Original Article

The Treatment Effect of Mandibular Protrusive Appliances on the Glenoid Fossa for Class II Correction

Elias G. Katsavrias, DDS, MSD[a]; John C. Voudouris, DDS, MSC(D)[b]

Abstract: A study was undertaken to determine the contribution of glenoid fossa modification in the correction of skeletal Class II malocclusions. Individually corrected lateral tomograms of 35 patients (18 boys and 17 girls) between the ages of 7.96 and 15.06 years were used. The subjects were selected on the basis of the criteria that they were suitable for treatment with a mandibular protrusive appliance (activator). The mean duration of activator treatment was 1.33 years. Tomograms were taken on a pre- and posttreatment basis. The tomograms were scanned and digitized on screen using a common software program. Points were located on each tomogram and specific linear measurements were used to evaluate any changes in glenoid fossa morphology. Paired *t*-tests were applied for the left and right sides separately and between the before and after treatment measurements. Paired *t*-tests were also applied between the left and right sides to test for any difference between the sides. The results of this study demonstrated that there are no positive radiographically depictable contributions from glenoid fossa modification for the correction of skeletal Class II malocclusions treated with mandibular protrusive appliances (activators). In addition, no statistically significant differences were found between right and left sides denoting relative symmetry. It is concluded that, contrary to animal research and magnetic resonance findings, it seems possible that glenoid fossa modeling is not induced by mandibular protrusive appliances during treatment of skeletal Class II problems. (*Angle Orthod* 2004;74:79–85.)

Key Words: Mandibular protrusive appliances; Glenoid fossa reaction

INTRODUCTION

It has been reported that the correction of a skeletal Class II malocclusion with mandibular protrusive appliances (functional appliances) originates from different sources and that a great share is contributed by the glenoid fossa.[1–6] These claims are based on clinical and animal research findings.

The basic question that is raised is whether the fossa possesses an adaptive capability. Human studies on the remodeling processes in the temporomandibular joint after condylar fractures,[7] posterior loss of teeth,[8–10] occlusal equilibration,[11,12] orthognathic surgery,[13–15] and loading changes have clearly shown that the temporomandibular joint is capable of significant modeling. Although this capability is not uniform, the articular eminence appears to show the greatest adaptability of all the glenoid fossa components. This differential adaptability is also reflected in that the articular eminence presents a growth plan following that of the face, whereas the remaining components follow more or less a neural one.[16–20] It has been reported that the articular eminence attains about 50% of its adult morphology by the age of two years and the rest, although not in a linear fashion, is achieved by the age of 30.[19–21]

Animal studies, including primates and nonprimates, have been conducted in an effort to clarify the role of the glenoid fossa in treating skeletal Class II malocclusions.[22–24] The results of these studies have shown that mandibular protrusion triggers bone deposition in the posterior region of glenoid fossa. Clinical studies have used laminograms,[25,26] cephalograms,[5,27] cephalograms and tomograms,[28] and magnetic resonance imaging.[29,30]

However, the findings of these studies are contradictory and confusing. In an effort to clarify the mode of action of mandibular protrusive (functional) appliances, it is imperative to clarify the role of the glenoid fossa. The purpose of this study was to explore the effect of mandibular protrusive appliances on the glenoid fossa morphology using corrected lateral tomograms.

[a] Associate Professor, Department of Orthodontics, School of Dentistry, University of Athens, Athens, Greece.

[b] Research Scientist, Division of Biological Sciences, Department of Orthodontics, College of Dentistry, New York University, Manhattan, NY.

Corresponding author: Elias G. Katsavrias, DDS, MSD, Department of Orthodontics, School of Dentistry, University of Athens, 2 Thivon Street, Goudi, 11527 Athens, Greece
(e-mail: elkats@otenet.gr).

