

# Anterior open bite with temporomandibular disorders treated with intermaxillary traction using skeletal anchorage system

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**Abstract** (J Korean Assoc Oral Maxillofac Surg 2012;38:284-94)

**Objectives:** The anterior open bite with temporomandibular disorders (TMD) is one of the most challenging cases both orthodontically and surgically. We introduce an intermaxillary traction treatment for patients with anterior open bite and TMD using a skeletal anchorage system (SAS).

**Materials and Methods:** This study was comprised of 52 patients with anterior open bite and TMD. A total of four mini-screws were inserted, two screws each into the maxilla and mandible, to obtain a class II pattern of elastic application with 120-200 g force. Adjunctive muscle relaxation treatments, such as splint therapy, medication, and botulinum toxin injection were applied during or before intermaxillary traction. At least one treatment among adjunctive muscle relaxation treatment, mentioned above, was applied to 96.2% of patients. We evaluated the clinical characteristics of patients, TMD symptom changes, amount of open bite improved. The degree of open bite improvement was compared between the open bite-reduced group (21 patients) and not-reduced group (5 patients).

**Results:** TMD symptoms (muscle/joint pain, joint sound, mouth opening) remained or improved in most patients, and worsened in about 10% of patients for each items. Anterior open bite was improved by a mean of 1.75 mm ( $P<0.01$ ) during treatment. The open bite-reduced group exhibited a significant open bite improvement compared to the not-reduced group ( $P<0.05$ ), with 37% of open bite improvement occurring during the first 3 months of treatment.

**Conclusion:** The intermaxillary traction technique using SAS is a valid modality for correction of anterior open bite and improvement of TMD symptoms.

**Key words:** Open bite, Malocclusion, Temporomandibular disorders, Intermaxillary traction

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## I. Introduction

Approaches to open bite treatment may be largely classified into orthodontic treatment and surgical treatment. Treatment through the intrusion of posterior teeth is widely accepted in terms of orthodontic treatment rather than treatment through the extrusion of anterior teeth. Nonetheless, it has been difficult to attain the targeted amount of molar intrusion by means of the existing orthodontic treatment methods<sup>1</sup>. As a means of surgical treatment, orthognathic one-jaw surgery or two-jaw surgery was performed. For one-jaw surgery, Le

fort I osteotomy alone using superior repositioning of the maxilla or bilateral sagittal split osteotomy alone has been performed<sup>2</sup>. Nonetheless, surgically established positions have showed considerable skeletal recurrence of increase in facial height, decrease in vertical overbite, or molar intrusion due to various reasons<sup>3</sup>.

Umemori et al.<sup>1</sup> started to use titanium screws for open bite treatment, naming them the skeletal anchorage system (SAS). Since then SAS has been applied in a variety of open bite cases. By providing absolute anchorage, SAS enabled performing the intrusion of posterior teeth, which was difficult to do orthodontically. It showed treatment effects that were significantly comparable with the effects of treatment of open bite cases using orthognathic surgery<sup>4</sup>. Additionally, it is simple and economical method compared with its treatment effects, SAS is emerging as an attractive open bite treatment method for both orthodontists and surgeons<sup>5</sup>.

Anterior open bite has been known as a significantly frequent form of malocclusion in patients with temporoman-

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dibular disorders (TMD)<sup>6-8</sup>. Note, however, that there have been few reports of intermaxillary traction using SAS for the treatment of anterior open bite with TMD. In present study, we introduced how to apply intermaxillary traction using SAS and investigated and analyzed clinical characteristics and treatment effects for patients with anterior open bite and TMD who visited our clinics between 2005 and 2011.

## II. Materials and Methods

### 1. Patient selection

Sixty-five patients whose chief complaint was TMD, visited department of oral and maxillofacial department of Gangnam Severance Hospital between August 2005 and July 2011 were included in this study. They exhibited anterior open bite and received intermaxillary traction treatment using SAS and elastics. We investigated items - patient distribution, clinical characteristics related to TMD - of 52 patients (8 males, 45 females) after patient exclusion according to criteria as follows. And improvement amounts and patterns of anterior open bite were investigated with 26 patients whose open bite records were fully written.

#### < Exclusion Criteria >

- 1) Patients who were treated by not only intermaxillary traction, but also orthodontic treatment for correction of anterior open bite.
- 2) Patients who were treated by intermaxillary traction for treatment of open lock or habitual luxation.
- 3) Patients with anterior open bite due to a long habit continued since their growth period, such as finger sucking since childhood.
- 4) Patients who did not wear elastics continuously due to their non-cooperation during intermaxillary traction treatment.

All patients had at least 6 months of treatment period by considering the period of muscular adaptation. Data were collected based on the medical records of the hospital by retrospective study. This study was performed after review and approval (IRB #3-2012-0115) by the Institutional Review Board of Gangnam Severance Hospital.

