Morphological Characteristics of Nasomaxillary Complex and Cranial Base in Maxillary Retrognathism

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Abstract

**Background and aim:** The cranial base is considered to be related to the growth and development of the maxillofacial structures morphologically, and is regarded as one of the factors in malocclusion. The purpose of this study was to extract morphological characteristics of maxillary retrognathism to analyze relationships among the cranial base, maxilla, and ethmoid and vomer bones constituting the nasal septum.

**Materials and methods:** Materials were the lateral cephalograms and computed tomography (CT) images of 26 pre-treatment mandibular prognathism patients (Japanese males, 24.8 ± 8.4 years). Subjects were divided into two groups based on the position of point A: a posterior group (n = 10) and an anterior group (n = 16). The posterior group was thought to correspond to maxillary retrognathism. Angular and linear measurements were made on lateral cephalograms and median sagittal plane CT images.

**Results:** Compared with the anterior group, the posterior group displayed a short anterior cranial base (S-N), a more posteriorly positioned posterior nasal spine, and counterclockwise inclination of the cranial base on cephalometric measurements. The posterior space of the vomer was smaller, and mid-facial height was smaller on CT measurements. No difference between groups was seen in shape of the cranial base or anteroposterior length of the hard palate (ANS-PNS).

**Conclusion:** The cranial base is inclined counterclockwise due to insufficient growth of the nasal septum, especially the posterior part of the vomer. These morphological factors are suggested to contribute to maxillary retrognathism.

Introduction

The cranial base is considered to be related to the growth and development of the maxillofacial structures morphologically (1–9), and cranial base form is regarded as one of the factors in malocclusion.

Class III malocclusion includes maxillary retrognathism and mandibular prognathism. The methods of treatment differ depending on whether the cause of skeletal mandibular prognathism is maxillary retrognathism, mandibular prognathism, or both. Values of SNA and/or SNB on lateral cephalograms, which are used to evaluate the anteroposterior positions of the maxilla and mandible, cannot accurately evaluate whether maxillary retrognathism or mandibular prognathism is present, because individual differences exist in the inclination of the cranial base.

Skeletal mandibular prognathism is thus not diagnosed by a specific measurement, but by a comprehensive evaluation of several parameters. Orthodontic treatment requires detailed knowledge of the etiology. For example, maxillary protraction is often performed as a treatment on the mandibular prognathism caused by maxillary retrognathism. In other words, etiology and treatment policy are closely related.

Many previous studies have been based on cephalograms. Even in orthodontic treatment, cephalograms are the predominant images used for analysis. Three-dimensional morphological analysis by computed tomography (CT) has

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also been applied in recent years, and more detailed research is required (9, 10). Use of CT images allows observation of the form of the nasal septum, which does not appear on cephalograms.

The purpose of the present study was to extract morphological characteristics of maxillary retrusion to facilitate early differentiation and diagnosis of mandibular prognathism. For that purpose, we made measurements from cephalograms and CT images among patients with mandibular prognathism to analyze the relationship between the cranial base, maxilla, and ethmoid and vomer bones of the nasal septum.

Materials and methods

This study was performed using lateral cephalograms and CT images from 26 Japanese male pre-treatment patients (mean age: 24.8 ± 8.4 years) with mandibular prognathism who came to Department of Orthodontic, Nihon University Hospital at Matsudo. Each patient underwent lateral cephalogram, and CT once using an Aquilion 64 system (Toshiba, Tokyo, Japan) under the following scan parameters: tube voltage, 120 kV; current, 100 mA; slice thickness, 0.5 mm.

Exclusion criteria were as follows: 1) previous orthodontic treatment; 2) presence of a congenital deformity in head and neck region and/or systemic syndrome, or previous trauma; or 3) presence of severe dental prostheses or dental caries, or multiple missing teeth affecting occlusion.

Figure 1 shows measurement points on the cephalograms. Using the data obtained from the above methods, In order to evaluate the anteroposterior position of the maxilla based on the Frankfurter plane (FH plane), N line–A (where the N line is defined as a line perpendicular to the FH plane that passes through point N; N line–A, distance between N line and point A (defined as positive when point A is located anterior to the N line and negative when posterior).

Fig. 1. Measurement points and planes on cephalograms.
1-1 Measurement points: A, point A; ANS, anterior nasal spine; B, point B; Ba, basion; N, nasion; Or, orbitale; PNS, posterior nasal spine; Po, porion; Pog, pognion; S, sella turcica.
1-2 Evaluation of an anteroposterior position of the maxilla: FH plane (Frankfort plane), the line extending from the upper rim of the external auditory meatus (Po) to the inferior border of the orbital rim (Or); N line, the line perpendicular to the FH plane that passes through point N; N line–A, distance between N line and point A (defined as positive when point A is located anterior to the N line and negative when posterior).
ethmoidal foramen. Although the border between the ethmoid and sphenoid bones varied individually, the most posterior ethmoidal foramen was thought to be close to the boundary between the ethmoid and sphenoid (12). Measurements of vertical distances from reference lines are shown in Figure 4.

