Diagnostic Image Analyses of Activator Treated Temporomandibular Joint in Growth and Maturing Stages


ABSTRACT: This study evaluates the condylar response to activator in growth and in maturing patients using radiographs and magnetic resonance images (MRI). Seven patients (four in growth and three in maturing stages) treated for mandibular distal occlusion were studied. In all seven patients, lateral roentgen cephalograms, panoramic radiograms, and MRIs were made before and following functional treatment. All patients' mandibles advanced during treatment. Downward and forward mandibular growth was observed by superimposition of lateral cephalograms. On the condylar posterior superior regions for both groups, double contours were observed on the panoramic radiograms following therapy. These double contours coincided with an area of high intensity in the MRIs for both groups. In the mature adult group, the double contours were more clearly observed when compared with those in the growth group. There were differences in the condylar adaptation types between the growth and mature development stages. Condylar adaptation to the newly created mandibular position was nevertheless found even in adult patients.

FunctionaL appliances have been used to promote the forward growth of the mandible during orthodontic treatment in growing patients. It is known that the temporomandibular joint (TMJ) has a high adaptability even in mature adult patients. For example, the condyle adapts after the mandibular osteotomy.1,3 In bone fractures, spontaneous healing is produced by secondary bone repair mechanisms in a "natural" process.4,5 McNamara, et al.6 histologically found that the cartilaginous layer increases even in juvenile and young adult rhesus monkeys during mandibular advancement.6,7 Ruf and Pancherz,8 Paulsen, et al.,9 Ruf and Pancherz,10 and Pancherz11 reported using radiographs and MRIs that the Herbst appliance can stimulate mandibular growth in young adults. Bonemark12 also showed in a cephalometric study that the condyle adapted to mandibular advancement using mandibular advancement splints after nocturnal treatment of adult patients for obstructive sleep apnea. Such studies suggest that functional appliances stimulate condylar remodeling even in adults. However, there are a number of points to be made clear regarding the TMJ reaction. Although the optimal method for

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evaluating the reaction of tissues is biopsy, this is often impossible in studies using humans. MR imaging can be used to estimate the conditions both of the soft and hard tissues, but radiography is superior to MR imaging in evaluating hard tissues delivering low signals in MRI.\textsuperscript{13}

The purpose of this present study is to evaluate the condylar response to a functional appliance, both during growth and maturity stages using radiographs and MR images.

**Materials and Methods**

**Subjects**

Seven patients, who visited Orthodontic Clinic, Kyushu Dental College Hospital, were the subjects for this study. All patients had Angle class II malocclusion with mandibular distal occlusion needing activator treatment. Informed consent was obtained from each patient or from his/her parent. Patients were divided into two groups (four in the growth group and three in the mature group) according to Turner's radiographic maturity staging of the radius.\textsuperscript{14} Patients of below stage H were defined as growth, and those of equal to or beyond stage H were defined as mature. The mean age before treatment was 11.3±1.6 years for the growth group, and 20.1±3.3 years for the mature group (Table 1).

**Appliance and Treatment**

The activator was made by heat curing resin to fit all occlusal surfaces both of the upper and lower teeth. The horizontal position for constructing the bite was the incisal edge-to-edge position. The vertically constructed

### Table 1

<table>
<thead>
<tr>
<th>Subject</th>
<th>Group</th>
<th>M/F</th>
<th>Age</th>
<th>Treatment Period</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>G</td>
<td>F</td>
<td>11y 6m</td>
<td>5m</td>
</tr>
<tr>
<td>B</td>
<td>G</td>
<td>M</td>
<td>12y 1m</td>
<td>6m</td>
</tr>
<tr>
<td>C</td>
<td>G</td>
<td>F</td>
<td>9y 1m</td>
<td>6m</td>
</tr>
<tr>
<td>D</td>
<td>G</td>
<td>F</td>
<td>12y 10m</td>
<td>6m</td>
</tr>
<tr>
<td>E</td>
<td>GU</td>
<td>M</td>
<td>23y 5m</td>
<td>4m</td>
</tr>
<tr>
<td>F</td>
<td>GU</td>
<td>F</td>
<td>20y 0m</td>
<td>6m</td>
</tr>
<tr>
<td>G</td>
<td>GU</td>
<td>F</td>
<td>16y 11m</td>
<td>9m</td>
</tr>
</tbody>
</table>

G: growth  
GU: mature

incisal distance was 5-8 mm (Figure 1). The activator was placed after correcting dental crowding and coordinating the upper arch with the lower one by multiple-bracket appliances. The patients wore the activator
continuously, both day and night, except at meal times and during tooth brushing. The appliance was used until a class I molar relationship was obtained at the retruded mandibular position, which was verified by manipulation. The mean treatment period was 5.8±0.5 months in the growth group and 6.3±2.5 months in the mature group.