### 2. Treatment protocol of intermaxillary traction

A total of four 1.6×8 mm screws (Orlus; Ortholution Co., Seoul, Korea) were used for the respective placement of two screws in the maxilla (upper jaw) and two screws in

the mandible (lower jaw). The screws were placed using only a driver under local anesthesia without cortical bone drilling prior to their placement. In general, screws were placed between the canine and premolar in the upper jaw and between the first and second premolars in the lower jaw. However, placement sites were each modified slightly according to the thickness of the interproximal bone or periodontal condition in each patient. Accordingly, rubber bands were made to take the form of class II elastics when applied; thus ensuring that anterior-superior traction force was applied to the mandible. Two weeks after the placement of screws, elastics were applied with force of about 120-200 g approximately. The screws were removed in case that anterior open bite was closed and retained at least 6 months or in case that there were no further changes in anterior open bite for at least 6 months. During the retention period, rubber bands were applied only during sleep every day or every other day.

### 3. Evaluation tools

#### 1) Patient distribution

Regarding the conditions of the patients at the initial examination, we investigated the timing of open bite initiated in each patient, the profile, changes of condylar shape, and changes in anterior open bite when forced on chin top antero-superiorly. In the first place, to investigate the timing of open bite initiated in each patient, we classified the patients into groups showed anterior open bite at the initial examination, groups showed anterior open bite during or after treatment of occlusal stabilization splint, and groups showed anterior open bite after orthognathic surgery. In the group with history of orthognathic surgery, we investigated only the patients for which at least 1 year had passed after the surgery to ensure differentiation from any surgical relapse that may occur immediately after surgery. The profiles of patients were classified into retrognathic, normal, and prognathic by analyzing their lateral cephalometric radiographs. We investigated whether or not there was any change in the shape of the condylar head based on their panoramic radiographs and lateral tomograms by classifying detailed items into the following: (1) normal bone; (2) morphological bony change; adaptive normal change in condylar head such as flattening of the condylar head, osteophyte formation, or subchondral sclerosis while maintaining an obvious cortical bone layer; (3) erosive bony change; loss of cortical bone layer in the condylar head and on the temporal bone surface<sup>9</sup>.

Evaluation of condylar change was recorded based on the severe side among condyle on both sides. Impression taking was performed to confirm occlusion in each patient. The occlusion of study model and the occlusion of actual patient were compared. In addition, we investigated and recorded whether there was a decrease in the amount of anterior open bite in the actual patient by applying external force to the chin top in the anterior and superior directions using a thumb at the initial clinical examination.(Fig. 1)

#### 2) Evaluation methods - temporomandibular disorders

Before or during intermaxillary traction treatment, several adjunctive treatments for muscle relaxation - splint therapy, medication, botulinum toxin injection (Botox; Allergan Inc., Irvine, CA, USA) - were applied and investigated. Muscle pain on temporalis, masseter, digastric muscle, joint pain, joint sound (clicking/popping/crepitus), and maximum mouth opening were recorded at both initial examination and after intermaxillary traction treatment. The changes in the maximum mouth opening before and after the treatment were statistically analyzed using the paired t test.

#### 3) Evaluation methods - anterior open bite

For measurement of amount of anterior open bite, the shortest distance between incisal edge of upper incisor and lower incisor was utilized and recorded<sup>10</sup>. The measurement of amount of anterior open bite was recorded as cumulative statistics at before treatment, 3, 6, 9, 12 months since start of treatment, and after the treatment finished. We classified the patients into the group showing an open bite reduced (reduced group) and the group showing no open bite reduced (not reduced group) according to whether or not there was a decrease in the amount of anterior open bite when anterior-

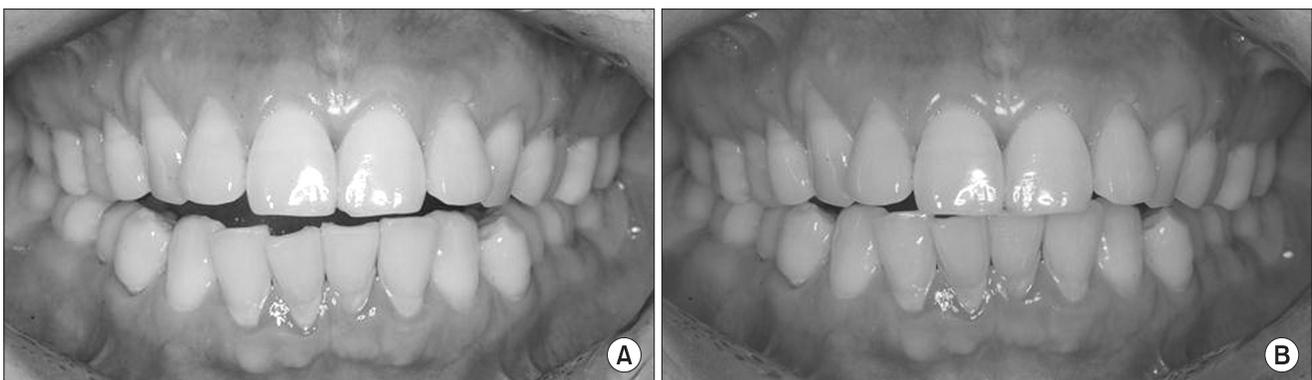
superior force was applied on chin top. By doing so, we presented both the cumulative statistics during the treatment period and the sectional statistics divided into each 0-3, 3-6, 6-9 and 9-12 months. Statistical data processing was performed using a statistical analysis software program (Statview version 9.2; SAS Institute Inc., NC, USA). The statistically significant differences among measurement values were tested using independent two sample t test together with the Wilcoxon rank sum test, which was also performed as a nonparametric test considering the number of samples. In addition, repeated measures for ANOVA were carried out to verify the statistical significance of the amounts of open bite improvement according to the periodic changes.