Descriptive statistics including distribution parameters were performed using JMP version 13.0 statistical software (SAS Institute Inc., Tokyo, Japan). Differences between median values from measurements were tested statistically using Wilcoxon rank sum tests.

This study was approved by the research ethics committee of Nihon University School of Dentistry at Matsudo (EC15-030).
Results

1. Measurements on cephalograms

The statistics of the anterior and posterior groups, and the results of statistical tests between the two groups are shown in Table 1.

1-1. Angular measurements

ANB angle was not significant difference between the two groups. This angle indicates the relative anteroposterior positions of the maxilla and mandible, and negative values represent mandibular prognathism. The convexity showed a negative value in both groups, with no significant inter-group difference. The convexity indicated the degree of protrusion of the maxilla, and negative values represent retraction of the maxilla. These results revealed that subjects in this study were characterized by mandibular prognathism.

The SNA, SNB, and SNPog angles did not differ significantly between the two groups. These angles represent the positions of points A and B, and the pogonion (Pog) with reference to the cranial base plane (SN plane). With reference to the FH plane, SN plane angle (SN-FH angle) was significantly larger in the anterior group than in the posterior group (Fig. 5). FH-NA angle, FH-NB angle, and facial angle, representing the positions of points A and B, and Pog with respect to the FH plane, were significantly larger than in the anterior group than in the posterior group (Fig. 5). NSBa angle showed no significant difference between groups.

In summarizing the above results, the shape of the cranial base could be said to not differ markedly between groups, but the cranial base in the posterior group was inclined counterclockwise on the right-side profile compared to the anterior group.

Since grouping was performed based on N line–A in this study, anteroposterior positions of the maxilla and mandible (ANB) were almost the same in the two groups. On the other hand, based on the FH plane, the maxilla and mandible were positioned more anteriorly in the anterior group than in the posterior group.

1-2. Linear measurements

S-N and N-Ba were significantly shorter in the posterior group than in the anterior group, but S-Ba was almost the same value in both groups (Fig. 5). This result indicated that the anterior cranial base was shorter in the posterior group than in the anterior group, and differences in anterior cranial base length were noted between groups.

ANS-PNS showed no significant difference between groups. This result represented that size of the hard palate did not relate to anteroposterior position of the maxilla.

The results of angular and linear measurements are summarized as follows. Compared with the anterior group, the posterior group showed a short anterior cranial base and a cranial base inclined counterclockwise on the right-side profile. No difference between groups was seen in shape of the cranial base or anteroposterior length of the hard palate.

2. Measurements on CT images

The basic statistics of angular and linear measurements
### Table 1. Basic statistics for measurements on cephalograms

|                          | Anterior group (n=16) | Posterior group (n=10) |
|--------------------------|-----------------------|------------------------|
|                          | Median | Range | Median | Range |
| **N line-A (mm)**        | 1.0    | 7.0   | -3.0   | 5.0   | **   |
| **Angular measurements (°)** |        |       |        |       |
| SNA                      | 82.0   | 10.0  | 81.0   | 13.0  |       |
| FH-NA                    | 90.8   | 9.5   | 87.3   | 14.0  | *    |
| SNB                      | 86.0   | 11.5  | 86.3   | 9.5   |       |
| FH-NB                    | 95.0   | 9.0   | 93.3   | 9.0   | *    |
| ANB                      | -4.3   | 10.0  | -3.8   | 7.5   |       |
| SNPog                    | 87.0   | 10.0  | 86.5   | 8.5   |       |
| Facial angle             | 95.3   | 9.0   | 93.8   | 8.0   | **   |
| Convexity                | -11.3  | 18.0  | -7.5   | 22.0  |       |
| SN-FH                    | 10.0   | 6.0   | 7.3    | 5.0   | **   |
| SN-Palatal               | 10.0   | 9.5   | 6.5    | 6.0   | *    |
| NSBa                     | 128.0  | 13.0  | 124.5  | 16.0  |       |
| **Linear measurements (mm)** |        |       |        |       |
| S-N                      | 65.5   | 5.0   | 63.4   | 8.6   | *    |
| S-Ba                     | 46.6   | 12.7  | 45.9   | 6.4   |       |
| N-Ba                     | 100.0  | 10.5  | 97.3   | 6.8   | **   |
| ANS-PNS                  | 48.2   | 11.4  | 48.9   | 10.9  |       |

Wilcoxon rank sum test
* P<0.05; ** P<0.01

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**Fig. 5.** Measurement items for which anterior group showed significantly smaller values than the posterior group on cephalograms. Significant differences are highlighted in red. Overlapping parts are shown in dark color.
on CT images are shown in Table 2.

