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The Effect of Mandibular Protrusive (Activator) Appliances on Articular Eminence Morphology

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ABSTRACT

In studying the response of the glenoid fossa to mandibular protrusive appliances, apart from the condyle, much attention has been focused on what happens to the posterior wall of the fossa (postglenoid process). Remarkably, the articular eminence has been overlooked, although it is the most adaptive area of the temporomandibular joint. The purpose of this study was to explore the type of response of the articular eminence morphology to the use of mandibular propulsive appliances (activators). The study material consisted of individually corrected pre- and posttreatment lateral tomograms of 35 patients (18 boys and 17 girls) who had been diagnosed as suitable for treatment with a mandibular protrusive appliance (activator). The tomograms were scanned and digitized on screen, and points located on each tomogram and linear measurements were used to evaluate any change in glenoid fossa morphology. Paired *t*-tests were applied separately for the left and right sides to compare pre- and posttreatment measurements. Paired *t*-tests were also applied to test any difference between the left and right sides. The results of this study show that there is no statistically significant change in articular eminence morphology (height and inclination) as a result of using mandibular protrusive appliances.

KEY WORDS: Functional appliances, Articular eminence morphology.

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INTRODUCTION Return to TOC

The common denominator of all so-called mandibular protrusive (functional) appliances is the forward and downward movement of the mandible to a position determined during bite registration. Depending on the type of appliance used, the mandible is kept in this protruded position part of the time, usually for 12–14 h/d, or full time and stays and functions in this new position as long as the appliance remains in the mouth.

With the appliance held in position in the mouth, the mandibular incisors are repositioned forward and downward as are the condyles. The path followed by the condyles is dictated by the articular eminence inclination and is reflected in the amount of molar and incisor separation. The steeper the articular eminence, the more vertical the separation of the molars and incisors.

Experience with corrected lateral tomograms shows that, to obtain an edge-to-edge incisor relationship with a vertical opening of three mm, in most cases a forward mandibular displacement brings the condyles to the top of the articular eminences, provided both the maxillary and mandibular incisors have normal axial inclination.

The articular eminence in humans is developed almost exclusively postnatally.[1–5] Therefore, it not only follows the facial growth plan, but also presents adaptive capabilities.[3] It has been reported that these alterations are greatly influenced by the dental function.[6]

When a mandibular protrusive appliance is inserted into the mouth, it displaces the mandible forward and downward into a position determined during bite registration. As long as the appliance is in the mouth, the condyles are displaced and kept over the top of the articular eminence. In this position, homeostatic temporomandibular joint mechanisms could be triggered and, because the articular eminence is susceptible to adaptations, one could hypothesize that morphological change would be induced by mandibular protrusive appliances.

The literature regarding articular eminence adaptations induced by mandibular protrusive appliances is scanty. To the best of our knowledge, these include the works of Birkedaek et al[7] and Dahan et al.[8] Regarding articular eminence, Birkedaek et al[7] reported a slight forward displacement without any change in its inclination. On the other hand, Dahan et al[8] found a forward and downward displacement of the articular eminence along with a reduction in its height.

The change in articular eminence morphology during treatment with functional appliances is very important because, if it really is displaced downward and forward, then the condyles and thus the mandible will also be displaced in the same direction, contributing to the Class II correction.

The purpose of this study was (1) to report on articular eminence morphology, regarding skeletal Class II cases and (2) to explore possible articular eminence morphology changes as a result of treatment with mandibular protrusive appliances.

MATERIALS AND METHODS Return to TOC

The material of this study consisted of corrected lateral tomograms of both joints from 35 patients, of whom 17 were girls and 18 boys (Figure 1). These children were diagnosed as suitable for treatment and were treated with a mandibular protrusive appliance (activator) until a Class I molar relationship was established. The tomograms were taken on a pretreatment and posttreatment basis. At the beginning of the study, the age for the whole group ranged from 7.96 years to 15.06 years.

