding was in discord with the study by Heliövaara et al.,[9] which reported that maxillary advancement in cleft patients resulted in the forward movement of columella without significant vertical displacement.

Significant forward movements were observed in the upper part of the upper lip in both C-CIII and NC-CIII groups (ΔPoint A'-y: -2.1 mm, $P<0.001$ and -2.3 mm, $P<0.01$), which was identical with the findings of Heliövaara et al.[9] However, the lower part of the upper lip moved downward in the C-CIII group (ΔLs'-z: -1.5 mm, $P<0.001$; ΔStms-z: -1.6 mm, all $P<0.001$) without a significant forward movement (ΔLs'-y: -0.9 mm, $P>0.05$). On the contrary, it was displaced more forward and less downward in the NC-CIII group (ΔLs'-y: -2.2 mm, $P<0.01$; ΔStms-z: -0.7 mm, $P<0.05$). These findings implied that since tight scar tissues in the upper part of the upper lip in CL/P patients were intertwined with the lower part of the upper lip, they eventually restricted a forward movement of the lower part of the upper lip.

Concerning the lower lip change, Park et al.[15] reported that the lower lip in cleft patients was protruded, instead of being retracted, resulting from maladaptation of perioral muscles to mandibular setback. However, in this study, the lower lips in both C-CIII and NC-CIII groups moved in the same direction; backward and downward (ΔLi'-y: 4.4 mm, $P<0.001$ and 3.1 mm, $P<0.05$; ΔStmi-z: -1.7 mm, $P<0.01$; -1.5 mm, $P<0.05$). These discrepant results might be attributed to differences in the preoperative conditions of hard/soft tissues, surgical procedures, the methodology of assessment, and individual variability.

4. Comparison of the bilateral soft tissue landmarks in the two groups (Table 7)

Alar curvature and subalare moved forward in both groups, just as the nose-related midline landmarks. However, the C-CIII group displayed distinctive movements of some bilateral soft tissue landmarks: (1) downward movement of subalare (Δsubal-L-z, $P<0.05$) and crista philtra (Δcph-R-z, $P<0.001$; Δcph-L-z, $P<0.01$), and (2) backward and downward movement of cheilion (Δch-R-y, Δch-R-z, Δch-L-y, all $P<0.01$; Δch-L-z, $P<0.001$). These cleft-specific movements could be explained by (1) the stiffness of scar tissues in the nose and upper lip, (2) imbalance of muscle forces, derived from disrupted anatomical integrity of the orbicularis oris muscle, (3) deficiency in the supporting hard tissues, including bone, nasal cartilage and alveolus, and (4) failure to adapt to the new position after BOGS.

5. Ratios of soft-to-hard tissue landmark movements in the two groups (Table 8)

Regarding the soft-to-hard tissue landmark movement ratios in the sagittal axis, there was a tendency of progressive increase from lower lip to chin in the C-CIII group [ΔLi'/ΔIi (0.94), ΔPoint B'/ΔPoint B (1.04), and ΔPog'/ΔPog (1.04)], which was similar to previous studies.[24,25] However, the ratios at the bottom of the nose (Sn) and the upper part of the upper lip (Point A') were higher than the ratio at the lower part of the upper lip (ΔSn/ΔANS, 1.08 and ΔPoint A'/ΔPoint A, 1.08 vs. ΔLs'/ΔIs, 0.72), which was not in line with the typical gradient of ratios in the NC-CIII group.

The higher ratios at ΔSn/ΔANS and ΔPoint A'/ΔPoint A in the C-CIII group expressed that more extensive soft tissue changes relative to the amount of maxillary advancement occurred at the bottom of the nose (Sn) and the upper part of the upper lip (Point A'), which might be relevant to stretch-resistant scar tissues in those areas. Meanwhile, the lower ratio at ΔLs'/ΔIs in the C-CIII group indicated that the lower part of the upper lip tended to stretch downward rather than forward. Consequently, it is necessary to consider responses of the upper and lower parts of the upper lip separately.

6. Comparison of the soft tissue variables in the two groups (Table 9)

In the evaluation of nasal changes during T1-T2, the C-CIII group showed increases in alar width ($P<0.001$) and alar base width ($P<0.05$), a decrease in columellar length ($P<0.001$), and no change in nasal tip angle ($P>0.05$), which were consistent with Davidson et al.'s findings.[16] Since the pronasale moved less forward in the C-CIII group than in the NC-CIII group (-0.8 mm vs. -1.2 mm), the transverse nasal prominence angle became more obtuse in the C-CIII group (0.4° vs. -0.3°, $P<0.05$). Increase in the nasolabial angle in the C-CIII group (6.9°) was in accordance with the results of previous studies.[9,10,14] The changes in all nose-related variables except the nasolabial angle represented esthetic impairment in the nasal morphology of cleft patients after BOGS. Previous studies reported that BOGS, even with rhinoplasty or V-Y plasty, could not meet expectations of nasal aesthetics due to scar tissues and pre-existing 3D anatomical malposition of facial structures around the nose.[9,16] Therefore, a secondary septo-rhinoplasty would be required in cleft patients.

The finding that upper lip height (1.5 mm, $P<0.01$) and philtrum height (1.1 mm, $P<0.001$) increased significantly in the C-CIII group during T1-T2 was consistent with previous studies,[8,9,14] which showed that upper lips elongated in CL/P patients in spite of their inherent shorter upper lip heights. The upper lip vermilion height did not change in the C-CIII group, while it increased significantly in the NC-CIII group (0.2 mm vs. 0.9 mm, $P<0.05$). Therefore, different mechanisms might be involved in the increase of the upper lip height between the C-CIII group (increase in philtrum height) and the NC-CIII group (increase in upper lip vermilion height).

The C-CIII group manifested a significant decrease in the upper lip prominence angle (-9.4°, $P<0.001$). The reasons might be associated with a less forward movement of the upper lip (Ls': -0.9 mm vs. -2.2 mm) and poor adaptation of the orbicularis oris muscle in C-CIII patients.

A significant decrease in the mentolabial angle (-9.5°, $P<0.01$) and increase in the lower lip prominence angle (4.9°, $P<0.001$) in the C-CIII group during T1-T2 could be explained by (1) changes in the strain of upper and lower lips by maxillary advancement/post impaction and mandibular setback, (2) tightness of the upper lip, developed from scar tissues and undermined/dissected tissues during BOGS, and (3) mal-adaptation of the orbicularis oris muscle, buccinator muscle, and mentalis muscle after BOGS.[15,16,25]

7. Limitation of this study and suggestions for future study

The limitations of this study are as follows: (1) The study design was a retrospective one; (2) The sample size was relatively small; (3) The cleft type was not confined; (4) The follow up period was quite short; and (5) The data were obtained from a single university hospital.

However, it is imperative to conduct well-designed prospective studies with larger samples in order to confirm the findings of the present study. Furthermore, comparisons of the facial soft tissue changes after BOGS according to cleft type (UCLP vs. BCLP) would help to further clarify post-surgical esthetic issues in cleft patients.

8. Clinical implications of the results from this study

The major clinical findings of this study are as follows: (1) Compared to the NC-CIII group, the C-CIII group exhibited more posteriorly positioned hard and soft tissue landmarks, and wider and more obtuse nose before BOGS and even after BOGS; (2) The C-CIII group had less number of the soft-to-hard tissue landmarks which showed high correlation (> 0.90) than the NC-CIII group (2 vs. 6); and (3) In the C-CIII group, the amount of movement in the bottom of the nose and the upper part of the upper lip exceeded those of the corresponding hard tissue landmarks; while that in the lower part of the upper lip did not. When compared to the NC-CIII group, these trends were more exaggerated. Therefore, clinicians should remind cleft patients and/or their parents of the possibility of unsatisfactory surgical outcomes in the nasolabial complex and necessity of adjunctive aesthetic surgeries after BOGS.

