Original Article

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Assessment of internal nasal valve change after Le Fort I osteotomy using CBCT

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Objective: The internal nasal valve (INV) is the narrowest portion of the nasal cavity and is affected by Le Fort I osteotomy (LF-IO). The objective of this study was to investigate the changes in the INV after LF-IO.

Materials and Methods: The retrospective cone beam computed tomography (CBCT) data of 57 patients who underwent LF-IO were evaluated before and 6–12 months postoperatively. The INV measurement (angle and cross-sectional area) was done at the reformatted coronal CBCT image perpendicular to the estimated nasal airflow axis. The patients were divided into 4 paired groups depending on the differences in the direction of the maxilla movement and investigated. (Group 1. Impaction vs. Inferior repositioning; Group 2. Impaction $\geq$5 mm vs. Impaction <5 mm; Group 3. Anterior movement vs. Non-anterior movement; Group 4. Impaction symmetry vs. Impaction asymmetry). Statistical significance was determined at $p<0.05$.

Results: Preoperatively, the mean INV angle and area of the patients was 18.92 ± 5.12^{o} and 76.63 ± 16.99 mm^2, respectively. After LF-IO, the mean INV angle of all patients was significantly increased by 2.31 ± 3.87^{o} ($p<0.001$), while the mean INV area was decreased by 0.34 ± 16.24^{o}, which was not significant ($p=0.826$). However, when the results of the four paired groups were evaluated, there were no significant differences in the INV angle and INV area. The correlation between changes in INV angle and changes in INV area was weak ($p=0.003$, r=.279).

Conclusions: LF-IO osteotomy increased the INV angle, however, the differences in the direction of the maxilla movement were not significant. Impaction and advancement movement of the maxilla might increase the INV angle more than the inferior and setback movement. The INV area was not significantly different after surgery. A weak positive correlation between changes in INV angle and changes in INV area was found.

Keywords: cone beam computed tomography, internal nasal valve angle, internal nasal valve area, Le Fort I osteotomy, maxilla movement

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Introduction

The internal nasal valve (INV) is the narrowest portion of the nasal airway and is associated with the maximum resistance flow. The complex three-dimensional construct consists of the caudal edge of the upper lateral cartilage laterally, the nasal septum medially, the nasal bony floor inferiorly, and the anterior head of the inferior turbinate posteriorly [1, 2]. The INV angle is typically measured between the septum and upper lateral cartilage accounting for 10–15^{o} in Caucasian people with a leptorrhine (tall and thin) nose [3, 4]. Narrowing of this area has been generally accepted as a common cause of nasal obstruction [5]. Nasal obstruction, problematic breathing while

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exercising, snoring, sleep apnea and repeated nose infections are typical associated symptoms [6, 7]. Chronic mouth breathing, caused by an obstruction of the upper airway, can also result in enlarged tonsils and adenoids, dry mouth, halitosis, periodontal disease and dental caries [8]. Furthermore, previous studies reported that an increase in the INV cross-sectional area correlated with a higher patient satisfaction level for breathing [9, 10]. Small changes in INV size resulted in a significant impact of airflow resistance affecting nasal function [11]. Although the normal INV angle of Caucasians has been discussed in multiple studies, the INV angle and area in Asians have not been reported.

Le Fort I osteotomy (LF-IO) is routinely performed in patients with a dentofacial deformity to correct malocclusion, and it has varying degrees of effect on the nasal airway form and function; hence, it is a possible factor affecting the INV [12]. Currently, there is no optimal method to diagnose INV obstruction [2]. Various modalities have been used for assessing the nasal airway region. However, the efficiency of these devices is limited. Anterior rhinomanometry is an indirect method used for evaluating dynamic function and determining nasal airway resistance; however, it is expensive, time consuming and inconspicuously preformed in cases with a nasal septum perforation [13, 14]. Although nasal endoscopy or rhinoscopy is a direct method used for evaluating anatomical changes in INV, it distorts the internal anatomy and has poor reproducibility [15, 16].