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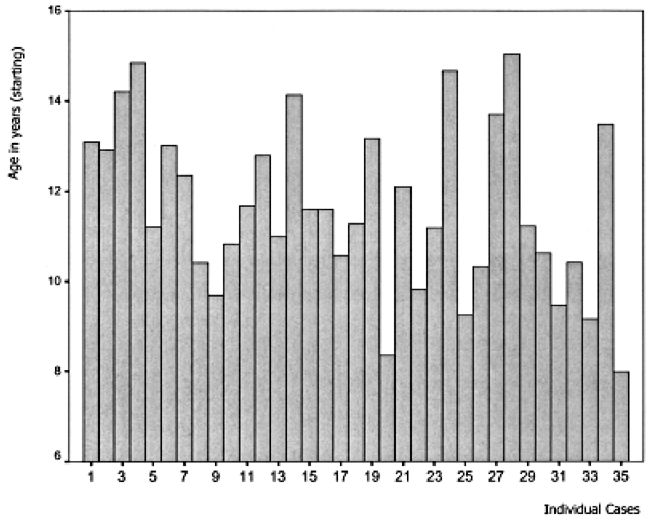

FIGURE 1. The starting age.

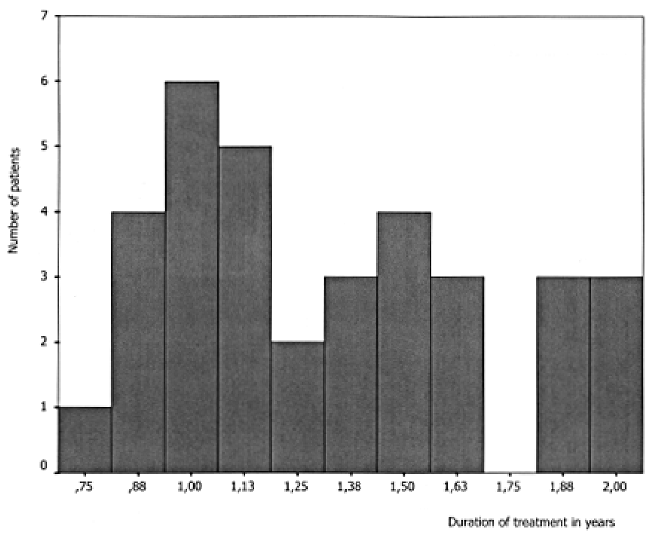

FIGURE 2. The duration of treatment with activator.

MATERIALS AND METHODS

The material of this study consisted of corrected lateral tomograms taken from both joints of 35 children of whom 18 were boys and 17 girls. These children were diagnosed as being suitable for treatment and were treated with functional appliance (activator) by one of the investigators (Dr Katsavrias). The age of the children at the start of the study ranged between 7.96 and 15.06 years with a mean of 11.63 $\pm$ 1.86 (Figure 1). The duration of treatment ranged from 0.72 years to two years (mean 1.33) and is depicted in Figure 2.

The bite registration was taken by bringing the incisors edge-to-edge with a vertical opening of three mm, regardless of the initial overbite and overjet. Before the start of activator treatment, the ability for free mandibular protrusion was evaluated, and in some patients where this was

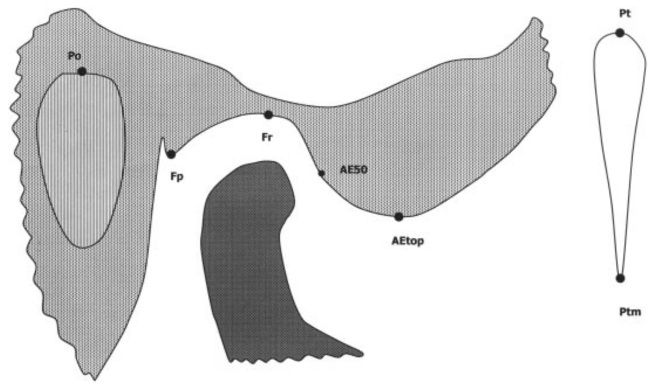

FIGURE 3. The points used in this study.

not possible, the necessary adjustments were made. These adjustments included maxillary expansion, maxillary or mandibular incisor leveling, and lower incisor uprighting. The activator used was a modification of Harvold type, and lower molars and premolars were free to erupt. The lower incisors were capped with acrylic, and no acrylic trimming was performed on the maxillary arch portion of the appliance[ed]. Patients were instructed to use the appliance for 12–14 hours per day, during sleep and for part of the daytime. A written report of the number of hours per day the appliance was used was turned in by all patients during their office visits.

