Comparison of the Mandibular Alveolar Bone Width in Skeletal Class III Malocclusion with Open Bite and Non-open Bite Using Cone-beam Computed Tomography

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Abstract

Introduction: For skeletal Class III malocclusions requiring surgical orthodontic treatment, labial inclination of the mandibular incisors is often necessary to improve dental compensation. However, the alveolar bone width of the mandibular symphysis in these patients is prone to be narrower than in patients with individual normal occlusion so that movement of the lower incisors is limited. Therefore, we investigated the alveolar bone width of the mandibular symphysis and molar areas in skeletal Class III malocclusion cases with either non-open bite or open bite without incisor attrition using cone-beam computed tomography (CBCT).

Materials and Methods: Among patients 16 years old or older with skeletal Class III malocclusion who underwent CBCT, we enrolled 30 patients with open bite without incisor attrition and 30 patients with non-open bite. Using CBCT, we measured the width of the lingual side cortical bone at 2.0, 4.0, 6.0, and 8.0 mm below the cementoenamel junction (CEJ) and the width of the alveolar bone of the symphysis at 10 mm below the CEJ of the lower central incisor.

Results: The mandibular anterior alveolar bone width, measured at 2.0, 4.0, 6.0, and 8.0 mm from the CEJ, was significantly narrower in the open-bite group than in the non-open-bite group. Between the distal root of the lower first molars and the second molars, the right buccal cortical bone of the open-bite group was significantly narrower at 6.0 mm and 8.0 mm from the CEJ than that of the non-open-bite group, but no significant difference was found in the left buccal cortical bone. Additionally, the right lingual cortical bone at 6.0 mm and the left lingual cortical bone at 2.0 mm and 4.0 mm from the CEJ were significantly narrower in the open-bite group than in the non-open-bite group. Furthermore, the width of the right alveolar bone was significantly narrower in the open-bite group than in the non-open-bite group at 8.0 mm from the CEJ.

Discussion: In the case of patients with skeletal Class III malocclusion, there was less mechanical stimulation in the open-bite group than in the non-open-bite group. This suggests that the occlusal forces were smaller and the width of the mandibular molar alveolar and buccal cortical bone narrower in the open-bite group than in the non-open-bite group.

Key words : mandibular symphysis, cone-beam computed tomography, open bite
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Introduction

For skeletal Class III malocclusions requiring surgical orthodontic treatment, labial inclination of the mandibular incisors is often necessary to improve dental compensation. However, the alveolar bone width of the mandibular symphysis in these patients is prone to be narrower than in patients with individual normal occlusion so that movement of the lower incisors is limited. Furthermore, tooth movement is limited within the cortical bone around the root due to excessive tipping of the lower incisors toward the labial side. In addition, treatment may be limited by root resorption and gingival recession¹⁻⁴⁾.

Kanai et al⁵⁾ classified patients into long-, normal-, and short-faced groups according to their mandibular symphysis and maxillofacial morphologies caused by their various mandibular plane angles and compared their symphyses. As a

result, mandibular symphysis was widest in the short-faced group, followed by the normal- and long-faced groups, respectively. However, although studies have shown the symphysis to be narrower in those with long faces compared to those with shorter faces^{6, 7)}, no study has compared the width of the mandibular symphyses and molar areas in patients with open or non-open bite and skeletal Class III malocclusion.

Therefore, we investigated the alveolar bone width of the mandibular symphyses and molar areas in skeletal Class III malocclusion cases with either non-open bite or open bite without incisor attrition using cone-beam computed tomography (CBCT)⁸⁻¹¹⁾.

Materials and Methods

Subjects

Subjects comprised 60 surgical orthodontic patients with skeletal Class III, 16 years old or older, undergoing orthogna-

thic surgery at the Showa University Dental Hospital. Thirty of these had open bite and the others had positive overbite (open bite group; average age: 21 years, range: 15.1–34.5 years) and 30 of these had non-open bite (non-open bite group; average age: 23 years, range: 16.2–49.3 years). Patients with prostheses or missing anterior mandibular teeth were excluded, as well as those with congenital or systemic diseases, such as cleft lip and palate. The selection criteria for skeletal Class III malocclusion were based on the classification of Arriola Guillén et al¹²⁾: (1) ANB $< 0^\circ$; (2) Angle Class III; (3) overjet ≤ -1 mm. The selection criteria for open bite were based on the classification of Arriola Guillén¹³⁾: (1) overbite ≤ -1 mm; (2) lack of anterior dental attrition. The preoperative overjet and overbite were measured by parallel modelling of the impressions taken for preoperative diagnostics. In these subjects, there was lateral incisor to contralateral incisor opening in 11 cases, canine to contralateral canine incision in 10 cases, and first premolar to contralateral first premolar incision in 9 cases.

This study was approved by the Showa University Dental Hospital clinical trials screening committee (registration number: DH2018-030).

Radiographic conditions and analysis

All patients in the study had jaw deformities requiring orthognathic surgery. For the purposes of diagnosis and treatment planning, lateral roentgenographic cephalography and CBCT were performed with the following conditions.

