Effects of Craniofacial Morphology on Nasal Respiratory Function and Upper Airway Morphology

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Background: Craniofacial skeletal patterns change after orthognathic surgery. The present study aimed to investigate the effects of different craniofacial patterns on nasal respiratory function and the upper airway.

Methods: Forty-seven healthy subjects were selected and divided into 3 groups according to their mandibular position. Sixteen were in the skeletal Class I group, 15 were in the skeletal Class II group, and 16 were in the skeletal Class III group. Cone beam computed tomography was performed, and nasal airflow and nasal resistance were measured. Differences in nasal respiratory functions and upper airway were compared among the groups. A correlation analysis was conducted for nasal respiratory function, upper airway, and skeletal patterns.

Results: There were significant differences among the 3 groups regarding dominant-side nasal inspiratory capacity ($P = 0.001$), bilateral nasal inspiratory capacity ($P = 0.005$), nasal partitioning ratio-inspiration ($P = 0.007$), and velopharyngeal minimum cross-sectional area ($P = 0.029$). The values were significantly higher for the skeletal Class III group than the skeletal Class I and II groups. A correlation analysis showed that the nasal partitioning ratio and nasal airway resistance were mostly negatively correlated with SNA, but the upper airway volume and cross-sectional area were positively correlated with SNB and negatively correlated with ANB. The dominant-side nasal expiratory capacity was mainly negatively correlated with the mean velopharyngeal cross-sectional area ($r = -0.324$, $P = 0.026$), mean glossopharyngeal cross-sectional area (Glosso-A mean) ($r = -0.293$, $P = 0.046$), and mean total airway cross-sectional area (Total-A mean) ($r = -0.307$, $P = 0.036$).

Conclusion: Craniofacial skeletal morphology may affect nasal respiratory function and the upper airway.

Key Words: Craniofacial morphology, nasal resistance, nasal respiration, upper airway

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Vertical and sagittal craniofacial skeletal patterns are the key factors to consider during orthognathic surgery. After orthognathic surgery, craniofacial skeletal patterns may change. Given various craniofacial skeletal patterns, are there any differences in airway morphology and nasal respiratory function? Should they be considered a factor affecting the vertical and sagittal controls of the maxilla and mandible in orthognathic surgery?

For a long time, numerous studies had shown that the craniofacial structure affected the size and morphology of the upper airway.[1–10] Previous studies had found that a large airway morphology often accompanied large bony structures and that a retracted maxilla or mandible might cause airway constriction.

Upper airway structure and respiratory functions are closely related, but because of auto-regulation of respiration, the upper airway structure cannot completely replace an assessment of respiratory function. In terms of respiratory function, nasal airflow (rhinospirometry) and nasal resistance (rhinomanometry) are 2 indicators for the objective evaluation of nasal ventilation. Nasal airflow is the volume of airflow passing through the nasal cavity over time that is used to evaluate nasal ventilation function. As for airflow resistance within the nasal cavity, nasal resistance is calculated by measuring airflow volume and pressure in the nasal cavity and is also widely used for the clinical assessment of nasal ventilation function.[11–16]

Nasal airflow and nasal resistance were closely related to the nasal airway morphology.[17,18] In addition, the craniofacial structure affected the upper airway morphology. Few studies have yet investigated the relationship among nasal respiratory function, upper airway morphology, and craniofacial structure. In the present study, we detected the nasal airflow and nasal resistance and measured the indicators for various upper airway segments for adults with different craniofacial skeletal patterns to determine potential differences in respiratory function and upper airway morphology among skeletal Class I, II, and III subjects based on a standard maxillary sagittal position. Then, we analyzed the correlation among nasal respiratory function, upper airway morphology, and craniofacial structure.

MATERIALS AND METHODS

Subjects

Subjects were selected from patients who visited the Orthodontics Department at Peking University School and Hospital of Stomatology: Inclusion criteria were as follows: between 18 and 35 years of age; body mass index (BMI) < 30 kg/m^2; no history of orthodontic treatment or orthognathic surgery; no history of cleft lip or palate treatment; dentition showing mild crowding, a normal maxillary sagittal position, and no apparent upper dental arch stenosis; no history of nasal cavity or sinus surgery; no subjective feeling of long-term nasal obstruction; and no acute upper respiratory tract infection in the past 2 weeks.