### III. Results

#### 1. Patient distribution

The average age of the patients as our study subjects was 26.1 years (13 to 51 years) at the time of starting intermaxillary traction treatment. For the patient distribution by age, 12 were in their teens (23.1%), 28 were in their twenties (53.8%), 7 were in their thirties (13.5%), 3 were in their forties (5.8%), and 2 were in their fifties (3.8%).

In classifying the patients according to the recognition time of open bite initiation, the number of patients observed to have anterior open bite at the initial examination, regardless of patient's recognition about exact timing, was 17 (32.7%), with 23 (44.2%) patients showing an open bite during or after treatment using occlusal stabilization splint, 4 (7.7%) patients exhibiting an open bite after orthognathic surgery, and 8 (15.4%) patients falling under the "others" category. Among the patients who showed an open bite after treatment



**Fig. 1.** Open bite reduced group when forced on chin top. A. Not forced on chin top. B. Forced on chin top.

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using an occlusal stabilization splint, 14 experienced an open bite immediately after treatment using the splint therapy. The 9 other people had a history of having undergone treatment using the splint therapy, but the time they showed an open bite did not correspond to the time they wore an occlusal stabilization splint. Among those in the “others” category, 2 people showed an open bite after orthodontic treatment, 3 experienced an open bite after temporomandibular joint (TMJ) open surgery, 1 started to have an open bite during the treatment of TMD, and 2 people showed no records about timing of open bite started.

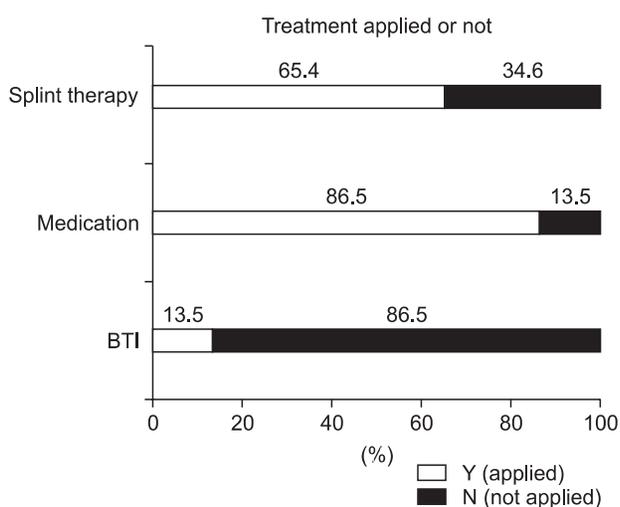
According to the result of investigating the profiles of patients except 7 people who lacked records of their profiles, the number of patients with retrognathic profile was 27 (51.9%), with patients having a normal profile numbering 18 (34.6%); there was no case of any patient with prognathic profile. In examining their condylar changes, the number of patients showing only morphological bony change was 14 (26.9%), with 24 people (26.2%) represented by patients showing obvious condylar resorption through erosive bony change and 14 people (26.9%) showing normal bone. Regarding age of patients, all patients in their forties or older showed morphological or erosive bony change in the condylar head. According to the result of investigating the changes in amount of anterior open bite when forced anterior-superiorly on chin top at initial examination, except 22 patient who lacked records, the patient groups were divided

into two groups - 24 people (80%) in the open bite reduced group (reduced group) and 6 people (20%) in the open bite not reduced group (not reduced group).

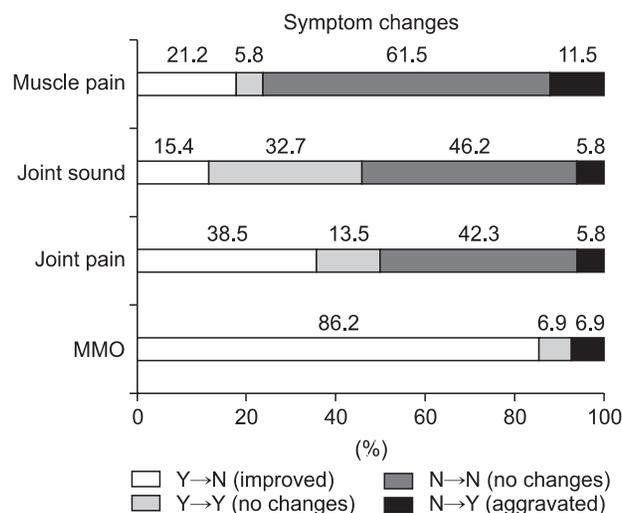
2. Results – temporomandibular disorders

For treatment of TMD as well as to aid muscular adaptation during traction treatment, adjunctive treatment for muscle relaxation was applied. We used anterior positioning splints for splint therapy and administered muscle relaxants and non-steroidal anti-inflammatory drugs for medication therapy. Injection of botulinum toxin was performed if necessary by applying 25-30 units per side (masseter muscle or masseter and temporalis muscles). Among the patients who underwent intermaxillary traction treatment, 50 (96.2%) received at least one or more kinds of adjunctive muscle relaxation treatment mentioned above, two patients (3.8%) did not receive any adjunctive treatment.(Fig. 2)

TMJ symptoms were evaluated before and after intermaxillary traction treatment using the following items: muscle pain, joint pain, joint sound, and maximum mouth opening. Most TMJ symptoms were improved or maintained, and the case of worsening TMJ symptoms accounted for about 10% or less of the patients for each item.(Fig. 3) The average maximum mouth opening increased from 45.0 mm before treatment to 46.5 mm after treatment finished with no statistical significance on paired t test.