Lateral roentgenographic cephalography and analysis

Using a cranial radiography machine (DRX-3724HD, TOSHIBA, Tokyo, Japan) owned by the Showa University Dental Hospital Radiology Department, we imaged the subject patient with the Frankfurt plane parallel to the floor under the conditions of X-ray tube-subject distance 220 cm, subject-film distance 22 cm, tube voltage 80 kV, and tube current 320 mA. After the scanning, a trace of the lateral roentgenographic cephalogram was created by reduction to a single unit¹⁴⁾ and analyzed¹⁵⁾ using lateral roentgenographic cephalometry software (Power Cephalo, ReazaNet Co., Tokyo, Japan). Measurements were obtained twice by the same person with an interval of at least 1 day, and the average was calculated.

CBCT and analysis

We used the Kavo 3D Exam (Kavo Dental GmbH, Biberach, Germany), a cone-beam CT device for the teeth and maxillofacial region installed in the Department of Radiology, Showa University Dental Hospital, under the conditions of X-ray tube voltage 120 kV, X-ray tube current 5 mA, and imaging time 17.8 seconds.

Measuring the symphysis width

Using the obtained CBCT images and InVivo5 (Anatomage, San Jose, CA), we measured the width of the lingual side cortical bone 2.0, 4.0, 6.0, and 8.0 mm below the cemento-enamel junction (CEJ) and the width of the alveolar bone of the symphysis 10.0 mm below the CEJ of the lower central incisor (Fig. 1). The measurement procedure was as follows.

(1) We drew a perpendicular line (b) from the midpoint of the line (a) along the root canal of the mandibular right and left central incisors (Fig. 2A, B).

(2) Over the perpendicular line (b) (Fig. 2B), we measured the lingual cortical bone width at 2, 4, 6, and 8 mm below the CEJ of the lower central incisor (Fig. 3A), and we measured the mandibular alveolar bone 10 mm below the CEJ of the lower central incisor (Fig. 3B).

(3) Measurements were obtained twice by the same person with an interval of at least 1 day, and the average was calculated.

Measuring the alveolar bone width in the mandibular molar area

Using the obtained CBCT images and the InVivo5 (Anatomage, San Jose, CA), we measured the buccolingual cortical and alveolar bone widths between the first and second molars at 2.0, 4.0, 6.0, and 8.0 mm below the CEJ of the second premolar and 10.0 mm below the CEJ of the first molars, respectively (Fig. 1). The measurement procedure was as follows.

(1) We drew a perpendicular line (d) from the midpoint of the line (c) passing through the center of the root canal of the mesial roots of the mandibular first molar and second premolar (Fig. 4A, B).

(2) Over the perpendicular line (d) (Fig. 4B), we measured the buccolingual cortical bone width 2.0, 4.0, 6.0, and 8.0 mm below the CEJ (Fig. 5A) and measured the mandibular alveolar bone width 10.0 mm below the mandibular molar

Fig. 1 A diagram of the interradiographic areas and different measurement heights

Fig. 2 We drew a perpendicular line (b) from the midpoint of the line (a) along the root canal of the mandibular right and left central incisors

A : Horizontal image of CBCT in the mandibular incisor region

B : Sagittal image of CBCT in the mandibular incisor region

Fig. 3 Pictures show distance measurement in the alveolar bone of symphysis

A : Measurement of the labial lingual side cortical bone between the right and left lower central incisor

B : Measurement of the mandibular alveolar bone width between the right and left side lower central incisor

Fig. 4 We drew a perpendicular line (d) from the midpoint of the line (c) passing through the center of the root canal of the mesial roots of the mandibular first molar and second premolar

A : Horizontal image of CBCT in the mandibular incisor region

B : Sagittal image of CBCT in the mandibular incisor region

Fig. 5 Pictures show distance measurement of alveolar bone between mandibular second premolar and first molar
 A : Measurement of the cortical bone of the buccal lingual side between the lower second premolar and first molar
 B : Measurement of the mandibular alveolar bone width between the lower second premolar and lower first molar

area CEJ (Fig. 5B).

(3) In addition, we drew a perpendicular line (f) from the midpoint of the line (e) passing through the center of the distal root of the mandibular first molar and the mesial root of the second molar (Fig. 6A, B).

(4) Over the perpendicular line (f) (Fig. 6B), we measured the buccolingual cortical bone width 2.0, 4.0, 6.0, and 8.0 mm below the CEJ (Fig. 7A) and measured the mandibular alveolar bone width 10 mm below the mandibular molar area CEJ (Fig. 7B).

(5) Measurements were obtained twice by the same person with an interval of at least 1 day, and the average was calculated.

Distance from the lower central incisor to the menton

We measured the distance of the mandibular central incisor edge from the menton, which is the lowest point of the midline image of the mandibular chin on the mandibular plane, on the left and right sides (Fig. 8). It was measured twice at intervals, and the average value was used as the measured value.

Electromyography analysis

Electromyography was performed for preoperative diagnostics. During electromyography, the cephalic position was stabilized parallel to the patient's Frankfurt plane. Electromyography was performed on six muscles, including the left masseter, right masseter, left anterior temporal complex, right anterior temporal complex, left posterior temporal, and right posterior temporal, using the K7 evaluation system EX (Myotronics-Noromed, Inc., Kent, WA)¹⁶⁾. The leads were attached parallel to the muscular fibers. The lead attachment sites were cleaned with 70% ethyl alcohol, and electrical resistance was lowered to the extent possible. Using isometric

Fig. 6 We drew a perpendicular line (f) from the midpoint of the line (e) passing through the center of the distal root of the mandibular first molar and the mesial root of the second molar

A : Horizontal image of CBCT in the mandibular incisor region
 B : Sagittal image of CBCT in the mandibular incisor region

voluntary muscle activity, we measured the maximal intensity of approximately 10 seconds of occlusion, followed by 20 repetitions of tapping exercises, performed twice. The action potentials were converted to absolute values and integrated¹⁷⁾ (Fig. 9).