The AI-assisted automated detection of the landmarks and evaluation of the skeletal and dental discrepancies is getting popular.[23,26-28] However, it is still necessary to develop the AI-assisted virtual surgical planning to reduce clinician's laborious and time-consuming works, to simulate the amount and direction of the required surgical movement, and to provide a preview of surgical outcome. However, for accurate prediction of the soft tissue change, it is mandatory to check surgical accuracy between virtually surgical simulation and actual surgical movements of the maxilla and mandible in the 3D coordinates. Further studies on 3D-printing of the osteotomy guide and surgical plates might be also important to increase the surgical accuracy.[29-32]

VI. CONCLUSIONS

Post-surgical scar tissues and contracted and abnormally attached muscles in the nose and upper lip induced by primary cheiloplasty and rhinoplasty might elicit different responses in the nasolabial soft tissues to BOGS, leading to suboptimal esthetic outcomes in the nasolabial complex in cleft patients.

Therefore, it is recommended to perform adjunctive aesthetic surgeries, including corrective rhinoplasty, cheiloplasty, and allograft after BOGS in cleft patients.

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TABLES

Table 1. Demographic data of the subjects

	Cleft-Class III group (n=18; 10 UCLP and 8 BCLP)		Noncleft-Class III group (n=16)		p-value
	Mean	SD	Mean	SD	
Sex †	15 males and 3 females		9 males and 7 females		0.1341
Genioplasty †	10 (6 in UCLP and 4 in BCLP)		11		0.1854
mean age at T1 ††	22.33	3.57	22.20	2.45	0.8973
mean age at T2 ††	23.25	3.63	22.79	2.47	0.6636

† Fisher's exact test was performed.

†† Mann-Whitney test was performed.

CL/P, cleft lip and palate; UCLP, unilateral cleft lip and palate; BCLP, bilateral cleft lip and palate; SD, standard deviation; T1, one-month before bimaxillary orthognathic surgery; T2, at least 3 months after bimaxillary orthognathic surgery.

Table 2. Definition of the reference planes and the landmarks

Reference			Definition
Reference planes	Coronal reference plane [naso-fronto-zygomatic (NFZ) plane]		constructed using the nasion (N) point and the right and left fronto-zygomatic (FZ) points
	Horizontal reference plane [right Frankfort horizontal (R-FH) plane]		constructed with the right porion (Po) and the orbitale (Or), perpendicular to the NFZ plane
	Mid-sagittal plane		constructed with the N point, perpendicular to the NFZ and R-FH planes
Hard tissue landmarks	nasion (N)		The most anterior point of the frontonasal suture in the midsagittal plane (0,0,0)
	orbitale (Or)		The most inferior point of the lower margin of the bony orbit
	porion (Por)		The most superior point of the external auditory meatus
	anterior nasal spine (ANS)		Tip of the anterior nasal spine of the palatal bone in the hard palate
	Point A		The deepest point on the anterior contour of the maxillary alveolar arch
	incisor superior (Is)		The midpoint of the incisal edge of the maxillary central incisors
	incisor inferior (Ii)		The midpoint of the incisal edge of the mandibular central incisors
	Point B		The deepest point on the anterior contour of the mandibular alveolar arch
	pogonion (Pog)		The most anterior point in the symphysis
	menton (Me)		The most inferior point in the symphysis
Soft tissue landmarks	midline	soft tissue nasion (N′)	The most concave point in the tissue overlying the area of the frontonasal suture
		pronasale (Prn)	The most prominent point of apex nasi
		columella (Cm)	The most anterior point on columella of nose, representing anterior delimiter of nasolabial angle
		subnasale (Sn)	The midpoint of the angle at the columella base where the lower border of the nasal septum and upper lip surface meet
		Point A'	The deepest point on the soft tissue contour of the upper lip
		Labialis superioris (Ls')	The most prominent upper midline point of the vermilion border of the upper lip
		Stomion superius(Stms)	stomion of the upper lip
		Stomion inferius (Stmi)	stomion of the lower lip
		Labialis inferioris (Li')	The most prominent point of the vermilion border of the cupid bow of the lower lip
		Point B'	The most concave point on the curve between Li' and Pog'
		Pog'	The most prominent or anterior point of the chin in the midsagittal plane
		Me'	The lowest point on the contour of the soft tissue of the chin
	bilateral	Exocanthion (ex-R, ex-L)	The most lateral point at the outer commissure of the eye fissure
		zygomatic point (Zy-R, Zy-L)	A point where a vertical line from ex-R/L and horizontal line from ac-R/L meet
		Subalare (subal-R, subal-L)	A point at the lower limit of each alar base, where the alar base disappears into the skin of the upper lip, reversed from left to right in left-sided UCLP
		Alar curvature (ac-R, ac-L)	The most lateral point on the curved baseline of each ala, indicating the facial insertion of the nasal wing base, reversed from left to right in left-sided UCLP
		Crista philtri (cph-R, cph-L)	The points on each elevated margin of the philtrum just above the vermilion line, reversed from left to right in left-sided UCLP
		Cheilion (ch-L, ch-R)	The points at the mouth corner on the labial commissure, reversed from left to right in left-sided UCLP

Table 3. Definition of the soft tissue variables

Soft tissue variables			Definition
Nose	Linear (mm)	Alar width	ac-R-ac-L
		Alar base width	subal-R-subal-L
		Columella length	Cm-Sn
	Angular (°)	Nasolabial angle	Prn-Sn-Ls′
		Nasal tip angle	N’-Prn-Sn
		Nasal prominence angle	Zy-R-Prn-Zy-L
Upper lip	Linear (mm)	Philtrum height	Sn-Ls’
		Philtrum width	cph-R-cph-L
		Lip width	ch-R-ch-L
		Upper lip height	Sn-Stms
		Upper lip vermilion height	Ls’-Stms
	Angular (°)	Upper lip prominence angle	ch-R-Ls’-ch-L in worm’s eye view
Lower lip	Linear (mm)	Lower lip height	Stmi-Pog’
		Lower lip vermilion height	Li’-Stmi
	Angular (°)	Lower lip prominence angle	ch-R-Li’-ch-L in worm’s eye view
		Mentolabial angle	Li’-Point B′-Pog’

Table 4. Comparison of cephalometric characteristics between C-CIII and NC-CIII groups

