Relationship between Inferior Turbinate Hypertrophy and Maxillofacial Morphology in Children

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Abstract

Objective: Chronic nasal airway disorders in growing children are thought to adversely affect the normal development of the maxillofacial morphology. This study aimed to clarify the relationship between severe inferior turbinate hypertrophy, which is the cause of chronic nasal airway disorders, and maxillofacial morphology in children.

Materials and Methods: The inferior turbinate hypertrophy group comprised 50 patients (30 boys, 20 girls, mean age 8.9±1.7 years) diagnosed with hypertrophic rhinitis at the Nose Clinic Tokyo and who had an enlarged inferior turbinate hypertrophy. The control group comprised 50 patients (18 boys, 32 girls, mean age 8.7±1.4 years) who visited Showa University Dental Hospital. Using cone-beam computed tomography, the maxillary bone width, upper anterior facial height, mandibular bone width, mandibular ramus height, length of the body of the mandible, maxillary dentition width, mandibular dentition width, anterior cranial base length, posterior cranial base length, cranial base angle, sella-nasion-point A angle, and sella-nasion-point B angle were measured. The differences between the groups were statistically analyzed using analysis of covariance.

Results: Increased upper anterior facial height, shortened length of the body of the mandible and mandibular ramus height, and small cranial base angle were significantly associated with inferior turbinate hypertrophy.

Conclusion: The study suggested that inferior turbinate hypertrophy caused by chronic rhinitis and allergic rhinitis could cause changes in the maxillofacial morphology. Promoting normal jaw development in childhood is crucial for preventing jaw deformities.

Key words: cone-beam computed tomography, craniofacial morphology, inferior turbinate hypertrophy

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Introduction

Normal bone development of the maxillofacial complex is associated with the physiological function of respiration, chewing, and swallowing1). Normally, air passes through the nasal valve, nasal septum, turbinate, and nasopharynx; however, morphological changes resulting from diseases block this airflow, causing nasal airway disorders2).

Inferior turbinate hypertrophy (ITH) is caused by allergic and chronic rhinitis. ITH, adenoid hypertrophy, and deflected nasal septum contribute to upper airway obstruction2).

According to Moss’ functional matrix theory, bone remodeling occurs in response to changes in the facial muscles and soft tissues1). Chronic nasal airway disorders cause intermittent hypoxia and often lead to mouth breathing, which causes a clockwise rotation of the mandible, narrowing of the maxillary dental arch, mandibular hypoplasia, and a high-arched palate; this consequently results in distorted growth and development of the orofacial structures, as reported in previous studies3,4).

The maxillofacial morphology was previously evaluated in two-dimensional (2D) images, such as cephalograms. However, the 2D representation of three-dimensional (3D) structures results in image distortion and inaccuracy of measurements. Cone-beam computed tomography (CBCT) is effective for analyzing the maxillofacial images owing to its short scan time, high-resolution imaging, and low radiation exposure7). In both otolaryngology and orthodontics, a comprehensive evaluation of the morphology by CBCT is useful for establishing the etiology, assessing risk, and determining subsequent management strategies.

The main causes of upper airway obstruction in children are adenoid hypertrophy and hypertrophic rhinitis8). Hypertrophic rhinitis is a condition in which ITH is caused by chronic and allergic rhinitis (Fig 1)9). Recently, the number of children suffering from respiratory problems related to allergic rhinitis has increased significantly10). Previous studies have evaluated the possibility of changes in the maxillofacial morphology considering adenoids and airflow as contributing factors3,5,11-13). Although ITH is one of the leading causes of chronic nasal airway disorders10), its effects on maxillofacial...
morphology have not yet been assessed.

Chronic nasal airway disorders due to ITH are extremely difficult to manage, and are often severe enough to involve surgery. It is considered that nasal airway disorders may induce jaw deformities and cause subsequent changes in the maxillofacial morphology. Therefore, in this study, CBCT was used to investigate the effect of chronic ITH on jaw formation and maxillofacial morphology in children.

Materials and Methods

The present study was a retrospective study comprising 100 participants that underwent CBCT scanning from 2012 to 2020. They were divided into two groups: the ITH and control groups. The ITH group included 50 patients (30 boys, 20 girls, mean age 8.9 ± 1.7 years) who visited the Nose Clinic, Tokyo, Japan; they were diagnosed with hypertrophic rhinitis and had a reduced ventilation area of the nasal cavity, that is, a large inferior turbinate thickening relative to the nasal cavity area. In the ITH group, the presence of nasal breathing disorder was confirmed by endoscopy, nasal air permeability test, and interview. Additionally, none of the patients were diagnosed with sleep apnea. The control group comprised 50 patients (18 boys, 32 girls, mean age 8.7 ± 1.4 years) who visited the Showa University Dental Hospital. The control group was confirmed by interview to have no history of otolaryngology and no mouth breathing. There were 19 patients with Angle Class Ⅰ and 31 patients with Angle Class Ⅱ in the ITH group, and 16 patients with Angle Class Ⅰ and 34 patients with Angle Class Ⅱ in the control group. Furthermore, to avoid introducing confounding factors, patients with a history of congenital diseases, craniofacial or growth abnormalities, maxillofacial tumors and lesions, throat surgery, tonsillectomy, and marked adenoid hypertrophy were excluded from this study. Patients with severe deflected nasal septa were also excluded from both groups.

