A CBCT Evaluation of Nasal Septal Deviation and Related Nasofacial Structures after Maxillary Skeletal Expansion

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Abstract: Background: The aim of this study was to evaluate three-dimensional (3D) changes in nasal septal deviation (NSD) and related nasofacial structures after maxillary skeletal expansion (MSE). Methods: This retrospective study evaluated 28 patients aged 12.0–48.4 years (mean age, 20.4 ± 7.3 years; 12 males, 16 females) diagnosed with transverse maxillary deficiency and treated with MSE. Cone-beam computed tomography (CBCT) images were taken at pre-expansion (T1), post-expansion (T2), and 6-months after MSE (T3) and were reoriented. Three-dimensional coordinates (x,y,z) were constructed using nasion (N) as the reference point (0,0,0). A paired-sample *t*-test and an independent sample *t*-test were performed to investigate and compare the 3D changes of the NSD and nasofacial structures after MSE, depending on the direction and amount of NSD and the amount of midpalatal expansion (MPE). Results: NSD was alleviated at T3–T1 in the coronal plane; nasal septal length increased significantly. The absolute nasal floor (NF) angle ($2.06°$ at T1) decreased at T2–T1 ($p > 0.05$) and increased at T3–T2 ($p < 0.05$). The midface moved forward and downward, and pogonion (Pog) and menton (Me) moved downward and backward. There were no significant differences between the higher and lower NSD groups and greater and lesser MPE groups. Conclusions: Consequently, NSD was alleviated with variable positive nasofacial changes after MSE in both the short and long term. Therefore, MSE can be used to improve or camouflage facial deformities.

Keywords: nasal septum deviation; transverse maxillary deficiency; maxillary skeletal expansion; nasofacial structures; cone-beam computed tomography; Cartesian coordinate system; 3-dimensional coordinates

1. Introduction

The nasal septum (NS) is the wall that separates the left and right nasal cavities and is composed of the ethmoid bone, vomer, maxilla, and palatine bone. The NS determines the shape and size of the nose and affects midfacial development and facial appearance [1]. Nasal septal deviation (NSD) refers to a curved septum that increases airway resistance and occurs at a rate of 19.5–26% in healthy adults [2]. The etiologies of NSD can be genetic influences, traumas, congenital anomalies, nasal polyps, and tumors or infections [1]. NSD can cause chronic sinus disease, nasal obstruction, snoring, sleep apnea, and facial and dental anomalies, showing a strong relationship with facial growth asymmetry [1–6].

Several studies [7–11] have been conducted to evaluate the effects of maxillary expansion on the NS. Schwarz et al. [9] suggested no significant positional change in the NS with surgically-assisted rapid maxillary expansion (SARME). Altug-Atac et al. [7] also

proposed that both RME and SARME did not change the position of the NS. On the other hand, Farronato et al. [8] reported that RME improved NSD and increased NS length. Aziz et al. [10] suggested a potentially positive effect of RME on NSD during childhood but no significant change during adolescence. Recently, Mehta et al. [11] concluded that rapid palatal expansion (RPE) and microimplant-assisted RPE (MARPE) significantly improved NSD in the short and long term.

RME is widely used to correct maxillary transverse deficiencies. RME separates the midpalatal suture and expands the maxilla skeletally and dentally, thereby increasing the maxillary width, arch perimeters, and nasal cavity volume, thus reducing nasal airway resistance to improve nasal breathing [7,12,13]. However, a conventional RME has several side effects, including dentoalveolar tipping and a lack of long-term stability [14,15]. In order to improve stability and increase the skeletal effect, a MARPE has recently been developed and is being widely used [11,16–18].

MARPE rendered almost parallel palatal expansion antero-posteriorly but showed an asymmetric nasomaxillary expansion at the rate of 30.3–50.0% [16,19,20]. Asymmetric nasomaxillary expansion after MARPE was influenced by initial facial asymmetry with chin deviation, initial asymmetric position of the mid-palatal suture, unilateral crossbite, asymmetric loosening of the circummaxillary suture, and discrepancies in zygomatic bone density and morphology, but it was impossible to predict the amount of asymmetric expansion initially [16,17,19,20].

The three-dimensional analysis of cone-beam computed tomography (CBCT) images have allowed 3D changes of NSD or nasofacial structures to be analyzed after maxillary skeletal expansion (MSE) using direct measurements of angles and lengths on the sectional images, and 3D superimpositions [11,16–22], while some studies have evaluated the 3D changes using a Cartesian coordinate system [18,23,24]. However, there was no study to evaluate the NSD using a 3D coordinate system. Therefore, the aim of this study was to use 3D coordinates to evaluate the 3D changes in NSD and the related nasofacial structures after MSE.

2. Materials and Methods

2.1. Subjects and Eligibility Criteria

This retrospective study evaluated 28 patients aged 12.0–48.4 years (mean age, 20.4 ± 7.3 years; 12 males, 16 females). The patients were diagnosed as having transverse maxillary deficiency and received orthodontic treatment at Wonkwang University Daejeon Dental Hospital in Daejeon, South Korea. This study was approved by the Institutional Review Board of Wonkwang University Daejeon Dental Hospital (IRB number: W2205/002-001).

The inclusion criteria were as follows: (1) patients who were treated with MSE, (2) the successful opening of the midpalatal suture, and (3) having CBCT images taken at pre-expansion (T1), post-expansion (T2), and 6-months after expansion (T3). The exclusion criteria were as follows: (1) patients with congenital craniofacial anomalies, (2) a history of facial or head trauma, and (3) previous orthodontic or orthopedic treatment and/or orthognathic surgery.

In this study, the same type of MARPE appliance, a maxillary skeletal expander (MSE) (BioMaterials Korea, Seoul, South Korea), was used on all patients. The MSE had four holes and was fixed with four mini-implants (1.5 mm in diameter and 11.0 mm in length). The activation was performed according to the manufacturer's instructions. The activation rate was 1 turn per day for early teens (<15 years), 2 turns per day for late teens (≥15 years), and 4 turns per day for adult patients (>20 years) before the midpalatal suture opening. Once the diastema was identified, the activation rate was set as 2 turns per day for all patients regardless of age until proper expansion was achieved (Figure 1).

CBCT images were taken at T1, T2, and T3. A CBCT scanner, Alphard-3030 (Asahi Roentgen Ind, Kyoto, Japan), was set at 80 kVp and 7.0 mA for adults, and 80 kVp and 3.0 mA for adolescents. The images were taken in a cranial mode (scan size, 200 × 179 mm; scan time, 17 s; voxel size, 0.39 mm; slice thickness, 1.0 mm).
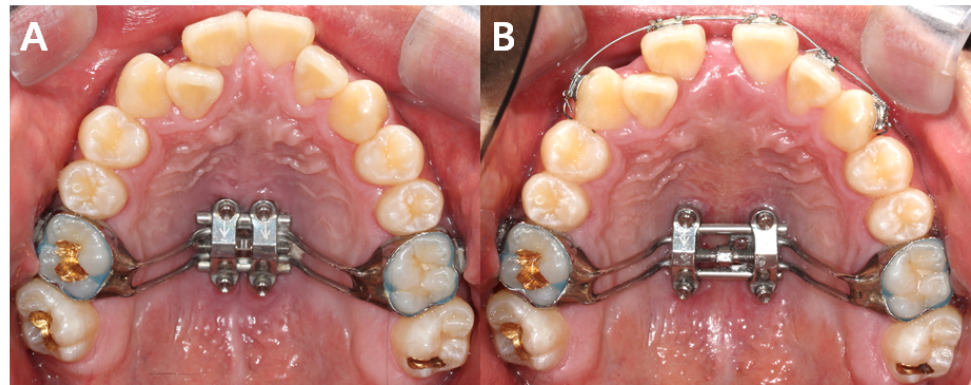
Figure 1. Maxillary skeletal expander. (**A**) Pre-expansion, (**B**) Post-expansion.