Recording and Analyzing
Lateral cephalographs were made using an Asahi Roentgen system (Kyoto, Japan). The lateral cephalograms of pre- and post-treatment were traced and then superimposed to permit analysis of skeletal and dentoalveolar changes. Angular measurements were \( \angle \text{SNA} \), \( \angle \text{SNB} \), \( \angle \text{ANB} \), \( \angle \text{Go} \), \( \angle \text{Mp-FH} \), \( \angle 1-\text{SN} \), and \( \angle 1-\text{Mp} \). Linear measurements made were Gn-Co, Go-Me, Co-Go, overjet and overbite. These values were compared between pre- and post-treatment.

Panoramic Radiography of the TMJ
Using a AUTO-1000EXR (Asahi Roentgen Ind. Co., Ltd., Kyoto, Japan), radiographs were made in the maximum mouth open position holding the head in the cephalostat with the FH (forehead head) plane parallel to the ground. Using the pre- and post-treatment images, the changes of the condyle by activator treatment were investigated.

MRI
Using a Visert/EX (Toshiba Co., Tokyo, Japan) 1.5 T MR system with TMJ surface coils, the bilateral images of the TMJ were made in the habitual occlusal position. Section thickness was three mm without interslice gaps. MR images were obtained in a parasagittal plane perpendicular to the long axis of condyle using fast spin echo sequencing with a repetition time of 1050 ms, an echo time of 18 ms, a field of view of 15x15 cm, and a matrix of 256x320 pixels. The central image from each section was divided equally into five sections for evaluation. MRIs were made before and after activator treatment to evaluate the changes of condyle through activator treatment.

Results
Occlusal Changes
In all patients, before starting functional treatment, molars were in Class II relationship. At the end of functional treatment, Class I molar relationships were obtained, and they remained stable for six months after removal of the functional appliance. Figure 2 shows intra-oral photographs of mature patient E.

Figure 2
Intraoral photographs. a. Before functional treatment in mature patient E, canine and molar teeth were occluded in Class II relationship; b. After functional treatment, canine and molar teeth were in Class I relationship; c. Six months after removal of the functional appliance. Class I relationship was maintained and intercuspsation became stable.
Cephalometric Change

Figure 3 demonstrates superimposition of lateral cephalograms between pre- and post-treatment in a growth subject. The mandible moved downward and forward through the condylar growth. Figures 4 and 5 illustrate the superimpositions of lateral cephalograms in a mature patient. The mandible moved downward and forward through an increase in mandibular length. In this patient a small relapse of the mandibular position was observed after removal of the functional appliance (Figure 5). During functional treatment, $\angle$ ANB decreased by 1.2$\pm$1.1 in growth and 1.2$\pm$0.3 in mature patients. Gn-Co increased by 3.4$\pm$1.0 in growth and 2.2$\pm$0.3 mm in mature patients. Co-Go increased by 3.1$\pm$3.3 in growth and 2.7$\pm$0.6 mm in mature patients (Tables 2 and 3).

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**Figure 3**
Superimposition of lateral cephalographic tracings in growth patient D.
A. Superimposition on the SN plane at S point, the mandible moved forward and downward; B. Superimposition on the mandibular plane at Menton (Me), mandibular length from Me to Condylion increased. Solid line: pre-treatment; Broken line: post-treatment.

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**Figure 4**
Superimposition of lateral cephalographic tracings in mature patient E.
A. Superimposition on the SN plane at S point, the mandible moved forward and downward; B. Superimposition on the mandibular plane at Menton (Me), mandibular length from Me to Condylion increased. Solid line: pre-treatment; Broken line: post-treatment.
Panoramic Radiographic Findings

Growth Group: In both condyles for growth patients A and D, double contours were seen in the posterosuperior region of condyle following treatment (Figure 6, a and b). The double contours were continuous with medullary bone not being separated by cortical bone. In both the condyles of the growth group (patients B and C), no clear double contours were observed following treatment (Figure 7, a and b).