The bite registrations were taken by bringing the incisors edge to edge, with a vertical opening of three mm, regardless of the initial overbite and overjet. Before starting activator treatment, the possibility of free mandibular protrusion was checked and, in cases where this was not achieved, the necessary corrections were made before the application of the protrusive appliance. These corrections included maxillary expansion, incisor leveling, and normalizing maxillary or mandibular incisor axial inclination. The duration of activator treatment ranged from 0.72 years to 2 years (mean 1.33).

Before exposing the tomograms, a submentovertex radiograph was taken to adjust orientation of the condylar heads with respect to the midsagittal plane and to calculate the depth of the cut of each tomogram. For this investigation, all tomograms were taken at the middle of the condyle with the teeth in maximum intercuspation. The cuts were 2.5 mm thick. The tomograms were digitized on screen using a commercial software program (Viewbox 3, Halazonetes, Athens, Greece), and the following points were located (Figure 2):

1. Fr—fossa roof (the highest point of the fossa);
2. Ae25, Ae50, and Ae75—these three points were digitized on the articular eminence curvature so as to divide the Fr-Ae curvature into four equal parts;
3. Ae—articular eminence height (the lowest point of articular eminence);
4. Po—porion (the highest point of auditory meatus);
5. Pt—the highest point of the pterygomaxillary fissure;
6. Ptm—the lowest point of the pterygomaxillary fissure;
7. Or—orbitale (an arbitrary point to the right of the pterygomaxillary fissure);
8. U6—upper molar mesial cusp;
9. U5—upper first premolar buccal cusp;
10. L6—lower molar mesial cusp;
11. L5—lower first premolar buccal cusp.

Using these points, the following planes were established (Figure 3):

1. Pt-Ptm—the long axis of the pterygomaxillary fissure;
2. FH plane—this plane was established as follows. From the corresponding cephalograms the angle FH and the pterygomaxillary fissure axis were recorded. In the tomograms the orbitale was displaced through the digitizing program until the FH-long axis of the pterygomaxillary fissure (Pt-Ptm) angle came to be the same as the one recorded from the cephalograms. In this way the real orientation of the FH plane was secured;
3. Occlusal plane—the occlusal plane was constructed through the program as the best-fit line to the digitized points (U6, U5, L6, and L5) on the maxillary and mandibular teeth;
4. Fr-Et plane;
5. The best-fitting plane of the articular eminence inclination, being constructed through the digitizing program as the best-fitting line connecting the E25, E50, and E75 points.

Articular eminence morphology was evaluated by studying its inclination and height (Figure 4). The inclination was recorded with reference to the FH and the occlusal planes and the height as the distance between Fr and Et (fossa roof–articular eminence height), also with reference to the FH plane. No gender differentiation was made.

It is unfortunate that we lacked corresponding data for untreated patients. We overcame this by using reciprocal data from dried skulls.[4,5]

Error study

For the error study, 14 pretreatment tomograms (seven left and seven right, not necessarily belonging to the same person) and their corresponding posttreatment counterparts were evaluated. Thus, a total of 28 tomograms were selected, and the entire procedure was reapplied. The initial measurements (set I) and the repeated measurements (set II) of these 28 tomograms were compared by using a paired *t*-test to check any systematic error. Random errors were checked using the Dahlberg formula. The *t*-test at the .05 level did not show any significance. The random error for the measurements varied between 0.43 and 0.52.

Statistics

Descriptive statistics for all variables used are presented in Table 1. After checking normality, paired *t*-tests were applied between pretreatment and posttreatment measurements, separately for the left and right sides (Table 2). The sample was used as a whole and not differentiated by sex. A paired *t*-test was also applied for pretreatment as well as posttreatment left and right sides to test for any asymmetrical responses (Table 2).

RESULTS Return to TOC

The common characteristic of all measurements was the great variability (Table 1).