Statistical analysis

The angle and distance measurements of the open and non-open bite groups were obtained from the lateral roentgenographic cephalograms, and the distance measurements of the lower jaw symphysis and the alveolar bone width in the mandibular molar area were obtained from the CBCT

Fig. 7 Pictures show distance measurement of alveolar bone between mandibular second and first molar
 A : Measurement of the cortical bone of the buccal, lingual side between the lower first molar distal root and second molar
 B : Measurement of the mandibular alveolar bone width between the lower first molar distal root and second molar

Fig. 8 Distance from menton to lower central incisor

images. These values and the integrals of the action potentials from the electromyograms were compared using the Mann-Whitney U-test; in this study, we judged that it would be difficult to guarantee the normality of continuous variables from the number of acquired data and thus used this non-parametric method. In each case, superiority was tested at a hazard ratio of 5%. We used the JMP Pro 14 software (SAS Institute Inc., Cary, NC) for all statistical analysis. The measurement error was measured using the Dahlberg formula¹⁸⁾.

Results

Model measurement and lateral cephalometric analysis

The overjet and overbite measurements and the means,

standard deviations, and statistical analyses of the lateral roentgenographic cephalogram measurements of the open and non-open bite groups are shown (Table 1). There was a significant difference in the average overbite measurements of the open and non-open bite groups (-2.8 mm vs. $+2.1$ mm). However, no significant differences were seen in the average overjet measurements between the open and non-open bite groups (-3.0 mm vs. -3.3 mm).

In contrast, the cephalometric analysis showed that the convexity, A-B plane angle, mandibular plane angle, and gonial angle of the open bite group were significantly larger than those of the non-open bite group. There were no significant differences between the groups in any other measurement.

CBCT analysis

The random error between each measurement using the Dahlberg formula was 0.09 at the minimum and 1.29 at the maximum and was considered to be small.

Symphysis width measurement

The means, standard deviations, and statistical analyses of the widths of the lingual cortical bone and alveolar bone of the symphysis in the open and non-open bite groups are shown (Table 2). The average bone width was 1.6 mm in the open bite group and 1.4 mm in the non-open bite group at 10.0 mm below the mandibular anterior lingual cortical bone CEJ, and the difference was significant. In contrast, the mandibular anterior alveolar bone width was significantly narrower in the open bite group than in the non-open bite group when measured 2.0, 4.0, 6.0, and 8.0 mm below the CEJ. There were no significant differences in any other measurement between the groups.

Alveolar bone width in the mandibular molar region

The means, standard deviations, and statistical analyses of

Fig. 9 Electromyographic findings of skeletal Cl. III
 Left side masseter (LMM), Right side masseter (RMM), Left side temporal anterior (LTA)
 Right side temporal anterior (RTA), Left side temporal posterior (LTP), Right side temporal posterior (RTP)

Table 1 Characteristics of the subjects in this study

	Openbite	Non openbite	
Model analysis	Average±SD	Average±SD	p-value
overjet (mm)	-3.0±2.5	-3.3±2.9	NS
overbite (mm)	-2.8±2.0	2.1±1.7	**
Cephalometric analysis	Average±SD	Average±SD	p-value
SNA (°)	80.7±3.9	80.6±2.8	NS
SNB (°)	83.2±4.3	84.6±3.0	NS
ANB (°)	-2.4±3.0	-3.9±2.7	NS
convexity (°)	-1.5±7.3	-8.7±5.0	**
A-B plane (°)	2.1±2.2	4.7±3.7	*
mandibular plane angle (°)	33.0±4.8	27.5±5.6	**
gonial angel (°)	132.7±6.3	127.7±7.7	**
Y-axis (°)	60.0±7.3	60.3±3.9	NS
U1 to FH (°)	112.6±21.4	112.4±6.7	NS
L1 to FH (°)	77.6±9.5	82.7±10.7	NS
occlusal plane angle (°)	10.6±2.7	7.6±5.0	NS
Gn-Cd (mm)	135.0±9.1	131.9±11.9	NS
Pog'-Go (mm)	84.9±5.9	84.3±7.6	NS
Cd-Go (mm)	65.4±6.2	68.2±7.0	NS

(* : $p < 0.05$, ** : $p < 0.01$)

the widths of the buccolingual cortical bone and the alveolar bone in the mandibular molar region of the open and non-open bite groups are shown in Tables 3 and 4. No significant differences were found in any measurements acquired

between the mandibular second premolars and first molars between the groups (Table 3), whereas, compared to the non-open bite group, the open bite group had a significantly narrower buccal cortical bone between the distal root of the

Table 2 Distance measurement results in the alveolar bone width of symphysis in the open bite and non-open bite

