Kinesiographic and sonographic changes in young Class II patients treated with functional appliances

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Introduction: The aim of this prospective, longitudinal, case-series study was to analyze the effect of orthodontic treatment by means of an activator appliance on the temporomandibular joint disc-condyle complex. Methods: The sample included 27 consecutively treated subjects with Class II Division 1 malocclusions (21 boys, 6 girls) who underwent orthodontic therapy with activators. The average pretreatment age was 11 years 2 months. Before treatment, all subjects were free of signs and clinical symptoms of temporomandibular joint disorders. The average treatment time with the activator appliance was 366 days; then all patients had Class I dental relationships. Kinesiographic and sonographic records before and after orthodontic treatment with the activator appliance were used to evaluate the disc-condyle complex. Univariate statistics were used in these outcome measurements to evaluate differences before and after treatment. Results: After treatment, the maximum opening increased significantly (4.81 mm), but the lateral and protrusive excursions did not change. The sonographic study showed no differences in temporomandibular joint sounds before and after treatment. Conclusions: These results suggest that orthodontic treatment with an activator in a child without signs and clinical symptoms of temporomandibular joint disorders before treatment is not a risk factor for the development of temporomandibular pathology or mandibular dysfunction. (Am J Orthod Dentofacial Orthop 2007;131:196-201)

The possible iatrogenic effect of orthodontic treatment on the temporomandibular joint (TMJ) has received increasing attention since the late 1980s. Although some studies suggest that orthodontic treatment might induce TMJ disorders,1-3 others claim that it can actually prevent them or have no effect on the development of temporomandibular dysfunction (TMD). 4-6 The prevalence of signs and symptoms of mandibular dysfunction in patients treated with either functional or fixed appliances was found to be similar to untreated subjects.7,9

In extensive reviews of the literature, various authors found no differences in regard to the risk of developing TMD when different types of orthodontic mechanics are compared.10,11 However, these conclusions are not supported by data from longitudinal studies in which mandibular dysfunction was assessed after various orthodontic therapies.12 Similarly, there are few studies on the possible influence of functional appliances, such as the activator, on the TMJ.

Keeling et al13 showed that the use of bionators did not increase the development of TMD signs immediately after early Class II treatment. However, other studies with the Herbst appliance showed that continuous mechanical jumping can lead to elongation of the inferior stratum of the posterior attachment14 and thus to disc displacement.15,16 Similarly, treatment with an activator has been associated with radiographic findings in the mandibular condyles.3 These functional appliances, therefore, might cause a condyle-disc discoordination and promote TMD. The most frequent symptom associated with TMD is pain, and patients with these disorders often have limited or asymmetric mandibular movements and TMJ sounds. Among the diagnostic tests used to evaluate TMJ function, a computerized sonographic record of TMJ sounds is the easiest and quickest noninvasive way to objectively document its intracapsular status.17 Ultrasonography is widely used in the diagnosis of TMD,18 because disc displacements produce sounds that are associated with higher-frequency oscillations that can be registered. Clicking sounds are caused when the condyle hits the meniscus and temporal components of the skull after having rapidly passed the posterior band of the meniscus.19 However, it has not been critically studied for disc

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displacement yet. Kinesiographic records have been widely used for the assessment of mandibular movements. This diagnostic technique uses the movement of the mandibular incisor to assess the full range of mandibular movements without interfering with its physiologic functions and ease of access.

The purpose of this study was to investigate the effect of orthodontic therapy with activator on the mandibular condyle-disc relationships by means of sonography and kinesiography in a consecutive series of preadolescent patients.

**SUBJECTS AND METHODS**

A total of 29 consecutive patients with Angle Class II Division I malocclusions received orthodontic treatment with activator appliances from the Faculty of Odontontology at the graduate orthodontic clinic of Complutense University in Madrid, Spain. The average pretreatment age was 11 years 2 months, and the mean treatment time was 366 days.

Children were selected for this study if they met the following criteria: bilateral Class II molar relationship of at least ½ cusp, no unilateral posterior crossbite, and hand-wrist radiographic stage before the peak of the pubertal growth spurt. Subjects were excluded if they had TMJ noises at clinical examination (open-close), capsular or muscle pain on palpation, trauma in the dentofacial region, systemic joint diseases, or previous orthodontic treatment, or were taking systemic medications such as steroids. Before the study, each subject received a full explanation on its purpose and design, and agreed to participate by signing an informed consent.