Mature Group: The double contours in the posterosuperior region of condyle were also seen in five of six TMJ of the mature group following treatment. The radiodensity was similar to that of medullary bone. The contour was separated by a radiopaque cortex surrounding medullary bone (Figure 8, a and b). This was different from that of growth group.
Table 3
Cephalometric Measurements in Mature Patients (N=3)

<table>
<thead>
<tr>
<th></th>
<th>Pre-treatment mean ± SD</th>
<th>Post-treatment mean ± SD</th>
<th>Difference mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>∠ SNA (°)</td>
<td>82.2±2.8</td>
<td>81.5±2.8</td>
<td>-0.7±0.7</td>
</tr>
<tr>
<td>∠ SNB (°)</td>
<td>75.5±4.4</td>
<td>76.0±4.8</td>
<td>0.5±0.5</td>
</tr>
<tr>
<td>∠ ANB (°)</td>
<td>6.7±3.0</td>
<td>5.5±2.8</td>
<td>-1.2±0.3</td>
</tr>
<tr>
<td>∠ Go (°)</td>
<td>114.0±12.8</td>
<td>113.8±12.1</td>
<td>-0.2±0.9</td>
</tr>
<tr>
<td>∠ Mp-FH (°)</td>
<td>23.0±6.6</td>
<td>22.5±6.9</td>
<td>-0.5±2.2</td>
</tr>
<tr>
<td>∠ 1-SN (°)</td>
<td>109.7±6.4</td>
<td>103.3±5.8</td>
<td>-6.3±0.8</td>
</tr>
<tr>
<td>∠ 1-Mp (°)</td>
<td>101.5±7.6</td>
<td>110.3±12.7</td>
<td>8.8±7.8</td>
</tr>
<tr>
<td>Gn-Co (mm)</td>
<td>116.2±13.7</td>
<td>118.3±13.7</td>
<td>2.2±0.3</td>
</tr>
<tr>
<td>Go-Me (mm)</td>
<td>72.7±10.1</td>
<td>72.8±9.4</td>
<td>0.2±0.8</td>
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<tr>
<td>Co-Go (mm)</td>
<td>64.2±6.8</td>
<td>66.8±7.3</td>
<td>2.7±0.6</td>
</tr>
<tr>
<td>overjet (mm)</td>
<td>8.8±5.4</td>
<td>2.7±4.0</td>
<td>-6.1±1.8</td>
</tr>
<tr>
<td>overbite (mm)</td>
<td>4.6±3.5</td>
<td>0.7±0.6</td>
<td>-0.4±3.0</td>
</tr>
</tbody>
</table>

**MRI Findings**

Growth Group: Before commencement of treatment, the MRI signal intensity was homogenous throughout the condylar head (Figure 6c); however, after functional treatment, a slightly stronger signal intensity than that of the medullary bone was observed in the posterosuperior region of the condyle (Figure 6d). This is where a double contour was observed in panoramic radiographs (Figure 6b). Although the condyles of growth subjects (patients B and C) did not show a double contour on the panoramic radiograph (Figure 7a), an area of increased MRI signal intensity was observed in the posterosuperior region of the condyle (Figure 7b).

Mature Group: In the mature group, the intensity of MRI was homogenous throughout the condylar head as in the growth group before functional treatment (Figure 8c). After functional treatment, the posterosuperior region of the condyle showed high intensity similar to that of the medullary bone (Figure 8d). This high intensity area was divided from the normal medullary bone by a low intensity band. The high intensity area corresponded to the double contour seen on panoramic radiographs.

**Discussion**

**Cephalometric Analysis**

Using the B-I measurement and superimposition of lateral cephalograms, we found that the mandible was displaced downward and forward due to the increase of ramus and body lengths in both growth and mature patients. It is hard to define the point condyion on cephalogram, and the condylar long axis does not coincide with the incident x-ray direction in lateral cephalography. Therefore, further information on the condyle is needed to detect the exact amount of bone formation behind the condylar head.