2-1. Angular measurement

V-PNS-ANS angle was significantly smaller (i.e., the posterior edge of the vomer bone was more upright) in the posterior group than in the anterior group (Fig. 6).

2-2. Linear measurements

No significant differences in N-E and E-S were evident between groups, meaning that the anteroposterior lengths of the ethmoid and sphenoid were almost the same in both groups.

N-ANS and SN-ANS were significantly smaller in the posterior group than in the anterior group (Fig. 6). Mid-facial height of the posterior group was thus small. PNS-V (palatal plane) were significantly smaller in the posterior group than in the anterior group, showing that the posterior space of the vomer bone was small in the posterior group (Fig. 6).

Results of CT measurements indicated that compared with the anterior group, the posterior space of the vomer was small in the posterior group, and mid-facial height was small.

Discussion

The craniofacial complex comprises four areas: cranial vault, cranial base, nasomaxillary complex and mandible. These four areas have different structures and functions, and are roughly divisible into the cranium and face. Each of these areas grows independently and in relation to each other, and each shows a distinctive growth pattern (13).

The nasomaxillary complex consists of the maxillary, palatal, nasal, vomer, and lacrimal bones, and part of the ethmoid bone; the lowermost part consists of the hard

| Table 2. Basic statistics for measurements on CT images |
|---------------------------------------------------------|
| Anterior group (n=16)                                   |
| Median | Range |
| Posterior group (n=10)                                  |
| Median | Range |
| Angular measurements (°)                                |
| V-PNS-ANS | 133.4 | 13.0 | 128.1 | 11.7 | * |
| Linear measurements (mm)                                |
| N-E    | 36.2  | 10.1 | 35.2  | 9.2  |
| E-S    | 30.2  | 9.5  | 30.6  | 10.6 |
| N-ANS  | 57.9  | 7.0  | 54.3  | 7.8  | * |
| E-PNS  | 49.0  | 12.6 | 51.4  | 12.0 |
| V-PNS  | 27.0  | 4.3  | 26.4  | 3.0  |
| ANS-EV | 38.4  | 14.5 | 34.6  | 17.0 |
| EV-V   | 37.0  | 14.4 | 35.8  | 15.6 |
| SN-V   | 25.3  | 8.5  | 27.2  | 9.1  |
| SN-PNS | 48.4  | 8.3  | 48.0  | 10.1 |
| SN-EV  | 32.9  | 10.3 | 32.3  | 8.9  |
| SN-ANS | 57.1  | 5.1  | 53.4  | 8.0  | * |
| Palatal-V | 20.1 | 7.1  | 20.3  | 4.4  |
| Palatal-EV | 18.8 | 14.6 | 18.1  | 8.4  |
| ANS-EV (Palatal) | 33.6 | 13.0 | 28.6  | 19.5 |
| PNS-V (Palatal) | 18.6 | 6.8  | 16.1  | 4.5  | ** |

Wilcoxon rank sum test

*, P<0.05; **, P<0.01
palate, with the nasal cavity including the maxillary sinus immediately above, and the uppermost part located adjacent to the cranial base. Growth of the nasomaxillary complex is influenced by adjacent bones in a reciprocal and complicated process, with noted effects from both the cranial and face (3, 5). Growth and structure of the nasomaxillary complex and cranial base have been reported (2, 4, 7-9). The results were as follows.

Anterior cranial base length (S-N) was in the order of class III, I and II, so morphological relationships in terms of malocclusion between the nasomaxillary complex and cranial base size were evident (2, 4). In class I and II, cranial base angle (NSBa angle) was related to the anteroposterior positions of the maxilla and mandible (7). The anteroposterior length of the ethmoid bone was long in the maxillary excess but the ethmoid bone was short in the maxillary deficiency. Anteroposterior length of the ethmoid thus played a role in regulating the length of the anterior cranial base (S-N) (8, 9).

Although previous studies have suggested that morphological relationships between the cranial base and nasomaxillary complex were evident, many analyses were conducted based on two-dimensional cephalograms. Furthermore, the nasal septum has not been analyzed in orthodontic studies. The load on the maxillary dentition may be transmitted to the cranial base through the nasal septum (6). Since the nasal septum is an important structure of the mid-face, and the structure plays a major role in growth of the face. In terms of both functional and morphological aspects, relationships between the nasal septum and maxilla are important. In this study, morphological relationships between the cranial base and nasomaxillary complex in patients with maxillary retrognathism were examined, and special attention was paid to structures of the nasal septum. Patients with mandibular prognathism were divided into two groups in the present study: anterior and posterior groups. The posterior group was considered to represent patients with maxillary retrognathism.