All subjects were asked to complete a sleep questionnaire and an Epworth sleep scale (ESS), and those with sleep disorders, sinusitis and severe turbinate hypertrophy were excluded. Until the group

TABLE 1. A Comparison of the Subjects' General Information and Skeletal Measurement Data for the 3 Groups

Measured Items	Skeletal Class I Group (n = 16)	Skeletal Class II Group (n = 15)	Skeletal Class III Group (n = 16)	Comparison Among Groups, P	Comparison of Skeletal Class I and II Groups, P	Comparison of Skeletal Class I and III Groups, P	Comparison of Skeletal Class II and III Groups, P
Gender (1 = male; 2 = female)	1.63 ± 0.50	1.93 ± 0.26	1.56 ± 0.51	0.059	0.453	1.000	0.237
Age, y	25.13 ± 4.21	25.67 ± 6.55	24.75 ± 5.13	0.911	0.904	0.941	1.000
SNA, °	82.78 ± 2.78	83.13 ± 2.86	81.17 ± 3.33	0.319	0.904	0.699	0.602
SNB, °	79.99 ± 2.96	76.09 ± 3.17	85.09 ± 3.28	0.000*	0.002*	0.000*	0.000*
ANB, °	2.79 ± 1.12	7.04 ± 1.59	-3.92 ± 3.23	0.000*	0.000*	0.000*	0.000*
BMI, kg/m^2	20.42 ± 2.61	20.31 ± 2.56	21.82 ± 3.19	0.465	0.965	0.699	0.719
ESS score	7.69 ± 3.07	7.80 ± 2.91	6.19 ± 2.20	0.352	0.987	0.415	0.159

BMI, body mass index; ESS, Epworth sleep scale.
*$P < 0.05$.

reached the number of people, the included subjects were divided into 3 groups based on their sagittal skeletal pattern: skeletal Class I group ($1° \leq$ ANB $\leq 4.5°$); skeletal Class II group (ANB $> 5°$); and skeletal Class III group (ANB $< 0°$). Grouping was stopped when the expected number of patients in each group was achieved.

We calculated the sample size according to the formula, which is used to perform multiple comparison of the sample means based on previous studies[1] and pre-experimental study, with 80% power to detect a comparable difference on a 2-tailed paired t test at a 95% confidence level.

A sample of at least 16 subjects was selected for each group. However, there was 1 subject who could not finish the nasal airflow test due to feeling uncomfortable. Thus, the number of skeletal Class II group is 15.

A total of 47 healthy subjects were selected. Among the 3 groups of subjects, there were no significant differences in gender, age, maxillary sagittal position (SNA), BMI, or ESS score. The subjects' general information and skeletal measurement data are shown in Table 1.

Craniofacial cone beam computed tomography (CBCT) was routinely taken for orthodontic needs. All subjects underwent rhinospirometry and rhinomanometry before their treatment.

The data from the 47 subjects were combined and analyzed. Correlation analysis was conducted for different skeletal types to study the relationships among nasal respiratory function, upper airway, and craniofacial structure.

The study was approved by the biomedical ethics committee of Peking University School and Hospital of Stomatology (Grant No PKUSSIRB-201417110), and all subjects signed an informed consent form.

Cone Beam Computed Tomography Scanning

All subjects underwent a routine CBCT (DCT PRO Dentofacial CBCT System, VATECH, Gyeonggi-do, South Korea) scan. During the scan, subjects sat upright, the orbital plane was parallel to the ground, the upper and lower lips were kept naturally closed, the posterior teeth were held gently in a central bite position, and the scan was conducted at the end of expiration.

Nasal Airflow Measurements

Nasal airflow was detected using an NV1 rhinospirometer (GM Instruments Ltd, Kilwinning, UK). Two rhinospirometers were aligned with the nostrils bilaterally, and contact was close enough to prevent air leaks. After subjects sat upright and breathed calmly, the bilateral nasal respiratory capacities were measured during inspiration and expiration for 20 seconds, and the nasal partitioning ratio (NPR) was calculated. Because the bilateral nasal respiratory capacities were asymmetric, inspiration or expiration on the dominant and nondominant sides were analyzed, respectively, and together. The measurement indicators included dominant-side nasal inspiratory capacity (NCdi), nondominant-side nasal inspiratory capacity (NCii), bilateral nasal inspiratory capacity (NCbi), nasal partitioning ratio-inspiration (NPRi), dominant-side nasal expiratory capacity (NCde), nondominant-side nasal expiratory capacity (NCie), bilateral nasal expiratory capacity (NCbe), and nasal partitioning ratio-expiration (NPRe).