The guardians were provided written informed consent, and the study was pursued after the ethical approval by the Showa University Dental Hospital (Approval number: DH2015-008).

To keep exposure low, all patients underwent CBCT imaging with Kavo 3DeXam (Kavo, Biberach, Germany) installed both at the Showa University Dental Hospital and at the Nose Clinic, Tokyo. Both facilities performed scans for patients who were judged to require diagnostic CBCT images. The scanning conditions were set at 120kV and 5 mA, the voxel size was 0.4 mm, and the scan time was 89 seconds. In the control group, CBCT imaging was performed because further information, such as the position and direction of impacted supernumerary tooth/impacted teeth, jaw deformity, and mandibular condyle morphology were needed. However, the radiation exposure during a CBCT examination, for children, should be considered carefully. The patients were seated and a natural head position was achieved after adjusting the chin rest; they were instructed to not move their heads or to swallow, and to maintain centric occlusion during the scanning, with their tongues relaxed.

Invivo dental software (Anatomage, San Jose, CA, USA) was used for analysis. In this study, all the measurements were examined on the CBCT images. To minimize error, the CBCT image was repositioned with the Frankfort horizontal plane as the horizontal reference plane. The sagittal plane of the CBCT image was set to a plane passing through N (the foremost point of the frontal nasal bone suture). The coronal plane of the CBCT image was set to the plane passing through the midpoint between the ANS and PNS (Fig 2).

Table 1 shows the definitions of the landmarks, reference planes, and measurement points. The following were measured: maxillary bone width (MaxR-MaxL), upper anterior facial height (N-ANS), mandibular bone width (GoR-GoL), length of the body of the mandible (Go-Me), mandibular ramus height (Cd-Go), maxillary dentition width (U6R-U6L), mandibular dentition width (L6R-L6L), S-N, S-Ba, cranial base angle (NSBa), SNA, and SNB (Fig 3). In addition, the adenoidal/nasopharyngeal ratio (AN ratio) was measured according to the method described by Fujioka et al. The distance between the outermost point of convexity of the adenoid shadow and basiocciput was defined as “adenoidal
Fig. 2 Measurements on the cone-beam computed tomography (CBCT) image

(A) Sagittal view of cone-beam computed tomography images reoriented using the FH (Frankfort horizontal) plane as the horizontal reference plane, which is defined as an imaginary line joining the right and left Po (porion) to the right and left Or (orbitale), respectively.

(B) The coronal plane of the CBCT image was set to the plane passing through the midpoint between the ANS (Anterior nasal spine) and the PNS (Posterior nasal spine).

(C) The area from the upper end of the inferior turbinate to the nasal floor was defined as the nasal cavity area. The solid line shows the inferior turbinate area, and the dotted line shows the nasal cavity area. We measured the inferior turbinate and nasal cavity area on a CBCT cross-section. We calculated the percentage of the difference between the nasal cavity area and the inferior turbinate area divided by the nasal cavity area to calculate the ventilation area of the nasal cavity for each of the inferior turbinate hypertrophy group and the control group. (The ratio of venting area of the nasal cavity (%) = [nasal cavity area-inferior turbinate area]÷nasal cavity area×100).