Computed tomography (CT) is a safe and non-invasive method for evaluating anatomical structures in the nasal valve region. Previous studies reported a high correlation between medical CT or MDCT (Multi-Detector Computed Tomography) findings and patient's complaints together with clinical examinations [17, 18]. Notably, cone beam computed tomography (CBCT), commonly used in dentistry, exhibited comparable diagnostic capabilities for sinonasal structures compared with conventional medical CT [19, 20]. Moreover, a significant correlation has been observed in the measurements of the sinonasal cross-sectional area using acoustic rhinometry and coronal CBCT images, particularly those obtained perpendicular to the acoustic axis. This was commonly referred to the "reformatted coronal CBCT image" or the "nasal base view" [13, 21]. This suggested that CBCT can be used to assess the nasal airflow and related anatomical features in the nasal valve region.

The purpose of this study was to evaluate the effects of LF-IO on the INV (angle and cross-sectional area) of Thai patients and to determine whether it was affected by differences in the direction of maxilla movement after LF-IO.

Materials and Methods

Patients

This retrospective study comprised 57 patients (17 men and 40 women) ranging from 24-42 years old (mean age 30.32 years). All patients underwent 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 inclusion criteria for this study were patients who were medically healthy, over 18 years of age, and had CBCT taken before and 6-12 months after the surgery. Patients with a craniofacial anomaly, post-traumatic facial deformity, Le Fort I fracture, reoperation for correcting complications, or a history of septorhinoplasty or turbinoplasty were excluded. The patients had a treatment plan established at the orthognathic conference by the oral and maxillofacial surgery department. The patients underwent a standard LF-IO under general anesthesia. To control the width of the alar base, before suturing the intraoral vestibular incision, an alar cinch suture was performed intraorally.

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.

Acquisition of CBCT images and radiographic measurement methodology

The CBCT of the patients were performed with a Kodak CS9500 machine (Carestream, New York, USA) using the following parameters: 90 kV, 10 mA, 10.8 sec exposure time, and 20.6x18 cm field of view. The voxel size was 0.3 mm.

For measuring INV (Figure 1), a reformatted coronal CBCT image perpendicular to the estimated acoustic axis was chosen 1 mm anterior to the head of the inferior turbinate [15, 17, 21]. For patients with an asymmetric appearance of the turbinate's head, coronal cuts were assessed 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 anterior soft tissue outline (exterior of the nasal soft tissue). The INV area was obtained by measuring the area of air density of the reformatted coronal CBCT image.

The INV angle and area were evaluated by the CBCT viewer (Carestream Dental software) and ImageJ (Research Services Branch, National Institute of Mental Health, Bethesda, Maryland, USA), respectively. The images were viewed in a dimly lit room on 23.8-inch Dell P2419H identical liquid crystal display (LCD) monitors with a screen resolution of 1920×1080 pixels and a color depth of 24-bits.

One researcher performed all radiographic analyses. The measurements were performed twice with a minimum time gap of 1 month to verify the reliability of the intra-observer results. Intraclass correlation coefficients at 95% confidence level for INV angle and area measurements that ranged from 0.992–0.997 exhibited almost perfect agreement.

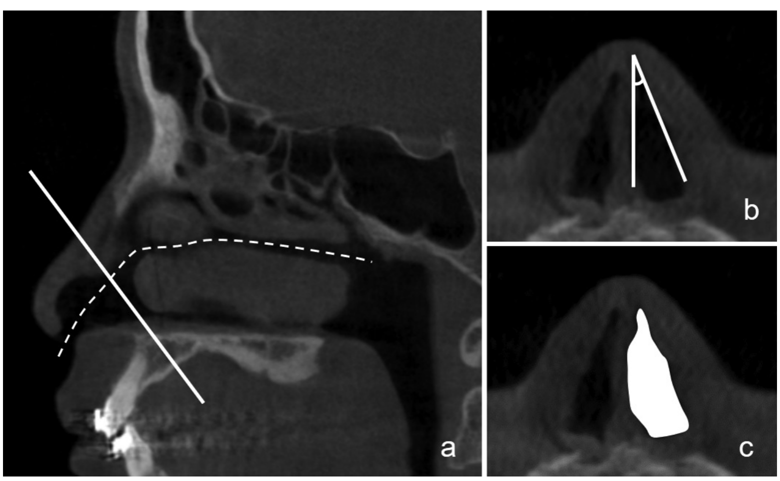

Figure 1 Measurements of the internal nasal valve angle and area at the reformatted coronal CBCT image: (a) A sagittal view shows the estimated acoustic axis (dotted line). A reformatted coronal plane perpendicular to the estimated acoustic axis was chosen to be 1 mm anterior to the head of the inferior turbinate; (b) a reformatted coronal plane showed the internal nasal valve angle; (c) a reformatted coronal plane shows the internal nasal valve area.