		Open bite		Non-open bite		p-value
		Average±SD(mm)	Dahlberg error	Average±SD(mm)	Dahlberg error	
①	2.0mm	0.9±0.2	0.09	1.0±0.2	0.11	NS
①	4.0mm	0.9±0.2	0.12	1.0±0.2	0.09	NS
①	6.0mm	0.9±0.2	0.09	0.9±0.2	0.10	NS
①	8.0mm	0.9±0.2	0.11	0.9±0.2	0.10	NS
①	10.0mm	1.3±1.1	1.29	1.0±0.2	0.11	NS
②	2.0mm	1.0±0.2	0.12	1.0±0.2	0.13	NS
②	4.0mm	1.1±0.3	0.09	1.2±0.3	0.10	NS
②	6.0mm	1.3±0.3	0.12	1.3±0.4	0.11	NS
②	8.0mm	1.4±0.3	0.13	1.3±0.4	0.12	NS
②	10.0mm	1.6±0.3	0.12	1.4±0.4	0.13	*
③	2.0mm	4.1±0.8	0.12	4.7±0.8	0.16	**
③	4.0mm	4.0±0.8	0.13	5.0±0.8	0.14	**
③	6.0mm	4.3±1.0	0.11	5.0±1.0	0.12	**
③	8.0mm	4.6±1.0	0.15	5.3±1.3	0.18	*
③	10.0mm	5.4±1.4	0.15	5.9±1.6	0.16	NS
Me-L1 (R)		42.7±2.7	0.38	42.1±3.5	0.38	NS
Me-L1 (L)		42.4±2.6	0.40	42.2±3.7	0.27	NS

① Labial cortical bone of symphysis

② Lingual cortical bone of symphysis

③ Alveolar bone width of symphysis

(*: p<0.05, **: p<0.01)

right mandibular first molar and the second molars at 6.0 mm and 8.0 mm below the CEJ. However, no significant difference was seen in the left buccal cortical bone. In the open bite group, the right lingual cortical bone measured 6.0 mm below the CEJ and the left lingual cortical bone measured 2.0 mm and 4.0 mm below the CEJ were significantly narrower than those of the non-open bite group. Furthermore, the right alveolar bone width of the open bite group was significantly narrower than that of the non-open bite group when measured 8.0 mm below the CEJ (Table 4).

Distance from the lower central incisor to the menton

There was no significant difference in the distance from the incisal margin of the mandibular central incisor to the menton in both the open and non-open bite groups (Table 2).

Electromyographic analysis

As seen by the integrated electromyography measurements, the activity of the anterior temporal complexes and posterior temporal muscles was significantly higher in the open bite group than in the non-open bite group. The activity of the right and left masseters tended to be higher in the non-open bite group than in the open bite group, but the difference was not significant (Table 5) (Fig. 10).

Discussion

In this study, CBCT was used to measure the symphysis and the alveolar bone width of the mandibular molar area in the open and non-open bite groups. We hypothesized that the alveolar bone width in the symphysis became thin due to a decrease in occlusal stimulation, whereas the alveolar bone width of the mandibular molar area thickened due to an increase in occlusal stimulation.

Subjects

In this study, 30 patients in the open bite group (average age: 21 years; age range: 15 to 34 years old) and 30 patients with mandibular prognathism without open bite (non-open bite group) (average age: 23 years; age range: 16–49 years old) for a total of 60 included patients. The age range was wide in both the open and non-open bite groups, and the results showed a significant difference in part of the alveolar bone width of the posterior part. It is speculated that in the future, it may be necessary to increase the number of cases and compare subjects by age.

Table 3 Distance measurement results of the alveolar bone width between the lower second premolar and first molar in the open bite and non-open bite

Open bite			Non-open bite		
	Average±SD(mm)	Dahlberg error	Average±SD(mm)	Dahlberg error	p-value
① 2.0mm	1.3±0.2	0.16	1.2±0.4	0.14	NS
① 4.0mm	1.3±0.3	0.11	1.2±0.4	0.12	NS
① 6.0mm	1.3±0.3	0.13	1.3±0.4	0.12	NS
① 8.0mm	1.6±0.9	0.12	1.6±0.5	0.14	NS
① 10.0mm	1.6±0.4	0.11	1.8±0.5	0.16	NS
② 2.0mm	1.2±0.3	0.09	1.4±0.7	0.15	NS
② 4.0mm	1.6±0.6	0.17	1.8±0.7	0.13	NS
② 6.0mm	2.0±0.5	0.15	2.1±0.4	0.13	NS
② 8.0mm	2.2±0.5	0.17	2.2±0.4	0.14	NS
② 10.0mm	2.2±0.5	0.14	2.2±0.5	0.16	NS
③ 2.0mm	9.0±1.1	0.22	9.3±1.3	0.15	NS
③ 4.0mm	9.7±1.5	0.15	10.2±1.7	0.17	NS
③ 6.0mm	10.4±1.4	0.19	11.0±1.6	0.15	NS
③ 8.0mm	10.8±1.5	0.19	11.5±1.7	0.18	NS
③ 10.0mm	11.1±1.7	0.14	11.7±2.1	1.27	NS
④ 2.0mm	1.0±0.2	0.12	1.1±0.3	0.20	NS
④ 4.0mm	1.1±0.2	0.11	1.1±0.2	0.10	NS
④ 6.0mm	1.1±0.2	0.11	1.2±0.3	0.11	NS
④ 8.0mm	1.3±0.3	0.13	1.4±0.4	0.13	NS
④ 10.0mm	1.5±0.3	0.11	1.5±0.3	0.14	NS
⑤ 2.0mm	1.1±0.5	0.15	1.1±0.4	0.12	NS
⑤ 4.0mm	1.6±0.6	0.13	1.6±0.6	0.11	NS
⑤ 6.0mm	2.0±0.5	0.13	2.0±0.4	0.19	NS
⑤ 8.0mm	2.2±0.3	0.16	2.5±0.7	0.16	NS
⑤ 10.0mm	2.2±0.4	0.11	2.2±0.4	0.11	NS
⑥ 2.0mm	8.9±1.3	0.15	8.9±1.1	0.16	NS
⑥ 4.0mm	9.6±1.5	0.17	9.9±1.2	0.23	NS
⑥ 6.0mm	10.1±1.5	0.16	10.7±1.3	0.19	NS
⑥ 8.0mm	10.4±1.7	0.18	11.2±1.3	0.17	NS
⑥ 10.0mm	10.7±1.7	0.17	11.5±1.4	0.12	NS