2.2. Standardized Reorientation of CBCT Images, 3D-Coordinate System, and 3D Measurement

All measurements were observed by an orthodontic resident (H.J.L.). CBCT images were re-oriented, and measurements were made using ON3D (3D ONS, INC., Seoul, South Korea) software. The 3D coordinates (x,y,z) were constructed using nasion (N) as the reference point (0,0,0). They were assigned according to the N point and the FH plane, which was defined as a plane passing through the bilateral orbitale (Or) points and the midpoint of the bilateral porion (Po) points (Figure 2) [21,22]. Three-dimensional landmarks were traced, and each landmark was assigned its 3D coordinates. The three-dimensional landmarks and values are described in Figures 3 and 4 and Tables 1 and 2.
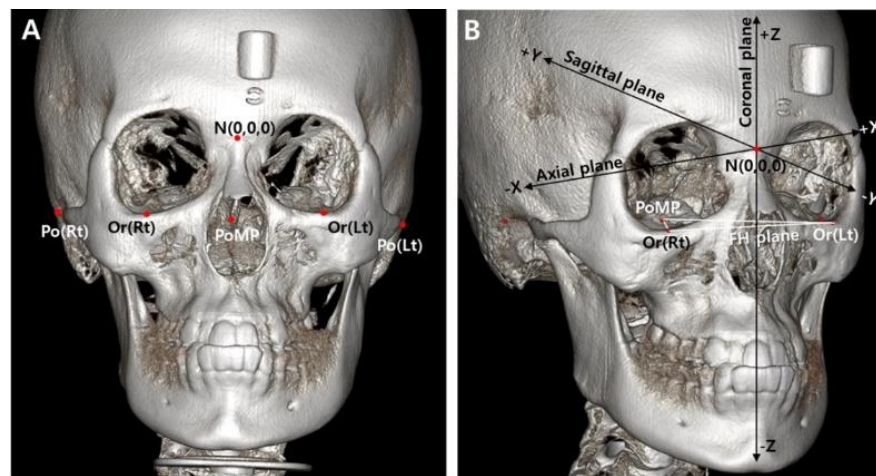
Figure 2. The 3-dimensional coordinate system and standardized reorientation of CBCT Images. (**A**) Frontal view. (**B**) Oblique view. The coordinate system consists of three axes (x, y, and z) with their origin (0,0,0) registered at nasion (N). Frankfort horizontal plane (FH plane) was constructed with bilateral orbitale (Or) points and the midpoint of bilateral porion (Po) points. The x-axis is a transverse axis passing through the N point and also parallel to the FH plane in the frontal view. The y-axis is the anteroposterior axis passing through the N point and perpendicular to the x-axis. The y-axis is parallel to the FH plane in the sagittal plane. The z-axis is the vertical axis perpendicular to both x- and y-axes. Positive values are to the left, posterior, and superior (LPS) to the N point of the subject. Negative values are to the right, anterior, and inferior (RAI) to the N point. PoMP, midpoint of bilateral porion (Po) points. Rt, right. Lt, left.
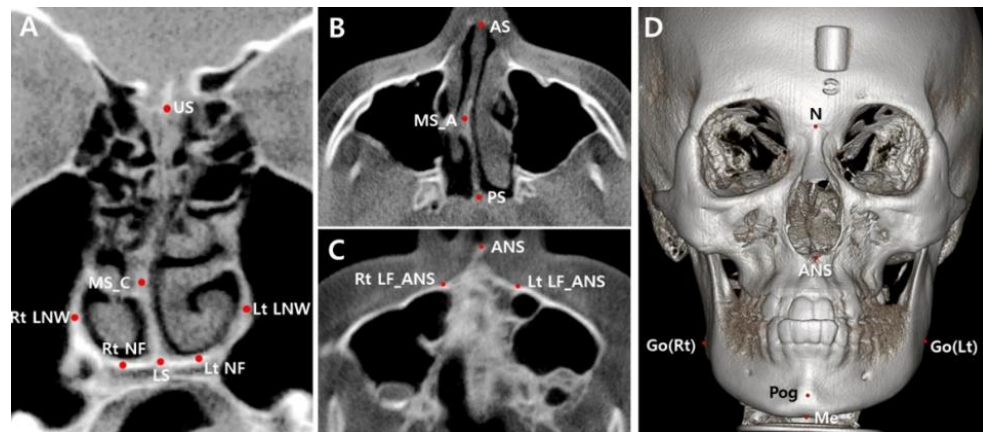
Figure 3. The 3-dimensional landmarks. (**A**) Nasal landmarks on the coronal section passing through the most deviated point in the nasal septum. (**B**) Nasal landmarks on the axial section passing through the most deviated point in the nasal septum. (**C**) Maxillary landmarks on the axial section passing through ANS. (**D**) Mandibular landmarks on the frontal view. Rt, right; Lt, left; US, upper septum; MS_C, middle septum_coronal; LS, lower septum; LNW, lateral nasal wall; NF, nasal floor; AS, anterior septum; MS_A, middle septum_axial; PS, posterior septum; ANS, anterior nasal spine; LF_ANS, lateral fossa_ANS; N, nasion; Pog, pogonion; Me, menton; Go, gonion.
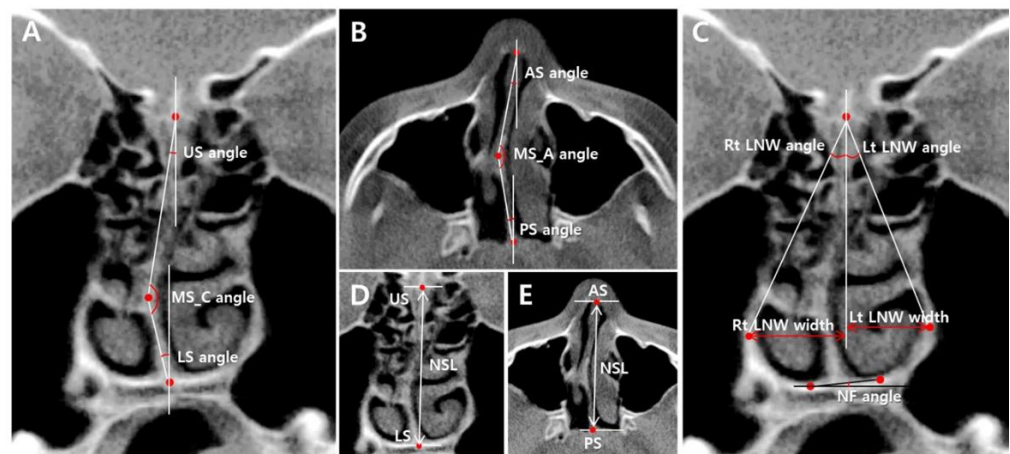
Figure 4. The 3-dimensional values. (**A**) Nasal septal angles (US, MS_C, and LS) in the coronal plane. (**B**) Nasal septal angles (AS, MS_A, and PS) in the axial plane. (**C**) Lateral nasal wall (LNW) angles and widths, and nasal floor (NF) angle. (**D**) Nasal septal length (NSL) in the coronal plane (between US and LS). (**E**) NSL in the axial plane (between AS and PS). Rt, right. Lt, left.

Table 1. Definitions of 3-dimensional landmarks.

Landmarks	Definitions
	Cranial Base landmarks
N (Nasion)	The most medial and superior point of the frontonasal suture
Or (Orbitale)	The most inferior point of the orbital rim
Po (Porion)	The most superior point of the external auditory meatus
	Nasal landmarks
US (upper septum)	The point where the nasal septum and cribriform plate met in the coronal measurement plane
MS_C (middle septum_coronal)	The outermost point of the nasal septum in the coronal measurement plane
LS (lower septum)	The point where the nasal septum and palate met in the coronal measurement plane
AS (anterior septum)	The most anterior point of the nasal septum in the axial measurement plane
MS_A (middle septum_axial)	The outermost point of the nasal septum in the axial measurement plane

Table 1. *Cont.*

Landmarks	Definitions
PS (posterior septum)	The most distal point of the nasal septum in the axial measurement plane
LNW (lateral nasal wall)	The outermost point of the lateral nasal wall in the coronal measurement plane
NF (nasal floor)	The lowest point of the nasal cavity in the coronal measurement plane
Maxillary landmarks	
ANS (Anterior nasal spine)	The most anterior point of the premaxillary bone in the sagittal plane
LF_ANS	The most concave point of the lateral fossa of the maxilla
Mandibular landmarks	
Pog (Pogonion)	The most anterior point in the mandibular chin area in the sagittal plane
Me (Menton)	The lowermost point on the symphysis menti in the sagittal and coronal plane
Go (Gonion)	The point in the inferoposterior outline of the mandible at which the surface turns from the inferior border into the posterior border in the sagittal plane

Table 2. Definitions of 3-dimensional values.

Values	Definitions
US angle (°)	The angle between US and sagittal line passing through US
MS_C angle (°)	The angle between US, MS_C and LS
LS angle (°)	The angle between LS and sagittal line passing through LS
US-LS (mm)	The length between US and LS
US (x,y,z)	The x,y,z coordinate values of US
MS_C (x,y,z)	The x,y,z coordinate values of MS_C
LS (x,y,z)	The x,y,z coordinate values of LS
AS angle (°)	The angle between AS and sagittal line passing through AS
MS_A angle (°)	The angle between AS, MS_A and PS
PS angle (°)	The angle between PS and sagittal line passing through PS
AS-PS (mm)	The length between AS and PS
AS (x,y,z)	The x,y,z coordinate values of AS
MS_A (x,y,z)	The x,y,z coordinate values of MS_A
PS (x,y,z)	The x,y,z coordinate values of PS
LNW angle (°)	Angle between LNW and sagittal line passing through US
NF angle (°)	The angle between NF and axial line
ANS (x,y,z)	The x,y,z coordinate values of ANS
LF_ANS (x,y,z)	The x,y,z coordinate values of LF_ANS
Mid LF_ANS (x,y,z)	The x,y,z coordinate values of Mid LF_ANS
Pog (x,y,z)	The x,y,z coordinate values of Pog
Me (x,y,z)	The x,y,z coordinate values of Me
Go (x,y,z)	The x,y,z coordinate values of Go

The three-dimensional values and coordinates were measured at T1, T1, and T3. The measurement planes were designated as a plane containing the most outward deviation of the NS between the anterior nasal spine (ANS) and posterior nasal spine (PNS) horizontally and between the cribriform plate of the ethmoid bone and the palatal process of the maxilla vertically. The direction and amount of NSD were determined by x and lxl of MS in the coronal plane, respectively. Two groups were divided into right (x, negative value) and left (x, positive value), and lower (lxl < 2.5 mm) and higher (lxl $\geq$ 2.5 mm). Absolute values were used for the x coordinates of the landmarks to obtain the amount of NSD after MSE. The amount of midpalatal expansion (MPE) was determined by dividing the amount of expansion in the ANS and PNS in half, and two groups were divided into lesser (<3.65 mm) and greater (>3.65 mm). All measurements were taken through a 23-inch screen with 1920 × 1080 resolution in a room with a moderate level of light.

2.3. Statistical Analysis

A power analysis using G*Power (version 3.19.2; Franz Faul, Christian-Albrechts-Universitat, Kiel, Germany) was performed to estimate the sample size required for this

study. In order to detect the independent sample *t*-test between group means, effect size and f = 0.90, 24 participants were required to achieve a power exceeding 0.63, *p* = 0.05.

To assess the reliability of the 3D measurements, CBCT scans of 12 subjects were re-digitized by the same operator and a dentist after 3 weeks. Intra- and interexaminer reliability was assessed by the intra- and interclass correlation coefficients, which showed excellent reliability of 0.938–1.000 and 0.940–1.000, respectively. SPSS software (version 27.0 for Windows; SPSS Corp., Chicago, IL, USA) was used for statistical analyses. A Shapiro-Wilk normality test was performed, and then a non-parametric test was performed when normality was not satisfied. A paired-sample *t*-test was performed to investigate the three-dimensional changes of the NSD and nasofacial structures after MSE. An independent sample *t*-test was performed to investigate and compare the three-dimensional changes of the NSD and nasofacial structures after MSE depending on the direction and amount of the NSD, and the amount of MPE. Significance was established at *p* < 0.05.

3. Results

NSD was alleviated in the coronal plane. NS lengths in the coronal and axial planes significantly increased at T3-T1. LS moved inferiorly at T2-T1 (*p* < 0.001) and T3-T1 (*p* < 0.01). MS_A and PS moved posteriorly at T3-T1 (*p* < 0.05). The angles and widths of the lateral nasal wall (LNW) increased (*p* < 0.001) at T2-T1 and maintained the increase at T3-T2. The absolute nasal floor (NF) angle (2.06° at T1) decreased at T2-T1 (*p* > 0.05) but increased at T3-T2 (*p* < 0.05). LNW and NF moved downward significantly. ANS moved forward and downward significantly. The right and left LF_ANS moved laterally and downward significantly. The mid LF_ANS moved downward (*p* < 0.01). The Pog and Me moved downward and backward significantly. The Me (lxl, 2.97 mm at T1) moved medially (*p* > 0.05) at T2-T1 but moved laterally at T3-T2 (*p* < 0.05), returning back nearly to the T1 value. Go moved backward (*p* < 0.001). The lzR-zLl of Go increased at T2-T1 (*p* < 0.01) (Table 3).

In the right NSD group [MS_C(x), −2.50; MS_A(x), −2.35], the LNW angles and widths were greater on the right than on the left. NF showed a left-up canting (NF angle, 1.12° at T1). ANS moved leftward at T3-T1 (*p* < 0.05). In the left NSD group [MS_C(x), 2.57; MS_A(x), 2.41], the LNW angles and widths were similar on both sides. NF showed a right-up canting (NF angle, −0.83° at T1) (Table 4).

The higher NSD group showed greater US, LS, AS, and PS angles, smaller MS angles than the lower NSD group, and a greater MS (lxl) with a statistical significance. The LNW angles and widths, NF angles, and lxl of ANS, Pog, Me, and Go showed no statistical differences between the higher and lower NSD groups (Table 5A). Most variables showed no statistical differences between the higher and lower NSD groups after MSE (Table 5B).