**Fig. 2.** Adjunctive treatment for muscle relaxation. (BTI: botulinum toxin A injection)  
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**Fig. 3.** Symptom changes of temporomandibular disorders between before and after treatment of intermaxillary traction using skeletal anchorage system. (MMO: maximum mouth opening, Y: symptoms exist, N: symptoms not exist)  
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### 3. Improvement amount and treatment duration of anterior open bite

The average treatment duration by intermaxillary traction was 19 months. Evaluation of the amounts of anterior open bite improvement was performed on 26 patients who have fully written medical records on both two items - changes on anterior open bite when forced on chin top at initial examination, fully recorded of amount of overbite on each regular follow-up visit. At initial examination, the patients showed an average amount of open bite of  $-2.42 (\pm 2.38)$  mm. The amount of open bite showed statistically significant decrease ( $P < 0.01$ ) as treatment progressed, thereby at the time of treatment finished, the amount of overbite gained was  $1.75 (\pm 1.33)$  mm on average. (Table 1, Figs. 4, 5)

Investigating whether or not anterior open bite gets reduced when anterior superior forced on chin top among 26 patients, 21 patients were in reduced group and 5 patients were not reduced group. Among the 21 patient of reduced group, 19 showed an improvement in their open bites and 2 had their open bites unchanged; there was no case of a patient's open bite worsening. Among the 5 patients in the non-reduced

group, 4 showed an improvement in their open bites; there was no cases of patient's open bite remaining unchanged, with one patient's open bite worsening. To compare the amount of anterior open bite between reduced group and not-reduced group periodically, reduced group showed a statistically significant amount of open bite improvement ( $P < 0.01$ ), but the same cannot be said for the non-reduced group. Statistically, both independent two sample t test as a parametric test and Wilcoxon rank sum test as a non-parametric test were performed and both presented the same result of statistical significance. For the convenience of describing descriptive statistics, we presented the result of parametric test in this paper. In both periodic cumulative statistics and sectional statistics, the reduced group showed a significantly large amount of open bite decrease ( $P < 0.05$ ) compared with the not-reduced group up to 3 months from traction treatment started. As the treatment progressed periodically up to treatment finished, the reduced group also showed a significantly large open bite decrease ( $P < 0.05$ ) compared with the not-reduced group in the cumulative statistics. (Tables 2, 3)

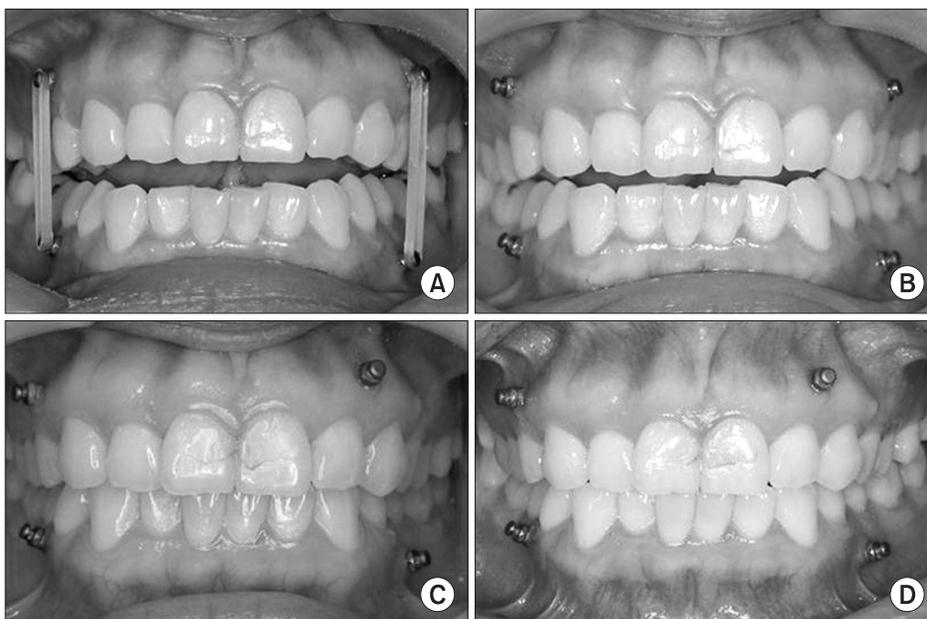
**Table 1.** Amount of overbite gained (=open bite closed) by treatment period (mean±SD, n=26)

Treatment period (months)	3	6	9	12	Final results	P-value*
Amount of overbite gained (mm)	0.64±0.64	1.04±0.92	1.28±0.92	1.48±1.09	1.75±1.33	0.0017

(SD: standard deviation)

\*Statistical analysis by repeated measures for ANOVA.