① The right mandibular molar buccal side cortical bone

(*: p<0.05, **: p<0.01)

② The right mandibular molar lingual side cortical bone

③ The right mandibular molar alveolar bone width

④ The left mandibular molar buccal side cortical bone

⑤ The left mandibular molar lingual side cortical bone

⑥ The left mandibular molar alveolar bone width

Facial morphology and mechanical stress

Chiba et al¹⁹⁾ conducted an experiment in which a compressive force was applied to the cultured long tube bone of a newborn rat. It was shown that the mechanism of induction of osteoclast differentiation by mechanical stress differs from that of pathological bone resorption by antigen stimulation associated with inflammation or bacterial endotoxins. They stated that there is a regulatory mechanism of the

interaction of osteoblasts and bone marrow cells. Shimizu et al²⁰⁾ conducted a study on the mechanism of bone remodeling due to mechanical stress, in which interactions occur between osteoblasts and bone marrow cells due to the load of mechanical stress, and these cells become bone resorption or bone formation systems. They stated that bone structure is produced by the production of converting interacting factors. Ringqvist et al²¹⁾ recorded the incisor and molar maximal

Table 4 Distance measurement results of the alveolar bone width between the lower first molar and second molar in the open bite and non-open bite

Open bite			Non-open bite		
	Average±SD(mm)	Dahlberg error	Average±SD(mm)	Dahlberg error	p-value
① 2.0mm	1.4±0.2	0.13	1.4±0.4	0.19	NS
① 4.0mm	1.4±0.4	0.10	1.5±0.3	0.16	NS
① 6.0mm	1.5±0.4	0.17	1.7±0.4	0.16	*
① 8.0mm	1.7±0.4	0.16	2.0±0.4	0.18	**
① 10.0mm	1.9±0.5	0.20	2.2±0.4	0.17	NS
② 2.0mm	1.4±0.3	0.17	1.5±0.3	0.10	NS
② 4.0mm	1.6±0.3	0.12	1.7±0.3	0.16	NS
② 6.0mm	1.6±0.3	0.10	1.9±0.3	0.13	**
② 8.0mm	1.7±0.3	0.15	1.9±0.3	0.15	*
② 10.0mm	1.8±0.3	0.14	1.8±0.3	0.15	NS
③ 2.0mm	10.2±1.1	0.16	10.5±1.4	0.18	NS
③ 4.0mm	10.9±1.1	0.20	11.5±1.4	0.18	NS
③ 6.0mm	11.5±1.4	0.17	12.1±1.5	0.17	NS
③ 8.0mm	11.9±1.4	0.22	12.7±1.5	0.17	*
③ 10.0mm	12.4±1.6	0.15	12.8±1.7	0.22	NS
④ 2.0mm	1.1±0.2	0.12	1.2±0.2	0.16	NS
④ 4.0mm	1.2±0.2	0.16	1.3±0.3	0.12	NS
④ 6.0mm	1.4±0.3	0.13	1.5±0.3	0.14	NS
④ 8.0mm	1.6±0.4	0.12	1.7±0.3	0.13	NS
④ 10.0mm	1.9±0.4	0.15	2.0±0.3	0.13	NS
⑤ 2.0mm	1.2±0.1	0.12	1.5±0.3	0.16	**
⑤ 4.0mm	1.4±0.2	0.09	1.7±0.3	0.15	**
⑤ 6.0mm	1.7±0.2	0.13	1.8±0.4	0.15	NS
⑤ 8.0mm	1.9±0.3	0.13	1.9±0.4	0.12	NS
⑤ 10.0mm	1.9±0.3	0.13	1.9±0.4	0.12	NS
⑥ 2.0mm	10.2±1.0	0.26	10.1±1.2	0.16	NS
⑥ 4.0mm	10.9±1.1	0.18	11.0±1.2	0.15	NS
⑥ 6.0mm	11.3±1.4	0.21	11.8±1.3	0.16	NS
⑥ 8.0mm	11.9±1.6	0.18	12.5±1.4	0.12	NS
⑥ 10.0mm	12.3±1.7	0.16	12.6±1.5	0.15	NS

① The right mandibular molar buccal side cortical bone

(*: p<0.05, **: p<0.01)

② The right mandibular molar lingual side cortical bone

③ The right mandibular molar alveolar bone width

④ The left mandibular molar buccal side cortical bone

⑤ The left mandibular molar lingual side cortical bone

⑥ The left mandibular molar alveolar bone width

occlusal forces in 29 women aged 19–23 years and studied the changes in occlusal forces and their association with the dimensions of the facial bones. The results suggested that the mandibular plane angle was strongly affected by occlusal forces because there was a strong association between the incisor and molar occlusal forces, which were primarily associated with mandibular length, mandibular plane angle, and gonial angle. These results suggest that the occlusal mechanical

stress influences the facial morphology, particularly the shape of the mandible. In this study, the convexity, A-B plane angle, mandibular plane angle, and gonial angle of the open bite group were significantly larger than those of the non-open bite group. These results suggest that the mandibular plane and gonial angles were larger in the open bite group than in the non-open bite group due to weaker occlusal forces. In the future, we plan to measure and examine the occlusal force.