Routine orthodontic records were taken: medical and dental histories, clinical examination, dental impressions, centric occlusion bite registration, dental casts mounted in an articulator, intraoral and extraoral photographs, lateral cephalometric, and panoramic and hand-wrist radiographs.

The anamnesis focused on the patient’s referral for TMJ sounds and TMJ or masticatory muscle pain, history of headaches, biting and chewing difficulties, and alterations of jaw movements. In addition to the usual orthodontic examination, a thorough clinical assessment of the TMJ was made. TMJ sounds were assessed by placing the index fingers over the joint and having the patient open and close several times. TMJ capsular pain was assessed by passively loading the joint. The masticatory muscles were palpated for the development of symptoms as described by Bumann and Lotzmann.

The Teuscher activator with extraoral high-pull headgear was used. To obtain the bite registration, the patients were asked to protrude their mandibles as far as possible, and, from this position, 4 mm were subtracted. Then the construction bite was registered. We standardized the construction bite for all patients using the George gauge (Great Lakes Orthodontics, Tonawanda, NY). This tool automates the bite registration for functional orthodontic appliances simply and accurately. We did not take the construction bite in an edge-to-edge position because that supposes a different advancement of the mandible for each patient, depending on overjet.

At the beginning of the treatment, each subject was instructed to wear the activator at least 14 hours daily. To assess the degree of compliance, we asked the patients to register their daily wearing times on special form.

Mandibular movements were recorded by using a kinesiographic computer system (K6, Myo-tronics, Seattle, Wash). This system uses a sensor array strapped to the patient’s head that tracks the spatial location of a magnet mounted on the mandibular incisors with a medical adhesive (Urihesive, Bristol Myers Squibb, New York, NY). The position of the magnet is set at zero in centric occlusion. The sensing devices are placed parallel to the Frankfort horizontal plane and at a right angle to the midsagittal and frontal planes, which serve as reference planes for all movements. The patient sits erect with adequate lumbar support and should be free of any ferromagnetic material. For the placement of the sensors, the alignment and calibration of the instruments, and the recording protocols, we followed the manufacturer’s instructions.

Mandibular movements were recorded during maximum excursions (opening-closing, protrusion, right and left lateral) before and after orthodontic treatment. To obtain a reading for maximum excursions, each patient was asked to open as wide as possible and close back to centric occlusion. Then he or she was asked to slide the jaw forward as far as possible and back to centric occlusion, and then to both sides. Simultaneous sagittal and frontal traces of the trajectory of these movements were recorded.

A computerized sound recording system with balanced transducers (ESG, Myo-tronics) was used to detect bilateral TMJ sounds. The amplitude, frequency, duration, and vertical position of the sound event was recorded. The patient was seated comfortably while viewing a metronome on the computer monitor. The speed of the metronome was adjusted according to the maximum opening capacity of each patient. At least 4 open/close cycles were recorded for each patient. Because of the patients’ inability to consistently reproduce identical sounds at each recording, we consid-
erred that a click was present when it was in at least in 3 sonographic records. The characteristics of the sound were a high-amplitude single sound of short duration (hard click) and a frequency distribution in the power spectrum generally up to 200 Hz with a single energy peak of less than 100 Hz. Many patients have sounds at near maximum opening because the condyle can subluxate over the articular eminence. Also, the “occlusal sound” might appear when the patient has reached the top of the closing cycle. These noises were not considered clicks, although they have similar sound characteristics.

Joint sounds produced on 1 side could be transmitted through the mandible and cranium, giving the impression of bilateral sounds. To solve this problem, we evaluated only the side with the greatest amplitude. The clicks were classified as 1 for presence and 0 for absence.

Statistical analysis

The normal distribution of the data was assessed by using the Shapiro-Wilk and Kolmogorov-Smirnov tests.

For the kinesiographic measurements, the means and 95% confidence intervals (CI) were calculated to indicate general tendencies. To analyze differences before and after treatment, the Student t test for paired samples was applied. In a similar manner, the McNemar test was used to assess the sonographic changes after orthodontic treatment. The level of significance was set at $P < .05$. For the assessment of whether activator treatment was a risk factor for TMD, 2 × 2 contingency tables were used to evaluate the presence or absence of clicks before and after treatment, and the relative risks, with the 95% CI, were estimated.