Table 1 Abbreviations in this study

| Abbreviation | Definition |
|--------------|------------|
| N            | Nasion: the most anterior point of the nasofrontal suture in the midsagittal plane |
| S            | Sella turcica: the midpoint of the sella turcica |
| Ba           | Basion: the median point of the anterior margin of the foramen magnum |
| Or           | Orbitale: the lowermost point on the inferior margin of the bony orbit |
| A            | Point A: the deepest midline point on the premaxilla between the anterior nasal spine and prosthion |
| B            | Point B: the most posterior point on the outer contour of the mandibular alveolar process |
| Po           | Porion: the midpoint on the upper edge of the external auditory canal |
| Me           | Menton: the most inferior point on the symphyseal outline |
| Cd           | Condylion: the most posterior superior point on the head of the condyle |
| Go           | Gonion: the intersection of lines tangent to the mandibular base and to the posterior margin of the ascending ramus |
| U6           | Mesial buccal cusp of the upper first molar |
| L6           | Mesial buccal cusp of the lower first molar |
| Max          | The deepest points on the curvature of the malar process of the maxilla |
| ANS          | Anterior nasal spine: the tip of the anterior nasal spine as seen on the lateral film |
| PNS          | Posterior nasal spine: the tip of the posterior nasal spine as seen on the lateral film |
| ANB          | Point A-nasion-point B angle: the anteroposterior relationship between the maxilla and mandible |
| FH plane     | Frankfort horizontal plane: the horizontal plane drawn from Porion to Orbitale |
| MaxR-MaxL    | The left and right maxillary bone width |
| N-ANS        | Upper facial height between nasion and anterior nasal spine |
| GoR-GoL      | The left and right mandibular bone width |
| Go-Me        | Length of the body of the mandible between gonion and menton |
| Cd-Go        | Mandibular ramus height between condylion and gonion |
| U6R-U6L      | The left and right maxillary dentition width |
| L6R-L6L      | The left and right mandibular dentition width |
| SN           | Anterior cranial base length, the distance between sella turcica and nasion |
| SBa          | Posterior cranial base length, the distance between sella turcica and basion |
| NSBa         | Nasion-Sella-basion angle: Cranial base angle, the angle between anterior and posterior skull base planes, representing skull base curvature |
| SNA          | Sella-nasion-point A angle: the positional relationship (anterior and posterior) of the maxilla with respect to the skull |
| SNB          | Sella-nasion-point B angle: the positional relationship (anterior and posterior) of the maxilla with respect to the skull |
size”. The distance between sphenoid synchondrosis and PNS was defined as “nasopharyngeal size”. The AN ratio was calculated using “adenoidal size” and “nasopharyngeal size” (Fig 4).

Statistical analyses were conducted using the SPSS Statistics 25 (IBM Corporation, Armonk, NY, USA). To investigate intraoperator errors, all CBCT images were reassessed after a 2-week interval under identical conditions. The measurement error was estimated according to Dahlberg’s formula: \( S^2 = \frac{\sum d^2}{2n} \). The intraclass correlation coefficient and Dahlberg’s error were > 0.8 and ≤ 0.5mm, respectively. Assuming that the effect size is medium (0.3) as sample size calculation because there is no information from previous studies, the required sample size was calculated to be 90 cases using G*Power (Heinrich-Heine Universität, Düsseldorf, Germany) with 80% power and 5% significance level. Therefore, the number of target cases was set to 100 in anticipation of the exclusion of approximately 10% of the cases.

The normality of the measured values was confirmed using the Shapiro-Wilk test and the Normal Q-Q Plot. The area from the upper end of the inferior turbinate to the nasal floor
was defined as the nasal cavity area. We measured the inferior turbinates and nasal cavity area on a CBCT cross-section and calculated the percentage of the difference between the nasal cavity area and the inferior turbinates divided by the nasal cavity area to calculate the ventilation area of the nasal cavity (the ratio of venting area of the nasal cavity (%) = [nasal cavity area - inferior turbinate area] ÷ nasal cavity area × 100) (Fig 2). The aeration area of the nasal cavity with respect to the nasal cavity area was 18.51% in the ITH group and 50.77% in the control group. Using the Welch’s t-test, we compared the ratio of venting area of the nasal cavity between the ITH group and control groups. Further, the Welch’s t-test and Chi-square test were performed to compare the descriptive statistics of the three items used for covariates. The analysis of covariance (ANCOVA) was performed with age, sex, and AN ratio as covariates. Statistical significance was defined as p < 0.05.

**Results**

Table 2 shows the descriptive statistics for each group. Based on the Welch’s t-test, there were significant differences in the ratio of venting area of the nasal cavity and AN ratio between the ITH and control groups; no significant differences were found between the ages of the two groups. The Chi-square test demonstrated a significant difference in sex between the two groups. Table 3 shows the results of the estimated marginal means and standard deviation obtained with the ANCOVA model. After adjusting for the age, sex, and AN ratio as covariates, the maxillofacial morphology was found to be statistically different between the ITH group and control groups. Compared with the control group, the ITH group had increased N-ANS, shortened Go-Me and Cd-Go, and small NSBa.

