

Original article

The effects of maxillary movement on nasal septum and internal nasal valve following Le Fort I osteotomy:

A CBCT study

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Abstract:

Objective: Le Fort I osteotomy (LF-IO) is a technique for the correction of dentofacial deformities, resulting in significant anterior nasal change. This study aimed to investigate the effect of different maxillary movements on the nasal septum (NS) and internal nasal valve (INV) after LF-IO with cone beam computed tomography (CBCT) images. **Materials and Methods:** A retrospective study including 39 patients who underwent LF-IO and received CBCT pre-operatively and 6-to-12-month post-operative evaluation was performed. All patients were divided into three groups according to their maxillary movement direction. Group 1 underwent maxillary advancement, group 2 underwent maxillary impaction, and group 3 (combination) underwent both maxillary advancement and impaction. NS angle at nasion level, INV angle, and INV area at pre-operative and post-operative period on CBCT images were measured and evaluated. **Results:** The median of NS angle and the mean INV angle had a significant increase post-operatively in all three groups. However, INV area showed no statistically significant change after surgery. When the amount of the changes among the three groups were compared, the results revealed no statistically significant change in all three groups. Correlation between changes of NS angle and the magnitude of maxillary advancement was moderately positive with statistically significant difference. **Conclusions:** Advancement and impaction of maxilla in LF-IO influenced an increase in the NS angle and INV angle. A moderately positive correlation between changes of NS angle and the magnitude of maxillary advancement was found.

Keywords: ● Nasal septum ● Internal nasal valve ● Le Fort I osteotomy ● Maxillary movement ● Cone beam computed tomography

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นิพนธ์ต้นฉบับ

ผลของการเคลื่อนขากรรไกรบนต่อผนังกันช่องจมูกและลิ้นจมูกส่วนใน หลังการศัลยกรรมตัดกระดูกแบบเลอฟอร์ตชนิดที่ 1: การศึกษาภาพรังสี ส่วนตัดอาศัยคอมพิวเตอร์ลำรังสีรูปกรวย

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¹กองทันตกรรม โรงพยาบาลพระมงกุฎเกล้า ²คณะทันตแพทยศาสตร์ สถาบันเทคโนโลยีพระจอมเกล้าคุณทหารลาดกระบัง ³ภาควิชาศัลยศาสตร์ช่องปาก และแม็กซิลโลเฟเชียล ⁴ภาควิชารังสีวิทยาช่องปากและแม็กซิลโลเฟเชียล คณะทันตแพทยศาสตร์ มหาวิทยาลัยมหิดล

บทคัดย่อ

วัตถุประสงค์ การศัลยกรรมตัดกระดูกแบบเลอฟอร์ตชนิดที่ 1 เป็นเทคนิคการผ่าตัดแก้ไขเคลื่อนที่กระดูกขากรรไกรบนทั้งขึ้นและรวมถึงฟันบนให้มาอยู่ในตำแหน่งที่เหมาะสม การวิจัยนี้มีวัตถุประสงค์เพื่อประเมินผลของการเคลื่อนขากรรไกรบนต่อผนังกันช่องจมูกและลิ้นจมูกส่วนใน ภายหลังจากการศัลยกรรมตัดกระดูกแบบเลอฟอร์ตชนิดที่ 1 **วิธี การวิจัย** การศึกษาย้อนหลังภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ลำรังสีรูปกรวยของ ผู้ป่วยจำนวน 39 คน ที่ได้รับการรักษาโดยการศัลยกรรมตัดกระดูกแบบเลอฟอร์ตชนิดที่ 1 โดยแบ่งผู้ป่วยออกเป็นสามกลุ่มตามการเคลื่อนที่ของขากรรไกรบน กลุ่มที่ 1 เคลื่อนกระดูกขากรรไกรบนมาทางด้านหน้า กลุ่มที่ 2 เคลื่อนกระดูกขากรรไกรบนไปทางด้านบน กลุ่มที่ 3 เคลื่อนกระดูกขากรรไกรบนมาทางด้านหน้าและไปทางด้านบน โดยมมผนังกันช่องจมูก มุมลิ้นจมูกส่วนใน และพื้นที่ลิ้นจมูกส่วนในจะถูกวัดก่อนและหลังรักษาและนำมาวิเคราะห์ **ผลการศึกษา** หลังการทำศัลยกรรม ค่ามัธยฐานของมุมผนังกันช่องจมูกและค่าเฉลี่ยของมุมลิ้นจมูกส่วนในของค่าเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติ เมื่อเปรียบเทียบระหว่างทั้งสามกลุ่มแล้วพบว่าแตกต่างกันอย่างไม่มีนัยสำคัญทางทางสถิติ ความสัมพันธ์ระหว่างการเปลี่ยนแปลงของมุมผนังกันช่องจมูกและระยะทางการเคลื่อนที่กระดูกขากรรไกรบนมาทางด้านหน้าพบว่ามีความสัมพันธ์เชิงบวกระดับปานกลางและมีนัยสำคัญทางทางสถิติ **สรุป** การเคลื่อนกระดูกขากรรไกรบนมาทางด้านหน้าและ/หรือไปทางด้านบนในงานศัลยกรรมตัดกระดูกแบบเลอฟอร์ตชนิดที่ 1 ส่งผลต่อการเพิ่มขึ้นของมุมผนังกันช่องจมูกและมุมลิ้นจมูกส่วนใน และพบความสัมพันธ์เชิงบวกระดับปานกลางระหว่างการเปลี่ยนแปลงของมุมผนังกันช่องจมูกและระยะทางการเคลื่อนที่กระดูกขากรรไกรบนมาทางด้านหน้า