Maxillary movement categories

The effect of the maxilla movement after LF-IO was analyzed in 4 groups:

Group 1. Impaction group vs. Inferior repositioning group

Based on the maxillary first molar, the patients were divided into the impaction group and the inferior repositioning group.

Group 2. Impaction ≥5 mm group vs. Impaction <5 mm group

Based on the amount of impaction in LF-IO on the maxillary first molar, the patients were divided into two impaction sub-groups: Those with impaction ≥5 mm (at least one side) and those with impaction <5 mm (both sides).

Group 3. Anterior movement group vs. Non-anterior movement group

Based on the direction of movement in LF-IO, the anterior group included patients who displayed anterior movement, whereas the non-anterior group of those who received a setback or did not display anterior movement.

Group 4. Asymmetrical impaction group vs. Symmetry impaction group

The patients were divided into asymmetrical and symmetrical impaction groups based on the maxillary first molar. The asymmetry impaction movement group comprised those with an impaction difference of ≥3 mm between the left and the right side, whereas the symmetry impaction movement group had an impaction difference of <3 mm between the left and right sides.

Statistical analysis

The Kolmogorov–Smirnov test was used and the results showed a normal data distribution. For comparing the patients, the differences between the preoperative mean value and postoperative mean INV value were analyzed by the paired sample t-test. For comparing within the patient paired groups, the Levene's test for equality of variances assumption and independent sample t-test was used. The correlation between changes in INV angle and changes in INV area was investigated using Pearson correlation and interpreted: 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 [22]. The statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 27.0. (IBM Corp., Armonk, NY, USA). The statistically significance level was set at $p<0.05$.

Results

Maxillary movement categories (Table 1)

Group 1, there were 34 patients in the total impaction group with more impaction on the right side and 34 patients in the inferior repositioning group with more elongation on the left side. Group 2, there were 9 patients in the ≥5 mm impaction group and 25 patients in the <5 mm impaction group. Group 3, there were 29 patients in the anterior movement group (2.21 ± 1.03 mm) and 28 patients in the no change and setback group (1.30 ± 1.77 mm). Group 4, there were 9 patients in the asymmetry impaction group (impaction difference 3.50 ± 0.75 mm) and 25 patients in the symmetry impaction group (impaction difference 1.02 ± 0.80 mm).

Before surgery (Tables 2 and 3)

Preoperatively, the mean INV angle of the patients was 18.29 ± 5.12º with no significant difference between sexes or sides. Among 114 samples, most of the INV angles were > 15º (73 samples or 64.04%), followed by INV angle of 10-15º (39 samples or 34.21%).

The mean INV area of the patients was 76.63 ± 16.99 mm^2. The INV area in males was significantly larger than in females ($p<0.01$).

Table 1 Directions and distances of maxilla movement after Le Fort I osteotomy in each paired group

Patient groups	n (%)	Distances of maxillary movement after Le Fort I osteotomy (mean ± SD)	
Group 1. Impaction group vs. Inferior repositioning group			
Impaction group	34 (59.65%)	Right impaction	3.45 ± 1.88 mm
		Left impaction	2.72 ± 2.00 mm
Inferior repositioning group	8 (14.04%)	Right elongation	1.25 ± 0.93 mm
		Left elongation	1.75 ± 1.75 mm
N/A	15 (26.31%)		
Group 2. Impaction ≥5 mm group vs. Impaction <5 mm group			
≥5 mm impaction group	9 (15.79%)	Right impaction	5.94 ± 1.04 mm
		Left impaction	4.22 ± 2.74 mm
<5 mm impaction group	25 (43.86%)	Right impaction	2.52 ± 1.13 mm
		Left impaction	2.18 ± 1.35 mm
N/A	23 (40.35%)		
Group 3. Anterior movement group vs. Non-anterior movement group			
Anterior movement group	29 (50.88%)	Advance	2.21 ± 1.03 mm
Not anterior movement group	28 (49.12%)	No change and Setback	1.30 ± 1.77 mm
Group 4. Asymmetry impaction group vs. Symmetry impaction group			
Asymmetry impaction group	9 (15.79%)	Impaction difference	3.50 ± 0.75 mm
Symmetry impaction group	25 (43.86%)	Impaction difference	1.02 ± 0.80 mm
N/A	23 (40.35%)		