Table 5 Electromyogram result of a measurement of the temporal muscle and masseter in the open bite and non-open bite group

	LMM (uV)	RMM (uV)	LTA (uV)	RTA (uV)	LTP (uV)	RTP (uV)
open bite	46.1	46.6	54.4	52.9	45.6	38.6
Non-open bite	49.1	49.8	50.9	52.0	29.6	25.7
p-value	NS	NS	NS	NS	NS	NS

Left side masseter (LMM), Right side masseter (RMM), Left side temporal anterior (LTA), Right side temporal anterior (RTA), Left side temporal posterior (LTP), Right side temporal posterior (RTP)

(* : $p < 0.05$, ** : $p < 0.01$)

Fig. 10 Electromyogram result of a measurement of the temporal muscle and masseter in the open bite and non-open bite group

Left side masseter (LMM), Right side masseter (RMM), Left side temporal anterior (LTA), Right side temporal anterior (RTA), Left side temporal posterior (LTP), Right side temporal posterior (RTP)

Electromyographic analysis

Electromyography is widely used for the functional analysis of masticatory muscles. Inman et al²²⁾ reported that the integrated electromyogram levels are proportional to muscular strength and occlusal force. Weijis et al²³⁾ reported that muscular strength was closely related to the cross-sectional area of the muscle. Because the integral of the temporal muscle electromyography value was higher in the open bite group than in the non-open bite group, the occlusal force from the temporal muscle was likely stronger in the open bite group than in the non-open bite group.

Morphology of the mandibular symphysis

Factors affecting the symphysis morphology include genetic and physiological effects. Regarding genetic effects, Stanley et al. reported that the size of the symphysis is independent of the mandibular size, the size of the arch, or the size of the teeth²⁴⁾. In terms of physiological effects, Walkhoff et al²⁵⁾

reported that the symphysis morphology is due to multiple muscle-induced stress on the tongue, hyoid bone, and mental spines. Furthermore, Beecher et al²⁶⁾ showed that the degree of the union of the symphysis differs among various species due to varying masticatory force. In this study, the mandibular anterior alveolar bone was significantly narrower in the open bite group than in the non-open bite group when measured at 2.0 mm, 4.0 mm, 6.0 mm, and 8.0 mm below the CEJ. These results suggest that the decrease in the alveolar bone width of the symphysis was due to the decrease in occlusal stimulation, similar to the results of the aforementioned reports. However, the lingual mandibular anterior cortical bone width measured 10.0 mm below the CEJ was, on average, 1.6 mm in the non-open bite group and 1.4 mm in the open bite group. This suggests that the apex of the lingual cortical bone of the mandibular anterior thickened to compensate for the whole symphysis having thinned; however, dynamic analysis is needed in future studies to confirm this suspicion.

Morphology of the mandibular molar area

Yoshimoto et al²⁷⁾ performed a photoelasticity experiment to observe mandibular bone remodeling and distortion of the mandibular surface in response to occlusal forces in mandibular dog bone, measuring the strain on the jawbone surface, cross-section, and center of the tooth root using the photoelasticity film method. As a result, when the occlusal force increased, concentrations in stress were observed in the apex, cervix, and leading edge of the ramus and the buccal and lingual alveolar crests became indented in the direction of the roots, accompanied by perpendicular movement and transformation of the teeth. Morikuni et al²⁸⁾ measured the association between occlusal forces and the morphology of the mandibular molar area using CBCT and occlusal pressure-sensitive film. A positive correlation was found between the width of the mandible at the midpoint connecting the root apex at the lowest point of the mandible, on the basis of occlusal force and Frankfort horizontal plane from the root apex, and stated that the width the mandibular molar area

increased with increasing occlusal force. Riise et al.²⁹⁾ demonstrated that the occlusal contact area score changed according to the magnitude of the occlusal force. They further stated that an increased ratio of cortical bone to maxillary bone in the mandible, is harder, but it is long bone to tie up articular head to unlike maxillary bone, and it is said that it is easy to transform it with the power that there is relatively few it easily³⁰⁾. One study showed that force applied to the mandible is absorbed and transformed by the whole bone³¹⁾. The results of the present study showed that ratio of the width of the alveolar bone in the mandibular molar area and the occlusive forces on the molar area were higher in the open bite group than in the non-open bite group. In other words, the width of the alveolar bone in the mandibular molar area of the open bite group may have thickened due to an increase in occlusal stimulation. However, the widths of the alveolar bone in the mandibular molar area and the buccal cortical bone between the distal root of the mandibular first molar and the second molars in the open bite group were narrower than those of the non-open bite group. Sas-souni³²⁾ classified the maxillofacial morphology into open and deep bite groups and showed that cases with deep bites had higher occlusal forces than those with open bites. Because the initial masticatory muscle function included decreased occlusal force from the temporal muscle in the open bite group compared to patients without skeletal Class III malocclusions³³⁾, and the occlusal contact area was smaller, there was limited mandibular arcuation, suggesting that these results were due to decreased mechanical stimulation. There was a left-right difference in part of the alveolar bone width of the mandibular molar and the cortical bone width of the mandibular molar, which included cases with jaw displacement in both the open and non-open bite groups. It is considered that there is a relationship, but it was considered necessary to increase the number of cases and study. We measured the occlusal contact site and occlusal force using an occlude; however, future studies examining the occlusal contact sites and occlusal forces of patients with open and non-open bites are needed in the future.