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● การเคลื่อนกระดูกขากรรไกรบน ● ภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ลำรังสีรูปกรวย

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Introduction

Le Fort I osteotomy (LF-IO) is generally used to correct maxillary position in three dimensions. It treats class II and III skeletal malocclusions, vertical maxillary excess, and hypoplasia.¹ This operation involves the nasal septal (NS) osteotomy and results in changes in the maxilla location that can potentially leave multiple adverse physiologic sequelae for the nasal structure as well as facial esthetics post-operatively.² In addition, LF-IO is known to have the potential to change the nasal airway, especially the most resistant region of the nasal airway which can also be called the internal nasal valve (INV).³ Due to racial differences, Asians have a larger INV, but a lower incidence and severity of NS deviation compared to Caucasians.^{4,5} We may presume different results between Caucasian and Asian patients after LF-IO.

Due to limitation of 2-dimensional information and superimposed images of various anatomic complex midface structures, multislice detector computed tomography (MDCT) is becoming an essential tool for diagnosis. Especially, dental CT or cone beam computed tomography (CBCT) has advantages in terms of lower radiation doses, higher resolution, and lower cost than the existing MDCT protocol.⁶

This study aims to evaluate the effects of LF-IO on the NS angle and INV (angle and cross-sectional area) as well as to investigate the influence of different directions of the maxillary movement on the NS angle and INV. We hypothesized that there were changes of NS angle and INV after maxillary impaction and advancement movements. In this CBCT study, the NS angle, INV angle, and INV area were measured and compared pre-operatively and post-operatively.

Methods

Study Design

This retrospective study consisted of 39 Thai, skeletal class III malocclusion patients who underwent one-piece LF-IO performed by one oral and maxillofacial surgeon at the Oral and Maxillofacial Clinic, Faculty of Dentistry, Mahidol University, Thailand, from January 2017 to December 2021. The following patients were included in this study: (1) patients who were medically healthy; (2) patients who were over 18 years of age; and (3) patients who had taken CBCT before and passed 6-to-12-month after the surgery. The following patients were excluded: (1) patients with craniofacial anomaly such as cleft lip and palate; (2) patients who post-traumatic facial deformity; (3) patients with a history of septorhinoplasty or turbinoplasty; (4) patients who underwent multi-piece LF-IO; and (5) patients who had asymmetrical impactions and correction of upper midline shift > 2 mm.

All patients had a treatment plan established at the orthognathic conference by the oral and maxillofacial surgery department. All patients underwent a standard LF-IO under general anesthesia. To control the width of the alar base, an alar cinch suture was performed intraorally prior to suturing the intraoral vestibular incision.