The amount of MPE was 1.8–5.5 mm (T2-T1, mean amount; 3.6 ± 1.0 mm). The greater MPE group showed greater US, LS, AS, and PS angles, smaller MS angles than the lesser MPE group, and greater AS and MS (lxl) with statistical significances. The LNW angles and widths, NF angles, and lxl of ANS, Pog, Me, and Go showed no statistical differences between the greater and lesser MPE groups (Table 6A). Most variables showed no statistical differences between the greater and lesser MPE groups after MSE (Table 6B).

Table 3. Three-dimensional values and changes of nasal septum and nasofacial structures after MSE.

Variables				T1 (n = 28)		T2 (n = 28)		T3 (n = 28)		T2-T1 (n = 28)			T3-T2 (n = 28)			T3-T1 (n = 28)		
Nasal Septum				Mean	SD	Mean	SD	Mean	SD	Mean	SD	*p*-Value	Mean	SD	*p*-Value	Mean	SD	*p*-Value
Coronal	Angle	US	(°)	4.82	2.38	5.07	2.50	4.87	2.52	0.26	0.83	0.113	−0.21	1.32	0.414	0.05	1.49	0.858
		MS	(°)	166.70	7.19	166.05	7.56	168.11	7.67	−0.65	2.61	0.197	2.07	3.85	0.009 **	1.41	3.66	0.051
		LS	(°)	8.40	5.43	8.92	5.64	6.91	5.79	0.51	2.29	0.245	−2.01	3.21	0.003 **	−1.49	2.99	0.014 *
	Length	US-LS	(mm)	47.16	3.41	47.87	3.34	47.82	3.39	0.71	0.92	0.000 ***	−0.05	1.42	0.852	0.66	1.09	0.004 **
Axial	Angle	AS	(°)	4.23	2.99	4.26	2.91	4.12	2.98	0.03	1.07	0.889	−0.14	1.10	0.507	−0.11	1.15	0.613
		MS	(°)	171.27	6.54	171.47	6.20	171.47	6.68	0.20	1.49	0.493	0.00	1.52	0.987	0.20	1.94	0.589
		PS	(°)	5.16	4.16	4.96	3.81	5.10	4.28	−0.21	1.00	0.287	0.15	1.58	0.631	−0.06	1.44	0.826
	Length	AS-PS	(mm)	64.73	7.37	64.99	7.30	65.63	7.05	0.26	1.00	0.188	0.64	1.82	0.076	0.89	1.99	0.025 *
Coronal	x,y,z	US	lxl	0.70	0.56	0.69	0.63	0.72	0.60	−0.02	0.40	0.813	0.03	0.40	0.698	0.01	0.24	0.806
			y	26.83	7.23	26.76	7.00	26.83	7.15	−0.07	1.31	0.765	0.07	1.78	0.835	0.00	1.06	0.984
			z	−5.76	3.43	−5.62	3.33	−5.84	3.52	0.13	0.56	0.219	−0.22	0.78	0.149	−0.09	0.49	0.358
	x,y,z	MS	lxl	2.52	1.31	2.59	1.31	2.38	1.44	0.06	0.46	0.484	−0.20	0.84	0.214	−0.14	0.77	0.343
			y	26.83	7.23	26.76	7.00	26.84	7.16	−0.07	1.31	0.765	0.08	1.75	0.800	0.01	1.03	0.959
			z	−35.31	4.46	−35.32	4.76	−35.43	4.55	−0.01	0.85	0.972	−0.11	1.37	0.672	−0.12	0.89	0.492
	x,y,z	LS	lxl	1.17	0.89	1.21	0.89	1.07	0.66	0.04	0.64	0.724	−0.15	0.77	0.323	−0.10	0.54	0.326
			y	26.83	7.23	26.76	7.00	26.83	7.15	−0.07	1.31	0.765	0.07	1.78	0.835	0.00	1.06	0.984
			z	−52.91	3.51	−53.48	3.53	−53.65	3.37	−0.58	0.71	0.000 ***	−0.17	1.22	0.474	−0.75	1.09	0.001 **
Axial	x,y,z	AS	lxl	1.31	1.14	1.21	0.85	1.14	1.01	−0.10	0.54	0.350	−0.07	0.50	0.495	−0.16	0.51	0.099
			y	−12.47	5.32	−12.47	5.20	−12.57	5.14	0.00	0.78	0.998	−0.10	1.11	0.624	−0.10	1.28	0.670
			z	−38.33	4.31	−38.18	4.14	−38.23	4.39	0.15	0.88	0.375	−0.05	1.48	0.859	0.10	1.24	0.673
	x,y,z	MS	lxl	2.37	1.46	2.41	1.47	2.37	1.54	0.04	0.43	0.620	−0.05	0.38	0.536	0.00	0.37	0.956
			y	24.43	6.78	24.88	6.43	25.14	6.37	0.44	1.29	0.081	0.26	1.60	0.394	0.70	1.61	0.028 *
			z	−38.33	4.31	−38.26	4.18	−38.23	4.40	0.07	0.71	0.624	0.03	1.48	0.915	0.10	1.23	0.683
	x,y,z	PS	lxl	1.43	1.15	1.56	1.19	1.42	1.13	0.13	0.58	0.264	−0.14	0.57	0.207	−0.01	0.31	0.825
			y	52.21	4.61	52.47	4.27	53.01	4.67	0.26	1.19	0.266	0.54	1.91	0.147	0.80	1.91	0.036 *
			z	−38.33	4.31	−35.40	15.13	−38.23	4.39	2.93	14.71	0.302	−2.83	14.74	0.319	0.10	1.24	0.673

Table 3. *Cont.*

Variables				T1 (n = 28)		T2 (n = 28)		T3 (n = 28)		T2-T1 (n = 28)			T3-T2 (n = 28)			T3-T1 (n = 28)		
Nasal Septum				Mean	SD	Mean	SD	Mean	SD	Mean	SD	*p*-Value	Mean	SD	*p*-Value	Mean	SD	*p*-Value
Lateral nasal wall	Angle	Right	(°)	23.77	2.51	25.00	2.53	24.89	2.29	1.22	0.86	0.000 ***	−0.11	0.80	0.464	1.11	0.72	0.000 ***
		Left	(°)	23.50	2.61	24.51	2.49	24.54	2.61	1.02	1.04	0.000 ***	0.03	1.08	0.875	1.05	0.96	0.000 ***
	x,y,z	Right	x	−16.59	1.68	−17.77	1.86	−17.71	1.61	−1.17	0.79	0.000 ***	0.06	0.80	0.700	−1.11	0.60	0.000 ***
			y	26.83	7.23	26.76	7.00	26.83	7.15	−0.07	1.31	0.76	0.07	1.78	0.835	0.00	1.06	0.984
			z	−43.29	3.98	−43.65	3.88	−43.89	3.83	−0.36	0.95	0.06	−0.25	1.13	0.260	−0.61	0.96	0.002 **
	x,y,z	Left	x	15.99	2.13	17.14	2.01	17.15	2.05	1.15	0.63	0.000 ***	0.01	0.63	0.940	1.15	0.70	0.000 ***
			y	26.83	7.23	26.76	7.00	26.83	7.15	−0.07	1.31	0.76	0.07	1.78	0.835	0.00	1.06	0.984
			z	−43.02	4.22	−43.64	3.97	−43.81	4.27	−0.62	1.01	0.003 **	−0.17	1.46	0.542	−0.79	1.29	0.003 **
Nasal floor		Angle	l°l	2.06	1.07	1.72	1.50	2.27	1.50	−0.33	1.32	0.193	0.54	1.25	0.029 *	0.21	1.54	0.471
		Right	x	−8.58	2.21	−9.72	2.19	−9.41	2.28	−1.15	0.87	0.000 ***	0.32	0.92	0.08	−0.83	1.16	0.000 ***
			y	26.83	7.23	26.76	7.00	26.83	7.15	−0.07	1.31	0.76	0.07	1.78	0.84	0.00	1.06	0.984
			z	−53.74	3.75	−54.26	3.69	−54.62	3.65	−0.52	0.58	0.000 ***	−0.36	0.83	0.028 *	−0.88	0.98	0.000 ***
		Left	x	8.15	2.14	9.32	2.25	9.10	2.38	1.17	0.82	0.000 ***	−0.22	0.95	0.24	0.95	0.93	0.000 ***
			y	26.83	7.23	26.76	7.00	26.83	7.15	−0.07	1.31	0.76	0.07	1.78	0.84	0.00	1.06	0.984
			z	−53.67	4.02	−54.13	3.99	−54.61	3.91	−0.46	0.65	0.000 ***	−0.48	0.87	0.006 **	−0.94	1.19	0.000 ***
Anterior nasal spine (ANS)			lxl	0.95	0.87	1.04	0.80	1.13	0.79	0.09	0.58	0.434	0.10	0.51	0.313	0.19	0.52	0.070
			y	−1.89	3.77	−1.93	3.91	−2.42	4.04	−0.05	0.79	0.755	−0.48	1.18	0.039 *	−0.53	1.18	0.025 *
			z	−53.61	4.10	−54.13	3.95	−54.20	3.73	−0.52	0.78	0.002 *	−0.07	0.74	0.616	−0.59	0.87	0.001 **
LF_ANS		Right	x	−10.18	2.09	−11.69	1.99	−12.02	2.19	−1.51	0.84	0.000 ***	−0.32	0.95	0.084	−1.84	1.27	0.000 ***
			y	7.51	3.89	7.47	4.04	7.38	3.97	−0.04	0.61	0.723	−0.09	0.72	0.515	−0.13	0.98	0.484
			z	−53.61	4.10	−54.13	3.95	−54.18	3.77	−0.52	0.78	0.002 **	−0.04	0.80	0.771	−0.56	0.87	0.002 **
		Left	x	10.03	2.61	11.62	2.61	11.84	2.41	1.59	1.00	0.000 ***	0.23	0.94	0.211	1.81	1.35	0.000 ***
			y	7.48	3.60	7.60	3.76	7.49	3.57	0.12	0.82	0.447	−0.11	0.65	0.377	0.01	1.00	0.963
			z	−53.61	4.10	−54.13	3.95	−54.20	3.73	−0.52	0.78	0.002 **	−0.07	0.74	0.616	−0.59	0.87	0.001 **
		Middle	lxl	0.81	0.84	0.84	0.84	0.77	0.87	0.03	0.39	0.686	−0.07	0.39	0.351	−0.04	0.43	0.628
			y	7.50	3.72	7.54	3.88	7.44	3.75	0.04	0.67	0.759	−0.10	0.65	0.416	−0.06	0.95	0.735
			z	−53.61	4.10	−54.13	3.95	−54.19	3.75	−0.52	0.78	0.002 **	−0.06	0.77	0.691	−0.58	0.86	0.001 **
Pogonion (Pog)			lxl	2.82	1.93	2.62	2.20	2.80	2.20	−0.20	0.97	0.288	0.18	0.93	0.325	−0.02	0.81	0.886
			y	1.73	8.33	3.33	8.36	2.99	8.32	1.60	1.25	0.000 ***	−0.34	1.58	0.266	1.26	1.68	0.000 ***
			z	−113.70	8.20	−114.76	7.86	−114.65	7.58	−1.06	1.12	0.000 ***	0.11	1.98	0.767	−0.95	2.09	0.023 *