(SD: standard deviation, vs: versus, N/A: not available)

Table 2 Preoperative internal nasal valve angle and area in all patients

	Right side Mean ± SD	Left side Mean ± SD	Average Mean ± SD	*p*-value†
Preoperative INV angle (degree)				
Female	18.05 ± 4.86	18.08 ± 5.05	18.06 ± 4.92	.947
Male	19.53 ± 5.66	18.12 ± 5.67	18.82 ± 5.62	.231
Total	18.49 ± 5.10	18.09 ± 5.19	18.29 ± 5.12	.354
p-value‡	.978	.321	.471	
Preoperative INV area (mm^2)				
Female	74.95 ± 16.96	71.11 ± 14.53	73.03 ± 15.81	.050
Male	85.25 ± 16.76	84.94 ± 17.46	85.09 ± 16.85	.947
Total	78.02 ± 17.42	75.23 ± 16.58	76.63 ± 16.99	.148
p-value‡	.040*	.003*	<.001*	

(SD: standard deviation, INV: internal nasal valve)

† According to paired samples t-test comparing between right and left of the INV angles/areas

‡ According to independent samples t-test comparing between sexes

*Statistically significant value

Table 3 Comparison of preoperative and postoperative internal nasal valve angles after Le Fort I Osteotomy

			Postoperative INV angle (n = 114)		
			<10 degrees	10-15 degrees	>15 degrees
Preoperative INV angle (n = 114)	<10 degrees	2 (1.75%)	0	2	0
	10-15 degrees	39 (34.21%)	0	13	26
	>15 degrees	73 (64.04%)	0	7	66
Total		114 (100%)	0 (0%)	22 (19.30%)	92 (80.70%)

(INV: internal nasal valve)

Changes in INV angle and area in all patients (Tables 3 and 4)

The mean postoperative INV angle was significantly increased by 2.31 ± 3.87° (p<0.001). Most of the postoperative INV angles were > 15° (92 samples or 80.70%), followed by INV angle of 10-15° (22 samples or 19.30%), and no sample with INV angle < 10°. However, the mean postoperative INV area was decreased by 0.34 ± 16.24 mm^2 with no statistical significance (p=0.826).

Changes of the INV angle and area in each paired group

The mean postoperative INV angle in every sub-group increased by an average difference ranging from 1.84-2.61°. (Table 5) However, there were no significant differences in the postoperative changes in INV angle according to the direction of the maxilla movement.

The mean postoperative INV area changed (ranging from -1.58 to 4.28 mm^2) but not significantly different for all paired groups. (Table 6)

Table 4 Changes in the internal nasal valve angle and area in all patients

	N (%)	Preoperative Mean ± SD	Postoperative Mean ± SD	Difference Mean ± SD	p-value†
INV angle (degree)					
All	114 (100%)	18.29 ± 5.12	20.42 ± 5.72	2.31 ± 3.87	<.001*
Increased	77 (67.54%)	17.68 ± 4.74	21.68 ± 5.97	4.00 ± 2.88	
No changed	14 (12.28%)	18.00 ± 3.33	18.00 ± 3.33	-	
Decreased	23 (20.18%)	20.52 ± 6.65	17.70 ± 4.60	-2.83 ± 2.76	
INV area (mm^2)					
All	114 (100%)	76.63 ± 16.99	76.29 ± 20.76	-0.34 ± 16.24	.826
Increased	54 (47.37%)	72.16 ± 15.47	84.78 ± 21.87	12.62 ± 12.44	
Decreased	60 (52.63%)	80.65 ± 17.40	68.66 ± 16.44	-12.00 ± 6.82	

(SD: standard deviation, INV: internal nasal valve)