This study was approved by Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, institutional Review Board with the certificate of approval COA.No.MU-DT/PY-IRB 2021/099.2812.

Data collection methods

All of the 39 patients' demographic data (sex and age) were recorded from their surgical records. All patients were divided into three groups according to their maxillary movement direction (thirteen participants per group). Group 1 underwent maxillary advancement, group 2 underwent maxillary impaction, and group 3 (combination) underwent both maxillary advancement and impaction. The magnitude of maxillary movements was recorded in mm based on the treatment plan and model surgery. On CBCT image, each patient's pre-operative and post-operative NS angle, INV angle, and INV area were measured.

CBCT measurement methodology

CBCT of all patients was performed with Kodak CS9500 machine (Carestream, New York, NY, USA) using the following parameters: 90 kV, 10 mA, 10.8-s exposure time and 20.6x18 cm field of view. The voxel size was 0.3 mm. The images were viewed in a dimly lit room on a 23.8-inch Dell P2419H identical liquid crystal display (LCD) monitors with a screen resolution of 1,920x1,080 pixels and a color depth of 24-bits.

For measurements on NS angle at nasion level (Figure 1), Frankfort horizontal planes were established as reference planes. Then, coronal sections at the nasion level were constructed. The NS angle was established by measuring the line from the palatal suture to the crista galli and the line from the crista galli to the apex of the most protruded septal deviation.

For measurements on INV (Figure 2), reformatted coronal CBCT image perpendicular to the estimated acoustic axis was chosen to be 1 mm anterior to the head of the inferior turbinate.^{5,7,8} For patients with asymmetric appearance of the turbinate's head, coronal cuts were assessed

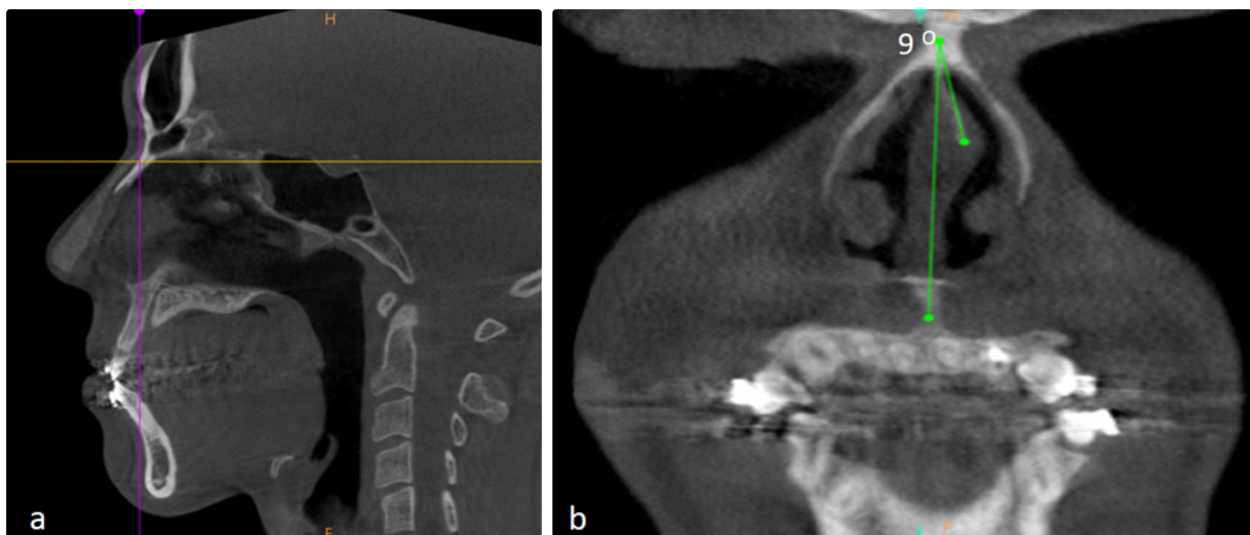
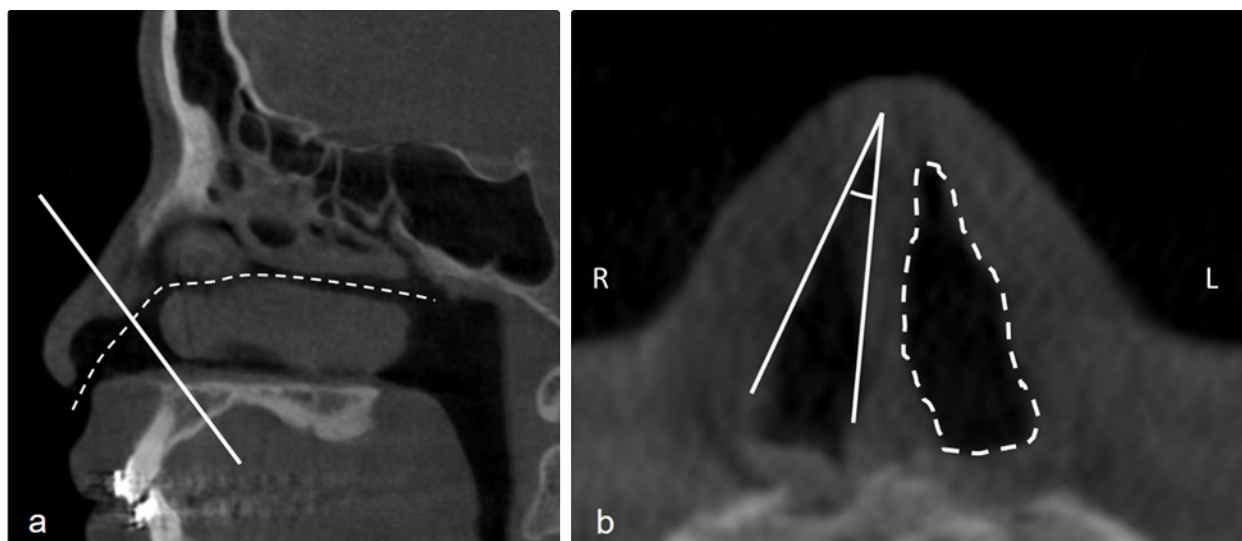