Table 3. *Cont.*

Variables			T1 (n = 28)		T2 (n = 28)		T3 (n = 28)		T2-T1 (n = 28)			T3-T2 (n = 28)			T3-T1 (n = 28)		
Menton (Me)		lxl	2.97	2.08	2.64	2.39	3.05	2.44	−0.33	0.97	0.088	0.41	1.03	0.047 *	0.08	0.92	0.649
		y	7.19	8.59	8.79	8.41	8.46	8.52	1.60	1.25	0.000 ***	−0.33	1.49	0.258	1.27	1.62	0.000 ***
		z	−120.04	8.14	−120.93	7.85	−120.99	7.52	−0.90	1.08	0.000 ***	−0.06	1.83	0.861	−0.96	1.98	0.016 *
Nasal Septum			**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	***p*-Value**	**Mean**	**SD**	***p*-Value**	**Mean**	**SD**	***p*-Value**
Gonion (Go)	Right	x	−47.74	3.36	−48.00	3.40	−47.84	3.26	−0.26	0.90	0.133	0.16	1.06	0.430	−0.10	0.85	0.524
		y	70.42	5.68	71.48	6.08	71.55	5.29	1.06	1.20	0.000 ***	0.06	1.77	0.848	1.13	1.07	0.000 ***
		z	−86.89	7.58	−86.69	7.81	−87.03	7.72	0.21	1.21	0.371	−0.35	1.71	0.295	−0.14	1.61	0.654
	Left	x	47.47	4.31	47.45	4.41	47.61	4.66	−0.02	0.88	0.883	0.16	1.04	0.420	0.14	1.01	0.477
		y	69.84	5.67	71.04	5.56	71.02	5.32	1.20	1.04	0.000 ***	−0.02	1.24	0.934	1.18	1.16	0.000 ***
		z	−86.21	7.59	−85.98	7.59	−86.18	7.43	0.23	1.01	0.239	−0.21	1.44	0.455	0.02	1.30	0.923
	lRight-Leftl	lxR-xLl	3.52	2.22	3.22	2.61	3.30	2.70	−0.30	1.18	0.195	0.08	1.39	0.776	−0.22	1.17	0.327
		lyR-yLl	1.93	1.39	2.09	1.73	2.02	1.28	0.16	1.34	0.526	−0.07	1.24	0.761	0.09	0.56	0.399
		lzR-zLl	1.78	1.84	2.24	2.00	2.06	2.10	0.46	0.79	0.005 **	−0.18	0.91	0.299	0.28	0.87	0.102

T1, pre-expansion; T2, post-expansion; T3, 6 months after expansion. The coordinate system consists of three axes (x, y, and z) with their origin (0,0,0) registered at nasion (N). Positive values are to the left, posterior, and superior (LPS) to the N point of the subject. Negative values are to the right, anterior, and inferior (RAI) to the N point. MSE, maxillary skeletal expansion. lxl, absolute value of x. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. A paired *t*-test was performed.

Table 4. Three-dimensional values and changes of nasal septum and nasofacial structures after MSE depending on the direction of NSD.

A. Right NSD Group			T1 (n = 18)		T2 (n = 18)		T3 (n = 18)		T2-T1 (n = 18)			T3-T2 (n = 18)			T3-T1 (n = 18)		
			Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	***p*-Value**	**Mean**	**SD**	***p*-Value**	**Mean**	**SD**	***p*-Value**
Nasal septum	Coronal	US	x	−0.12	0.83	−0.06	0.94	−0.06	0.88	0.06	0.43	0.583	0.00	0.44	0.987	0.06	0.31	0.405
		MS	x	−2.50	1.46	−2.55	1.40	−2.08	1.99	−0.05	0.49	0.654	0.47	1.41	0.178	0.38	1.37	0.255
		LS	x	−0.21	1.42	0.01	1.49	−0.23	1.23	0.22	0.79	0.251	−0.24	1.01	0.326	−0.01	0.56	0.928
	Axial	AS	x	0.31	1.05	0.52	1.00	0.34	0.97	0.21	0.52	0.111	−0.18	0.57	0.198	0.03	0.55	0.825
		MS	x	−2.35	1.66	−2.46	1.63	−2.34	1.73	−0.10	0.44	0.331	0.11	0.44	0.288	−0.01	0.42	0.929
		PS	x	−0.40	1.75	−0.65	1.95	−0.39	1.81	−0.25	0.73	0.170	0.26	0.75	0.165	0.00	0.31	0.953

Table 4. *Cont.*

A. Right NSD Group				T1 (n = 18)		T2 (n = 18)		T3 (n = 18)		T2-T1 (n = 18)			T3-T2 (n = 18)			T3-T1 (n = 18)		
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	*p*-Value	Mean	SD	*p*-Value	Mean	SD	*p*-Value
Lateral nasal wall	Angle	Right	(°)	24.25	2.74	25.55	2.71	25.37	2.40	1.31	0.86	0.000 ***	−0.18	0.95	0.423	1.12	0.67	0.000 ***
		Left	(°)	23.85	2.74	24.73	2.75	24.76	2.83	0.88	1.00	0.001 **	0.03	1.10	0.912	0.91	1.02	0.001 **
	x,y,z	Right	x	−16.66	1.63	−17.82	1.96	−17.75	1.49	−1.16	0.89	0.000 ***	0.08	0.94	0.740	−1.09	0.50	0.000 ***
			y	27.19	7.79	27.08	7.76	27.16	7.98	−0.05	1.37	0.747	0.08	2.17	0.883	0.03	1.11	0.924
			z	−42.59	3.95	−42.81	3.88	−43.21	3.69	−0.23	0.93	0.314	−0.40	1.23	0.188	−0.63	0.93	0.011 *
	x,y,z	Left	x	15.89	2.10	17.04	2.00	16.99	1.98	1.15	0.62	0.000 ***	−0.05	0.62	0.738	1.10	0.62	0.000 ***
			y	27.19	7.90	27.08	7.76	27.16	7.98	−0.11	1.37	0.747	0.08	2.17	0.883	−0.03	1.11	0.924
			z	−41.90	3.66	−42.73	3.46	−42.81	3.64	−0.82	1.05	0.004 **	−0.08	1.53	0.818	−0.90	1.33	0.010 *
Nasal floor	Angle		(°)	1.12	1.93	1.24	1.95	0.65	2.56	0.12	1.30	0.706	−0.58	1.43	0.103	−0.46	2.35	0.414
			l°l	2.01	0.88	1.83	1.37	2.16	1.44	−0.18	1.17	0.516	0.33	1.28	0.284	0.15	1.51	0.677
		Right	x	−8.73	2.37	−9.74	2.37	−9.40	2.27	−1.01	0.89	0.000 ***	0.34	0.91	0.135	−0.67	0.96	0.009 **
			y	27.19	7.90	27.08	7.76	26.61	9.00	−0.11	1.37	0.747	−0.48	3.28	0.883	−0.59	2.67	0.924
			z	−52.89	3.20	−53.54	3.33	−53.89	3.13	−0.65	0.52	0.000 ***	−0.35	0.99	0.149	−1.00	1.11	0.001 **
		Left	x	8.39	1.88	9.64	2.00	9.28	2.07	1.25	0.76	0.000 ***	−0.36	1.10	0.188	0.89	0.85	0.000 ***
			y	27.19	7.90	27.08	7.76	27.16	7.98	−0.11	1.37	0.747	0.08	2.17	0.883	−0.03	1.11	0.924
			z	−52.64	3.40	−53.16	3.38	−53.67	3.26	−0.52	0.51	0.000 ***	−0.51	1.07	0.057	−1.03	1.34	0.004 **
Anterior nasal spine (ANS)			x	−0.13	0.99	−0.12	0.98	0.10	1.05	0.01	0.51	0.960	0.22	0.76	0.225	0.28	0.53	0.037 *
LF_ANS		Right	x	−10.03	2.11	−11.64	2.13	−11.85	2.41	−1.61	0.91	0.000 ***	−0.21	0.87	0.317	−1.94	1.08	0.000 ***
		Left	x	9.38	2.72	10.96	2.78	11.04	2.50	1.58	1.06	0.000 ***	0.08	0.89	0.716	1.79	1.15	0.000 ***
		Middle	x	−0.32	0.85	−0.34	0.86	−0.40	0.81	−0.01	0.45	0.890	−0.07	0.63	0.657	−0.08	0.58	0.592
Pogonion (Pog)			x	−0.48	3.69	−0.45	3.69	−0.55	3.88	0.03	1.15	0.925	−0.10	1.10	0.712	−0.18	0.82	0.359
Menton (Me)			x	−0.48	3.96	−0.56	3.90	−0.32	4.32	−0.08	1.24	0.778	0.24	1.42	0.476	0.03	0.93	0.899
Gonion (Go)		Right	x	−47.52	3.57	−47.80	3.65	−47.58	3.44	−0.28	1.07	0.289	0.23	1.21	0.439	−0.13	0.84	0.527
		Left	x	46.48	3.73	46.54	3.54	46.78	4.12	0.06	0.91	0.773	0.24	1.26	0.432	0.28	1.07	0.292