† According to paired samples t-test comparing the preoperative and postoperative of the INV angles/areas

*Statistically significant value

Table 5 Changes in the internal nasal valve angle according to the maxilla movement

Group	n	Preoperative Mean ± SD (degree)	Postoperative Mean ± SD (degree)	Difference Mean ± SD (degree)	*p*-value†
Group 1. Impaction group vs. Inferior repositioning group					
Impaction group	68	17.88 ± 4.71	20.37 ± 5.81	2.49 ± 3.76	.660
Inferior repositioning group	16	20.69 ± 5.86	22.69 ± 6.30	2.00 ± 4.77	
Group 2. Impaction ≥5 mm group vs. Impaction <5 mm group					
≥5 mm impaction group	18	17.78 ± 5.22	20.39 ± 5.34	2.61 ± 4.86	.870
<5 mm impaction group	50	17.92 ± 4.57	20.36 ± 6.02	2.44 ± 3.33	
Group 3. Anterior movement group vs. Non-anterior movement group					
Anterior movement group	58	17.95 ± 5.32	20.36 ± 6.47	2. 41 ± 3.68	.431
Not anterior movement group	56	18.64 ± 4.94	20.48 ± 4.88	1.84 ± 4.08	
Group 4. Asymmetry impaction group vs. Symmetry impaction group					
Asymmetry impaction group	18	17.44 ± 4.13	19.94 ± 5.55	2.50 ± 3.73	.985
Symmetry impaction group	50	18.04 ± 4.93	20.52 ± 5.95	2.48 ± 3.80	

(SD: standard deviation, vs: versus)

† According to independent sample t-test comparing the difference between paired groups

Table 6 Changes in the internal nasal valve area according to the maxilla movement

Group	n	Preoperative Mean ± SD (mm^2)	Postoperative Mean ± SD (mm^2)	Difference Mean ± SD (mm^2)	*p*-value†
Group 1. Impaction group vs. Inferior repositioning group					
Impaction group	68	73.67 ± 16.14	74.91 ± 21.94	1.23 ± 17.46	.549
Inferior repositioning group	16	86.04 ± 16.45	84.46 ± 14.57	-1.58 ± 13.91	
Group 2. Impaction ≥5 mm group vs. Impaction <5 mm group					
≥5 mm impaction group	18	74.28 ± 14.78	74.55 ± 17.71	0.28 ± 16.72	.789
<5 mm impaction group	50	73.45 ± 16.74	75.03 ± 23.43	1.58 ± 17.87	
Group 3. Anterior movement group vs. Non-anterior movement group					
Anterior movement group	58	79.47 ± 17.66	78.87 ± 19.30	-0.60 ± 16.52	.861
Not anterior movement group	56	73.69 ± 15.89	73.62 ± 22.02	-0.06 ± 16.10	
Group 4. Asymmetry impaction group vs. Symmetry impaction group					
Asymmetry impaction group	18	76.70 ± 12.41	80.98 ± 25.39	4.28 ± 22.39	.393
Symmetry impaction group	50	72.58 ± 17.27	72.72 ± 20.40	0.14 ± 15.44	

(SD: standard deviation, vs: versus)

† According to independent sample t-test comparing the difference between paired groups

The correlation between the changes INV angle and changes of INV area was positive, but weak (p=0.003, r=.279). (Figure 2)

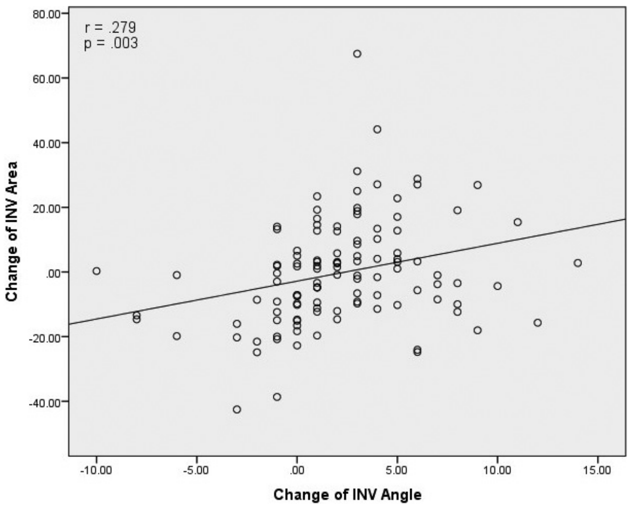

Figure 2 The scatter plot of the relationship between the changes in INV angles and changes in INV areas