**Panoramic and MRI Findings**

There are some histological differences in the condyle between the growth and mature patients. In the condyle during growth, cartilage is found immediately above the medullary bone, and cartilaginous ossification is progressive. Cartilage first increases, then it is resorbed by chondroclasts derived from the medullary bone. Osteoblasts forming new bone are found on the medullary bone side. Therefore, cartilage serves as a guidance path to increase medullary bone, and then is replaced by medullary bone. In the condyle of the mature subjects, cartilage is separated from medullary bone by cortical bone and no marked cell division is noted. Hence, it could be predicted that condylar adaptation in mature patients would differ from that of growth patients. In fact, McNamara, et al. reported that an increase the cartilaginous layer was observed above the cortical bone in juvenile and young adult rhesus monkeys during mandibular advancement. McNamara, et al. found that in young adult rhesus monkeys, chondrocytic proliferation is accompanied to varying degrees by a highly involved in cartilage-bone interface, with evidence of incorporation...
of calcified cartilage into newly formed bony spicules. This suggests that new bone is formed under cartilage and above the cortical bone in the mature condyle. Ruf, et al. hypothesized that the high MRI signal intensity area in the posterosuperior region of the condyle indicates an increase of the cartilagenous layer, because it corresponded in his patients to the time of changes in the prechondroblastic or chondroblastic cartilagenous layer in which water content increased.

In the current study, we considered the high MRI signal intensity area found after treatment representative of newly generated bone both in the growth and the mature patients. This conclusion is based on the fact that the high intensity signal area observed in the condylar posterosuperior region was as bright as that found for medullary bone, and also because the area could be detected by panoramic radiography as like newly generated medullary bone similar to that formed after an increase in cartilage in the young adult rhesus monkeys studied by McNamara, et al.

In MRIs of the growth group, the high intensity area observed in the posterosuperior region of the condyle following treatment seemed also to correspond to the double contour found in panoramic radiographs, but the findings were not marked. It is possible that bone induction in the existing medullary bone, which progressed with growth before treatment, was enhanced by the treatment. Hence, panoramic radiographs were less able to detect the double contour, while MRI did detect the induced new bone.

In MR images of the mature patients' condyles, the high intensity area was observed in conjunction with a low intensity area of cortical bone. No increased signal
intensity was found continuous to medullary bone. In the panoramic radiographs, area with radiodensity apparently equal to that of medullary bone was found adjacent to cortical bone. This suggested that cartilage on the cortical bone, whose activity was low but not lost, might have been reactivated to form new medullary bone.

Voudouris, et al. hypothesized that the viscoelastic tissue connecting the condyle and glenoidal fossa act to draw the condyle in a posterosuperior direction during advancement of the mandible, resulting in developmental adaptation of the condyle. Since viscoelastic tissue is also present in the adult condyle, the effect is also possible in adults. The changes observed in the present study were also in the posterosuperior region which could suggest that remodeling by viscoelastic tissue was induced. However, as Ruf et al. stated, interpretation based solely on images is still speculative.

Clinical Consideration

It has been difficult to indicate the effect of this appliance clinically; however, MRI findings show that condylar remodeling was activated by the placement of an appliance. It is probable that the condylar growth is stimulated by the activator. The appliance in this study was used orthodontically to correct mandibular retrusion in growth and mature patients by advancement of the mandible. It is suggested that this appliance facilitated condylar reconstruction by forming new bone in the condylar posterosuperior region. In patients with temporomandibular disorders, a repositioning appliance for the mandible is frequently used. In those patients a newly replaced mandibular position can be held following mandibular repositioning treatment. As this treatment effect was observed during a relatively short period, an investigation of the long-term effects of the activator is suggested.

References

Figure 8
Panoramic radiographic and MRI findings after functional treatment in mature patient G.

a and c: Before functional treatment. In the panoramic radiograph, the condyle is surrounded by cortical bone. The intensity of the MRI signal is homogenous throughout the condylar head as in growth patients. b and d: After functional treatment, a double contour is clearly seen. This is clearly separated from the main portion of the condylar head by a dense and thick cortical layer (white arrow). A calcified area above the cortical layer of the condyle had similar radiodensity to that of medullary bone. The posterosuperior area of the condyle showed high MRI signal intensity similar to that of medullary bone. The area was separated from the main body of the condylar head by a low intensity band (black arrow).

9. Paulsen HU, Karle A, Bakke M, Herskind A: CT-scanning and radiographic analysis of temporomandibular joints and cephalometric analysis in a case...