Table 4. *Cont.*

B. Left NSD Group			T1 (n = 10)		T2 (n = 10)		T3 (n = 10)		T2-T1 (n = 10)			T3-T2 (n = 10)			T3-T1 (n = 10)		
		x,y,z	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*p*-Value	Mean	SD	*p*-Value	Mean	SD	*p*-Value
Nasal septum	Coronal	US	x	−0.25	1.04	−0.25	0.96	−0.28	1.05	0.00	0.47	0.984	−0.04	0.52	0.828	−0.03	0.14	0.447
		MS	x	2.57	1.04	2.65	1.21	2.34	1.27	0.08	0.44	0.584	−0.31	1.28	0.465	−0.23	1.22	0.564
		LS	x	−0.49	1.57	−0.48	1.59	−0.01	1.38	0.01	0.61	0.944	0.47	0.50	0.017 *	0.48	0.61	0.034 *
	Axial	AS	x	0.74	2.52	0.66	1.95	0.68	2.14	−0.08	0.66	0.705	0.02	0.46	0.894	−0.06	0.54	0.727
		MS	x	2.41	1.09	2.34	1.18	2.35	1.34	−0.07	0.43	0.619	0.01	0.44	0.950	−0.06	0.30	0.530
		PS	x	−0.60	1.96	−0.53	1.86	−0.44	1.84	0.06	0.37	0.605	0.09	0.36	0.448	0.15	0.20	0.039 *
Lateral nasal wall	Angle	Right	(°)	22.92	1.85	24.00	1.91	24.02	1.89	1.08	0.90	0.004 **	0.01	0.45	0.917	1.09	0.84	0.002 **
		Left	(°)	22.86	2.35	24.12	2.01	24.16	2.24	1.26	1.12	0.006 **	0.04	1.10	0.915	1.29	0.84	0.000 ***
	x,y,z	Right	x	−16.47	1.83	−17.67	1.76	−17.64	1.88	−1.20	0.62	0.000 ***	0.03	0.47	0.849	−1.17	0.77	0.001 **
			y	26.19	6.19	26.17	5.70	26.23	5.69	−0.02	1.25	0.962	0.06	0.80	0.814	0.04	1.01	0.898
			z	−44.55	3.91	−45.15	3.58	−45.12	3.97	−0.60	0.99	0.088	0.03	0.92	0.925	−0.57	1.06	0.124
	x,y,z	Left	x	16.18	2.27	17.32	2.13	17.44	2.24	1.14	0.66	0.000 ***	0.11	0.67	0.602	1.26	0.87	0.001 **
			y	26.19	6.19	26.17	5.70	26.23	5.69	−0.02	1.25	0.962	0.06	0.80	0.814	0.04	1.01	0.898
			z	−45.03	4.59	−45.28	4.47	−45.61	4.92	−0.25	0.86	0.376	−0.32	1.39	0.479	−0.58	1.25	0.178
Nasal floor	Angle		(°)	−0.83	2.50	−0.94	2.19	−1.19	2.81	−0.11	1.85	0.849	−0.25	1.54	0.624	−0.36	1.90	0.563
			l°l	2.13	1.39	1.53	1.78	2.45	1.67	−0.60	1.58	0.259	0.92	1.16	0.032 *	0.32	1.66	0.554
	Right		x	−8.30	1.97	−9.70	1.93	−9.42	2.43	−1.40	0.82	0.000 ***	0.28	0.98	0.384	−1.12	1.46	0.038 *
			y	26.19	6.19	26.17	5.70	26.23	5.69	−0.02	1.25	0.962	0.06	0.80	0.814	0.04	1.01	0.898
			z	−55.27	4.32	−55.55	4.12	−55.94	4.29	−0.28	0.65	0.205	−0.39	0.48	0.031 *	−0.67	0.68	0.013 *
	Left		x	7.72	2.60	8.75	2.66	8.78	2.95	1.03	0.95	0.007 **	0.03	0.55	0.858	1.06	1.09	0.013 *
			y	26.19	6.19	26.17	5.70	26.23	5.69	−0.02	1.25	0.962	0.06	0.80	0.814	0.04	1.01	0.898
			z	−55.53	4.53	−55.88	4.58	−56.32	4.57	−0.35	0.88	0.242	−0.44	0.37	0.004 **	−0.78	0.91	0.023 *
Anterior nasal spine (ANS)			x	0.64	1.65	0.75	1.66	0.90	1.70	0.10	0.87	0.716	0.15	0.67	0.490	0.26	0.64	0.236

Table 4. *Cont.*

B. Left NSD Group			T1 (n = 10)		T2 (n = 10)		T3 (n = 10)		T2-T1 (n = 10)			T3-T2 (n = 10)			T3-T1 (n = 10)		
		x,y,z	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*p*-Value	Mean	SD	*p*-Value	Mean	SD	*p*-Value
LF_ANS	Right	x	−10.45	2.13	−11.80	1.80	−12.32	1.78	−1.34	0.72	0.000 ***	−0.52	1.09	0.166	−1.86	1.42	0.003 **
	Left	x	11.20	2.05	12.79	1.84	13.29	1.41	1.60	0.95	0.000 ***	0.50	1.00	0.152	2.09	1.44	0.001 **
	Middle	x	0.37	1.55	0.50	1.55	0.49	1.50	0.13	0.48	0.419	−0.01	0.53	0.940	0.12	0.51	0.492
Pogonion (Pog)		x	1.26	2.83	1.38	2.76	1.47	2.74	0.12	0.67	0.572	0.09	0.69	0.690	0.21	0.66	0.329
Menton (Me)		x	1.26	2.91	1.35	2.74	1.61	2.90	0.10	0.79	0.708	0.26	0.50	0.143	0.35	0.51	0.055
Gonion (Go)	Right	x	−48.12	3.08	−48.36	3.05	−48.32	3.03	−0.24	0.51	0.169	0.04	0.76	0.862	−0.20	0.71	0.403
	Left	x	49.26	4.91	49.07	5.49	49.10	5.41	−0.18	0.84	0.508	0.02	0.50	0.886	−0.16	0.80	0.545

T1, pre-expansion; T2, post-expansion; T3, 6 months after expansion. The coordinate system consists of three axes (x, y, and z) with their origin (0,0,0) registered at nasion (N). Positive values are to the left, posterior, and superior (LPS) to the N point of the subject. Negative values are to the right, anterior, and inferior (RAI) to the N point. MSE, maxillary skeletal expansion. lxl, absolute value of x. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. A paired *t*-test was performed.

Table 5. Three-dimensional values (A) and changes (B) of nasal septum and nasofacial structures after MSE depending on the amount of NSD.

(A)																		
Variables				T1 (n = 28)					T2 (n = 28)					T3 (n = 28)				
			NSD	NSD < 2.5 mm (n = 14)		NSD ≥ 2.5 mm (n = 14)			NSD < 2.5 mm (n = 14)		NSD ≥ 2.5 mm (n = 14)			NSD < 2.5 mm (n = 14)		NSD ≥ 2.5 mm (n = 14)		
Nasal Septum			x,y,z	Mean	SD	Mean	SD	*p*-Value	Mean	SD	Mean	SD	*p*-Value	Mean	SD	Mean	SD	*p*-Value
Coronal	Angle	US	(°)	3.27	1.90	6.36	1.74	0.000 ***	3.60	2.42	6.55	1.56	0.001 **	3.54	2.05	6.19	2.27	0.003 **
		MS	(°)	171.44	4.68	161.95	6.07	0.000 ***	170.49	5.81	161.60	6.51	0.001 **	172.55	4.33	163.67	7.80	0.001 **
		LS	(°)	5.27	3.64	11.54	5.19	0.001 **	5.87	4.32	11.97	5.24	0.002 **	3.53	3.13	10.30	5.93	0.001 **
	Length	US-LS	(mm)	47.42	3.24	46.91	3.68	0.698	47.84	3.47	47.90	3.33	0.963	48.03	3.26	47.60	3.62	0.744
Axial	Angle	AS	(°)	2.45	1.69	6.02	2.98	0.001 **	2.83	1.89	5.70	3.09	0.007 **	2.47	1.91	5.77	2.99	0.002 **
		MS	(°)	174.52	4.03	168.03	7.07	0.006 **	174.39	4.11	168.55	6.67	0.010 *	174.65	4.92	168.30	6.83	0.009 **
		PS	(°)	3.50	3.02	6.83	4.57	0.031 *	3.32	2.60	6.59	4.20	0.020 *	3.30	3.17	6.91	4.58	0.023 *
	Length	AS-PS	(mm)	67.24	8.83	62.23	4.62	0.071	67.71	8.72	62.27	4.31	0.047 *	68.18	8.11	63.07	4.83	0.053

Table 5. *Cont.*

			(A)															
			T1 (n = 28)					**T2 (n = 28)**					**T3 (n = 28)**					
Variables		**NSD**	**NSD < 2.5 mm (n = 14)**		**NSD ≥ 2.5 mm (n = 14)**			**NSD < 2.5 mm (n = 14)**		**NSD ≥ 2.5 mm (n = 14)**			**NSD < 2.5 mm (n = 14)**		**NSD ≥ 2.5 mm (n = 14)**		
Nasal Septum		**x,y,z**	**Mean**	**SD**	**Mean**	**SD**	*p*-**Value**	**Mean**	**SD**	**Mean**	**SD**	*p*-**Value**	**Mean**	**SD**	**Mean**	**SD**	*p*-**Value**
Coronal	US	lxl	0.71	0.43	0.70	0.69	0.987	0.77	0.58	0.60	0.69	0.483	0.72	0.50	0.71	0.70	0.961
	MS	lxl	1.44	0.59	3.61	0.81	0.000 ***	1.54	0.59	3.63	0.94	0.000 ***	1.40	0.61	3.37	1.35	0.000 ***
	LS	lxl	1.07	0.79	1.27	0.99	0.572	1.34	0.75	1.09	1.02	0.467	0.99	0.51	1.15	0.80	0.549
Axial	AS	lxl	1.16	0.85	1.46	1.39	0.504	1.18	0.78	1.24	0.94	0.866	1.14	0.96	1.15	1.09	0.967
	MS	lxl	1.39	0.70	3.36	1.37	0.000 ***	1.52	0.73	3.31	1.49	0.001 **	1.42	0.82	3.32	1.52	0.000 ***
	PS	lxl	1.24	0.90	1.62	1.36	0.385	1.44	0.98	1.67	1.41	0.632	1.27	0.98	1.57	1.29	0.489
Lateral nasal wall	Angle Right	(°)	23.57	3.42	23.98	1.14	0.675	25.09	3.29	24.91	1.58	0.855	24.74	3.07	25.03	1.19	0.748
	Angle Left	(°)	24.14	2.59	22.85	2.55	0.193	25.10	2.51	23.92	2.40	0.214	24.87	2.56	24.22	2.71	0.524
	Right x,y,z x	x	−16.26	1.74	−16.93	1.60	0.303	−17.60	2.14	−17.93	1.60	0.642	−17.26	1.50	−18.16	1.64	0.140
	y	y	27.59	7.31	26.08	7.34	0.589	27.46	7.30	26.06	6.88	0.606	27.57	7.31	26.09	7.18	0.593
	z	z	−43.85	4.87	−42.73	2.92	0.469	−44.14	4.71	−43.16	2.94	0.516	−44.22	4.63	−43.56	2.97	0.657
	Left x,y,z x	x	16.74	2.11	15.25	1.93	0.062	17.67	2.11	16.61	1.84	0.168	17.63	2.09	16.66	1.96	0.218
	y	y	27.59	7.31	26.08	7.34	0.589	27.46	7.30	26.06	6.88	0.606	27.57	7.31	26.09	7.18	0.593
	z	z	−43.55	4.86	−42.49	3.56	0.519	−44.20	4.76	−43.07	3.07	0.461	−44.17	4.88	−43.45	3.72	0.663
Nasal floor	Angle	l°l	1.88	1.02	2.23	1.12	0.395	1.91	1.48	1.54	1.55	0.517	2.31	1.31	2.22	1.72	0.880
	Right x	x	−8.09	1.97	−9.06	2.40	0.251	−9.16	1.96	−10.28	2.32	0.179	−8.67	1.92	−10.14	2.44	0.089
	y	y	27.59	7.31	26.08	7.34	0.589	27.46	7.30	26.06	6.88	0.606	27.57	7.31	26.09	7.18	0.593
	z	z	−54.19	4.11	−53.29	3.43	0.531	−54.69	4.03	−53.83	3.40	0.543	−55.02	4.19	−54.22	3.12	0.571
	Left x	x	8.79	2.19	7.51	1.97	0.115	9.88	2.47	8.76	1.94	0.192	9.70	2.56	8.51	2.11	0.189
	y	y	27.59	7.31	26.08	7.34	0.589	27.46	7.30	26.06	6.88	0.606	27.57	7.31	26.09	7.18	0.593
	z	z	−53.90	4.43	−53.44	3.71	0.766	−54.25	4.30	−54.00	3.83	0.871	−54.65	4.30	−54.58	3.65	0.960
Antterior nasal spine (ANS)		lxl	0.82	0.70	1.07	1.03	0.458	1.04	0.82	1.03	0.80	0.991	1.14	0.81	1.13	0.81	0.993