Measurements of Nasal Resistance

The NR6 rhinomanometer (GM Instruments Ltd) was used for the measurement of nasal resistance. The pressure tube was tightly fixed in front of the nasal cavity, without air leaks. A mask was applied and attached, so the subject maintained pressure against it. The subject was asked to breathe calmly through the nose after closing the mouth. Two calculation methods were used—specific pressure point measurement: the nasal resistance values at points with transnasal pressure differences of 150, 100, and 75 Pa (150 Pa is the international standard, but the transnasal pressure difference was <150 Pa in some patients; thus, we added other specific pressure points for measurement), and those at flow rates of 150, 100, and 75 mL/s; and continuous pressure measurement: Broms method, in which the nasal resistance was calculated at a 200 radius. Measurement indicators included 150 Pa, 100 Pa, 75 Pa, 150 mL/s, 100 mL/s, and 75 mL/s, as well as Broms nasal resistance for inspiration (NRi) and expiration (NRe).

Imaging Measurements

The CBCT data for all subjects were numbered, encoded, and imported into Dolphin Imaging 11.8 software (Dolphin Imaging and Management Solutions, Chatsworth, CA) after the patient information was anonymized. The measurement was performed by the same person who was not aware of the data grouping. The images were slightly adjusted, so the mandibular plane–Frankfort horizontal plane (MP-FH) was parallel to the ground. Those images were converted into lateral cephalometric radiographs for the craniofacial measurement. The measurement indicators included sagittal (SNA, angle between sella and point B at nasion-SNB, and ANB) and vertical skeletal indicators (MP-SN and MP-FH).

The upper airway measurement was performed using an airway analysis module. The boundaries of upper airway are distinguished automatically by Dolphin Imaging 11.8 software according to computed tomography value of different mater. The volume and minimum cross-section area are given by the software immediately

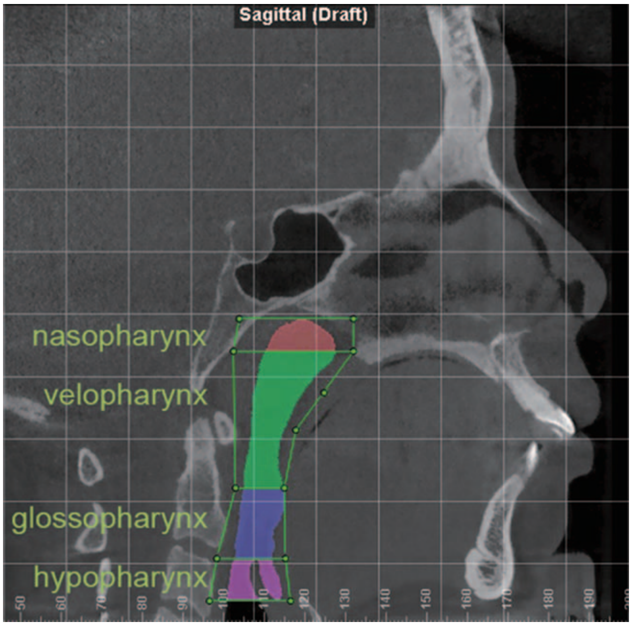

FIGURE 1. Airway measurement on sagittal plane of middle line.

after we give the upper and lower bounds based on the side profile (Figs. 1-2). The vault of the nasopharyngeal airway was taken as the roof, and the bottom of the epiglottis was chosen as the floor for measuring the whole airway. Nasopharynx is needed to determine its front boundary. The anterior wall of upper airway was defined as the vertical line of posterior nasal spine (PNS) to horizontal plane. The entire airway was divided into the nasopharynx, velopharynx, glossopharynx, and hypopharynx by the PNS, soft plate tip, and epiglottis apex planes. The volume, height, and minimum cross-sectional area (A min), and mean cross-sectional area (A mean) of the nasopharynx (Naso-), velopharynx (Velo-), glossopharynx (Glosso-), hypopharynx (Hypo-), and total airway (Total-) were measured. The Naso-A min and Total-A min located at the roof of the nasopharynx. As the anterior part of nasopharynx was connected with the nasal cavity, the measurement of Naso-A min in our determination could not represent the narrowest part of nasopharynx. Therefore, Naso-A min and Total-A min were excluded from the airway measurements. In addition, the bilateral volume ratio for the nasal cavity (Naso-Vr) was calculated based on the bilateral nasal cavity volumes at the nasopharyngeal airway level.