Variables	C-CIII group (n=18)							NC-CIII group (n=16)							Comparison of C-CIll and NC-CIII groups		
	T1		T2		ΔT2-T1		Comparison of T1 and T2	T1		T2		ΔT2-T1		Comparison of T1 and T2	T1	T2	ΔT2-T1
	mean	SD	mean	SD	mean	SD	p-value	mean	SD	mean	SD	mean	SD	p-value	p-value	p-value	p-value
SNA	74.20	5.32	76.30	5.08	2.44	1.62	0.0018**	80.06	4.28	82.26	3.30	2.20	1.44	0.0004***	0.0010**	0.0005***	0.5459
SNB	76.38	6.07	73.18	5.65	-2.70	3.19	0.0018**	83.84	4.28	79.50	4.04	-4.35	1.29	0.0004***	0.0003***	0.0007***	0.0756
ANB	-2.18	3.03	3.12	2.87	5.14	3.09	0.0003***	-3.78	1.97	2.77	1.50	6.55	1.91	0.0004***	0.1049	0.2695	0.3170
A to N-Perp	-4.21	4.90	-2.17	4.79	2.26	2.26	0.0043**	0.51	3.82	1.94	3.33	1.43	1.69	0.0084**	0.0024**	0.0079**	0.2017
Pog to N-Perp	-0.95	10.86	-7.59	9.38	-5.83	6.92	0.0021**	11.96	7.51	0.17	6.86	-11.80	4.41	0.0004***	0.0008***	0.0173*	0.0064**
APDI	91.96	7.76	82.88	6.29	-8.80	5.42	0.0003***	98.34	6.80	87.98	5.68	-10.37	5.50	0.0004***	0.0228*	0.0454*	0.4687
Facial convexity	-6.63	7.01	3.33	6.34	9.64	6.64	0.8617	-11.03	5.89	3.37	3.12	14.40	6.17	0.0703	0.0008***	0.0003***	0.3884
Facial plane angle (Jarabak)	77.27	5.95	74.74	5.25	-2.01	2.84	0.0707	85.13	4.06	80.74	4.03	-4.39	2.15	0.2343	0.7171	0.8495	0.4902
Saddle angle	127.70	4.81	127.58	4.03	-0.41	1.90	0.4460	120.64	5.24	119.73	5.27	-0.91	1.94	0.0200*	0.9450	0.5346	0.1840
Articular angle	145.18	6.36	146.67	6.69	1.53	3.94	0.0096**	146.12	6.96	147.41	4.89	1.29	3.87	0.0174*	0.0977	0.1898	0.3254
Gonial angle	125.86	9.08	127.12	9.67	0.87	6.82	0.0057**	126.80	7.18	129.56	6.49	2.76	4.14	0.0004***	0.1473	0.3697	0.0024**
Bjork sum	398.73	8.62	401.37	8.52	1.98	4.35	0.0386*	393.56	6.10	396.70	5.95	3.14	4.91	0.0016**	0.5346	0.8902	0.0228*
Mandibular Body length	78.08	5.80	74.56	5.79	-3.32	4.92	0.0582	81.71	5.89	72.27	4.47	-9.44	4.63	0.1960	0.3697	0.2549	0.9450
Ramus height	55.21	5.52	53.38	6.50	-1.09	3.55	0.0096**	56.60	6.39	52.36	6.27	-4.25	4.29	0.0174*	0.0728	0.2142	0.2142
Facial height ratio (PFH/AFH)	65.04	5.69	63.83	5.58	-0.71	3.04	0.0084**	67.12	4.47	66.23	5.08	-0.89	4.10	0.0072**	0.3340	0.6538	0.1840
Mandibular plane angle (SN-MP)	36.49	7.76	38.76	8.01	1.84	3.40	0.0406*	31.51	5.35	34.62	5.39	3.11	4.08	0.0011**	0.2549	0.7301	0.0909
FMA	26.33	7.90	29.41	7.77	2.59	4.57	0.0099**	23.26	6.05	27.41	5.74	4.15	4.92	0.0004***	0.3170	0.4687	0.0942
SN-OP	18.58	7.08	21.34	8.92	2.33	5.13	0.0005***	15.99	5.06	20.95	4.16	4.96	3.46	0.0004***	0.0418*	0.1898	0.2548
FH-PP	-0.41	2.32	2.70	4.64	2.84	4.09	0.0009***	-1.91	3.58	3.86	2.88	5.77	3.23	0.0004***	0.0064**	0.6048	0.0492*
AB-MP	61.30	7.14	70.41	5.56	9.05	7.24	0.0003***	56.49	5.02	68.47	4.26	11.99	3.69	0.0004***	0.0909	0.7301	0.0701
ODI	60.90	7.27	73.12	7.70	11.89	9.98	0.0021**	54.58	4.03	72.34	4.36	17.76	4.50	0.0004***	0.0001***	0.0013**	0.0097*
U1-SN	101.02	9.42	98.59	9.99	-2.37	5.80	0.0707	111.74	8.51	106.40	8.57	-5.34	4.83	0.0011**	0.0027**	0.0208*	0.1049
IMPA	90.47	7.99	89.31	7.45	-0.48	6.25	0.3560	84.40	5.13	86.40	6.40	2.00	5.36	0.1208	0.0297*	0.2695	0.1840
Interincisal angle	129.78	10.10	130.73	10.20	0.87	4.95	0.4204	130.31	8.50	130.50	9.62	0.19	5.39	0.8767	0.6788	0.9450	0.4902

† Wilcoxon signed-rank test was performed.

†† Mann-Whitney test was performed.

* P<0.05, ** P<0.01, *** P<0.001

Table 5. Comparison of changes in the midline hard tissue landmarks between cleft-Class III and noncleft-Class III groups

Variables		C-CIII group (n=18)							NC-CIII group (n=16)							Comparison of C-Clll and NC-CIII groups		
		T1		T2		ΔT2-T1		Comparison of T1 and T2	T1		T2		ΔT2-T1		Comparison of T1 and T2	T1	T2	ΔT2-T1
		mean	SD	mean	SD	mean	SD	p-value	mean	SD	mean	SD	mean	SD	p-value	p-value	p-value	p-value
ANS	x	−0.84	2.49	−0.97	2.32	−0.12	1.77	0.4954	−0.27	1.22	−0.15	1.27	0.12	0.87	0.5303	0.2695	0.3006	0.8083
	y	−3.01	3.25	−4.56	3.96	−1.55	1.53	0.0019**	−4.46	4.05	−6.38	4.14	−1.92	2.56	0.0090**	0.4902	0.3254	0.4375
	z	−54.63	4.04	−55.97	3.59	−1.35	1.57	0.0049**	−55.01	4.28	−56.07	4.56	−1.07	2.05	0.0140*	0.6048	0.9312	0.9862
Point A	x	−0.11	1.89	−0.76	1.54	−0.66	1.83	0.0980	−0.44	1.21	−0.45	1.12	−0.02	0.77	0.6377	0.6788	0.4901	0.1330
	y	3.93	4.60	2.01	5.14	−1.93	1.60	0.0005***	−1.15	4.03	−3.01	4.19	−1.86	2.35	0.0027**	0.0034**	0.0047**	0.2925
	z	−63.74	3.95	−64.94	4.11	−1.21	1.60	0.0033**	−62.40	4.75	−63.21	5.13	−0.82	2.70	0.0072**	0.4687	0.2141	0.9725
Is	x	0.15	2.28	−0.50	1.66	−0.65	2.03	0.1989	−0.39	1.49	−0.61	0.87	−0.22	1.07	0.3520	0.5574	0.7300	0.5345
	y	−0.11	6.24	−1.31	6.34	−1.20	2.33	0.0347*	−5.97	5.17	−7.56	5.45	−1.59	2.83	0.0386*	0.0143*	0.0092**	0.8225
	z	−82.85	6.21	−84.08	5.65	−1.23	1.32	0.0009***	−83.10	6.42	−83.18	6.07	−0.08	3.15	0.3343	0.8360	0.6047	0.4075
Ii	x	−0.18	2.38	−0.51	2.08	−0.33	1.69	0.4703	−0.04	2.15	−0.46	1.19	−0.42	1.74	0.3942	0.9176	0.8902	0.7822
	y	−3.88	7.80	0.79	6.77	4.67	3.19	0.0004***	−8.98	6.66	−4.71	5.32	4.26	5.33	0.0262*	0.0977	0.0172*	0.6413
	z	−83.66	6.00	−83.33	5.67	0.33	1.93	0.3064	−83.47	7.41	−81.56	6.07	1.92	3.87	0.0437*	0.9725	0.4274	0.0727
Point B	x	0.10	2.60	−0.40	2.14	−0.50	2.20	0.2761	0.14	2.27	−0.70	1.20	−0.84	1.75	0.1089	0.9176	0.5459	0.8766
	y	3.47	8.93	8.92	7.70	5.45	3.53	0.0003***	−5.50	7.73	−0.14	6.61	5.36	5.55	0.0084**	0.0079**	0.0032**	0.4901
	z	−104.32	7.24	−103.07	6.36	1.25	2.79	0.0352*	−102.08	9.32	−99.42	8.38	2.66	3.93	0.0199*	0.3515	0.1571	0.4477
Pog	x	0.03	3.12	−0.59	2.81	−0.62	2.65	0.2461	0.27	2.75	−0.71	1.53	−0.98	2.12	0.0626	0.9450	0.9725	0.7561
	y	2.68	10.24	7.60	8.77	4.92	3.69	0.0004***	−7.97	8.98	−2.61	8.08	5.36	7.22	0.0174*	0.0042**	0.0030**	0.4076
	z	−120.05	7.18	−118.01	6.86	2.04	3.19	0.0123*	−116.59	9.78	−112.17	8.57	4.42	5.15	0.0072**	0.3170	0.0435*	0.1473
Me	x	−0.01	3.38	−0.48	2.98	−0.47	2.58	0.3520	0.30	2.82	−0.74	1.63	−1.04	2.07	0.0691	0.7825	0.9450	0.5344
	y	8.70	9.98	13.73	8.69	5.02	3.70	0.0003***	−1.76	9.26	3.63	8.09	5.39	7.52	0.0231*	0.0042**	0.0024**	0.4076
	z	−127.07	7.64	−125.81	7.18	1.26	2.87	0.0777	−123.90	10.11	−119.58	8.91	4.32	4.60	0.0038**	0.4274	0.0418*	0.0249*

x-axis, the horizontal reference plane, right Frankfort horizontal (R-FH) plane; y-axis: the coronal reference plane, naso-fronto-zygomatic (NFZ) plane; and z-axis: the mid-sagittal plane, a plane passing Nasion point, perpendicular to the NFZ and R-FH planes. A positive (+) sign indicated the left side and posterior and superior side to N point in the x-, y- and z-axis, respectively, while a negative (−) sign meant the opposite. The changes in x, y and z denoted the transverse, anteroposterior and vertical movement, respectively.