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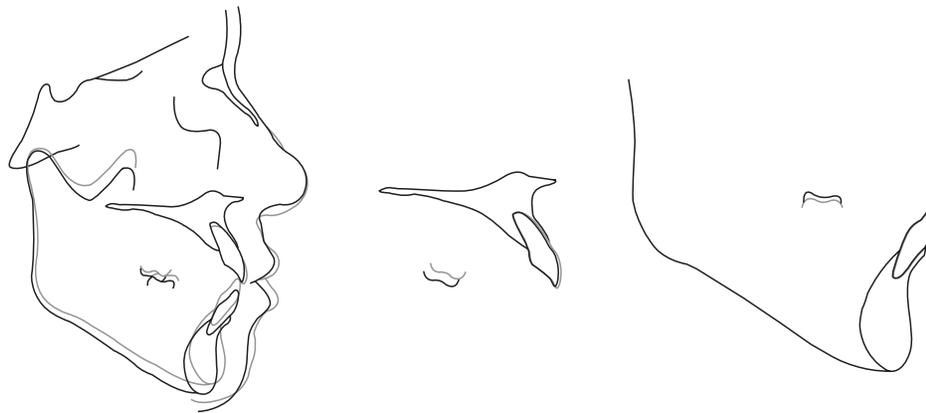


**Fig. 4.** Intraoral photographs during intermaxillary traction treatment using skeletal anchorage system. A. Start of traction. B. 3 months later. C. 9 months later. D. 1 year 3 months later. Hye-Sun Kim et al: Anterior open bite with temporomandibular disorders treated with intermaxillary traction using skeletal anchorage system. J Korean Assoc Oral Maxillofac Surg 2012

A



B



**Fig. 5.** A. Lateral cephalometric radiographs. Left: pretreatment, middle: anterior open bite closed, right: the most posterior teeth extruded for occlusion seating. B. Superimposition of cephalometric tracings before (black line) and after (gray line) intermaxillary traction treatment using skeletal anchorage system. Left: superimposed on sella-nasion plane at sella, middle: superimposed on palatal plane at anterior nasal spine, right: superimposed on mandibular plane at menton.

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**Table 2.** Comparison of overbite gained (=open bite closed) between the “open bite reduced group” and “not reduced group” when forced on chin top-statistical data by cumulative treatment period (mean±SD, n=26)

Treatment period	Open bite, when forced on chin top		P-value*
	Y (n=21)	N (n=5)	
3 months	0.76±0.64	0.10±0.22	0.0351
6 months	1.14±0.90	0.60±0.96	0.2411
9 months	1.37±0.96	0.90±0.65	0.3165
12 months	1.69±0.89	0.58±1.50	0.0379
Final result	2.05±1.14	0.50±1.46	0.0159
P-value**	0.0003	0.8357	

(SD: standard deviation, Y: open bite reduced group, N: open bite not reduced group)

\*Statistical analysis by independent two sample t test between the Y group and N group, \*\*statistical analysis by repeated measures for ANOVA to evaluate periodic progress in each group.

The amount of overbite gained (unit, mm).

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#### IV. Discussion

Classification of the timing of open bite recognition is

**Table 3.** Comparison of overbite gained (=open bite closed) between the “open bite reduced group” and “not reduced group” when forced on chin top-statistical data by sectional treatment period (mean±SD, n=26)

Treatment period (sectional)	Open bite, when forced on chin top		
	Y (n=21)	N (n=5)	P-value*
0-3 months	0.76±0.64	0.10±0.22	0.0351
3-6 months	0.38±0.50	0.50±0.87	0.6814
6-9 months	0.22±0.53	0.03±0.45	0.7683
9-12 months	0.32±0.60	-0.32±1.07	0.0761

(SD: standard deviation, Y: open bite reduced group, N: open bite not reduced group)

\*Statistical analysis by independent two sample t test.

The amount of overbite gained (unit, mm).

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correlated with the etiological factors of open bite. Note, however, that this investigation was performed within the category of patients with TMD; therefore classification of the timing of open bite recognition should not be regarded straight ahead as the classification of causative factors.