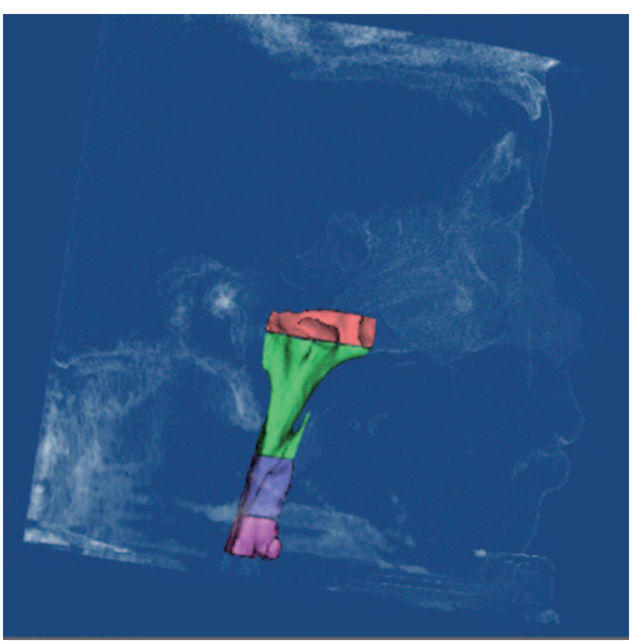

FIGURE 2. Airway on sagittal plane.

The same person measured the data 3 times for 1 group. The intraclass correlation coefficient was >0.9.

Statistical Analysis

SPSS 22.0 was used for data analysis. Because most samples were not normally distributed, the nonparametric Kruskal–Wallis test was used for comparison of the nasal airflow, nasal resistance, and upper airway among the 3 groups; and the nonparametric Kolmogorov–Smirnov test was used for a pair-wise comparison of the data for the 3 groups.

Partial correlation was used for a correlation analysis of the nasal airflow, nasal resistance, upper airway, and sagittal craniofacial skeletal pattern. And partial correlation was also used for a correlation analysis of the nasal airflow, nasal resistance, upper airway, and vertical craniofacial skeletal pattern. Spearman rank correlation coefficient was used in a correlation analysis of the nasal airflow, nasal resistance, and upper airway.

If the data meet a normal distribution, the data are expressed as mean ± standard deviation; if the data did not meet a normal distribution, the data are expressed as median (quartile). A significance level of 0.05 was adopted.

RESULTS

Differences in the Nasal Airflow, Nasal Resistance, and Upper Airway for 3 Skeletal Patterns

Because the transnasal pressure differences for some patients were <150 Pa during the nasal resistance test, the skeletal Class I, II, and III groups had 8, 5, and 9 patients, respectively, for the 2 items of data using a 150 Pa nasal resistance (the measurement results for these 2 issues were not significant). In the remaining measured items, the 3 groups included 16, 15, and 16 patients, respectively.

A comparison of the nasal airflow and nasal resistance among the 3 groups showed significant differences in NCdi ($P = 0.001$), NCbi ($P = 0.005$), and NPRi ($P = 0.007$). There were significant differences between the skeletal Class I and III groups and between the skeletal Class II and III groups, but there were no significant differences between the skeletal Class I and II groups.

A comparison of the upper airway showed a significant difference in velopharyngeal minimum cross-sectional area (Velo-A min) ($P = 0.029$). There was a significant difference between the skeletal Class I and III groups and between the skeletal Class II and III groups, but there was no significant difference between the skeletal Class I and II groups. There were no significant differences in any other measured item. The significant differences are shown in Table 2.

Correlation of the Sagittal Skeletal Patterns, Nasal Airflow, Nasal Resistance, and Upper Airway

After controlling the vertical craniofacial positions (MP-SN and MP-FH), a partial correlation was detected for the nasal airflow, nasal resistance, upper airway, and craniofacial sagittal skeletal

TABLE 2. Differences in Nasal Airflow, Nasal Resistance, and Upper Airway in the Skeletal Class I, II, and III Groups