† Wilcoxon signed-rank test was performed.

† † Mann-Whitney test was performed.

* P<0.05, ** P<0.01, *** P<0.001

Table 6. Comparison of changes in the **midline** soft tissue landmarks between C-CIII and NC-CIII groups

Variables		C-CIII group (n=18)							NC-CIII group (n=16)							Comparison of C-CIll and NC-CIII groups		
		T1		T2		ΔT2-T1		Comparison of T1 and T2	T1		T2		ΔT2-T1		Comparison of T1 and T2	T1	T2	ΔT2-T1
		mean	SD	mean	SD	mean	SD	p-value	mean	SD	mean	SD	mean	SD	p-value	p-value	p-value	p-value
Prn	x	−0.64	2.01	−0.51	1.88	0.13	0.59	0.3452	0.21	1.28	−0.02	0.89	−0.24	0.82	0.1797	0.1289	0.2548	0.2413
	y	−24.00	4.73	−24.84	5.11	−0.84	1.04	0.0013**	−28.08	5.39	−29.23	5.65	−1.15	1.03	0.0011**	0.0368*	0.0384*	0.1047
	z	−48.28	3.67	−48.52	3.93	−0.24	0.80	0.2804	−46.62	4.39	−45.77	4.78	0.85	2.11	0.2238	0.3170	0.1049	0.0830
Cm	x	−0.24	1.56	−0.34	1.72	−0.10	0.75	0.9175	0.13	1.25	0.05	1.07	−0.08	0.98	0.7960	0.5232	0.6290	0.8630
	y	−18.39	5.41	−18.43	5.21	−0.03	0.49	0.6191	−22.95	5.34	−23.44	5.33	−0.49	1.89	0.3935	0.0845	0.0272*	0.7300
	z	−57.68	3.91	−58.03	4.15	−0.35	0.69	0.0148*	−54.57	4.76	−54.37	4.94	0.20	2.21	0.3519	0.0384*	0.0353*	0.8766
Sn	x	−1.07	2.24	−1.11	2.05	−0.04	0.55	0.6872	−0.24	1.22	−0.36	1.11	−0.12	0.87	0.6495	0.2272	0.2142	0.6536
	y	−10.50	4.55	−12.18	5.14	−1.68	1.52	0.0014**	−15.33	4.95	−17.17	4.97	−1.84	2.08	0.0032**	0.0071**	0.0107*	0.8630
	z	−60.41	3.99	−60.49	4.10	−0.09	0.80	0.5564	−57.70	4.62	−57.40	4.91	0.30	2.15	0.9176	0.0728	0.0435*	0.7170
Point A′	x	−1.07	2.07	−0.51	1.74	0.56	1.11	0.0217*	−15.33	1.12	−0.21	0.96	0.03	0.63	0.5701	0.1840	0.7561	0.0453*
	y	−8.92	4.85	−10.99	5.28	−2.07	1.47	0.0005***	−14.03	4.62	−16.29	4.80	−2.25	2.14	0.0023**	0.0064**	0.0058**	0.8630
	z	−63.72	4.50	−63.81	4.42	−0.09	1.00	0.8684	−62.05	5.95	−61.26	5.98	0.79	2.31	0.1089	0.4076	0.1125	0.1048
Ls′	x	0.08	2.50	−0.15	2.16	−0.22	0.83	0.5228	−0.14	1.29	−0.06	1.02	0.08	0.83	0.4560	0.3883	0.6047	0.3419
	y	−13.39	6.12	−14.26	5.99	−0.87	2.23	0.1221	−18.95	5.27	−21.15	5.28	−2.20	2.87	0.0072**	0.0130*	0.0024**	0.2695
	z	−71.79	4.93	−73.34	5.14	−1.54	1.74	0.0008***	−69.94	6.71	−70.04	6.84	−0.10	3.11	0.1398	0.6048	0.1840	0.2339
Stms	x	−0.28	1.79	−0.30	1.95	−0.01	0.71	0.6192	−0.01	1.59	−0.21	1.06	−0.20	0.89	0.6495	0.6915	0.8091	0.4789
	y	−11.01	6.12	−11.35	5.78	−0.34	2.48	0.4204	−16.05	5.80	−17.32	5.64	−1.28	3.11	0.0884	0.0533	0.0058**	0.7693
	z	−78.48	5.63	−80.11	5.78	−1.63	1.62	0.0005***	−77.14	6.61	−77.81	6.39	−0.67	2.87	0.0309*	0.5346	0.2407	0.5010
Stmi	x	−0.07	2.18	−0.23	1.92	−0.16	1.59	0.8446	−0.20	1.91	−0.28	1.09	−0.08	1.32	0.8160	0.7300	0.8091	0.9725
	y	−13.58	7.41	−9.89	6.82	3.69	3.56	0.0012**	−17.72	6.78	−15.73	5.74	1.99	4.57	0.0557	0.2695	0.0130*	0.4076
	z	−81.49	6.50	−83.16	6.44	−1.67	2.93	0.0049**	−79.20	6.65	−80.65	6.75	−1.45	3.35	0.0262*	0.3340	0.3339	0.9725
Li′	x	0.09	2.26	−0.16	1.92	−0.25	1.69	0.5349	−0.23	1.98	−0.41	1.24	−0.17	1.43	0.6791	0.4478	0.5345	0.7561
	y	−17.12	8.05	−12.71	7.03	4.41	2.93	0.0004***	−22.04	7.04	−18.90	6.42	3.14	5.26	0.0299*	0.1675	0.0297*	0.5346
	z	−91.78	7.66	−93.30	7.23	−1.52	2.76	0.0198*	−88.26	7.50	−90.15	6.58	−1.89	4.06	0.0782	0.2549	0.2272	0.5575
Point B′	x	0.13	2.35	−0.18	2.27	−0.31	2.00	0.4080	−0.07	1.98	−0.42	1.25	−0.35	1.43	0.4631	0.4902	0.5121	0.7558
	y	−10.10	8.88	−4.46	7.94	5.64	3.10	0.0002***	−17.51	7.51	−12.67	6.48	4.84	5.86	0.0200*	0.0228*	0.0037**	0.7825
	z	−100.01	7.39	−100.87	6.88	−0.86	2.62	0.1634	−96.57	8.65	−97.10	7.17	−0.53	3.98	0.4080	0.3697	0.0977	0.9176
Pog’	x	0.18	2.68	−0.39	2.72	−0.56	2.39	0.2396	0.01	2.23	−0.45	1.17	−0.45	1.85	0.4631	0.8902	0.6537	0.7170
	y	−10.19	9.45	−5.09	8.35	5.11	3.64	0.0004***	−18.80	7.83	−13.97	7.13	4.83	6.02	0.0151*	0.0118*	0.0042**	0.6413
	z	−112.62	7.36	−112.96	6.92	−0.34	2.16	0.3942	−111.29	9.34	−108.27	7.63	3.02	4.51	0.0437*	0.7301	0.0533	0.0324*
Me′	x	0.31	3.57	0.18	3.08	−0.13	2.47	0.8313	0.62	2.96	0.00	1.80	−0.61	2.18	0.4080	0.8766	0.9862	0.7043
	y	8.58	9.89	12.97	8.49	4.39	3.54	0.0004***	−2.17	8.53	3.76	7.39	5.94	6.66	0.0113*	0.0019	0.0034**	0.0977
	z	−135.14	8.68	−133.65	7.85	1.50	2.86	0.0854	−130.98	9.79	−127.36	8.66	3.62	4.81	0.0131*	0.3515	0.0418*	0.0845

Table 6. Continued

x-axis, the horizontal reference plane, right Frankfort horizontal (R-FH) plane; y-axis: the coronal reference plane, naso-fronto-zygomatic (NFZ) plane; and z-axis: the mid-sagittal plane, a plane passing Nasion point, perpendicular to the NFZ and R-FH planes.