RESULTS

The final sample consisted of 27 patients from the 29 that started the study. Two subjects left the study because they were not willing to wear the appliances. In

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Mean</th>
<th>95% CI</th>
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<th>95% CI</th>
<th>Difference Mean</th>
<th>95% CI</th>
<th>Student t test P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum opening</td>
<td>35.37</td>
<td>33.46</td>
<td>37.27</td>
<td>39.86</td>
<td>4.81</td>
<td>3.09</td>
<td>.000 S</td>
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<td>2.91</td>
<td>0.53</td>
<td>0.87</td>
<td>1.49</td>
<td>.259 NS</td>
</tr>
<tr>
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<td>8.82</td>
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<td>.111 NS</td>
</tr>
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<tr>
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<td>9.14</td>
<td>0.54</td>
<td>10.08</td>
<td>.225 NS</td>
</tr>
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S, Significant; NS, not significant.

<table>
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<td>12</td>
<td>5</td>
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2 subjects, the sonographic data could not be recorded successfully because of poor patient compliance; thus, the evaluation of this outcome variable was limited to 25 patients (19 boys, 6 girls). The average length of orthodontic treatment was 366 days (range, 241-637 days). The end of treatment was considered when a Class I occlusion was attained.

No patients had face or jaw trauma during the observation period.

Kinesiographic results

All kinesiographic data had normal distributions according to the Shapiro-Wilk and Kolmogorov-Smirnov tests.

Table I shows the outcome variables considered in the analysis of mandibular movements before and after activator treatment.

After treatment, the maximum opening increased significantly (4.81 mm; CI, 3.09-6.54). The lateral and protrusive excursions did not change after treatment.

In regard to a mandibular shift during opening and closing, the mean value decreased after treatment; however, the values were heterogeneous, as shown by the CI (–0.47 to 2.91 and –0.87 to 1.94).

Sonographic results

Table II is a 2 × 2 contingency table of the pooled data on clicks before and after treatment. Fifteen patients did not have TMJ sounds before treatment, but 3 had sounds after orthodontic therapy. Five patients had clicks before and also after treatment. Before treatment, only 2 patients had reciprocal clicking in the

Table I. Means and CIs of kinesiographic data (mm) of mandibular movements before and after treatment

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Table II. Total clicks before and after treatment

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<tbody>
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right joint, and, in 1 of them, the click disappeared after activator treatment. One patient had reciprocal clicking in the left joint after treatment. The relative risk was 1.89 with a 95% CI from 0.73 to 4.84, indicating no significant association.

We analyzed the changes before and after treatment according to the right and left sides and the opening and closing movements (Table III). We found more clicks in the left joints after treatment than in the right joints. The relative risk could not be estimated for either the right or left joints during opening movements because there were no subjects in some cells of the 2 × 2 tables. The relative risk was 1.02 (95% CI from 0.55 to 1.88) for the right joint during closing and 0.91 (95% CI from 0.61 to 1.34) for the left joint during the same movement, showing no significant association.

When we performed statistical tests (McNemar test) to assess whether these changes were statistically significant, we found no difference for either the pooled or segmented data.

**DISCUSSION**

We measured the mandibular movements with a kinesiograph that used the mandibular incisors as the reference point. Other authors studied the accuracy of this method and concluded that the linearity and quantitative accuracy ranged from an error of 0 to 0.1 mm at intercuspation.24,25

The ability to open the mouth and move the mandible in any direction of the space has been correlated in several studies with the subject’s age and body height26 and might be reduced by craniofacial disorders.27 In this study, the mandibular movements were within the physiologic range,28 and our results showed that the opening capacity significantly increased after treatment. Vanderas29 showed a significant correlation between age and mandibular movements. Therefore, our patients’ increases could be explained by their increases in age. Maximum mandibular protrusion did not change with activator treatment; however, lateral mandibular movements were slightly reduced. These changes could be due to the development of a more vertical movement pattern in the activator patients, because functional appliances allow vertical movements but not lateral movements of the mandible.