Measured Items	Skeletal Class I Group (n = 16)	Skeletal Class II Group (n = 15)	Skeletal Class III Group (n = 16)	Comparison of Groups, *P*	Comparison of Skeletal Class I and II Groups, *P*	Comparison of Skeletal Class I and III Groups, *P*	Comparison of Skeletal Class II and III Groups, *P*
Dominant-side nasal inspiratory capacity (NCdi), L	−0.81 (−1.14, −0.55)	−0.90 (−1.53, −0.73)	−1.51 (−2.06, −1.32)	0.001*	0.811	0.000*	0.021*
Bilateral nasal inspiratory capacity (NCbi), L	−1.57 (−2.08, −0.96)	−1.56 (−2.79, −1.35)	−2.22 (−3.52, −2.03)	0.005*	0.890	0.000*	0.002*
Nasal partitioning ratio-inspiration (NPRi), %	8.75 (3.55, 11.75)	9.50 (6.60, 24.00)	20.50 (9.03, 39.75)	0.007*	0.069	0.001*	0.563
Nasal partitioning ratio-expiration (NPRe), %	9.65 (4.73, 16.00)	9.40 (3.80, 20.00)	24.00 (5.53, 49.25)	0.184	0.995	0.211	0.044*
Velopharyngeal minimum cross-sectional area (Velo-A min), mm^2	105.20 (81.25, 143.88)	85.30 (73.60, 132.50)	161.65 (125.00, 219.60)	0.029*	0.507	0.013*	0.018*

*$P < 0.05$.

positions (SNA, SNB, and ANB). The results showed that the NPR and nasal airway resistance were mostly negatively correlated with the maxillary sagittal position (SNA), but the upper airway volume and cross-sectional area were positively correlated with the mandibular sagittal position (SNB) and negatively correlated with relative position of maxillary and mandible (ANB). Significant differences are shown in Table 3.

Correlation of the Vertical Skeletal Patterns, Nasal Airflow, Nasal Resistance, and Upper Airway

After controlling for the craniofacial sagittal skeletal positions (SNA, SNB, and ANB), a partial correlation was detected for the nasal airflow, nasal resistance, upper airway, and vertical craniofacial positions (MP-SN and MP-FH). The results showed that the indicators for the nasal airflow and nasal resistance were not significantly correlated with MP-SN and MP-FH, and only Velo-A min and mean glossopharyngeal cross-sectional area (Glosso-A mean) were positively correlated with MP-SN and MP-FH; other measured items for the upper airway were not significantly correlated with MP-SN or MP-FH. Significant differences are shown in Table 4.

Correlation Among the Upper Airway, Nasal Airflow, and Nasal Resistance

Spearman rank correlation coefficient was used for a correlation analysis of the nasal airflow and nasal resistance, as well as various indicators of the upper airway. The significant differences are shown in Table 5.

TABLE 3. Correlation of the Craniofacial Sagittal Skeletal Patterns, Nasal Airflow, Nasal Resistance, and Upper Airway After Controlling for Vertical Craniofacial Skeletal Patterns

	SNA (MP-SN and MP-FH Were Controlled)		SNB (MP-SN and MP-FH Were Controlled)		ANB (MP-SN and MP-FH Were Controlled)	
Measured Items	Correlation Coefficient (*r*)	*P*	Correlation Coefficient (*r*)	*P*	Correlation Coefficient (*r*)	*P*
Nasal airflow, nasal resistance						
Nasal partitioning ratio-expiration (NPRe), %	−0.364	0.014*	0.170	0.265	−0.345	0.020*
100 Pa nasal resistance for expiration (NRe), Pa/s cm^3	−0.336	0.042*	−0.099	0.562	−0.095	0.577
100 mL/s nasal resistance for expiration (NRe), Pa/s cm^3	−0.328	0.047*	−0.130	0.443	−0.064	0.707
75 Pa nasal resistance for expiration (NRe), Pa/s cm^3	−0.313	0.046*	−0.072	0.657	−0.115	0.473
Broms nasal resistance for expiration (NRe), Pa/s cm^3	−0.308	0.050*	−0.111	0.491	−0.080	0.261
Upper airway						
Nasopharyngeal volume (Naso-V), mm^3	−0.023	0.879	0.334	0.025*	−0.289	0.054
Nasopharyngeal height (Naso-H), mm	−0.208	0.170	0.243	0.107	−0.318	0.033*
Velopharyngeal volume (Velo-V), mm^3	0.029	0.852	0.368	0.013*	−0.289	0.054
Minimum velopharyngeal cross-sectional area (Velo-A min), mm^2	−0.003	0.983	0.478	0.001*	−0.397	0.007*
Mean velopharyngeal cross-sectional area (Velo-A mean), mm^2	0.012	0.936	0.411	0.005*	−0.333	0.025*
Glossopharyngeal volume (Glosso-V), mm^3	−0.037	0.808	0.338	0.023*	−0.301	0.045*
Mean glossopharyngeal cross-sectional area (Glosso-A mean), mm^2	−0.042	0.782	0.419	0.004*	−0.371	0.012*
Total airway volume (Total-V), mm^3	−0.030	0.846	0.397	0.007*	−0.346	0.020*
Mean total airway cross-sectional area (Total-A mean), mm^2	−0.009	0.953	0.406	0.006*	−0.341	0.022*

*$P < 0.05$.