A positive (+) sign indicated the left side and posterior and superior side to N point in the x-, y- and z-axis, respectively, while a negative (−) sign meant the opposite.

The changes in x, y and z denoted the transverse, anteroposterior and vertical movement, respectively.

† Wilcoxon signed-rank test was performed.

†† Mann-Whitney test was performed.

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

Table 7. Comparison of the change in the **bilateral** soft tissue landmarks between cleft-Class III and noncleft-Class III groups

Variables		C-CIII group (n=18)							NC-CIII group (n=16)							Comparison of C-CIII and NC-CIII groups		
		T1		T2		ΔT2-T1		Comparison of T1 and T2	T1		T2		ΔT2-T1		Comparison of T1 and T2	T1	T2	ΔT2-T1
		mean	SD	mean	SD	mean	SD	p-value	mean	SD	mean	SD	mean	SD	p-value	p-value	p-value	p-value
Zy-R	x	-49.45	2.76	-49.42	2.76	0.03	0.71	0.3938	-49.86	2.56	-49.57	2.41	0.30	0.70	0.0499*	0.3884	0.7042	0.0551
	y	3.18	4.13	2.14	4.41	-1.04	1.22	0.0031**	1.05	4.29	0.27	4.72	-0.77	1.60	0.1157	0.1572	0.2848	0.3250
	z	-52.17	4.16	-52.27	4.19	-0.10	0.64	0.2461	-51.20	3.83	-50.66	4.07	0.54	1.73	0.7529	0.6915	0.4687	0.1568
Zy-L	x	49.76	2.71	49.90	2.58	0.15	0.25	0.0090**	49.54	2.96	49.35	2.79	-0.20	0.85	0.8067	0.9450	0.7561	0.1460
	y	4.48	4.32	3.49	4.88	-0.99	1.20	0.0052**	1.60	3.30	0.69	3.73	-0.91	1.29	0.0277*	0.0272*	0.0624	0.6532
	z	-52.22	3.64	-52.04	3.66	0.17	0.44	0.1476	-50.69	4.35	-50.49	4.22	0.20	1.76	0.8068	0.4274	0.3883	0.1722
subal-R	x	-8.07	15.92	-8.16	16.08	-0.09	0.55	0.3379	-15.70	1.18	-15.77	1.30	-0.07	0.58	0.6415	0.6788	0.6047	0.8630
	y	-4.55	4.93	-6.42	5.04	-1.88	1.55	0.0007***	-7.81	4.28	-10.49	4.41	-2.68	2.28	0.0045**	0.0909	0.0297*	0.1290
	z	-58.59	4.77	-58.95	4.62	-0.36	0.94	0.1167	-57.59	4.60	-57.10	4.77	0.48	1.99	0.6909	0.5346	0.2694	0.2017
subal-L	x	8.66	16.14	8.71	16.49	0.05	0.94	0.9133	16.06	1.85	15.90	1.29	-0.16	1.31	0.8361	0.7043	0.4075	0.9313
	y	-4.04	4.72	-6.41	5.10	-2.37	1.42	0.0003***	-7.18	4.12	-9.86	4.00	-2.68	2.32	0.0019**	0.1049	0.0453*	0.7043
	z	-58.86	3.97	-59.25	4.12	-0.39	0.73	0.0429*	-57.15	4.57	-56.67	4.67	0.48	1.96	0.6050	0.4274	0.1049	0.1049
ac-R	x	-10.68	19.07	-10.83	19.47	-0.15	0.88	0.5694	-20.07	1.58	-20.16	2.09	-0.09	0.93	0.5720	0.6168	0.7561	0.8901
	y	-6.55	4.47	-8.31	4.73	-1.77	2.17	0.0056**	-9.61	4.79	-13.13	4.70	-3.52	2.80	0.0011**	0.0845	0.0087**	0.0845
	z	-52.10	4.05	-52.16	4.21	-0.06	0.59	0.2450	-50.99	3.99	-50.28	4.33	0.72	2.11	0.2559	0.6538	0.3006	0.1616
ac-L	x	9.68	19.99	9.80	20.64	0.12	1.10	0.6791	19.51	1.79	19.58	1.33	0.07	1.49	0.1520	0.8091	0.4076	0.6042
	y	-6.71	4.37	-8.89	4.17	-2.18	1.30	0.0002***	-10.71	4.41	-12.60	4.62	-1.89	2.34	0.0045**	0.0272*	0.0249*	0.5232
	z	-52.08	3.67	-52.02	3.80	0.06	0.54	0.6190	-50.82	4.14	-50.19	4.29	0.64	2.08	0.2455	0.5121	0.3515	0.4074
cph-R	x	-4.39	8.61	-4.42	8.17	-0.03	1.11	0.9058	-7.16	1.36	-7.14	1.41	0.02	1.07	0.9250	0.6290	0.8630	0.8902
	y	-11.97	5.83	-13.02	5.97	-1.05	2.15	0.0778	-17.31	5.34	-19.53	5.22	-2.22	2.55	0.0032**	0.0228*	0.0024**	0.2848
	z	-69.67	5.32	-71.49	5.29	-1.82	1.79	0.0002***	-67.88	6.51	-67.82	6.75	0.06	2.98	0.0980	0.6048	0.1205	0.0272*
cph-L	x	3.57	7.18	3.20	7.74	-0.37	1.17	0.5321	6.27	1.53	6.14	0.97	-0.13	1.11	0.6909	0.8766	0.8630	0.4474
	y	-12.33	5.76	-13.12	5.77	-0.78	1.90	0.1024	-17.50	5.13	-19.59	5.10	-2.09	2.79	0.0066**	0.0272*	0.0021**	0.1784
	z	-70.00	4.94	-71.49	5.22	-1.49	2.07	0.0038**	-67.79	6.75	-67.63	6.72	0.16	3.35	0.2330	0.4174	0.0977	0.2016
ch-R	x	-10.64	22.34	-10.56	21.20	0.08	1.79	0.8446	-24.09	2.06	-23.31	2.25	0.78	1.75	0.0980	0.1125	0.1898	0.3170
	y	-2.66	6.35	-0.55	5.89	2.11	2.96	0.0084**	-7.78	6.19	-7.15	4.73	0.63	5.48	0.3935	0.0418*	0.0014**	0.3006
	z	-82.00	5.68	-83.72	6.16	-1.72	2.05	0.0038**	-80.80	6.33	-81.25	5.86	-0.45	2.98	0.1627	0.7301	0.2407	0.3515
ch-L	x	10.73	22.09	10.55	21.86	-0.18	1.55	0.6475	24.39	2.41	23.35	1.15	-1.05	2.06	0.0664	0.0845	0.6047	0.1729
	y	-2.67	6.62	-0.19	6.08	2.48	3.34	0.0074**	-7.23	5.38	-6.76	4.46	0.47	4.23	0.3942	0.0728	0.0025**	0.0977
	z	-82.23	5.42	-83.99	5.63	-1.76	1.30	0.0005***	-80.54	6.28	-81.20	6.19	-0.67	2.52	0.0783	0.5575	0.1473	0.1957

Table 7. Continued

x-axis, the horizontal reference plane, right Frankfort horizontal (R-FH) plane; y-axis: the coronal reference plane, naso-fronto-zygomatic (NFZ) plane; and z-axis: the mid-sagittal plane, a plane passing the N point, perpendicular to the NFZ and R-FH planes.

A positive (+) sign indicated the left side and posterior and superior side to N point in the x-, y- and z-axis, respectively, while a negative (−) sign meant the opposite. Landmarks (subal-R/L, ac-R/L, cph-R/L and ch-R/L) of left-sided UCLP patients were reversed from left to right side so that all the UCLP patients would have their cleft defects on the right side homogeneously.

The changes in x, y and z denoted the transverse, anteroposterior and vertical movement, respectively.