Table 5. *Cont.*

(A)

Variables		NSD	T1 (n = 28)					T2 (n = 28)					T3 (n = 28)				
			NSD < 2.5 mm (n = 14)		NSD ≥ 2.5 mm (n = 14)			NSD < 2.5 mm (n = 14)		NSD ≥ 2.5 mm (n = 14)			NSD < 2.5 mm (n = 14)		NSD ≥ 2.5 mm (n = 14)		
Nasal Septum		x,y,z	Mean	SD	Mean	SD	*p*-Value	Mean	SD	Mean	SD	*p*-Value	Mean	SD	Mean	SD	*p*-Value
LF_ANS	Middle	lxl	0.69	0.74	0.93	0.93	0.451	0.74	0.68	0.94	0.99	0.543	0.61	0.77	0.93	0.96	0.339
Pogonion (Pog)		lxl	2.40	1.90	3.25	1.93	0.250	2.26	1.94	2.98	2.45	0.398	2.50	2.16	3.10	2.27	0.477
Menton (Me)		lxl	2.54	1.98	3.40	2.16	0.284	2.32	2.13	2.97	2.66	0.481	2.71	2.29	3.39	2.62	0.473
Gonion (Go)	lRight-Leftl	lxR-xLl	3.76	2.36	3.28	2.13	0.573	3.36	2.83	3.09	2.48	0.791	3.68	3.20	2.92	2.16	0.467
		lyR-yLl	1.63	1.30	2.23	1.46	0.260	2.23	2.02	1.95	1.44	0.676	1.65	1.28	2.40	1.21	0.124
		lzR-zLl	1.71	1.53	1.85	2.17	0.849	2.12	1.80	2.36	2.25	0.755	1.95	1.69	2.16	2.51	0.795

(B)

Variables		NSD	T2-T1 (n = 28)					T3-T2 (n = 28)					T3-T1 (n = 28)				
			NSD < 2.5 mm (n = 14)		NSD ≥ 2.5 mm (n = 14)			NSD < 2.5 mm (n = 14)		NSD ≥ 2.5 mm (n = 14)			NSD < 2.5 mm (n = 14)		NSD ≥ 2.5 mm (n = 14)		
Nasal Septum		x,y,z	Mean	SD	Mean	SD	*p*-Value	Mean	SD	Mean	SD	*p*-Value	Mean	SD	Mean	SD	*p*-Value
Coronal	Angle	US (°)	0.32	0.71	0.19	0.97	0.688	−0.06	0.84	−0.36	1.70	0.561	0.27	0.69	−0.16	2.01	0.457
		MS (°)	−0.95	2.69	−0.35	2.60	0.553	2.06	2.37	2.07	5.02	0.995	1.11	1.88	1.72	4.91	0.670
		LS (°)	0.60	2.43	0.43	2.23	0.851	−2.35	2.30	−1.67	3.98	0.585	−1.75	2.23	−1.24	3.67	0.659
	Length	US-LS (mm)	0.42	0.76	1.00	1.00	0.099	0.20	1.66	−0.30	1.14	0.369	0.62	1.25	0.70	0.96	0.843
Axial	Angle	AS (°)	0.38	0.83	−0.32	1.19	0.085	−0.36	1.26	0.08	0.91	0.305	0.02	0.90	−0.24	1.37	0.556
		MS (°)	−0.13	0.80	0.52	1.94	0.266	0.26	1.41	−0.25	1.64	0.383	0.14	1.67	0.27	2.24	0.862
		PS (°)	−0.17	1.02	−0.24	1.02	0.873	−0.02	1.86	0.31	1.28	0.585	−0.20	1.46	0.08	1.45	0.626
	Length	AS-PS (mm)	0.46	1.10	0.05	0.88	0.279	0.47	2.42	0.80	0.99	0.646	0.94	2.70	0.85	0.93	0.906
Coronal		US lxl	0.07	0.47	−0.10	0.31	0.279	−0.05	0.42	0.11	0.36	0.293	0.02	0.30	0.01	0.16	0.932
		MS lxl	0.10	0.49	0.02	0.44	0.655	−0.14	0.52	−0.27	1.09	0.695	−0.04	0.31	−0.24	1.05	0.485
		LS lxl	0.27	0.62	−0.18	0.61	0.066	−0.35	0.79	0.06	0.72	0.168	−0.08	0.58	−0.12	0.53	0.850
Axial		AS lxl	0.02	0.50	−0.22	0.58	0.254	−0.05	0.58	−0.09	0.43	0.840	−0.02	0.46	−0.30	0.53	0.150
		MS lxl	0.13	0.41	−0.05	0.45	0.298	−0.10	0.38	0.01	0.39	0.485	0.03	0.31	−0.04	0.43	0.624
		PS lxl	0.21	0.71	0.04	0.43	0.470	−0.18	0.75	−0.10	0.33	0.715	0.03	0.27	−0.05	0.35	0.497

Table 5. *Cont.*

				(B)													
				T2-T1 (n = 28)					T3-T2 (n = 28)					T3-T1 (n = 28)				
Variables			**NSD**	**NSD < 2.5 mm (n = 14)**		**NSD ≥ 2.5 mm (n = 14)**			**NSD < 2.5 mm (n = 14)**		**NSD ≥ 2.5 mm (n = 14)**			**NSD < 2.5 mm (n = 14)**		**NSD ≥ 2.5 mm (n = 14)**	
Nasal Septum			**x,y,z**	**Mean**	**SD**	**Mean**	**SD**	**p-Value**	**Mean**	**SD**	**Mean**	**SD**	**p-Value**	**Mean**	**SD**	**Mean**	**SD**	**p-Value**
Angle	Right		(°)	1.52	0.63	0.93	0.98	0.071	−0.34	0.77	0.12	0.79	0.126	1.17	0.68	1.05	0.78	0.660
	Left		(°)	0.96	1.11	1.07	1.00	0.775	−0.24	1.03	0.30	1.09	0.190	0.72	1.03	1.38	0.78	0.069
Lateral nasal wall	x,y,z Right	x	−1.34	0.85	−1.01	0.72	0.282	0.34	0.90	−0.22	0.58	0.058	−1.00	0.54	−1.23	0.65	0.302	
		y	−0.13	1.45	−0.02	1.19	0.822	0.11	2.45	0.03	0.77	0.908	−0.02	1.26	0.01	0.86	0.935	
		z	−0.29	0.79	−0.43	1.11	0.708	−0.09	1.31	−0.40	0.94	0.470	−0.38	1.10	−0.83	0.77	0.218	
	x,y,z Left	x	0.93	0.66	1.36	0.53	0.067	−0.04	0.56	0.06	0.71	0.701	0.89	0.57	1.42	0.74	0.046 *	
		y	−0.13	1.45	−0.02	1.19	0.822	0.11	2.45	0.03	0.77	0.908	−0.02	1.26	0.01	0.86	0.935	
		z	−0.66	1.21	−0.58	0.81	0.838	0.04	1.59	−0.38	1.34	0.465	−0.62	1.55	−0.95	1.00	0.508	
Nasal floor	Angle		l°l	0.03	1.39	−0.70	1.17	0.147	0.40	1.43	0.69	1.08	0.551	0.43	1.69	−0.01	1.41	0.462
	Right	x	−1.07	0.81	−1.22	0.95	0.661	0.49	1.06	0.15	0.76	0.329	−0.58	0.94	−1.08	1.33	0.267	
		y	−0.13	1.45	−0.02	1.19	0.822	0.11	2.45	0.03	0.77	0.908	−0.02	1.26	0.01	0.86	0.935	
		z	−0.50	0.61	−0.54	0.58	0.857	−0.33	1.00	−0.40	0.65	0.833	−0.83	1.09	−0.94	0.90	0.775	
	Left	x	1.09	0.80	1.25	0.86	0.615	−0.18	0.99	−0.25	0.94	0.847	0.91	0.84	1.00	1.04	0.804	
		y	−0.13	1.45	−0.02	1.19	0.822	0.11	2.45	0.03	0.77	0.908	−0.02	1.26	0.01	0.86	0.935	
		z	−0.35	0.53	−0.56	0.76	0.401	−0.40	1.12	−0.57	0.56	0.602	−0.75	1.41	−1.14	0.94	0.397	
Antterior nasal spine (ANS)			lxl	0.21	0.44	−0.04	0.68	0.254	0.10	0.51	0.10	0.53	0.997	0.31	0.57	0.06	0.44	0.204
LF_ANS	Middle		lxl	0.05	0.40	0.01	0.40	0.783	−0.13	0.37	−0.01	0.42	0.425	−0.08	0.42	0.00	0.46	0.640
Pogonion (Pog)			lxl	−0.13	0.88	−0.26	1.08	0.725	0.23	0.80	0.12	1.07	0.753	0.10	0.79	−0.15	0.84	0.433
Menton (Me)			lxl	−0.22	0.89	−0.43	1.07	0.591	0.39	0.96	0.42	1.13	0.950	0.17	0.83	−0.01	1.04	0.620
Gonion (Go)	lRight-Leftl	lxR-xLl	−0.41	1.19	−0.19	1.21	0.639	0.32	1.57	−0.17	1.19	0.360	−0.08	1.32	−0.36	1.04	0.544	
		lyR-yLl	0.60	1.58	−0.28	0.88	0.080	−0.59	1.46	0.44	0.72	0.025*	0.02	0.47	0.17	0.64	0.489	
		lzR-zLl	0.41	0.75	0.51	0.85	0.729	−0.17	0.80	−0.20	1.03	0.932	0.24	0.69	0.32	1.05	0.822	

T1, pre-expansion; T2, post-expansion; T3, 6 months after expansion. The coordinate system consists of three axes (x, y, and z) with their origin (0,0,0) registered at nasion (N). Positive values are to the left, posterior, and superior (LPS) to the N point of the subject. Negative values are to the right, anterior, and inferior (RAI) to the N point. MSE, maxillary skeletal expansion. lxl, absolute value of x. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. An independent sample *t*-test was performed.

Table 6. Three-dimensional values (A) and changes (B) of nasal septum and nasofacial structures after MSE depending on the amount of midpalatal expansion.