TABLE 4. Correlation of the Craniofacial Vertical Skeletal Patterns, Nasal Airflow, Nasal Resistance, and Upper Airway After Controlling for Sagittal Craniofacial Skeletal Patterns

	MP-SN (SNA, SNB, and ANB Were Controlled)		MP-FH (SNA, SNB, and ANB Were Controlled)	
Measured Items	Correlation Coefficient (r)	P	Correlation Coefficient (r)	P
Velopharyngeal minimum cross-sectional area (Velo-A min), mm^2	0.401	0.007*	0.391	0.009*
Mean glossopharyngeal cross-sectional area (Glosso-A mean), mm^2	0.341	0.023*	0.310	0.040*

*$P < 0.05$.

DISCUSSION

Effects of a Sagittal Skeletal Pattern on Nasal Respiratory Function and Upper Airway

In previous studies, regarding the respiratory function, Rezaeetalab et al found that airway resistance was significantly increased after correcting a Class III malocclusion with bimaxillary surgery.[19] Regarding the airway morphology, El et al found that the posterior airway space, area of the most constricted region at the base of the tongue, and oropharyngeal airway volume were the largest in Class III mandibular protrusion group and the smallest in Class II mandibular retrusion group. A significant difference in the nasal passage volume was observed only in Class I group and Class II mandibular retrusion group.[1] Alves et al studied the difference between skeletal Class I and II patients and found that skeletal Class II patients had a significantly smaller airway volume and minimum axial area than skeletal Class I patients.[2] Iwasaki et al used CBCT to demonstrate that skeletal Class III children had a more substantial oropharyngeal airway than skeletal Class I children.[4] The results of this study were similar to those of the above studies, and the effect of a sagittal craniofacial skeletal pattern on the upper airway morphology was similar to that of the previous studies. As for the effect of the craniofacial skeletal pattern on the nasal respiratory function, the craniofacial skeletal pattern might affect upper airway morphology and consequently affect nasal respiratory function.

The results of this study showed that the NPR of the skeletal Class III group was larger than that of the other 2 groups, indicating that the nasal respiration asymmetry was slightly more obvious in the skeletal Class III group. Although there were no significant differences among the 3 groups in terms of the bilateral nasal cavity volume ratio (Naso-Vr), previous studies had shown that the facial asymmetry ratio was slightly higher in skeletal Class III patients.[20]

A comparison of the craniofacial skeletal groups showed that the NCi of the skeletal Class III group was higher than that of the other 2 groups. A correlation analysis showed that all upper airway segments were positively correlated with SNB but negatively correlated with ANB. It showed that an increase in mandibular protrusion caused the craniofacial structure to be closer to that of a skeletal Class III pattern, the larger the upper airway segments, and the higher the nasal respiratory flow were. Under various transnasal pressure differences, NRe was negatively correlated with SNA. A possible reason was that maxillary retrusion reduces the upper airway size and increases nasal resistance.