† Wilcoxon signed-rank test was performed.

†† Mann-Whitney test was performed.

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

Table 8. Correlations and ratios of the hard-to-soft tissue landmark movement

	C-CIII group									NC-CIII group								
	x-axis			y-axis			z-axis			x-axis			y-axis			z-axis		
	R	p-value	ratio	R	p-value	ratio	R	p-value	ratio	R	p-value	ratio	R	p-value	ratio	R	p-value	ratio
ΔANS : ΔSn	0.327	0.185	0.33	0.621	0.006**	1.08	0.226	0.366	0.06	-0.057	0.835	-0.97	0.907	0.000***	0.81	0.779	0.000***	1.05
ΔPoint A : ΔPoint A′	0.158	0.531	-0.85	0.780	0.000***	1.08	0.057	0.824	0.07	0.140	0.606	-1.77	0.908	0.000***	0.91	0.768	0.001**	0.86
ΔIs : ΔLs′	0.615	0.007**	0.34	0.792	0.000***	0.72	0.422	0.081	1.26	0.250	0.350	-.036	0.856	0.000***	1.01	0.906	0.000***	0.99
ΔIi : ΔLi′	0.783	0.000***	0.75	0.838	0.000***	0.94	0.294	0.237	-4.59	0.942	0.000***	0.41	0.933	0.000***	0.99	0.756	0.001**	0.74
ΔPoint B : ΔPoint B′	0.914	0.000***	0.62	0.913	0.000***	1.04	0.790	0.000***	-0.69	0.970	0.000***	0.42	0.967	0.000***	1.06	0.651	0.006**	1.01
ΔPog : ΔPog’	0.909	0.000***	0.91	0.942	0.000***	1.04	0.500	0.035*	-0.17	0.869	0.000***	0.47	0.986	0.000***	0.83	0.531	0.034*	0.88
ΔMe : ΔMe′	0.879	0.000***	0.28	0.840	0.000***	0.87	0.917	0.000***	1.19	0.922	0.000***	0.59	0.971	0.000***	0.89	0.920	0.000***	1.05

x-axis, the horizontal reference plane, right Frankfort horizontal (R-FH) plane; y-axis: the coronal reference plane, naso-fronto-zygomatic (NFZ) plane; and z-axis: the mid-sagittal plane, a plane passing Nasion point, perpendicular to the NFZ and R-FH planes.

Bivariate Pearson correlation test was performed to estimate correlations between changes in the hard and the corresponding soft tissue landmarks.

R, correlation coefficient; Ratio, ratio of the amount of change in the hard-to-soft tissue landmark movement; A positive (+) sign indicated the change with the same direction and a negative (-) sign, the opposite direction.

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

Table 9. Comparison of changes in soft tissue measurement variables between C-CIII and NC-CIII groups

Variables	UCLP group (n=10)							BCLP group (n=8)							Comparison of UCLP and BCLP		
	T1		T2		ΔT2-T1		Comparison of T1 and T2	T1		T2		ΔT2-T1		Comparison of T1 and T2	T1	T2	ΔT2-T1
	mean	SD	mean	SD	mean	SD	p-value	mean	SD	mean	SD	mean	SD	p-value	p-value	p-value	p-value
Alar width	42.79	4.28	43.87	4.28	1.09	0.93	0.0009 ***	39.72	2.79	39.43	3.28	-0.29	2.42	0.6051	0.0272 *	0.0030 **	0.0728
Alar base width	35.03	4.25	35.57	4.08	0.54	1.14	0.0429 *	31.77	2.10	31.40	1.90	-0.36	1.84	0.8361	0.0173 *	0.0024 **	0.1379
Nasolabial angle	116.30	14.69	123.19	15.25	6.89	9.14	0.0029 **	112.32	10.85	112.88	10.57	0.56	9.74	0.2343	0.5346	0.1048	0.1572
Nasal tip angle	107.65	7.75	108.36	9.38	0.71	2.70	0.2485	101.29	5.02	102.23	5.35	0.93	2.91	0.1788	0.0190 *	0.0297 *	0.7562
Nasal prominence angle	120.87	4.99	121.29	4.77	0.42	1.35	0.2860	118.37	6.73	118.03	7.65	-0.34	3.04	0.1961	0.2695	0.2141	0.0249 *
Columellar length	8.51	1.96	6.90	1.65	-1.61	1.51	0.0005 ***	8.18	1.35	6.95	1.10	-1.23	1.29	0.0038 **	0.3884	0.8360	0.6291
Philtrum height	12.39	2.64	13.45	2.23	1.06	1.24	0.0038 **	13.01	2.86	13.13	2.96	0.12	1.98	0.5014	0.5575	0.8091	0.1290
Philtrum width	16.49	2.62	16.47	2.69	-0.02	1.28	0.9826	13.55	1.34	13.45	1.30	-0.10	1.28	0.9176	0.0010 **	0.0003 ***	0.7825
Lip width	48.03	2.54	46.77	2.43	-1.27	2.09	0.0279 *	48.55	3.92	46.50	2.89	-2.05	2.96	0.0200 *	0.7043	0.3515	0.5121
Upper lip height	18.40	3.38	19.88	3.11	1.48	1.34	0.0012 **	19.69	3.13	20.33	2.63	0.63	1.83	0.1337	0.3697	0.7300	0.2408
Upper lip vermilion height	7.34	1.73	7.50	1.97	0.16	1.20	0.8446	7.98	0.90	8.88	1.30	0.90	1.19	0.0151 *	0.2848	0.0384 *	0.0249 *
Upper lip prominence angle	116.01	9.69	106.57	7.70	-9.44	5.79	0.0002 ***	113.09	7.86	103.55	5.29	-9.55	8.13	0.0045 **	0.4478	0.2271	0.5121
Lower lip height	31.66	3.69	30.47	2.91	-1.20	2.57	0.0707	31.81	4.72	28.03	2.51	-3.78	4.78	0.0097 ***	0.8902	0.0249 *	0.1675
Lower lip vermilion height	11.09	1.85	10.66	1.67	-0.43	1.59	0.4204	10.09	1.49	10.19	1.02	0.10	1.54	0.8361	0.0624	0.2141	0.5121
Lower lip prominence angle	107.34	6.25	112.25	4.99	4.92	4.68	0.0007 ***	112.32	7.34	114.37	7.03	2.05	6.03	0.1208	0.0418 *	0.5120	0.1784
Mentolabial angle	138.91	12.85	129.39	10.56	-9.52	10.82	0.0043 **	144.28	15.23	128.90	12.55	-15.39	13.82	0.0023 **	0.1205	0.8630	0.0785

† Wilcoxon signed-rank test was performed.

†† Mann-Whitney test was performed.