Articular eminence morphology

The mean height of the articular eminence at the beginning of the study was recorded as 7.14 mm (life size 6.35 mm) for the left side and 7.15 mm (life size 6.36 mm) for the right side. The inclination of the articular eminence measured as the angle of Fr-Et and the FH plane was 29.98° for the left side and 29.37° for the right side. The same angle, referenced to the occlusal plane, was 29.04° and 26.74° for the left and right sides, respectively.

When the inclination was measured as the best-fitting line, in reference to the FH plane, it was 47.01° for the left side and 48.34° for the right side, whereas in reference to the occlusal plane it was 46.07° and 45.18° for the left and right sides, respectively.

Eminence height changes

During the treatment with mandibular protrusive appliances, both sides of the articular eminence remained unchanged because the recorded difference was negligible (0.01–0.11 mm). These values correspond well with findings from dried skulls,[5] where the articular eminence height increased from five mm to seven mm between the ages of seven years and 15 years. A total increase of two mm over seven years gives a mean growth rate of about 0.28 mm/y.

Eminence inclination changes

Fossa roof–articular eminence top. When the articular eminence inclination was measured as the Fr-Ae (fossa roof–articular eminence top) line, there was a trend toward a decrease that was not statistically significant. This decrease was 0.9° and 0.8° for the left and right sides in reference to the FH plane and 2.05° and 1.71°, in reference to the occlusal plane, respectively. The dried skull study[4] showed an 8° decrease between the ages of seven years and 15 years, ie, 1°/y.

Best-fit line. When the articular eminence was measured as the best-fitting line, regardless of the plane of reference (FH or occlusal), there was a trend toward a decrease, which was not statistically significant. This reduction was 2.79° and 2.86° for the left and right sides in reference to the FH plane and 2.22° and 3.78° with reference to the occlusal plane, respectively. In the dried skull study, there was a 10° reduction between the ages of 7 and 15 years, ie, 1.25°/y.[4]

DISCUSSION Return to TOC

The inclination of the articular eminence dictates the path of condylar movement as well as the degree of rotation of the disk over the condyle. The steeper the articular eminence, the further the condyle is forced to move inferiorly as it shifts anteriorly. This results in greater vertical movement of the condyle, mandible, and mandibular arch upon opening.[9] It has been reported that during opening, the posterior disk rotation is more prominent in joints with a steep articular eminence than in joints with a less steep eminence.[10,11] During treatment of skeletal Class II deficiencies with mandibular protrusive appliances, the condyles shift anteriorly and inferiorly and, depending on the bite registration, they may reach the top of the articular eminence.

According to our concept for treating skeletal Class II anomalies, and on the basis of the premise that not all Class II cases are suitable to be treated with mandibular protrusive appliances, correct mandibular and maxillary axial incisor inclination should always be secured before embarking on mandibular protrusive appliance therapy to free mandibular protrusion. A bite registration with the incisors brought to edge-to-edge relationship and a three-mm vertical separation brings, almost always, the condyles to the top of the eminence (Figure 5). This statement is based on observations of corrected lateral tomograms when the bite registration was taken using the above method.

In this position, the condyles are separated from the top of the articular eminences with the middle zone of the disk and the superior and inferior retrodiscal laminae in tension. A popular view states that once the mandible is displaced as a result of using the mandibular protrusive appliance, isometric contractions are triggered, and these forces are responsible for whatever results may occur. According to Hinton,[5] a condyle positioned at the top of the articular eminence will cause an increase in articular eminence inclination and height. Hinton's assumption is valid, when incisor biting is taking place. With mandibular protrusive appliances, while the condyle is displaced toward the top of the eminence, it is not certain that forces will also develop. As a matter of fact, the recorded degree of horizontal forces applied to the maxilla during treatment with an activator shows that the magnitude is about 100 g, which, according to current concepts, is not suitable for an orthopedic effect.[12,13]

The results of our study show that neither the height nor the inclination of the articular eminence was changed by the treatment with mandibular protrusive appliances. Nevertheless, it should be reported that there was a trend toward reduction, especially of the inclination, denoting a decrease of steepness. This trend is the same regardless of the reference plane used.