Significance of the first phase treatment for patients with skeletal Class III malocclusion

Maki et al.³⁴⁾ showed that chewing function imbalances, including malocclusion of the lateral teeth in childhood, are likely to result in heteromorphic growth of the mandible; is strongly associated with the distribution of equivalent stress created during occlusion and the bone density distribution of the mandible and reported that thinning of the jawbone may occur during growth due to the absence of functional load from insufficient masticatory muscles. Because it is likely that occlusal stimulation affects the width of the alveolar

bone of the symphysis and mandibular molar area, in this study, we hypothesized that we could intentionally induce appositional bone growth through the application of functional loads, such as occlusal stimulation, during treatment for stage I in growing patients.

Conclusions

Our results suggest that a decrease in occlusal stimulation in the anterior mandible is a factor for decreased width of the alveolar bone in the symphysis. In patients with skeletal Class III malocclusion and an open bite, the function of the masticatory muscles and the occlusal forces from the temporal muscles were higher than those of patients with normal or non-open bite and there was limited mandibular arcuation, possibly due to decreased mechanical stimulus due to a decreased occlusal contact area.

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References

- 1) Mulie, R.M., et al.: The limitations of tooth movement within the symphysis, studied with laminagraphy and standardized occlusal films. *J Clin Orthod*, 10: 882-893, 1976.
- 2) Wehrbein, H., et al.: Mandibular incisors, alveolar bone, and symphysis after orthodontic treatment. A retrospective study. *Am J Orthod Dentofacial Orthop*, 110: 239-246, 1996.
- 3) Artun, J., et al.: Periodontal status of mandibular incisors following expensive proclination. A study in adults with surgically treated mandibular prognathism. *Am J Orthod Dentofacial Orthop*, 91: 225-232, 1987.
- 4) Lupi, J.E., et al.: Prevalence and severity of apical root resorption and alveolar bone loss in Orthodontically treated adults. *Am J Orthod Dentofacial Orthop*, 109: 28-37, 1996.
- 5) Kanai, M., et al.: Cone-beam computed tomography evaluation of mandibular symphysis. *Dental Med Res*, 31: 16-23, 2011.
- 6) Denise, S.: Cross-sectional human mandibular morphology as assessed in vivo by cone-beam computed tomography in patients with different vertical facial dimensions. *Am J Orthod Dentofacial Orthop*, e377-e389, 2011.
- 7) Manabu, N.: Relationship between the mandibular symphysis and orthodontic measurement points on the craniofacial skeleton. *J Osaka Odontol Soc*, 5: 335-362, 1994.
- 8) Genevive, L., et al.: CBCT imaging - a boon to orthodontics. *Saudi Dent J*, 27: 12-21, 2015.
- 9) Kapila, S.D., et al.: CBCT in orthodontics: assessment of treatment outcomes and indications for its use. *Dentmaxillofac Radiol*, 44: 20140282, 2015.
- 10) Ludlow, J.B., et al.: Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 106: 106-114, 2008.
- 11) Schulze, D., et al.: Radiation exposure during midfacial imaging using 4- and 16-slice computed tomography, cone