* P<0.05, ** P<0.01, *** P<0.001

FIGURES

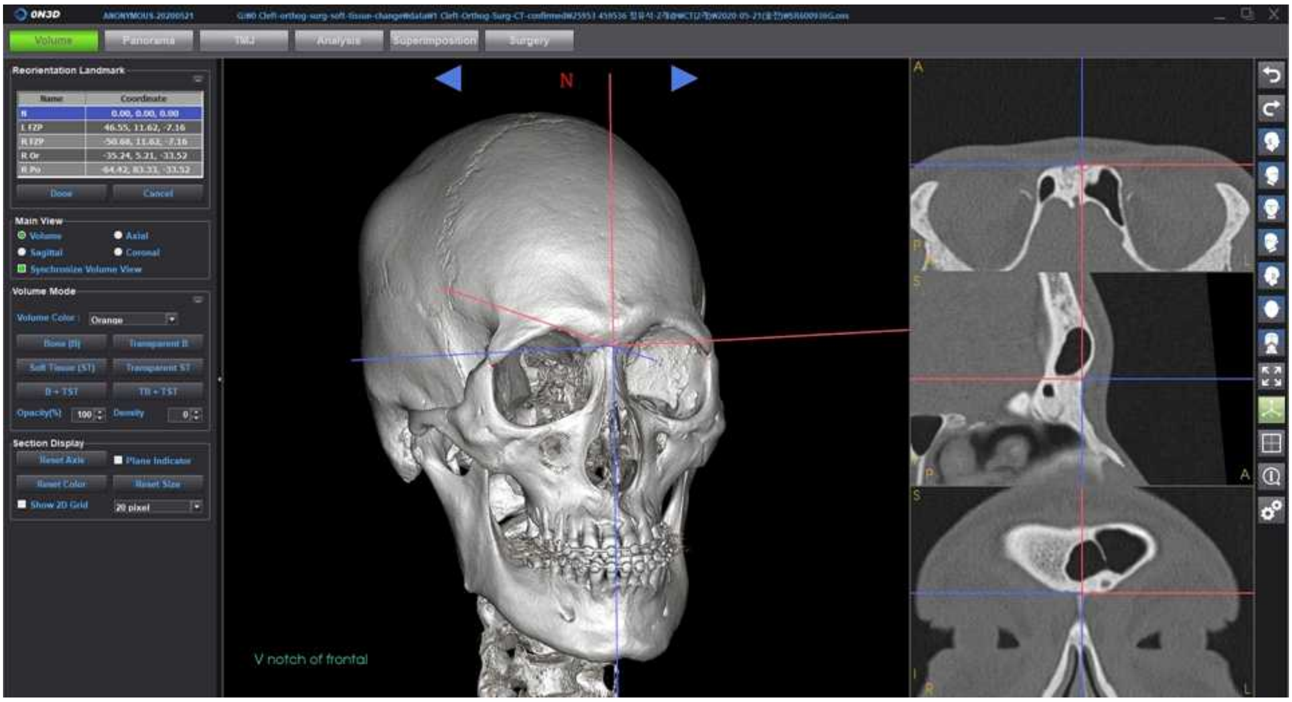

Figure 1. Reference planes: 1, coronal plane [y-axis; naso-fronto-zygomatic (NFZ) plane]; 2, horizontal plane [x-axis; right Frankfort horizontal (R-FH) plane]; 3, mid-sagittal plane (z-axis; a plane passing Nasion point, perpendicular to the NFZ and R-FH planes).

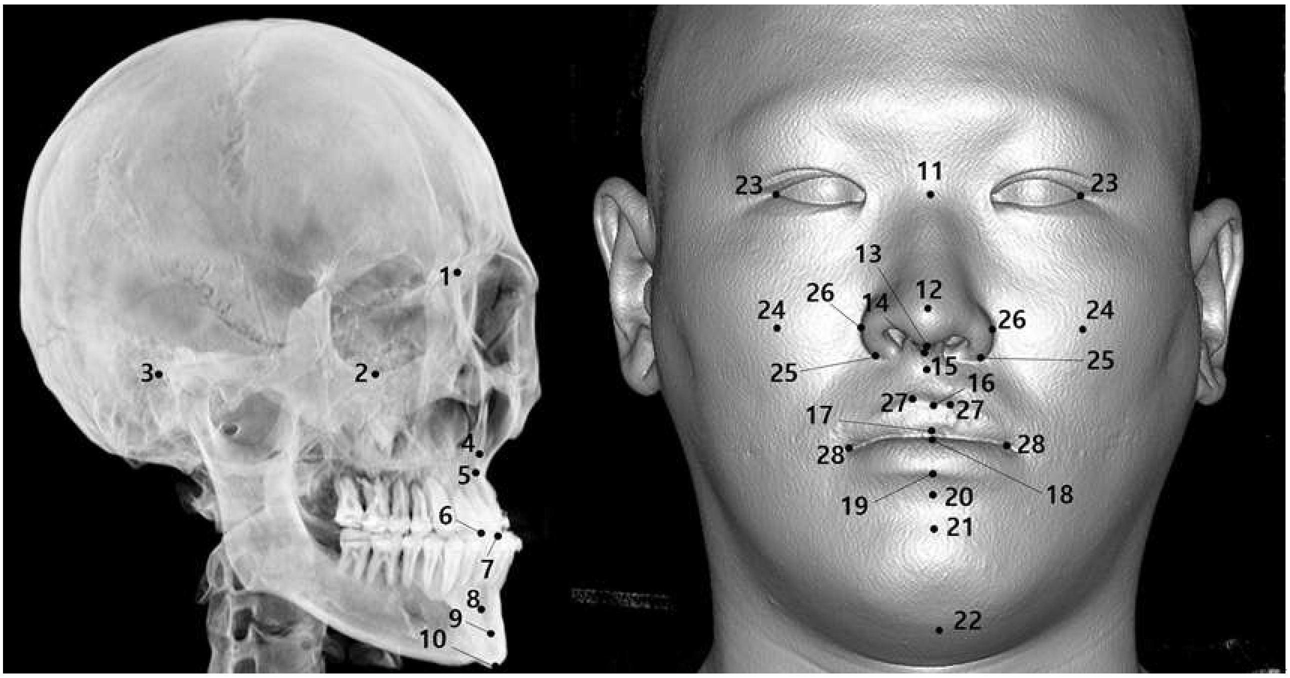

Figure 2. Hard and soft tissue landmarks. Midline hard tissue landmarks: 1, N (nasion); 2, Or (orbitale); 3, Por (porion); 4, ANS (anterior nasal spine); 5, Point A; 6, Is (incisor superior); 7, Ii (incisor inferior); 8, Point B; 9, Pog (pogonion); 10, Me (menton). Midline soft tissue landmarks: 11, N'; 12, Prn; 13, Cm; 14, Sn; 15, Point A'; 16, Ls′; 17, Stms; 18, Stmi; 19, Li′; 20, Point B'; 21, Pog'; 22, Me', Bilateral soft tissue landmarks: 23, ex (-R/-L); 24, Zy (-R/-L); 25, subal (-R/-L); 26, ac (-R/-L); 27, cph (-R/-L); 28, ch (-R/-L).