We found great variability in the sonographic records both within the same subject and between subjects; however, we defined a click only when the noise was present 3 times in different recordings. These findings agree with those of Wabeke et al,30 who found that, in an interval of half an hour, the reproducibility decreased substantially. The poor reproducibility of recording joint sounds could be explained by the variability of the phenomenon itself and by variability in the jaw trajectories of the same patient.31 However, other authors reported high reproducibility in consecutive joint sound measurements.32

Few authors of longitudinal studies studied the influence of functional appliances such as the activator on the TMJ.13 Investigations with the Herbst appliance14,33 and the activator34 reported that continuous mechanical jumping results in temporary subclinical capsulitis of the inferior stratum of the posterior attachment because of its permanent expansion as a consequence of the jumped mandibular position. Chronic loading of the inferior stratum of the posterior attachment that stabilizes the disc might lead to permanent elongation and thus cause instability.35 This instability could be the first step in the discoordination of the condyle and the disc, and the beginning of partial anterior displacement. Therefore, functional appliances might in theory produce internal derangements and clicks.

Ren et al36 suggested that the evaluation criteria for a normal TMJ should not only be based on the absence of clinical signs and symptoms, but should also include the visualization of a normal disc position by magnetic resonance imaging (MRI) because disc displacement can occur in asymptomatic persons.37,38 For that reason, silent joints in the clinical examination, as in our patients before therapy, do not necessarily mean healthy joints. Some signs are difficult to detect even with MRI: anteromedial or anterolateral disc displacement can be viewed as a form of slight or moderate disc displacement.39 These forms of rotational disc displacement are the most prevalent forms of displacement in children and are associated with clicks during

<table>
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<th>Final sound in TMJ</th>
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<td></td>
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<td>Right side, closing</td>
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<td>No</td>
<td>16</td>
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<td>23</td>
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<td>2</td>
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<td>Left side, closing</td>
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<td>14</td>
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Therefore, we decided to study potential internal derangements, analyzing clicks with sonographic records before and after activator treatment instead of using MRI. Our data showed that, in preadolescent patients without clinically detected TMJ sounds and without muscle or TMJ capsular pain, there is no immediate risk of developing TMD after activator treatment. Pancherz and Anehus-Pancherz obtained similar results using the Herbst appliance. In that study, the TMJ sounds (clicking) disappeared, and no sounds were noticed in the posttreatment clinical evaluation. The same results were found by other authors in subjects with pretreatment physiologic disc positions.

In our study, there were patients with a single click or with reciprocal clicking, although an inclusion criterion was the absence of TMD symptoms. The reason is that these subclinical symptoms were not detected during the initial clinical examination because a disc that is partially displaced anteriorly has a softer click than a disc displacement with reduction. We observed 12 patients without noises before and after treatment, 5 patients with clicks both before and after treatment, 5 patients with clicks before treatment that disappeared after treatment, and 3 patients with the opposite condition. The 5 patients with clicks before treatment that disappeared after the use of the activator did not progress to disc displacement without reduction status because they did not develop deviations to the affected side during opening movement of the mandible. It could even happen that, in some patients with clicks before the treatment, the activator acts as a disc-repositioning appliance. According to the disc-repositioning theory, the condyle is forced forward and downward in the glenoid fossa so that it might recapture the disc. The functional appliance would achieve a similar function as a disc-repositioning appliance because it allows the condyle to come forward and downward. When the disc is recaptured and returns to an appropriate position, the sound is eliminated. An orthodontic approach in the treatment of clicking in children or adolescents could be forward repositioning of the mandible and at the same time increasing the vertical dimension that could help to recapture the disc. The clicking could recur later if the mandible returns to its original position. Therefore, for the stability of the recaptured disc, a stable occlusion should be provided by fixed orthodontic treatment.

Our results also indicate that in some patients the click persisted after treatment with the activator. In other studies, after placement of the disc-repositioning splint, the disc recapture was evaluated with MRI scans and classified as complete capture, partial capture, or no capture. A small percentage of patients still had clicking after treatment. In those patients, the click could be due to partial anterior displacement of the disc in the medial part of the joint. Westesson and Lundh suggested that medial displacement of the disc is more difficult to treat. Unfortunately, we have no critical information about the type of disc displacement in our investigation, but it could be a reason that the clicking did not disappear or was present after treatment in some patients. However, according to other studies, there was no evidence of disc recapture in any children with disc displacement after treatment with the activator and Twin-block appliances.

**CONCLUSIONS**

After orthodontic treatment of Class II malocclusion with the activator appliance, mandibular movements were not affected. The increase in the range of some mandibular movements was associated with the patients’ growth during the treatment period. We observed no significant change in TMJ function regarding clicking. We concluded that activator treatment in children with no signs and clinical symptoms of TMD before treatment is not a risk factor for TMJ noises or mandibular dysfunction.

**REFERENCES**