(A)

Variables				T1 (n = 28)					T2 (n = 28)					T3 (n = 28)				
			MPE	MPE < 3.65 mm (n = 14)		MPE > 3.65 mm (n = 14)			MPE < 3.65 mm (n = 14)		MPE > 3.65 mm (n = 14)			MPE < 3.65 mm (n = 14)		MPE > 3.65 mm (n = 14)		
Nasal Septum			x,y,z	Mean	SD	Mean	SD	*p*-Value	Mean	SD	Mean	SD	*p*-Value	Mean	SD	Mean	SD	*p*-Value
Coronal	Angle	US	(°)	4.47	2.62	5.16	2.15	0.448	4.71	2.58	5.44	2.46	0.452	4.05	2.57	5.68	2.26	0.088
		MS	(°)	168.64	8.67	164.76	4.90	0.157	168.17	8.31	163.93	6.32	0.141	170.97	8.21	165.26	6.09	0.046 *
		LS	(°)	6.80	6.59	10.01	3.50	0.119	7.31	6.24	10.53	4.64	0.134	5.27	6.12	8.55	5.13	0.136
	Length	US-LS	(mm)	47.25	3.58	47.08	3.36	0.895	47.70	3.38	48.04	3.41	0.794	47.35	3.77	48.29	3.03	0.474
Axial	Angle	AS	(°)	2.67	2.52	5.80	2.64	0.004 **	2.72	2.41	5.81	2.56	0.003 **	2.48	2.56	5.76	2.48	0.002 **
		MS	(°)	173.39	7.01	169.16	5.49	0.087	174.06	6.27	168.88	5.09	0.024 *	173.89	7.29	169.06	5.18	0.054
		PS	(°)	4.60	4.61	5.73	3.75	0.484	4.15	4.02	5.77	3.55	0.270	4.20	4.66	6.00	3.82	0.274
	Length	AS-PS	(mm)	65.36	8.32	64.11	6.55	0.662	65.31	8.03	64.67	6.77	0.821	65.60	8.25	65.65	5.93	0.985
Coronal		US	lxl	0.80	0.59	0.61	0.54	0.385	0.71	0.65	0.66	0.64	0.857	0.82	0.63	0.62	0.57	0.385
		MS	lxl	2.07	1.17	2.98	1.32	0.064	2.17	1.08	3.00	1.43	0.093	1.76	1.14	3.00	1.47	0.019 *
		LS	lxl	1.15	0.94	1.20	0.87	0.885	1.21	0.85	1.22	0.96	0.992	1.00	0.70	1.13	0.64	0.614
Axial		AS	lxl	1.18	0.92	1.44	1.35	0.560	1.23	0.69	1.19	1.01	0.914	1.15	0.92	1.14	1.12	0.990
		MS	lxl	1.63	1.07	3.11	1.46	0.005 **	1.66	1.01	3.16	1.49	0.005 **	1.58	1.20	3.16	1.46	0.004 **
		PS	lxl	1.35	1.11	1.51	1.22	0.721	1.46	1.00	1.65	1.39	0.676	1.30	0.95	1.54	1.31	0.584
Lateral nasal wall	Angle	Right	(°)	23.92	2.68	23.63	2.42	0.768	25.04	2.73	24.96	2.42	0.931	24.80	2.48	24.98	2.17	0.840
		Left	(°)	23.93	2.95	23.06	2.24	0.385	24.72	2.68	24.30	2.35	0.665	24.89	2.64	24.20	2.62	0.494
	x,y,z	Right	x	−16.96	2.01	−16.23	1.23	0.262	−18.06	2.35	−17.48	1.22	0.420	−17.86	1.95	−17.55	1.23	0.618
			y	26.61	8.38	27.06	6.19	0.874	26.43	7.68	27.09	6.52	0.807	27.19	8.40	26.47	5.95	0.796
			z	−43.80	5.17	−42.77	2.38	0.508	−44.11	4.92	−43.19	2.58	0.544	−44.39	4.97	−43.40	2.30	0.508
	x,y,z	Left	x	16.43	2.71	15.56	1.28	0.292	17.21	2.54	17.07	1.40	0.860	17.22	2.51	17.07	1.55	0.848
			y	26.61	8.38	27.06	6.19	0.874	26.43	7.68	27.09	6.52	0.807	27.19	8.40	26.47	5.95	0.796
			z	−43.83	5.30	−42.21	2.72	0.320	−44.10	5.19	−43.17	2.32	0.548	−44.29	5.22	−43.33	3.19	0.561

Table 6. *Cont.*

			(A)														
			T1 (n = 28)					**T2 (n = 28)**					**T3 (n = 28)**				
Variables		**MPE**	**MPE < 3.65 mm (n = 14)**		**MPE > 3.65 mm (n = 14)**			**MPE < 3.65 mm (n = 14)**		**MPE > 3.65 mm (n = 14)**			**MPE < 3.65 mm (n = 14)**		**MPE > 3.65 mm (n = 14)**		
Nasal Septum		**x,y,z**	**Mean**	**SD**	**Mean**	**SD**	***p*-Value**	**Mean**	**SD**	**Mean**	**SD**	***p*-Value**	**Mean**	**SD**	**Mean**	**SD**	***p*-Value**
	Angle	l°l	1.89	1.15	2.22	0.99	0.414	1.23	1.13	2.22	1.70	0.083	2.13	1.20	2.40	1.78	0.645
		x	−8.89	2.57	−8.26	1.82	0.457	−9.83	2.25	−9.62	2.19	0.801	−9.51	2.16	−9.30	2.47	0.807
	Right	y	26.61	8.38	27.06	6.19	0.874	26.43	7.68	27.09	6.52	0.807	27.19	8.40	26.47	5.95	0.796
Nasal floor		z	−54.31	4.07	−53.17	3.45	0.427	−54.64	4.04	−53.88	3.41	0.594	−54.87	4.21	−54.38	3.13	0.727
		x	8.08	2.49	8.22	1.83	0.864	8.83	2.53	9.81	1.89	0.254	8.90	2.80	9.31	1.96	0.652
	Left	y	26.61	8.38	27.06	6.19	0.874	26.43	7.68	27.09	6.52	0.807	27.19	8.40	26.47	5.95	0.796
		z	−54.49	4.19	−52.85	3.81	0.289	−54.65	4.16	−53.61	3.90	0.502	−54.89	4.12	−54.34	3.84	0.717
Antterior nasal spine (ANS)		lxl	1.02	0.82	0.88	0.95	0.694	1.28	0.92	0.79	0.58	0.106	1.20	0.87	1.07	0.74	0.684
LF_ANS	Middle	lxl	0.85	0.91	0.77	0.78	0.794	0.93	0.82	0.75	0.87	0.591	8.51	3.57	6.52	3.45	0.144
Pogonion (Pog)		lxl	2.41	1.91	3.23	1.92	0.267	2.54	1.84	2.71	2.58	0.84	2.55	2.14	3.04	2.31	0.565
Menton (Me)		lxl	2.44	2.02	3.50	2.07	0.183	2.49	1.99	2.79	2.80	0.747	2.71	2.30	3.39	2.61	0.467
		lxR-xLl	4.12	2.30	2.92	2.04	0.154	4.03	2.77	2.42	2.26	0.104	4.26	3.00	2.34	2.06	0.059
Gonion (Go)	lRight-Leftl	lyR-yLl	1.61	1.00	2.25	1.67	0.232	2.26	1.87	1.92	1.62	0.61	1.95	1.13	2.10	1.46	0.767
		lzR-zLl	1.45	1.42	2.10	2.19	0.361	1.85	1.79	2.63	2.19	0.307	1.89	1.70	2.22	2.50	0.686

Table 6. *Cont.*

				(B)														
				T2-T1 (n = 28)					**T3-T2 (n = 28)**					**T3-T1 (n = 28)**				
Variables			**MPE**	**MPE < 3.65 mm (n = 14)**		**MPE > 3.65 mm (n = 14)**			**MPE < 3.65 mm (n = 14)**		**MPE > 3.65 mm (n = 14)**			**MPE < 3.65 mm (n = 14)**		**MPE > 3.65 mm (n = 14)**		
Nasal Septum			**x,y,z**	**Mean**	**SD**	**Mean**	**SD**	**p-Value**	**Mean**	**SD**	**Mean**	**SD**	**p-Value**	**Mean**	**SD**	**Mean**	**SD**	**p-Value**
Coronal	Angle	US	(°)	0.24	0.69	0.27	0.98	0.926	−0.66	1.54	0.24	0.91	0.072	−0.41	1.90	0.52	0.75	0.100
		MS	(°)	−0.47	2.64	−0.83	2.67	0.722	2.80	4.25	1.33	3.40	0.321	2.33	4.01	0.50	3.16	0.190
		LS	(°)	0.51	2.18	0.52	2.48	0.996	−2.04	3.00	−1.98	3.52	0.960	−1.53	2.83	−1.46	3.26	0.954
	Length	US-LS	(mm)	0.45	0.97	0.96	0.82	0.144	−0.35	1.24	0.25	1.57	0.269	0.10	0.56	1.21	1.23	0.005 **
Axial	Angle	AS	(°)	0.05	1.05	0.01	1.13	0.937	−0.23	1.28	−0.05	0.92	0.669	−0.19	0.58	−0.04	1.55	0.738
		MS	(°)	0.67	1.22	−0.27	1.62	0.095	−0.17	1.68	0.17	1.39	0.565	0.50	1.26	−0.10	2.46	0.484
		PS	(°)	−0.45	1.10	0.04	0.86	0.202	0.05	1.82	0.24	1.35	0.764	−0.40	1.39	0.28	1.46	0.223
	Length	AS-PS	(mm)	−0.05	0.59	0.56	1.24	0.114	0.29	2.08	0.99	1.52	0.321	0.24	2.28	1.55	1.44	0.082
Coronal		US	lxl	−0.09	0.51	0.05	0.26	0.354	0.11	0.50	−0.05	0.25	0.310	0.02	0.21	0.01	0.27	0.907
		MS	lxl	0.10	0.53	0.03	0.40	0.684	−0.41	1.13	0.00	0.32	0.214	−0.31	1.04	0.03	0.30	0.874
		LS	lxl	0.07	0.63	0.02	0.67	0.852	−0.21	0.69	−0.08	0.86	0.671	−0.14	0.57	−0.06	0.54	0.705
Axial		AS	lxl	0.05	0.44	−0.24	0.61	0.158	−0.08	0.49	−0.05	0.52	0.874	−0.03	0.40	−0.29	0.58	0.175
		MS	lxl	0.03	0.50	0.05	0.38	0.889	−0.09	0.45	−0.01	0.30	0.587	−0.06	0.30	0.05	0.44	0.472
		PS	lxl	0.11	0.78	0.14	0.30	0.880	−0.16	0.74	−0.12	0.34	0.834	−0.05	0.24	0.03	0.37	0.504
Lateral nasal wall	Angle	Right	(°)	1.12	1.06	1.33	0.64	0.545	−0.24	0.90	0.02	0.69	0.392	0.88	0.71	1.35	0.68	0.086
		Left	(°)	0.79	1.34	1.24	0.57	0.257	0.17	1.08	−0.10	1.10	0.514	0.96	0.78	1.14	1.13	0.621
	x,y,z	Right	x	−1.10	1.03	−1.25	0.48	0.638	0.19	1.03	−0.08	0.47	0.382	−0.91	0.56	−1.32	0.59	0.067
			y	−0.18	1.47	0.03	1.16	0.667	0.76	1.90	−0.62	1.40	0.038 *	0.58	0.99	−0.59	0.80	0.002
			z	−0.31	0.91	−0.41	1.02	0.767	−0.28	1.09	−0.21	1.22	0.872	−0.59	0.87	−0.63	1.08	0.918
	x,y,z	Left	x	0.78	0.61	1.51	0.39	0.001 **	0.02	0.43	0.00	0.80	0.951	0.80	0.50	1.51	0.71	0.005 **
			y	−0.18	1.47	0.03	1.16	0.667	0.76	1.90	−0.62	1.40	0.038 *	0.58	0.99	−0.59	0.80	0.002 **
			z	−0.28	0.98	−0.96	0.95	0.072	−0.19	0.78	−0.15	1.95	0.951	−0.46	0.93	−1.11	1.54	0.188