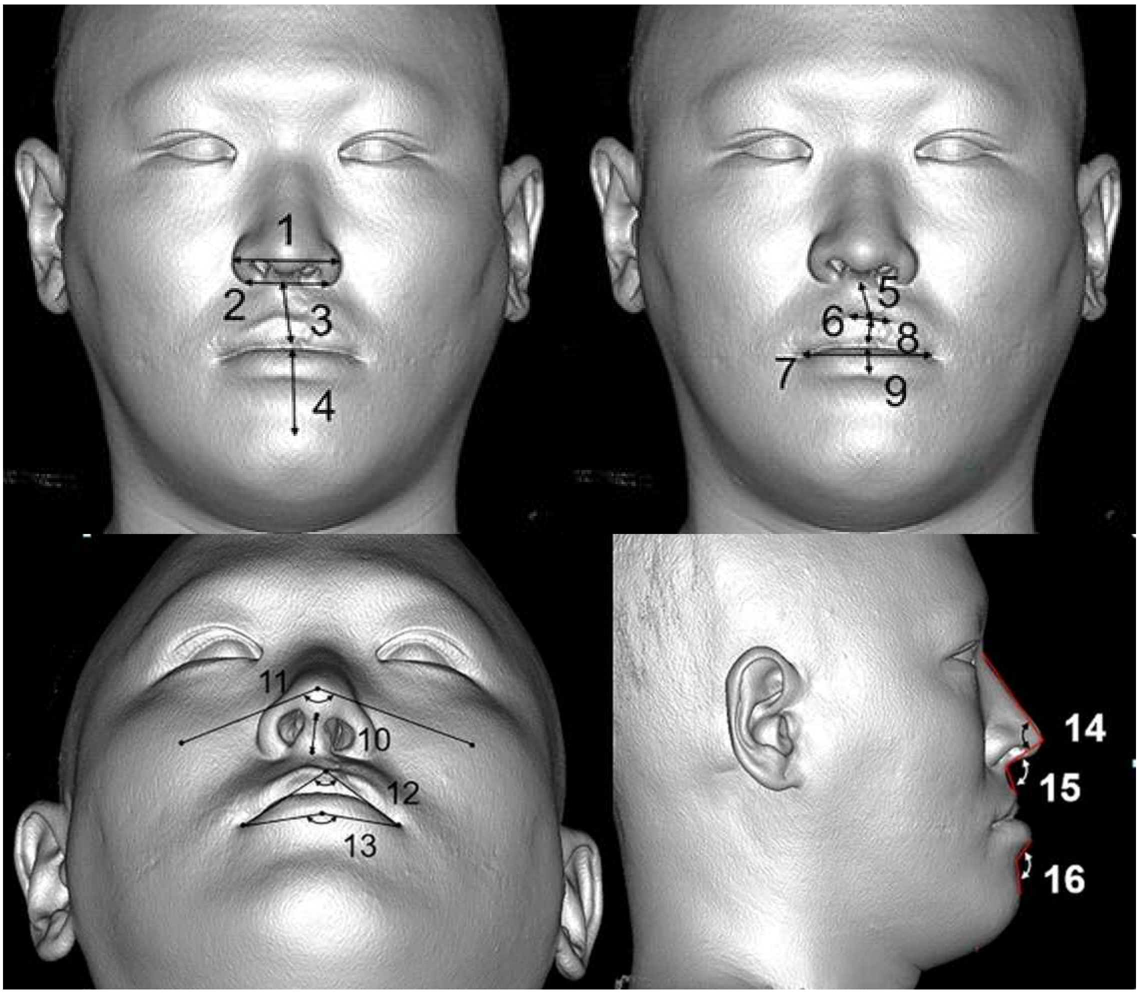

Figure 3. Soft tissue measurement variables. 1, Alar width; 2, Alar base width; 3, Upper lip height; 4, Lower lip height; 5, Philtrum height; 6, Philtrum width; 7, Lip width; 8, Upper lip vermilion height; 9, Lower lip vermilion height; 10, Columella length; 11, Nasal prominence angle; 12, Upper lip prominence angle; 13, Lower lip prominence angle; 14, Nasal tip angle; 15, Nasolabial angle; 16, Mentolabial angle.

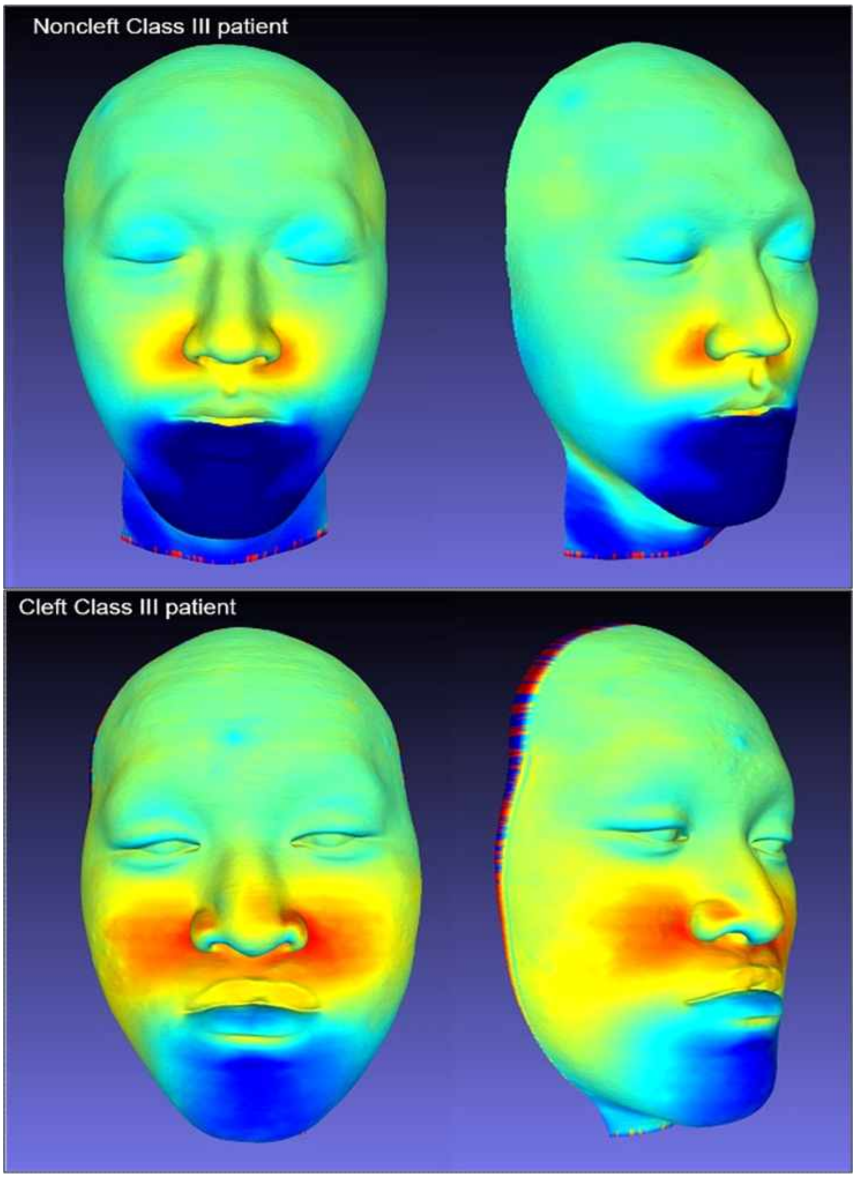

Figure 4. Examples of the typical facial soft tissue changes in cleft class III patients and noncleft class III patients. After the volume data of computed tomography were converted into the surface data as stereolithography (STL) files with Amira 6.3.0 software (Thermo Scientific Inc, Waltham, MA), heat maps were generated with open-source software Meshlab.

국문 초록

구순구개열 환자의 양악 악교정수술 후 3차원 안면 연조직 변화 분석

서 지 희

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목적: 본 연구는 구순구개열 환자에서 양악 악교정수술 시행 이후 코와 상하순, 턱을 포함한 안면 연조직의 3차원적인 변화를 연구하기 위해 시행되었다.

방법: 연구 대상은 2015년부터 2020년까지 서울대학교치과병원에서 양악 악교정수술을 받은 34명의 한국인 골격성 III급 부정교합 환자로 구성되었으며, 18명의 구순구개열 III급 수술 환자군 (실험군. C-CIII group)과 16명의 일반 III급 수술환자군 (대조군, NC-CIII group)으로 분류하였다. 3차원 컴퓨터 단층 촬영 영상을 수술 한 달 전(T1)과 술후 3달 이상 경과한 시점(T2)에 촬영하여, 34개의 경조직 및 연조직 랜드마크를 소프트웨어 상에서 자동으로 식별하였다. 수술 전후

랜드마크의 이동량과 방향 및 16개 연조직 변수의 변화 양상을 측정하였다. 만-휘트니 검증 (Mann-Whitney test), 윌콕슨 부호 순위 테스트 (Wilcoxon signed-rank test), 카이제곱검정 (Chi-square test), 피셔의 정확검정 (Fisher's exact test) 및 이변량 상관 분석 (bivariate correlation analysis) 을 시행하였다.

결과: C-CIII 군은 NC-CIII 군과 비교하여 T1과 T2 단계 모두에서, 경조직과 연조직 랜드마크가 더 후방에 위치하였고, 비익 (ala), 비익 기저부 (alar base) 및 인중 (philtrum)의 폭이 더 길었으며, 비첨 (nasal tip)은 더 둔각이었다. 경조직 이동에 따른 연조직 변화 비율에서, C-CIII 군이 비저 (ΔSn/ΔANS, 1.08 vs. 0.81)와 상순의 상부 (UL, ΔPoint A'/ΔPoint A, 1.08 vs. 0.91) 에서 더 높은 값을, 상순의 하부 (ΔLs'/ΔIs, 0.72 vs. 1.01) 에서 더 낮은 값을 보였다. 0.90 이상의 높은 상관 관계를 보이는 경조직-연조직 랜드마크의 수는 C-CIII 군이 NC-CIII 군보다 작았다 (2 vs. 6).

결론: 구순구개열 환자들은 일차 구순성형술과 비성형술로 유발된 코와 상순에 존재하는 반흔 조직과 수축되고 비정상적으로 연결된 근육들로 인해 양악 악교정 수술 이후 비순부 연조직 (nasolabial soft tissue) 이 일반 골격성 III급 수술 환자들과는 다른 반응 행태를 보인다.

주요어: 3차원 분석; 안면 연조직 변화; 양악 악교정 수술; 구순구개열

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