Discussion

Numerous methods are useful for evaluating nasal obstruction and INV, including CT. Poetker *et al.* [21] reported the most reliable INV angles were determined by "reformatted coronal CBCT images". In contrast, the INV angle measured in the traditional coronal plane or a plane perpendicular to the hard palate significantly underestimated the values [17, 21]. Additionally, the reconstructed CT method was either good for reproducibility or good sensitivity and specificity values for INV area assessment [13, 23]. Thus, this study used the reconstructed CBCT images perpendicular to the estimated nasal airflow.

Preoperatively, the mean INV angle and area values of the patients were 18.29 ± 5.12° and 76.63 ± 16.99 mm^2, respectively. Our results revealed that the Thai INV angle was larger than that of Caucasians, but narrower than that of Koreans [15] with an average of 21.6°. These results might be associated with the Asian race that typically showed a mesorrhine (medium or intermediate) nose [3]. However, no difference was found between our INV area and previous studies that ranged from 73.2-90.34 mm^2 [17, 24, 25].

LF-IO is widely used for correcting dentofacial deformities and it has varying degrees of effect on nasal airway form and function, especially the INV region [9]. However, the effects of LF-IO on the nasal airway are unresolved. Erbe *et al.* [26] found no nasal airway changes after impaction or advancement of the maxilla, while other studies [27-29] found an increasing cross-sectional area and decreasing nasal resistance after impaction and advancement of the maxilla due to opening of the internal nose dimensions. However, these articles focused on rhinoscopy, anterior rhinomanometry, and acoustic rhinometry. There was only one CT study by Dilaver *et al.* [25] that found that the INV angle and INV area were significantly increased after LF-IO, however, the strong influence of the direction of maxilla movement was not evaluated.

The focus of this present study was on the anatomic changes in CBCT images after LF-IO on the INV region, and on determining whether these were affected by differences in the direction of maxilla movement. Post-surgery, the results of this study showed only a significant increase of the mean INV angle of all patients. In addition, all sub-groups were increased, but there were no significant differences when the four paired groups were evaluated. These results reflected that all directions of the maxilla movement of LF-IO resulted in an increased INV angle. However, impaction and advancement movement of the maxilla increases the INV angle more than that influenced by inferior and setback movement. In contrast, the INV area of all patients and all four paired groups revealed no significant differences.

An increase in INV angle presented clinically visible flaring of the alar base of the nose and a change in shape from narrow taper to ovoid. An increased INV area was suspected. This study observed a significant increase of the mean INV angle of all patients, but no significant difference for the INV area. Consequently, the correlation between changes in INV angle and changes in INV area was investigated and the results indicated a weak positive correlation. To our knowledge, this study is the first report on the correlation between changes in INV angle and changes in INV area after IF-IO. The low correlation due to the INV area may be influenced by other factors after LF-IO, such as nasal septal deviation, septal body, turbinate hypertrophy, concha bullosa, alar width, nasal height, internal surface irregularities, mucosal hypertrophy and intrinsic muscles of the nose (such as nasalis, dilator naris, and levator alae) [23, 26, 30]. According to Spalding *et al*. [31], it is impossible to predict the nasal function parameters for individual patients following maxillary surgery.

For the limitation in this research, all LF-IO cases were corrected with the maxilla in a 3-dimensional aspect of pitch, roll, and yaw rotations. Because only one axis was compared each time, confounding factors due to the remained two axes could not be avoided. The combination of patient symptoms and physical examination findings may be a more appropriate assessment of the INV because of its dynamic evaluation of the nasal airway rather than the static images of the CBCT. Due to its retrospective design, the present study has not investigated the relationship between the nasal airway function and anatomical INV changes. Further prospective studies should be performed.