This investigation was intended for better understanding of process of an open bite occurrence. Firstly, the patient group that anterior open bite was observed at initial examination regardless of patient's recognition formed relatively large portion of 32.7% (17 patients). This patient group can be explained in two aspects as muscular factors and condylar resorption. First, there were patients showing only joint space narrowing together with an anterior open bite without any morphological change in their condylar heads in their panoramic radiographs and lateral tomograms. We think the excessive tension of the masticatory muscle serves as an excessively heavy load on the TMJ portion, resulting in the narrowing of the joint space and - instead of molar intrusion - the clockwise rotation of the mandible with the most posterior molar playing the role of the lever fulcrum, considered to induce an anterior open bite. Second, there were patients showing an obvious morphological change in their condylar heads in their radiographs. Most patients in this group showed the aspect of anterior open bite due to idiopathic or progressive condylar resorption. Arnett et al.<sup>11,12</sup> presented two main causative factors of idiopathic or progressive condylar resorption-the continuous excessive physical stress on the TMJ portion and the decreased adaptability of patients. One of the contributing elements for decreased host adaptability is the age of the patient. Age groups whose environmental adaptability decrease are group of twenties to thirties presenting progressive condylar resorption due to unknown reasons and groups of fifties to sixties presenting degenerative condylar changes<sup>11</sup>. Accordingly, this patient distribution by age was corresponded with the distribution in our study. Though both idiopathic condylar resorption and degenerative arthritis show mechanism differences, these have similar process of morphological change of condyle - if severe physical stress is applied exceeding host adaptability to TMJ portion, morphological change occurs in the condylar head and in the glenoid fossa, thereby resulting in a decrease in the posterior mandibular vertical height. This shows decreased mandibular growth in a growing child and gives rises to an anterior open bite together with progressive mandibular retrusion in an adult<sup>11,13</sup>. Similarly, the patient group with retrognathic profile accounted for the largest proportion at 51.9% and there was no patient group with prognathic profile in this study.

In the classification of the timing of open bite recognition, 23 patients (44.2%) showed an open bite during or after splint therapy. The splint therapy was chosen as a conservative therapy to decrease the load on TMJ and reduce the hyper-

activity of tense muscles. But an anterior open bite may occur as a side effect especially in a patient wearing the splint all day long or a patient wearing a partial coverage appliance. If a splint becomes worn as a result of long-time use or if it is not checked properly, an anterior open bite may occur due to the selectively excessive eruption of molar teeth<sup>14</sup>. In addition, several research were reported that use of splint altered the masticatory muscle activity, so occlusal force were newly set up and vertical height got changed; thus resulting the positional change of mandible itself, not the movement of teeth, which leads to the occurrence of an anterior open bite<sup>15,16</sup>. Based on the results of this study, 9 patients (17.3%) had a history of having undergone splint therapy, but the time of open bite recognition did not match the time of wearing a splint. We think they are patients combined with two causative factors - anterior open bite after splint therapy or splint therapy during progression of idiopathic condylar resorption which may lead to anterior open bite.

In classification of the timing of open bite recognition, 4 patients (7.7%) showed an open bite after orthognathic surgery. The positional change of bone segments, which occurs during orthognathic surgery, gives rise to a compressive force being applied to the condylar head in the glenoid fossa; if it continues, it may give rise to TMJ pain and condylar resorption, thereby causing a delayed relapse in the mandible<sup>12,17,18</sup>. In their evaluation of the long-term stability after orthognathic surgery, Hoppenreijts et al.<sup>19</sup> reported the frequent occurrence of progressive condylar resorption, especially in the case of mandibular advancement surgery through sagittal split ramus osteotomy. Condylar resorption after orthognathic surgery is aggravated by the muscular action of the masseter muscle and the medial pterygoid muscle; thus causing the mandible to be retruded posteriorly, which gives rise to an anterior open bite<sup>12</sup>.

The existing treatment of anterior open bite that has been suggested so far are largely divided into orthodontic treatment and surgical treatment. In the 1980s to 1990s, open bite treatment through the extrusion of anterior teeth was mainly used as a kind of orthodontic treatment. Note, however, that the extrusion of anterior teeth leads to show poor profiles resulting from the clockwise rotation of the mandible. Also in the evaluation of long-term stability for 10 years by extrusion of anterior teeth, over 35% of the patients were said to show a relapse of more than 3 mm<sup>20</sup>. Molar intrusion provides more efficient and more stable treatment results, and attempts have been made to use bite plates, springs, high pull headgears, fixed appliances, vertical elastics, and multi-

loop edgewise archwire (MEAW) for this. Nonetheless, it has been difficult to attain the required amount of molar intrusion<sup>21-23</sup>. Surgical treatment can solve the problem of anterior open bite mainly through superior repositioning of the maxilla and counterclockwise rotation of the mandible, however the evaluation of long term stability revealed that maxilla was mainly accompanied by vertical relapse. Approximately 10% of the patients who had underwent surgery showed a significant 2-4 mm relapse of anterior open bite<sup>24</sup>. In the evaluation of the one-year post-operative stability by Oliveira and Bloomquist<sup>25</sup>, the average rate of skeletal relapse was found to be 33.42%. In addition, there are several factors causing relapse - condylar resorption by a compressive force due to the movement of bone segments causes delayed relapse as mentioned above, an increase in the posterior facial height occurring during the counterclockwise rotation of the mandible may result in the elongation of the pterygomasseteric sling, and the mandibular symphysis moving away from the hyoid bone cause elongation of the suprahyoid muscle<sup>2</sup>. On the other hand, orthodontic treatment using SAS can attain relatively easily the required amount of molar intrusion, which has been difficult using the existing orthodontic treatment means and have shown comparable treatment effect with the effect of surgical treatment in the post-treatment cephalometric analysis<sup>4</sup>. As in the case of a relatively low relapse rate of 10.36% in orthodontic treatment using SAS as reported by Lee and Park<sup>21</sup>, orthodontic treatment using SAS has merits in terms of stability after treatment since it provides time for the slow adaptation of muscles compared with surgical treatment.