Figure 1 Angular measurement of the nasal septal deviation at nasion level

(a) Nasion plane on mid sagittal view; (b) Nasal septal angle on coronal view at nasion plane



(a) A sagittal view showed estimated acoustic axis (dotted line). Then a reformatted coronal plane perpendicular to the estimated acoustic axis was chosen to be 1 mm anterior to the head of the inferior turbinate.

(b) A reformatted coronal plane showed internal nasal valve angle (right) and internal nasal valve area (left)

Figure 2 Measurements of internal nasal valve angle and area at the reformatted coronal CBCT image

separately for each side. After obtaining the reformatted CBCT image, the INV angle was measured along both the medial and lateral nasal airway lumen margins. Irregularities in the medial and lateral walls were averaged. The apex of both margins was extended to the exterior of the nasal soft tissue. The INV area was obtained by measuring the area of air density of the reformatted coronal CBCT image.

NS angle, INV angle, and INV area were evaluated by the CBCT viewer (Carestream Dental software). One researcher performed all radiographic analyses. The measurements were performed twice with a minimum time gap of 2 weeks to verify the reliability of intra-observer results. Intraclass correlation coefficients with 95 percent confidence level ranged from 0.892 to 0.995, exhibiting almost perfect agreement.

Statistical analysis

Normal distribution was tested by using the Kolmogorov–Smirnov test. For comparison within each group, the differences between pre-operative and post-operative values were analyzed with paired sample t-test in normal distribution data or Wilcoxon test was used in nonparametric data. For comparison of the number of changes among the three maxillary movement groups, the data were analyzed by one-way ANOVA in normal distribution data or Kruskal-Wallis test was used in nonparametric data. The correlation analyses between the number of changes in parameters

and the magnitude of the maxilla movement were investigated using Pearson correlation and interpreted as follows: Negligible 0.00-0.10, weak 0.10-0.39, moderate 0.40-0.69, strong 0.70-0.89, and very strong 0.90-1.00.⁹ All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 27.0. (IBM Corp., Armonk, NY, USA). *P*-values less than 0.05 were considered as statistical significance.