- beam computed tomography systems and conventional radiography. *Dentomaxillofac Radiol*, 33:83-86, 2004.
- 12) Arriola-Guillén, L.E., et al.: Semi-longitudinal study of the mcnamara cephalometric triangle in Class II and Class III subjects grouped by cervical vertebrae maturation stage. *Acta Odontol Latinoam*, 28:222-230, 2015.
 - 13) Arriola-Guillén, L.E., et al.: Molar heights and incisor inclinations in adults with Class II and Class III skeletal open bite malocclusions. *Am J Orthod Dentofacial Orthop*, 145:325-332, 2014.
 - 14) Iizuka, T., et al.: Reference value of the case analytical procedure with the roentgenographic cephalogram. *J Jpn Orthod*, 16:4-12, 1957.
 - 15) Broadbent, B.H.: A new X-ray technique and its application to orthodontia. *Angle Orthop*, 109:28-37, 1996.
 - 16) Ishioka, Y., et al.: Basics and application of the jaw functional analysis. *Dental Diamond*, 176-187, 1991.
 - 17) Manchanda, S., et al.: Recording myocentric relation in a partially edentulous patient. *J Int Oral Health*, 7:92-95, 2015.
 - 18) Galão, M. C. de S., et al.: Dahlberg formula-a novel approach for its evaluation. *Dental Press J Orthod*, 17:115-124, 2012.
 - 19) Chiba, M.: Study on bone remodeling mechanism by mechanical stress. *J Jpn Orthod*, 48:585-600, 1989.
 - 20) Shimizu, Y., et al.: A study of bone remodeling mechanism induced by mechanical stress. *Jpn J Oral Biol*, 32:123-134, 1990.
 - 21) Ringqvist, M.: Isometric bite force and its relation to dimensions of the facial skeleton. *Acta Odontol Scand*, 31:35-42, 1973.
 - 22) Inman, V.T., et al.: Relation of human electromyogram of muscular tension. *Electromyogr Clin Neurophysiol*, 4:187-194, 1952.
 - 23) Weijis, W.A., et al.: Cross sectional areas and estimated intrinsic strength of the human jaw muscles. *Acta Morphol Neerl-Secand*, 23:267-274, 1985.
 - 24) Garn, S.M., et al.: The inheritance of symphyseal size during growth. *Angle Orthod*, 33:222-231, 1963.
 - 25) Walkoff, O.: Die menschliche sprache in ihrer bedeutung fur die funktionelle gestalt des unterkiefers. *Anat anz*, 24:129-139, 1903.
 - 26) Beecher, R.M.: Functional and fusion at the mandibular symphysis. *Amer J Phys Anthropol*, 47:325-335, 1977.
 - 27) Yoshimoto, S.: Mandibular mechanical response to occlusal force. *Jpn J Oral*, 18:286-310, 1976.
 - 28) Morikuni, H., et al.: Relationship between occlusal force and morphology in the mandibular molar region using a dental cone beam CT. *Shika Igaku*, 78:1-6, 2015.
 - 29) Riise, C., et al.: Clinical study of number of occlusal tooth contacts in the intercusp position at light and hard pressure in adults. *J Oral Rehabil*, 9:469-477, 1982.
 - 30) Burch, J.G., et al.: Method for study of mandibular arch width change. *J Dent Res*, 49:463-463, 1970.
 - 31) Suzuki, M.: The relationship between three-dimensional occlusal force and tooth displacement depending on clenching force in function. *J Stomatol Soc Jpn*, 73:79-89, 2006.
 - 32) Sassouni, V.: A classification of skeletal facial types. *Amer J Orthodont*, 55:109-123, 1969.
 - 33) Maki, K.: The orthodontics future. *The Nippon Dental Review*, 6:11-13, 2017.
 - 34) Maki, K., et al.: Computer-assisted simulations in orthodontic diagnosis and the application of a new cone beam X-ray computed tomography. *Orthod Craniofac Res*, 6:95-101, 2003.

開咬を伴う骨格性反対咬合症例と開咬を伴わない骨格性反対咬合症例の CBCT 画像を用いた下顎歯槽骨幅径の比較

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外科的矯正治療が必要となる骨格性下顎前突症においては、術前矯正を行う事が一般的である。この際、dental compensationを解消させるために下顎前歯の唇側傾斜が必要となる。しかし骨格性下顎前突症患者は正常咬合者に比べて symphysis の歯槽部幅径が小さく、歯の移動が制限される。そこで、本研究は骨格性下顎前突症患者において前歯に咬耗のない開咬を伴う症例と開咬を伴わない症例の symphysis と下顎臼歯部の歯槽骨幅径に関連があるか cone-beam computed tomography (以下、CBCT) を用いて分析、解明することを目的とした。

CBCT を撮影した 16 歳以上の骨格性下顎前突症患者のうち、前歯部咬耗がない開咬を伴う下顎前突症患者 30 名（開咬群）と開咬を伴わない下顎前突症患者 30 名（非開咬群）の計 60 名を選択した。CBCT 画像を用いて、InVivo5 (Anatomage, San Jose, CA) を使用し下顎中切歯、下顎臼歯部の cemento-enamel junction (以下、CEJ) から各 2, 4, 6, 8, 10mm 下方の symphysis と下顎臼歯部の唇舌側（頬舌側）皮質骨、下顎歯槽骨幅径の距離を計測した。統計処理は、距離計測の比較に Mann-Whitney's U test を用いた。統計解析用ソフト JMP Pro 14 (SAS Institute Inc., Cary, NC) を用いて、優位性を危険率 5% で検定した。

計測の結果、非開咬群と比較して、開咬群の convexity, A-B Plane angle, Mandibular plane angle, gonial angle は有意に大きな値を示し 2 群の間で差が認められた。下顎前歯部歯槽骨幅径は CEJ から 2.0mm, 4.0mm, 6.0mm, 8.0mm の平均値で開咬群が非開咬群に対し有意に小さな値を示した。下顎第一大臼歯遠心根・第二大臼歯間においては、開咬群の右側頬側皮質骨は CEJ から 6.0mm, 8.0mm において非開咬群に対して有意に小さい値を示したが、左側頬側皮質骨には有意差が認められなかった。また、開咬群の右側舌側皮質骨は CEJ から 6.0mm, 左側舌側皮質骨は CEJ から 2.0mm, 4.0mm において非開咬群に対して有意に小さい値を示した。さらに、開咬群の右側歯槽骨幅径は CEJ から 8.0mm において非開咬群に対して有意に小さい値を示した。

1) 前歯部の咬合刺激低下により symphysis の歯槽骨幅径が小さくなった。2) 骨格性下顎前突症患者の場合、開咬群の咬合力は非開咬群より小さく、機械的刺激が低下するため、下顎臼歯部歯槽骨幅径、頬側皮質骨幅径の一部で非開咬群に比べて小さい値を示す、と示唆された。以上より、成長期の骨格性下顎前突傾向のある患者に意図的に矯正装置による咬合刺激を与え、symphysis 等の厚みを変化させることで、術前矯正における下顎前歯移動の制限や歯根吸収、歯肉退縮を予防出来る可能性があると考えた。

キーワード: 下顎骨体結合部正中断面像, CBCT, 開咬