**Discussion**

In this study, the upper facial height was larger in the ITH group than in the control group. Previous studies have also reported an increased downward growth of the maxilla in cases with severe nasal airway disorders. Many different theories have been proposed to explain the growth and development of the nasomaxillary complex; some hypothesize that the nasal septum is the growth center of the nasomaxillary complex; some hypothesize that the nasal septum is the growth center of the maxilla. However, the functional matrix theory states that the directionality and degree of growth and development of various bones depend on the growth and development of the soft tissues. Nonetheless, other theories suggest that the nasomaxillary complex develops through the interactions between adjacent bones. Enlow suggests that the entire nasal maxillary complex rotates in a clockwise or counter-clockwise direction, based on the growth of the cranial suture of the cranial base and of the midface. Furthermore, bone formation at multiple sutures causes displacement; thus, the direction and quantitative degree of growth are changed by the displacement of the entire bone. Nasal airway disorders induce mouth breathing, which affects the function and development of the perioral muscles. As a result, in the ITH group, the positions of the bones and cartilage affecting the maxilla were different from those in the control group, and it is possible that there was a difference in the growth amount of the periosteal callus and the sutured region. Therefore, we speculated that the direction of growth of the nasal septum (e.g., the vomer and ethmoid bones) and surrounding bones was affected, and the downward growth of the nasomaxillary complex may have increased.

In the present study, the length of the body of the mandible and mandibular ramus height tended to be shorter in the ITH group than in the control group. There are several reports of animal experiments on the anteroposterior and superoinferior hypogrowth of the mandible caused by nasal airway disorders. Growing rats exposed to intermittent hypoxia showed induced microstructural changes in the mandibular condyle and delayed mandibular growth. In addition, some studies have reported that in rats with intermittent hypoxia, jaw-closing muscles, such as the masseter and temporalis, are poorly developed. In addition to the histological changes in the mandibular condyle and the poor development of the jaw-closing muscles owing to intermittent hypoxia, we speculated that differences in the direction of the muscle pull may also play a role in the mandibular growth and development. However, muscle traction direction was not measured in this study and it will be a subject of future studies.

In the measurement of the cranial base in this study, the values of the NSBa tended to be reduced in the ITH group compared with the control group. ITH may have some effect on the cranial base development; however, this was not revealed in this study.

The limitation of this study is that we were unable to compare the maxillofacial morphology between participants with and without ITH over several years. However, the difficulty in confirming temporal changes in the maxillofacial morphology is also a problem faced in human studies. The duration of ITH could not be compared in this study because we lacked the pertinent data, such as the age of onset. However, long-term nasal airway disorders can have a significant impact on the maxillofacial development. Future studies should encompass the measurements of the maxillofacial morphology, examination of the relationship between otolaryngological diseases and the maxillofacial morphology, and evaluation of the growth direction of the nasomaxillary complex in greater...
We believe that early medical treatment is important, such as the removal of ITH and allergy management during the deciduous dentition and mixed dentition periods, to promote normal jaw development. Further, patients with improved nasal airway disorders should be trained to establish proper nasal breathing habits. Elucidation of the relationship between ITH caused by allergic and chronic rhinitis and maxillofacial morphology could lead to appropriate otolaryngological and dental treatment during childhood, thereby improving patients’ quality of life in the future.

**Conclusion**

The findings of this study suggest that ITH caused by chronic rhinitis and allergic rhinitis could result in changes in the maxillofacial morphology. Treatment for ITH may contribute to preventing imbalanced growth and development of
the craniofacial complex.

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小児における下鼻甲介肥大と顎顔面形態の関係

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目的: 成長期の小児における慢性的な鼻呼吸障害は、顎顔面形態の発育に影響を及ぼすことが示唆されている。本研究では、鼻呼吸障害の原因である重度の下鼻甲介肥大と小児の顎顔面形態の関係を明らかにすることを目的とした。

方法: 本研究では、下鼻甲介肥大群は鼻のクリニック東京で肥厚性鼻炎と診断され、下鼻甲介肥大を伴う患者 50 名（男児 30 名、女児 20 名、平均年齢 8.9 ± 1.7 歳）、対照群は昭和大学歯科病院に来院された患者 50 名（男児 18 名、女児 32 名、平均年齢 8.7 ± 1.4 歳）であった。歯科用コーンビーム CT 画像を用いて上顎骨幅、上顎面の高さ、下顎骨幅、下顎体の長さ、下顎歯列幅、顎顔面基底、顎顔面橋基底部の前後的位置関係および下顎顔面基底部の前後的位置関係を計測した。共分散分析を使用して、グループの違いを統計的に分析した。

結果: 上顎面の高さの増大、下顎体の長さや下顎歯列の短縮および小さな頭蓋底角が有意に下鼻甲介肥大と関連していた。

結語: 慢性鼻炎やアレルギ性鼻炎などが原因で生じる下鼻甲介肥大により、顎顔面形態に変化が生じる可能性が示唆された。顎顔形態の予防のため、小児期において正常な顎の発達を促すことが重要である。

キーワード: 歯科用コーンビーム CT、顎顔面形態、下鼻甲介肥大

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