As for mandibular prognathism, the classification is based on etiology: odontogenic, functional or skeletal. Furthermore, the skeletal mandibular prognathism includes maxillary retrognathism, mandibular prognathism, and both, and should be classified and evaluated (14, 15). Skeletal mandibular prognathism is evaluated by angular and linear measurements from the cephalogram and plaster cast, and soft-tissue condition (15, 16). Skeletal mandibular prognathism is not diagnosed from any one specific measurement item, but rather by comprehensively evaluating several parameters.

Anteroposterior aplasia of the mid-face has been reported to occur in patients with removal of the cartilage from the nasal septum due to trauma or inflammation (13, 17, 18). Similar results were obtained in an experiment that involved removal of the cartilage from the nasal septum in young rabbits (19). Findings from those studies suggested that the nasal septum plays an important role in the development and formation of the mid-face.

In the early fetal period, the nasal septum consists of a cartilaginous plate (the ethmovomerine cartilage) (20). The postero-superior part of this cartilage ossifies to form the perpendicular plate of the ethmoid bone, while the antero-inferior part remains as septal cartilage. The vomer bone ossifies in the membrane covering the postero-inferior part (20), and the ossification starts at latest 100 mm embryo (around 4 months) (21). In childhood, most of the nasal septum comprises cartilage, and as ossification of the vomer
bone and perpendicular plate of the ethmoid bone progresses, the ossified area of nasal septum grows until adolescence (6, 22).

A recent CT study reported the detailed findings for age-related changes in the nasal septum (10). The area of the whole nasal septum increased with growth up to the teen years, and the osseous area (perpendicular plate of the ethmoid bone and vomer bone) also increased until the teen years. However, the septal cartilage was largest in adolescence, then remaining almost constant up to the forties, and subsequently decreasing with age. The cartilaginous part of the nasal septum is relatively reduced, and the osseous part increases with age. These results confirm previous research.

If developmental insufficiency of the mid-face occurs due to influences on the nasal septal cartilage, morphological change may also occur in the bone derived from this septum. In addition, a relationship can be considered to exist between developmental failure of the mid-face and the structure of the bone derived from the nasal septum cartilage. In this study, morphological differences of the vomer bone as part of the nasal septum were noted. The posterior space of the vomer bone (PNS-V) was significantly shorter in the posterior group than in the anterior group, and the posterior edge of the vomer bone (V-PNS-ANS angle) was more upright in the posterior group than in the anterior group. The morphology of the vomer bone thus appears to be involved in the anteroposterior position of the maxilla.

Anteroposterior growth in the anterior cranial base occurs at the sphenofrontal, fronto-ethmoidal and sphenethmoidal sutures. Growth at the fronto-ethmoidal and sphenethmoidal sutures stops from around 7 years of age. The border between the frontal bone and cribiform plate also enters a resting stage at 6–7 years old. Subsequent growth of the anterior cranial base is due to the development of the frontal sinus (18). From 6 to 16 years old in boys, S-N increased about 7 mm, while S-Ba increased by about 14 mm (23). After later childhood, growth is less in the anterior cranial base and more in the posterior cranial base. Also, compared with the nasal septum, growth of the anterior cranial base stops early (6). In this study, the anterior cranial base was significantly shorter in the posterior group than in the anterior group. Since growth of the anterior cranial base is completed early, the posterior group seemed to show a tendency to be small from the early childhood. In addition, since the growth of the cranial base completed earlier than other cranial parts, the shortness of the anterior cranial base at which growth is preceding may have some influence on the size and position of the nasal septum and maxilla. This is considered to be one of the important indicators for early diagnosis of maxillary retrognathism.

The posterior group showed a significantly shorter posterior part of the vomer bone (PNS-V) than the anterior group, and the angle was also small (V-PNS-ANS angle). In the posterior group point A located more posterior than the anterior group. From these results, the PNS appears to be located posterosuperiorly in the posterior group. The posterior group had a shorter anterior cranial base (S-N) than the anterior group, but no significant difference was seen in total length of the cranial base (S-Ba). NSBa angle, representing the shape of the cranial base, also showed no significant difference. The PNS can thus be considered to be located posterosuperiorly because the cranial base is inclined counterclockwise on cephalogram. Despite the fact that no significant difference in anteroposterior diameter (ANS-PNS) of the hard palate was identified, PNS of the posterior group was located posterosuperiorly, so point A was located in a more posterior direction when the FH plane was taken as a reference. This suggests that these morphological factors caused maxillary retrusion.

In conclusion, the morphological factor causes maxillary retrusion is as follows: the cranial base appears inclined counterclockwise on cephalogram, due to insufficient growth of the nasal septum, especially the posterior part of the vomer.

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