Since malocclusion is related to the malposition of the mandibular condyle in the glenoid fossa, it is an important causative factor of TMD<sup>26,27</sup>. As one can see in the epidemiological study conducted by Egermark et al.<sup>28</sup> and Henrikson et al.<sup>29</sup>, anterior open bite is closely related to TMD among other kinds of malocclusion. Therefore, special consideration for those patients with TMD and anterior open bite patients has become acutely required. Regarding this in the case of surgical treatment, Aghabeigi et al.<sup>30</sup> reported that orthognathic surgery was not effective for anterior open bite patients with TMD but was found to lead to condylar resorption. Though, orthodontic treatment using SAS makes molar intrusion effectively and has several merits - normalization of condylar position in glenoid fossa by counterclockwise rotation of mandible, having enough time for muscle adaptation to newly position<sup>31,32</sup>, there was also a case wherein a decrease in the posterior facial height rather

increased loading on condyle; thus triggering condylar resorption.

Besides surgical treatment and orthodontic treatment of patients with anterior open bite and TMD, attempts have been made to reduce the compressive force on TMJ portion to prevent the progress of condylar resorption, which may lead to an anterior open bite. For this, intermaxillary traction by button attachment at buccal crown of premolars had been tried, but has side effects of extrusion of button attached-premolars. Intermaxillary traction by Pivot splint had also been tried, but it was hard to reduce the loading in joint space and has limitation to resolve anterior open bite<sup>14,33</sup>. In this study, we applied the treatment of intermaxillary traction using SAS, and evaluated symptom changes related to TMJ and improvement amount of anterior open bite. Before starting treatment, we took an impression and made the study model of upper and lower dentition of each patient, then we investigated whether maximum intercuspitation could be induced on study model or not, and compared the occlusion between study model and actual occlusion of patients. One of the aspects differentiating treatment by intermaxillary traction from the existing orthodontic treatment methods is the fact that it has obtained treatment effects only by elastic traction after mini-screw placement instead of using bracket or wire orthodontically. The other differentiating point is the placement area of mini-screws which is placed on molar area for molar intrusion orthodontically, but placed on premolar area for intermaxillary traction used in this study. If there are some cases that obvious premature contact of premolars on study model exist, we applied intermaxillary traction using SAS first for relieve TMJ symptom and improve anterior open bite, then referred to orthodontist to eliminate premature contact ; these cases were excluded for this study. As a result of treatment, molar intrusion led to improve patient's profile of retruded chin through closure of anterior open bite. Therefore, B point (most posterior point on the bony curve between infradentale and pogonion) moved forward and the value of ANB (angle formed by A point, nasion, and B point) became improved.(Fig. 5) There was a decrease in the mandibular plane angle and a decrease in the anterior facial height due to the counterclockwise rotation of the mandible, thereby easing the tension of muscles around the lips. An increase in the joint space may also be expected due to the counterclockwise rotation of the mandible, but it was difficult to measure joint space change in lateral cephalometrics. From the result of tracing the lateral cephalometrics, both molar intrusion and mild extrusion of anterior teeth were occurred

together by existing orthodontic approach, but the treatment effect was appeared mainly by molar intrusion rather than anterior teeth extrusion by intermaxillary traction using SAS in this study. In the case of patients with a large amount of anterior open bite, the most posterior molars may play a role as lever fulcrum by condylar resorption on anterior-superior surface, thereby the most posterior molars come to be compressed by bite force continuously. If intermaxillary traction treatment applied in these patients, additional longer retention period is required after closure of anterior open bite to expect occlusal seating of the most posterior molars. (Fig. 5) As a result of treatment by intermaxillary traction, the final amount of anterior open bite improvement was found to be  $1.75 \pm 1.33$  mm on average, and it took 6 months of treatment period to achieve open bite improvement of about 1 mm. Adjunctive treatment for muscle relaxation was applied to patients before or during intermaxillary traction treatment. The adjunctive treatment was performed not only to relieve muscle pain and relax the tense muscles, but also to have expectation for maintaining the treatment effects after treatment finished by giving muscles enough time to adapt to changed skeletal position. In other words, repositioning of the condylar head, easing the tension of surrounding muscles, and physiological adaptation through intermaxillary traction are important elements for solving the symptoms of TMD. For this purpose, we used medication treatment, physical treatment, injection of botulinum toxin, and splint therapy<sup>34</sup>. Muscle relaxants and non-steroidal anti-inflammatory drugs (NSAIDs) were mainly used for medication treatment. Muscle relaxants are known to control the convulsion and pain withdrawal reflex of the masticatory muscle<sup>35</sup>. As for physical treatment, hot wet pack treatment and mandibular exercise treatment were used. Hot wet packs ease muscles and help perform exercise treatment under the condition of relieved pain. Exercise treatment was performed to build up the strength of muscles, prevent the contraction of joints, and maintain the range of functional jaw movement<sup>36</sup>. Injection of botulinum toxin was carried out when reducing the contraction and strength of the masticatory muscle was additionally required. Splint therapy reduces the load on the TMJ and reduces the hyperactivity of muscles. In this study, anterior positioning splints were used for treatment with splint therapy. This splint make condyle to place on center or slightly anterior inferior portion of glenoid fossa, which was originally positioned at posterior superior portion of glenoid fossa by excessive action of jaw-closing muscles before treatment; so that it can reduce the load on condyle, reduce

inflammation surrounding joint, increase range of mandibular movement, and relieve symptoms of TMD<sup>37</sup>. When intermaxillary traction and splint therapy were performed in combination, in the initial stage, we had the patients wear elastics for intermaxillary traction during daytime and both elastics and anterior positioning splints when sleeping. When occlusion had become stable along with increasing overbite, and their TMJ symptoms had improved, we had them wear elastics without any splint only when sleeping.