Table 6. *Cont.*

			(B)														
			T2-T1 (n = 28)					**T3-T2 (n = 28)**					**T3-T1 (n = 28)**				
Variables		**MPE**	**MPE < 3.65 mm (n = 14)**		**MPE > 3.65 mm (n = 14)**			**MPE < 3.65 mm (n = 14)**		**MPE > 3.65 mm (n = 14)**			**MPE < 3.65 mm (n = 14)**		**MPE > 3.65 mm (n = 14)**		
Nasal Septum		**x,y,z**	**Mean**	**SD**	**Mean**	**SD**	***p*-Value**	**Mean**	**SD**	**Mean**	**SD**	***p*-Value**	**Mean**	**SD**	**Mean**	**SD**	***p*-Value**
	Angle	l°l	−0.66	1.43	−0.01	1.15	0.198	0.90	1.14	0.19	1.29	0.132	0.25	1.77	0.18	1.33	0.908
	Right	x	−0.94	0.97	−1.36	0.74	0.207	0.32	0.98	0.32	0.90	0.994	−0.62	0.98	−1.04	1.32	0.350
		y	−0.18	1.47	0.03	1.16	0.667	0.76	1.90	−0.62	1.40	0.038 *	0.58	0.99	−0.59	0.80	0.002 **
Nasal floor		z	−0.33	0.65	−0.71	0.45	0.078	−0.23	0.43	−0.50	1.10	0.406	−0.56	0.53	−1.21	1.22	0.076
	Left	x	0.75	0.90	1.59	0.45	0.004 **	0.07	0.52	−0.50	1.19	0.118	0.82	0.91	1.09	0.96	0.447
		y	−0.18	1.47	0.03	1.16	0.667	0.76	1.90	−0.62	1.40	0.038 *	0.58	0.99	−0.59	0.80	0.002 **
		z	−0.16	0.69	−0.76	0.47	0.012 *	−0.24	0.40	−0.73	1.14	0.142	−0.40	0.73	−1.49	1.33	0.013 *
Antterior nasal spine (ANS)		lxl	0.26	0.57	−0.09	0.55	0.105	−0.08	0.43	0.28	0.54	0.058	0.18	0.62	0.19	0.42	0.972
LF_ANS	Middle	lxl	0.08	0.48	−0.01	0.30	0.571	7.59	4.03	5.76	3.45	0.210	7.66	4.08	5.75	3.42	0.191
Pogonion (Pog)		lxl	0.13	0.50	−0.52	1.21	0.075	0.02	0.66	0.34	1.14	0.376	0.14	0.74	−0.19	0.87	0.288
Menton (Me)		lxl	0.05	0.52	−0.70	1.18	0.037 *	0.21	0.67	0.60	1.30	0.334	0.27	0.67	−0.11	1.12	0.298
		lxR-xLl	−0.09	1.26	−0.50	1.11	0.376	0.23	1.62	−0.08	1.16	0.571	0.13	1.26	−0.58	1.00	0.111
Gonion (Go)	lRight-Leftl	lyR-yLl	0.65	1.60	−0.33	0.81	0.051	−0.32	1.62	0.17	0.67	0.306	0.34	0.42	−0.15	0.58	0.017 *
		lzR-zLl	0.39	0.78	0.53	0.82	0.649	0.05	0.67	−0.41	1.07	0.185	0.44	0.86	0.12	0.89	0.344

T1, pre-expansion; T2, post-expansion; T3, at least 6 months post-expansion. The coordinate system consists of three axes (x, y, and z) with their origin (0,0,0) registered at nasion (N). Positive values are to the left, posterior, and superior (LPS) to the N point of the subject. Negative values are to the right, anterior, and inferior (RAI) to the N point. MSE, maxillary skeletal expansion. lxl, absolute value of x. * $p < 0.05$, ** $p < 0.01$. An independent sample *t*-test was performed.

4. Discussion

In this study, the US angle increased in the short term but decreased in the long term after MSE, which was a slightly different result than what was seen in a previous study [11] that found a significant decrease in the US angle in the short and long term. In the previous studies [3,5,11,25], the authors used the US angle to evaluate NSD. On the other hand, in this study, the MS_C angle significantly increased and the LS angles significantly decreased in the long term, causing the NSD to improve. MS_C and LS angles showed greater changes than the US angle. Therefore, MS_C and LS should be considered when evaluating NSD.

Additionally, in this study, NS angles were measured in the axial plane, which showed the same tendency for NSD improvement as in the coronal plane but greater NSD in the coronal plan than in the axial plane. Absolute values (lxl) of MS in the coronal plane decreased at T3-T1, which meant the NSD improved with the expansion of the maxilla, but the absolute values (lxl) of MS in axial plane were not changed at T3-T1. Therefore, vertical NSD might be more alleviated than horizontal NSD after MSE. Kang et al. [3] and Lee et al. [26] proposed a strong relationship between NSD and facial asymmetry. However, Hartman et al. [27] insisted that NSD was mainly associated with an asymmetry in the nasal floor and palatal region, not with an overall facial asymmetry. Therefore, MSE might decrease NSD, but further studies are needed to evaluate MSE effects on facial asymmetry.

In this study, the vertical NS length increased in the coronal plane after MSE, which was consistent with a previous study [11] that reported a pyriform height increase. Additionally, in this study, the horizontal NS length also increased in the axial plane. These results might be due to the downward movement of LS and posterior movement of MS_A and PS, thereby affecting the NS angles and improving NSD. Farronato et al. [8] suggested that vertical NS length increased in the lower third, improving NSD, which was consistent with the results of this study. Therefore, increasing nasal length in the vertical and horizontal planes might be helpful to alleviate NSD and improve the nasal airway, but further studies are needed to evaluate this.

In this study, LNW widths and angles on both sides increased after MSE, which was consistent with the results of previous studies [11,13,20,28]. Furthermore, the dimensions were greater on the right side than on the left side, and the results that were similar to those in a previous study [3] suggested more frequent facial asymmetry towards the right side of face. In this study, LNW widths and angles had a greater increase on the left side than on the right side at T3-T1 after MSE, which had the effect of reducing nasal asymmetry.

Park et al. [29] reported that nasal floor canting was highly related to NSD and facial asymmetry, and NSD headed towards the lower nasal floor side. Koo et al. [25] suggested that nasal floor canting occurred in the opposite direction to NSD. These findings were consistent with those in our study. Therefore, the direction of the nasal floor canting should be considered when planning to correct facial asymmetry.

The midface moved downward and forward, increasing SNA and ANB angles after MSE in other studies [18,20,28,30,31], which was consistent with our study in which ANS and LF_ANS moved forward and downward. The mandible moved downward and backward after MSE in our study, which was consistent with the results in a previous study [28] in which MARPE caused a clockwise rotation of the mandible, thereby decreasing the SNB angle and increasing anterior facial height. This information might be helpful when planning to treat camouflage skeletal Class III malocclusion with a retruded maxilla and a protruded mandible.

In this study, the ANS and Mid LF_ANS deviation was found to exist in the same direction as NSD. Cantarella et al. [17] reported the asymmetrical expansion of ANS moving more than the contralateral ANS by 1.1 mm, which was consistent with our results but insignificant in our study. On the other hand, an asymmetric maxillary expansion greater than a 1.0 mm difference was observed in 46.4% of the subjects in our study. Kim et al. [19] reported that 30.3% of the subjects treated with tooth-bone-borne RPE showed an asymmetric nasomaxillary expansion. Bazzani et al. [20] reported that 44.0% of

asymmetric maxillary expansion occurred after MARPE. Almaqrami et al. [16] reported that the presence of an asymmetric mid-palatal suture was the main causative factor of asymmetric maxillary expansion, and 46.9% of patients showed an asymmetric maxillary expansion of 1.0 mm or more after MARPE, which was consistent with our study. However, the reason why the maxilla expanded asymmetrically in the transverse direction after MSE has not been clearly elucidated. Therefore, asymmetric expansion should be carefully considered before maxillary expansion.

On the contrary, the transverse asymmetry of the mandible (Pog, Me, and Go) was slightly alleviated after MSE in this study. Evangelista et al. [32] reported that craniofacial asymmetry was alleviated in the long term, but this was not consistent with the findings in our study that showed improvement of the mandibular asymmetry in the short term but a regression back to the T1 value in the long term. The results from the other study might have differed from those in our study because the previous study [32] evaluated the mandibular changes after RME in growing patients, while our study looked at the mandibular changes after MSE in both growing and non-growing patients.

The small sample size limited this study to evaluate the NSD and nasofacial changes according to age, gender, skeletal pattern, and asymmetry, and soft tissue was not included in the evaluation. We have attempted to compare as many variables as possible to evaluate NSD. However, we could not obtain the sample size to improve the statistical verification. Therefore, further studies might be needed with a larger sample size and soft tissue measurements.

These days, MSE is widely used for several purposes, such as maxillary expansion, anchorage for a facemask, total mesialization and distalization of the dentition, and changing the three-dimensional adjacent craniofacial structures. According to the results from this study, variable positive nasofacial changes will occur after MSE. Therefore, more studies would be helpful to improve or camouflage facial deformities.

5. Conclusions

Within the limitations of this study, NSD was alleviated with variable positive nasofacial changes in the short and long term after MSE, as outlined below.

- Changes in MS_C and LS angles improved NSD more than changes in the US angle.
- Vertical and horizontal NS length increased significantly.
- NF canting was in the opposite direction to NSD.
- The frequency of asymmetric maxillary expansion greater than 1.0 mm was 46.4%, but the amount of asymmetric maxillary expansion was not statistically significant.
- LNW, NF, ANS, and LF_ANS moved forward and downward.
- Pog, Me, and Go moved downward and backward.
- There were no significant differences between the higher and lower NSD groups and the greater and lesser MPE groups.

Consequently, MSE can be used to improve or camouflage facial deformities.

Institutional Review Board Statement: This study was approved by the Institutional Review Board of Wonkwang University Daejeon Dental Hospital (W2205/002-001).

Informed Consent Statement: Written informed consent was obtained from the patient for publication of this short report and any accompanying images.

Data Availability Statement: The authors declare that the materials are available.

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