Results

This retrospective study included 39 patients (14 females, 25 males) with an average age of 25.56 ± 2.83 years. The mean maxillary advancement was 2.63 ± 0.64 mm (min: 2.0 - max: 4.0) and the maxillary impaction amount was 2.67 ± 0.76 (min: 2.0 - max: 5.0) in all subjects. These data were shown in Table 1.

Before surgery, the majority of patients (25 out of 39 or 64.10%) had the NS deviation ranged from 2 to 10 degrees (mean $\pm$ SD, 3.94 ± 2.08) whereas the rest (14 of 39 or 35.90%) were detected with the straight NS. The presence or absence of post-operative NS deviation according to the maxillary movement was presented in Table 2. The mean INV angle and area of the patients at pre-operative period were 15.63 ± 2.54 degrees (min: 10.0 - max: 23.0) and 78.90 ± 11.86 mm² (min: 55.46 - max: 119.32), respectively.

Table 3 showed comparison of all values between pre-operative and post-operative within each group and the number of changes among the three groups according to the maxillary movement.

Table 1 Demographic variables of the sample

	Total (n = 39)	Maxillary movement		
		Advancement (n = 13)	Impaction (n = 13)	Combination (n = 13)
Sex, n(%)				
Male	14 (35.9)	5 (38.5)	6 (46.2)	3 (23.1)
Female	25 (64.1)	8 (61.4)	7 (53.8)	10 (76.9)
Age (years)				
mean $\pm$ SD	25.56 ± 2.83	23.69 ± 2.39	27.00 ± 2.48	26.00 ± 2.68
median (min-max)	25 (21-30)	23 (21-30)	27 (21-30)	26 (22-30)
Magnitude of advancement (mm)				
mean $\pm$ SD	2.64 ± 0.64	2.85 ± 0.77		2.42 ± 0.40
median (min-max)	2.5 (2-4)	3 (2-4)		2.5 (2-3)
Magnitude of impaction (mm)				
mean $\pm$ SD	2.67 ± 0.76		2.81 ± 0.95	2.54 ± 0.52
median (min-max)	2.5 (2-5)		2.5 (2-5)	2.5 (2-3.5)

Table 2 Presence or absence of post-operative nasal septum deviation according to the maxilla movement

Parameters (n = 39)	Pre-operative deviated nasal septum		Post-operative deviated nasal septum	
	No n (%)	Yes n (%)	No n (%)	Yes n (%)
Maxilla advancement (n=13)	7 (53.85)	6 (46.15)	5 (38.46)	8 (61.54)
Maxilla impaction (n=13)	5 (38.46)	8 (61.54)	3 (23.08)	10 (76.92)
Combination (n=13)	2 (15.38)	11 (84.62)	0 (0.00)	13 (100.00)
	14 (35.90)	25 (64.10)	8 (20.50)	31 (79.50)
		mean±SD, 3.94±2.08 degrees		mean±SD, 5.13±2.21 degrees

%, Row percent

Table 3 Comparison of all pre-operative and post-operative values within each group and the number of changes among the three groups

Parameters		Comparison of the pre-operative and post-operative values within each group			Comparison of the amount of the changes(ΔT1-T0) among the three groups	
		Pre-operatively (T0)	Post-operatively (T1)	p-value	mean (95%CI)	p-value [§]
Nasal septal angle (degree), median (IQR)	Advancement	0 (0, 3)	3.5 (0, 5)	0.048 ^{†*}	1.19 (0.04, 2.34)	0.632
	Impaction	3 (0, 3.75)	5 (1.5, 7)	0.021 ^{†*}	1.58 (0.29, 2.86)	
	Combination	3 (2.5, 3.5)	5 (3.25, 6)	0.003 ^{†*}	1.88 (1.04, 2.73)	
Internal nasal valve angle (degree), mean±SD	Advancement	16.31±3.07	17.73±3.13	0.012 ^{†*}	1.42 (0.37, 2.48)	0.284
	Impaction	15.04±2.44	17.73±1.70	< 0.001 ^{†*}	2.69 (1.51, 3.88)	
	Combination	15.54±2.05	17.27±3.26	0.028 ^{†*}	1.73 (0.22, 3.24)	
Internal nasal valve area (mm ²), mean±SD	Advancement	81.08±13.94	80.94±14.73	0.962 [‡]	-0.14 (-6.45, 6.17)	0.798
	Impaction	78.83±13.15	80.11±11.04	0.621 [‡]	1.28 (-4.21, 6.76)	
	Combination	76.80±8.28	79.03±11.17	0.293 [‡]	2.24 (-2.20, 6.67)	