Conclusions

LF-IO osteotomy resulted in an increased INV angle. Impaction and advancement movement of the maxilla might increase the INV angle more than inferior and setback movement. In contrast, the INV area demonstrated no significant change after surgery. A weak correlation between changes in INV angle and changes in INV area was found.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

References

1. Chandra RK, Patadia MO, Raviv J. Diagnosis of nasal airway obstruction. *Otolaryngol Clin North Am*. 2009 Apr;42(2):207-225. doi: 10.1016/j.otc.2009.01.004.
2. Rhee JS, Weaver EM, Park SS, Baker SR, Hilger PA, Kriet JD, *et al*. Clinical consensus statement: diagnosis and management of nasal valve compromise. *Otolaryngol Head Neck Surg*. 2010 Jul;143(1):48-59. doi: 10.1016/j.otohns.2010.04.019.
3. Aung SC, Foo CL, Lee ST. Three dimensional laser scan assessment of the oriental nose with a new classification of Oriental nasal types. *Br J Plast Surg*. 2000 Mar; 53(2):109-116. doi: 10.1054/bjps.1999.3229.
4. Shia Ng L, Lo S. Management of the internal nasal valve. *Int J Otorhinolaryngol Clin*. 2013 Jan-Apr;5(1):43-45. doi: 10.5005/jp-journals-10003-1109.
5. Ozturan O. Techniques for the improvement of the internal nasal valve in functional-cosmetic nasal surgery. *Acta Otolaryngol*. 2000 Mar;120(2):312-315. doi: 10.1080/000164800750001152
6. Gelardi M, Intiglietta P, Porro G, Quaranta VN, Resta O, Quaranta N. The role of the nasal valve in patients with obstructive sleep apnea syndrome. *Acta Biomed*. 2019 Jan;90(Suppl 2):15–18. doi: 10.23750/abm.v90i2-S.8097.
7. Michels Dde S, Rodrigues Ada M, Nakanishi M, Sampaio AL, Venosa AR. Nasal involvement in obstructive sleep apnea syndrome. *Int J Otolaryngol*. 2014;2014:717419. doi: 10.1155/2014/717419.
8. Tamkin J. Impact of airway dysfunction on dental health. *Bioinformation*. 2020 Jan;16(1):26–29. doi: 10.6026/97320630016026.
9. Sipilä J, Suonpää J. A prospective study using rhinomanometry and patient clinical satisfaction to determine if objective measurements of nasal airway resistance can improve the quality of septoplasty. *Eur Arch Otorhinolaryngol*. 1997;254(8):387-390. doi: 10.1007/BF01642556.