The TMJ symptoms of the patients mostly improved after both intermaxillary traction for condylar repositioning and adjunctive treatment for muscle relaxation. In the evaluation of the treatment results, however, patients showing no change in their TMJ symptoms before and after treatment accounted for a large proportion, this can be interpreted in two ways. First, since they were anterior open bite patients accompanied with TMD, if treatment of their TMD was performed prior to treatment by intermaxillary traction, it could be written in medical record, immediately before traction treatment, that TMJ symptoms had been relieved; then there could be no change in TMJ symptoms before and after intermaxillary traction treatment. In other cases which there was no change in the TMJ symptoms, if TMD were related with socio-psychological factors or compounded with pain on other part of body, their TMD may have persisted or failed to respond to any accepted treatment.

We investigated the differences in the amount of open bite improvement according to whether or not anterior open bite was reduced by anterior superior force on chin top. If anterior open bite was not reduced by force on chin top, the causes may be considered in two ways. Firstly, in the lateral view of occlusal pattern, a wedge-shaped open bite from the incisor to the most posterior molar could be observed, just same as open bite pattern of 'reduced group' when forced on chin top. In this case, the amount of anterior open bite is not reduced by external force because of muscular factors - excessive strong strength of masticatory muscle or stiffened muscle. Second, in the view of occlusal pattern on study model, these are the cases that maximum intercuspitation had not been induced on study model. Patients who having had a bad habit such as finger sucking or tongue thrusting in their childhood or patients exhibiting stable occlusion state of anterior open bite by extruded premolar teeth were belonged to these group of occlusal pattern and excluded from the scope of this study. In the cumulative statistics by treatment period, 'reduced group' showed significantly greater amount of open bite improvement than 'not-reduced group' at periodic points of 3

months, 12 months, final treatment. In the sectional statistics by treatment period, which reflects improvement speed of anterior open bite, 'reduced group' exhibited significantly greater amount of open bite improvement than 'not reduced group' for up to 3 months from treatment initiation. In other words, 'reduced group' finally showed greater amount of open bite improvement than 'not reduced group', and about 37% of this improvement amount occurred for the first three months of intermaxillary traction treatment. The numerical figures from results above could be utilized to predict prognosis of treatment more easily for clinicians.

There were several limitations to perform this study. First, since this was a retrospective study, we had to exclude some patients, such as patients who did not have enough records to perform this study or patients who did not apply elastics regularly due to poor cooperation, therefore the number of study individuals was lower compared with the number of individuals who underwent the actual treatment. Second, we evaluated the open bites of the patients in relation to the symptoms of TMD. Since TMD were often related to the psychological factor of patients, and it was also difficult for evaluators to be objective, there were also limitations to perform study. Third, this study did not use a control patient group, such as patient group who underwent orthodontic treatment or surgical treatment; hence the difficulty in comparing the treatment results objectively. In existing literature, authors expressed difficulty in establishing a control group in the treatment of open bites. The authors who established a control group used it only to examine and ascertain the characteristics of the patients prior to treatment, but there were few cases wherein a control group was established in the true sense<sup>21</sup>. To address this problem, we believe prospective studies need to be carried out on a great number of patients based in some objective criteria and indications to enable providing useful information for clinicians. For future research on advanced treatment by intermaxillary traction, studies should be performed with regard to the changes of the condylar position and joint space during treatment. Also, there is a need to conduct studies on long-term stability of intermaxillary traction treatment and how muscular adaptation actually has effect on treatment result.

## V. Conclusion

In this study, we performed treatment of anterior open bite patients from the perspectives of TMD and these patients were treated by intermaxillary traction by SAS and adjunctive

muscle relaxation treatment for control of TMD; thus achieving average open bite decrease of 1.75 mm ( $P<0.01$ ) and improvement of TMD in about 90% of our study patients. In addition, when anterior and superior force was applied on chin top, patients who showed reduction of anterior open bite exhibited a significantly greater amount of open bite improvement compared with the patients who did not. Therefore, if the following conditions are satisfied among anterior open bite patients with TMD - 1) open bite pattern shows a wedge-like shape from the most posterior molar to the incisor area, 2) occlusion is favorable when maximum intercuspitation is induced in the study model obtained by impression taking, and 3) there is a reduction in the amount of anterior open bite when anterior and superior force was applied on chin top - we believe treatment by intermaxillary traction using SAS is an effective treatment method for the improvement of both anterior open bite and TMJ symptoms.

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