[†]Data were analyzed with Wilcoxon signed ranks test; [‡]Paired t-test; [§]One-way ANOVA*Statistically significant at the 0.05 level ($\alpha = 0.05$)

Post-operatively, the medians of NS angle were increased with statistical significance in the maxillary advancement group ($p = 0.048$), the maxillary impaction group ($p = 0.021$), and the combination group ($p = 0.003$). After the number of changes among the three groups were compared, the means of post-operative NS angle were increased ranging from 1.19 to 1.88 degrees with no statistically significant difference ($p = 0.632$). There was persistence of a new NS perforation (Figure 3) in 10.26% (4 of 39 patients) of the following surgery. Three cases were in the impaction group and one case was in the combination group.



Figure 3 Post-operative nasal septal perforation (white arrow)

Table 4 The result of correlation analysis between the number of changes in parameters and magnitude of the maxilla movement using Pearson correlation

Parameters	Change of nasal septal angle, r (p-value)	Change of internal nasal valve angle, r (p-value)	Change of internal nasal valve area, r (p-value)
Maxillary advancement	0.603 (0.029*)	0.010 (0.490)	0.118 (0.701)
Maxillary impaction	0.282 (0.351)	0.218 (0.474)	0.253 (0.404)
Combination	0.367 (0.217)	0.067 (0.828)	0.248 (0.413)

*Statistically significant at the 0.05 level ($\alpha = 0.05$)

There were significant increases in the means of post-operative INV angle in the maxillary advancement group ($p = 0.012$), the maxillary impaction group ($p < 0.001$), and the combination group ($p = 0.028$). The means of postoperative INV angle rose from 1.42 to 2.69 mm; however, comparison of the number of changes among the three groups revealed no statistically significant difference ($p = 0.284$). The means of post-operative INV area were changed ranging from -0.14 to 2.24 mm² with no statistically significant difference.

According to the correlation analysis between changes in parameters and magnitude of the maxillary movement (Table 4), most results were weak positive correlation with no statistically significant difference, except for the changes of NS angles and the magnitude of maxillary advancement were moderately positive with statistically significant difference ($p = 0.029$, $r = 0.603$).

Discussion

With any surgical procedure, LF-IO presented complications due to the anatomy of the region and the surgical technique. In LF-IO, NS osteotomy and a down fracture of the maxilla were achieved. Then, the bony interference and cartilage of NS were checked and resected before repositioning of maxillary segment. The NS deviation or buckling of NS may occur owing to inadequate reduction of interference when there was a large amount of forward or total impaction of the maxilla.¹⁰ In addition, post-operative NS deviation was affected by nasotracheal intubation and dislocation of the NS cartilage by an incompletely deflated cuff during extubation.^{11, 12} The NS is the main structural support for the nasal dorsum and also the most medial aspect of the INV. As a result, NS deviation has been shown to play a critical role in nasal obstruction symptom which can *lead to obstructive sleep apnea*.^{13,14} According to a systematic review conducted by Aziz et al.¹⁵, deviated NS can be diagnosed by anterior rhinoscopy, acoustic rhinometry, and CT scan. However, the acoustic rhinometry is a favorable instrument for evaluation of nasal airflow resistance caused by structural abnormality. In addition, imaging studies such as CT scans provided an accurate 3-dimensional diagnosis of NS deviation and demonstrated a positive correlation between acoustic rhinometry and INV area from CT results.¹⁶

The INV is the narrowest portion of the nasal airway and is associated with the maximum resistance flow.¹⁷ On reformatted coronal CBCT image or the nasal base view obtained perpendicular angle to the acoustic axis, the INV angle typically measures for 10-15 degrees in Caucasian people.^{18,19} A radiographically measured INV area of $< 30 \text{ mm}^2$ or INV angles of < 10 degrees suggests clinical narrowing and may predispose the patient to INV collapse on inspiration.^{20,21}

In this current study, we examined how maxillary advancement and maxillary impaction in LF-IO affected the anterior region of nose, focusing on NS (at nasion level), INV angle, and INV area. Patients with asymmetrical impactions and correction of upper midline shift $> 2 \text{ mm}$ were excluded in order to avoid confounding factors of Y-axis and Z-axis.