10. Stewart MG, Smith TL. Objective versus subjective outcomes assessment in rhinology. *Am J Rhinol*. 2005 Sep-Oct;19(5):529-535.
11. Lee J, White WM, Constantinides M. surgical and nonsurgical treatments of the nasal valves. *Otolaryngol Clin North Am*. 2009 Jun;42(3):495-511. doi: 10.1016/j.otc.2009.03.010.
12. Eliason MJ, Schafer J, Archer B, Capra G. The impact on nasal septal anatomy and physiology following Le Fort I osteotomy for orthognathic surgery. *J Craniofac Surg*. 2021 Jan-Feb;32(1):277-281. doi: 10.1097/SCS.0000000000007024.
13. Cakmak O, Coşkun M, Celik H, Büyüklü F, Ozlüoğlu LN. Value of acoustic rhinometry for measuring nasal valve area. *Laryngoscope*. 2003 Feb;113(2):295-302. doi: 10.1097/00005537-200302000-00018.
14. Ottaviano G, Scadding GK, Coles S, Lund VJ. Peak nasal inspiratory flow; normal range in adult population. *Rhinol*. 2006 Mar;44(1):32-35.
15. Suh MW, Jin HR, Kim JH. Computed tomography versus nasal endoscopy for the measurement of the internal nasal valve angle in Asians. *Acta Otolaryngol*. 2008 Jun; 128(6):675-679. doi: 10.1080/00016480701663391
16. Fattahi T. Internal nasal valve: significance in nasal air flow. *J Oral Maxillofac Surg*. 2008;66(9):1921-1926. doi: 10.1016/j.joms.2006.10.064
17. Bloom JD, Sridharan S, Hagiwara M, Babb JS, White WM, Constantinides M. Reformatted computed tomography to assess the internal nasal valve and association with physical examination. *Arch Facial Plast Surg*. 2012 Sep-Oct;14(5):331-335. doi: 10.1001/archfacial.2012.50.
18. Montgomery WM, Vig PS, Staab EV, Matteson SR. Computed tomography: a three-dimensional study of the nasal airway. *Am J Orthod*. 1979 Oct;76(4):363-375. doi: 10.1016/0002-9416(79)90223-9
19. Hagiwara M, Policeni B, Juliano AF, Agarwal M, Burns J, Dubey P, *et al*. ACR appropriateness criteria® sinonasal disease: 2021 Update. *J Am Coll Radiol*. 2022 May;19(5S):S175-S193. doi: 10.1016/j.jacr.2022.02.011
20. Han M, Kim HJ, Choi JW, Park DY, Han JG. Diagnostic usefulness of cone-beam computed tomography versus multi-detector computed tomography for sinonasal structure evaluation. *Laryngoscope Investig Otolaryngol*. 2022 Mar;7(3):662-670. doi: 10.1002/lio2.792
21. Poetker DM, Rhee JS, Mocan BO, Michel MA. Computed tomography technique for evaluation of the nasal valve. *Arch Facial Plast Surg*. 2004 Jul-Aug;6(4):240-243. doi: 10.1001/archfaci.6.4.240
22. Schober P, Boer C, Schwarte LA. Correlation coefficients: appropriate use and interpretation. *Anesth Analg*. 2018 May;126(5):1763-1768. doi: 10.1213/ANE.0000000000002864.
23. Moche JA, Cohen JC, Pearlman SJ. Axial computed tomography evaluation of the internal nasal valve correlates with clinical valve narrowing and patient complaint. *Int Forum Allergy Rhinol*. 2013 Jul;3(7):592-597. doi: 10.1002/alr.21128
24. Yoon A, Abdelwahab M, Liu S, Oh J, Suh H, Trieu M, *et al*. Impact of rapid palatal expansion on the internal nasal valve and obstructive nasal symptoms in children. *Sleep Breath*. 2021 Jun;25(2):1019-1027. doi: 10.1007/s11325-020-02140-y.
25. Dilaver E, Ak KB, Süzen M, Altın G, Uçkan, S. Evaluation of internal nasal valve using computed tomography after Le Fort I osteotomy: A cross-sectional study from a tertiary center. *Med Bull Haseki*. 2021;59(5): 400-404. doi: 10.4274/haseki.galenos.2021.7386.
26. Erbe M, Lehotay M, Gode U, Wigand ME, Neukam FW. Nasal airway changes after Le Fort I—impaction and advancement: anatomical and functional findings. *Int J Oral Maxillofac Surg*. 2001 Apr;30(2):123–129. doi: 10.1054/ijom.2000.0001.
27. Pourdanesh F, Sharifi R, Mohebbi A, Jamilian A. Effects of maxillary advancement and impaction on nasal airway function. *Int J Oral Maxillofac Surg*. 2012 Nov; 41(11):1350-1352. doi: 10.1016/j.ijom.2012.03.024.
28. Ghoreishian M, Gheisari R. The effect of maxillary multidirectional movement on nasal respiration. *J Oral Maxillofac Surg*. 2009 Oct;67(10):2283-2286. doi: 10.1016/j.joms.2009.04.064.
29. Haarmann S, Budihardja AS, Wolff KD, Wangerin K. Changes in acoustic airway profiles and nasal airway resistance after Le Fort I osteotomy and functional rhinosurgery: a prospective study. *Int J Oral Maxillofac Surg*. 2009 Apr;38(4):321-325. doi: 10.1016/j.ijom.2009.01.006.
30. Park J, Suhk J, Nguyen AH. Nasal analysis and anatomy: anthropometric proportional assessment in Asians-aesthetic balance from forehead to chin, part II. *Semin Plast Surg*. 2015 Nov;29(4):226-231. doi: 10.1055/s-0035-1564818.
31. Spalding PM, Vig PS, Lints RR, Vig KD, Fonseca RJ. The effects of maxillary surgery on nasal respiration. *Int J Adult Orthodon Orthognath Surg*. 1991;6(3):191-199.