The fact that we lack data from untreated subjects for comparison forced us to use reciprocal data from dried skull studies.[4,5] The growth rate of articular eminence height in skulls[5] was 0.17 mm/y. Considering that the mean treatment time with mandibular protrusive appliances was 1.33 years, it follows that the change expected in skulls comes to 0.22 mm, which is almost threefold the values found in this study.

With regard to the articular eminence inclination (best fit), the remarkable difference between skulls and this study is that in skulls there was an increase, whereas in this study there was a decrease. For the skulls, the annual increase was 1.25°/y, which, equalized to the period of this study, comes to 1.6°. In our study, the decrease (mean value of the left and right sides) comes to 2.8°.

It is obvious that the results of this study point to a possible effect of functional appliances on articular eminence characteristics. It seems that they cause both height reduction and inclination decrease. In other words, they shorten and flatten the articular eminence. However, our statistical analysis does not support such a conclusion because no significant difference was found before and after treatment. It is important to note that the possibility for type II error exists because of the size of our sample.

However, even if our sample had been increased and the possibility for type II error had been eliminated, the most important feature of this study is the biological significance of our findings. This raises the question, “How does less than 3° (2.79° and 2.86° for the left and right sides, respectively) of reduction of the articular eminence inclination affect the outcome of treatment with a functional appliance?” It follows then that the treatment significance of these findings is negligible and other mechanisms of the possible effective action of functional appliances should be sought.

Animal research[14–17] and clinical studies[18,19] have documented bone deposition on the anterior surface of the postglenoid process, and investigators claim that this bone deposition contributes to the total correction of a skeletal Class II discrepancy. Unfortunately, these studies do not report on the response, if any of the articular eminence. Combining our findings with those of the references cited above and hypothesizing that both are valid, it follows that during treatment with mandibular protrusive appliances, the glenoid fossa length (anteroposterior dimension) is reduced. One could argue that the articular eminence remodels forward, keeping its inclination and height stable, and thus the fossa length remains unchanged.

However, this is not the case because it has been found that the glenoid fossa morphology is not affected by mandibular propulsive appliances.[20] It follows then that animal research findings are not applicable to humans who, furthermore, do not possess such a well-developed postglenoid process.[21]

Birkedaek et al[7] conducted a similar study, but instead of individualized condylar rotation, they used 0.12° and 44° rotation. They reported a small decrease of articular eminence height, about 0.3 mm, but the inclination remained the same. The opposite results have been reported by Dahan et al,[8] who found a decrease in articular eminence height. However, neither the cutting depth nor the angulation of radiation was individualized, and these characteristics may explain the contradictions in their findings.

It has been reported that the inclination of the articular eminence plays a significant role in the direction of condylar growth and thus in the morphogenesis of the mandible.[22] Specifically, it has been reported that a steep or flat articular eminence inclination directs condylar growth vertically or posteriorly, respectively. On the basis of our findings it can be safely deduced that because the articular eminence inclination does not change, the direction of condylar growth also does not change with the use of mandibular protrusive appliances. This is a hypothesis that remains to be tested.

On the basis of the results of this sample, and considering that there is a possibility of introducing a type II error, this study supports the concept that functional appliances cause a minor decrease of articular eminence height and inclination, which is not statistically or clinically significant.

CONCLUSIONS Return to TOC

Based on the results of this study, the following conclusions can be drawn:

1. The height of the articular eminence is not affected by the use of mandibular protrusive appliances.

2. The inclination of the articular eminence, measured either as the best-fit line or the fossa roof and the eminence top line, undergoes minor changes as a result of using mandibular propulsive appliances. These changes, however, are not statistically significant.