Pre-operatively, the majority of the sample (64.10%) in our study had relatively lower NS deviation compared to population from various geographic regions around the world (89.2%).²² Most of these deviations (both before and after surgery) were less than 10 degrees and were classified as 'mild' in severity. Among 39 samples, most of the INV angles were > 15 degrees (mean $\pm$ SD, $15.63\pm 2.54 \text{ mm}^2$). The results revealed that INV angle of Thais was wider than that of Caucasians. However, pre-operative INV area of this present study (mean $\pm$ SD, $78.90\pm 11.86 \text{ mm}^2$) was similar to previous studies that ranged from 73.2 to 90.34 mm^2 .^{2, 7, 23, 24}

Post-operatively, NS deviation of this present study was increased from 64.10% to 79.5%. According to the maxillary movement, the medians of all three groups were significantly increased. The means of post-operative NS angle of all three groups were increased ranging from 1.19 to 1.88 degrees with statistically significant difference. In addition, the magnitude of maxilla advancement

group and the number of change of NS angle revealed a moderate positive correlation with statistically significant difference. Our result was consistent with the study by On et al.¹⁰ which proved that maxillary advancement can worsen NS deviation anteriorly and a positive correlation between the amount of forward maxilla movement and NS deviation at nasion level was found. However, the result reported by On et al.¹⁰ exhibited that the maxillary impaction also caused deterioration of NS angle anteriorly. There are two previous articles that showed contrary results. Firstly, the study by Baeg et al.²⁵ reported a decrease of NS angle after LF-IO but there was no statistical significance. Secondly, the study by Atakan et al.²⁶ showed no significant change of NS angle after LF-IO and no significant correlation between the NS angle and extent of maxilla movement.

The incidence of NS perforation after LF-IO was found up to 20.0%²⁷, but there was only 10.26% in this present study which may result from over-reduction of the NS prior to the maxillary impaction. Clinically, malodor and epistaxis may be found together with sinonasal airflow changes, and no additional treatment was required for this complication.^{28,29}

This CBCT result of this present study and that reported by Dilaver et al.²³ proved a statistically significant increase in INV angle following LF-IO. An increase in INV angle presented clinically visible flaring of the alar base of the nose and the change in shape from narrow taper to ovoid.³⁰ Then, the change of INV area was suspected. Interestingly, our results showed no statistically significant change in INV area after LF-IO in all parameters. Most of previous studies found an increasing cross-sectional INV area and decreasing nasal resistance after impaction and advancement of the maxilla due to opening of the internal nose dimensions.^{23,31-33} Additionally, the INV area may be influenced by various factors, especially the *alar base cinch suture*, which is often used to mitigate the unfavorable increase in interalar width after impaction or advancement of the maxilla in LF-IO.³⁴ A positive correlation between the total INV area and interalar width were pervasively reported.^{23,30}

There was a remarkable result found with the positive value of NS angle and INV angle. With the comparison between the pre-operative and post-operative stages within each groups, the number of changes increased with statistical significance. However, comparison of the number of the changes among three groups showed no statistically significant difference. The combination group did not reveal a sharp significant increase compared to the value of the maxillary advancement group and the maxillary impaction group.

Owing to the retrospective nature of this study, it only analyzed NS and INV region with 3-dimensional reconstructed images. Moreover, the absence of clinical correlation between other investigations such as questionnaire and nasal endoscopy was limitation of this study. For future prospective clinical trials, larger study cases with maxilla impaction > 5 mm are needed to be evaluated.

Conclusion

Advancement and impaction of the maxilla in LF-IO affected an increase in the NS angle and INV angle. A moderately positive correlation between changes of the NS angle and the magnitude of maxilla advancement was detected. However, the INV area showed no statistically significant change.

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