TABLE 5. Correlation of the Upper Airway, Nasal Airflow, and Nasal Resistance

	Volume (V), mm^3		Height (H), mm		Minimum Cross-Sectional Area (A min), mm^2		Mean Cross-Sectional Area (A mean), mm^2	
Measured Items	Correlation Coefficient (r)	P	Correlation Coefficient (r)	P	Correlation Coefficient (r)	P	Correlation Coefficient (r)	P
Nasopharyngeal airway (Naso-)								
Nasal partitioning ratio-expiration (NPRe), %	0.221	0.136	0.326	0.025*	—	—	−0.017	0.907
Velopharyngeal airway (Velo-)								
Dominant-side nasal expiratory capacity (NCde), L	−0.222	0.134	0.195	0.189	−0.094	0.531	−0.324	0.026*
Bilateral nasal expiratory capacity (NCbe), L	−0.182	0.221	0.241	0.102	−0.134	0.368	−0.297	0.042*
150 Pa nasal resistance for inspiration (NRi), Pa/s cm^3	0.058	0.799	−0.063	0.780	0.609	0.003*	0.072	0.749
150 mL/s nasal resistance for inspiration (NRi), Pa/s cm^3	−0.010	0.945	0.039	0.796	0.340	0.019*	−0.042	0.780
100 Pa nasal resistance for inspiration (NRi), Pa/s cm^3	−0.014	0.930	0.082	0.619	0.409	0.010*	−0.055	0.741
75 Pa nasal resistance for inspiration (NRi), Pa/s cm^3	−0.029	0.851	0.038	0.810	0.389	0.010*	−0.057	0.715
Broms nasal resistance for inspiration (NRi), Pa/s cm^3	−0.009	0.951	0.036	0.812	0.334	0.022*	−0.039	0.792
Glossopharyngeal airway (Glosso-)								
Dominant-side nasal expiratory capacity (NCde), L	−0.144	0.334	0.188	0.207	0.038	0.802	−0.293	0.046*
Hypopharyngeal airway (Hypo-)								
Nasal partitioning ratio-expiration (NPRe), %	0.057	0.704	0.027	0.856	0.312	0.033*	0.040	0.787
75 Pa nasal resistance-inspiration (NRi), Pa/s cm^3	−0.314	0.040*	−0.289	0.061	0.129	0.410	−0.267	0.084
Total airway (Total-)								
Dominant-side nasal expiratory capacity (NCde), L	−0.232	0.117	0.261	0.076	—	—	−0.307	0.036*

*$P < 0.05$.

Effects of a Vertical Skeletal Pattern on Nasal Respiratory Function and Upper Airway

There had been many studies on the impact of a vertical skeletal pattern on airway morphology. Ucar and Uysal found significant differences in the nasopharyngeal airway space and upper posterior airway space among low-, average-, and high-angle patients, nasopharyngeal airway space and upper posterior airway space measurements were larger in low-angle than in high-angle subjects.[7] Celikoglu et al found that the high-angle population had a significantly smaller upper airway volume than the low- or average-angle population.[8] de Freitas et al also had similar results and considered that the vertical skeletal pattern affected the upper airway morphology.[9] Zhong et al found that the vertical skeletal pattern mainly affected the upper aspect of the upper airway, and for skeletal Class I patients, the larger the mandibular plane angle was the smaller the nasopharyngeal and velopharyngeal sagittal diameters.[10]

In the present study, a correlation analysis of the vertical skeletal pattern, nasal airflow, nasal resistance, and upper airway showed no significant differences between the vertical skeletal pattern and various indicators of the nasal respiratory function. A possible reason was that the subjects were included according to sagittal skeletal pattern. They showed minimum discrepancies in the vertical skeletal pattern.

Strengths and Limitations

This study had some limitations. The sample size for this study was based on a power of 80% to detect a comparable difference. The sample size would have to increase to 50 per group so as to obtain the power of 90%. The present study mainly concerned the effects of sagittal development of mandible. If other possible factors as maxillary development and vertical development were taken into consideration, the sample size should be increased.

During the nasal resistance measurement, only 22 patients met the international standard (150 Pa) in this study. Asians should set up new standards. We added 100 and 75 Pa, as well as used the Broms method to make up for this shortcoming, the sample size should be increased in follow-up studies to reduce this kind of error.

The soft tissue may affect the nasal resistance. However, there are no normal values of thickness of turbinates, mucosa, etc. We tried to reduce the influence of soft tissue by sample selection. Certain inclusion criteria were set to control the effect of BMI on nasal respiratory function. And we had observed nasal cavity images of each recruiter. There was no obvious mucosa swelling, sinusitis secretion, etc. For the future, the nasopharyngofiberscope should be used to remove the sample with hypertrophy of soft tissue.

Moreover, further investigations should be intended in the causal relationship between nasal function and skeletal patterns.

CONCLUSIONS

Craniofacial morphology might affect nasal respiratory function and the upper airway. There might be differences in nasal respiratory function and upper airway morphology between the skeletal Class III population and skeletal Class I and II populations. Nasal airway resistance was mostly negatively correlated with SNA, but the upper airway volume and cross-sectional area were positively correlated with SNB. During orthognathic surgery, controlling the sagittal positions of the maxilla and mandible should be considered.

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