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TABLES Return to TOC

TABLE 1. Descriptive Statistics for All Variables Used in the Study[a]

			Left Side									
			Before					After				
a/a	Variables	n	X	SD	SEM	Min	Max	X	SD	SEM	Min	Max
1	Height of articular eminence	35	7.14	2.2	0.35	2.5	14.4	7.15	2.27	0.36	0.8	13.6
2	Best fit and FH	35	49.01	11.89	1.9	19.2	70.9	46.22	12.7	2.03	11.6	72
3	Fr-Ae and FH	35	29.37	9.01	1.44	9.1	47.1	29.28	10.09	1.61	3.01	49.8
4	Best fit and occlusal plane	35	46.07	9.5	1.52	19.6	66.1	43.85	12.19	1.95	14.2	76.6
5	Fr-Ae and occlusal plane	35	29.04	6.32	1.01	13.5	45.5	26.99	9.89	1.58	5.7	47.1

[a] X indicates mean; SD, standard deviation; SEM, standard error of mean; Min, minimum; and Max, minimum.

TABLE 1. Extended

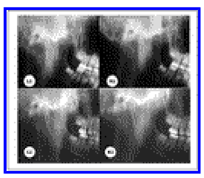
Right Side									
Before					After				
X	SD	SEM	Min	Max	X	SD	SEM	Min	Max
7.45	2.25	0.36	3.6	14.7	7.34	2.46	0.39	2.5	14
48.34	10.52	1.68	23.5	74	45.48	12.64	2.02	20.9	77.2
29.9	9.15	1.46	14	48.7	29.10	10.34	1.65	10.4	51.5
45.18	8.83	1.41	27.3	62	41.40	10.49	1.68	24.9	67.2
26.74	7.07	1.13	15.6	40.4	25.03	8.62	1.38	14.1	46.3

TABLE 2. *P* Values of Comparison of Left Side Before and After Treatment, Right Side Before and After Treatment, and Left vs Right Side Before and After Treatment[a]

a/a	Variables	Left Side (Before-After)	Test	Right Side (Before-After)	Test	Left-Right Side (Before)	Test	Left-Right Side (After)	Test
1	Height of articular eminence	.991	NS	.971	NS	.562	NS	.746	NS
2	Best fit and FH	.86	NS	.621	NS	.922	NS	.519	NS
3	Fr-Ae and FH	.165	NS	.138	NS	.602	NS	.484	NS
4	Best fit and occlusal plane	.741	NS	.621	NS	.538	NS	.267	NS
5	Fr-Ae and occlusal plane	.203	NS	.123	NS	.063	NS	.145	NS

[a] NS indicates no significance.

FIGURES Return to TOC



Click on thumbnail for full-sized image.

FIGURE 1. Corrected lateral tomograms used in this study. L1, R1 before and L2, R2 after treatment of left and right sides, respectively

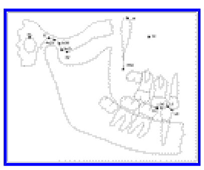


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FIGURE 2. The points used in this study

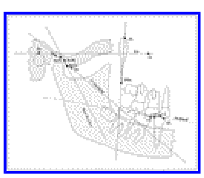

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FIGURE 3. The planes used in this study

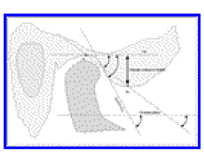

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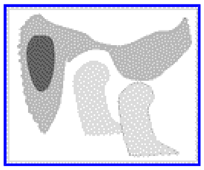
FIGURE 4. From the fossa roof (Fr) a parallel was drawn to the FH plane. The articular eminence height was measured as the distance of Ae to this plane. The articular eminence inclination was measured in two ways: as the angle of the best-fit line and as the angle of the Fr-Ae line with the FH and the occlusal planes. The angles for measuring the articular eminence inclination were the lower right angles



Click on thumbnail for full-sized image.

FIGURE 5. When upper and lower incisors have normal axial inclination, an edge-to-edge bite registration with a three-mm vertical opening brings the condyles almost always on top of the articular eminence

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