The tomograms were taken on a pretreatment and posttreatment basis. Before taking the tomograms, a submentovertex projection was taken to orient the condylar heads with respect to the midsagittal plane and to calculate the depth of the cut of each tomogram. To achieve this objective, all tomograms were taken at the middle of the condyles and with the teeth in maximum intercuspation. The sections 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 3):

1. Porion, Po (uppermost point of auditory meatus).
2. Fossa posterior, Fp (the top of postglenoid process and when it was absent the most anterior point of the squamo-tympanic suture).
3. Roof of the fossa, Fr (the highest point of the fossa).
4. Articular eminence midpoint, AE50 (the middle point between roof of the fossa and the height of the articular eminence).
5. Height of the articular eminence, AEtop.
6. Pt (top of the pterygomaxillary fissure) and the Ptm (the bottom point of the pterygomaxillary fissure).

Using these points the following distances were measured. (Figure 4):

1. FossaPosterior-FossaRoof (Fp-Fr).

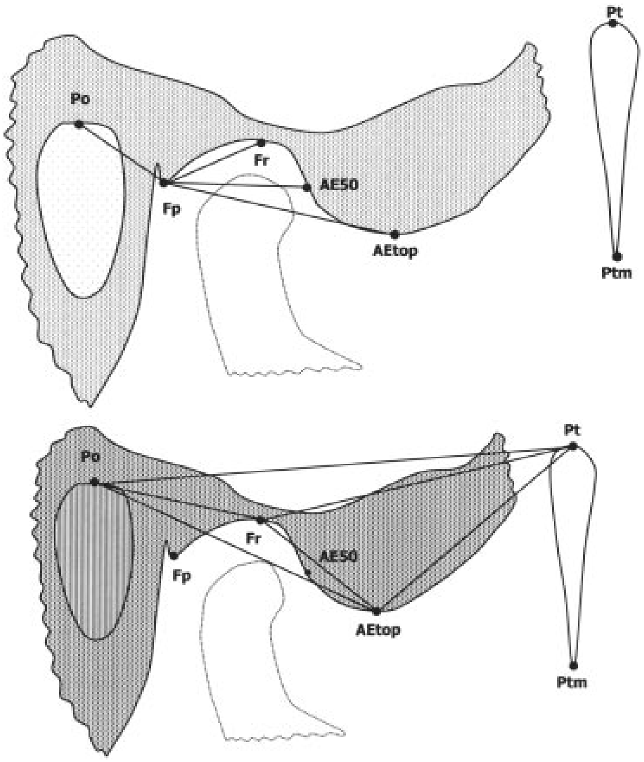

FIGURE 4. The linear measurements used in this study.

2. FossaPosterior-Articular Eminence midpoint (Fp-Em50).
3. FossaPosterior-Articular Eminence Top (Fp-AEtop).
4. FossaRoof-Articular Eminence Top (Fr-AEtop).
5. FossaRoof-Pterygomaxillary Fissure Top (Fr-Pt).
6. Articular Eminence Top-Pterygomaxillary Fissure Top (EMtop-Pt).
7. Porio-FossaRoof (Po-Fr).
8. Porio-FossaPosterior (Po-Fp).
9. Porio-Articular Eminence Top (Po-AEtop).
10. Porio-Pterygomaxillary Fissure Top (Po-Pt).

Statistics

Descriptive statistics for all variables used are presented in Table 1. Normality was tested and paired *t*-tests were applied between pre- and posttreatment measurements, separately for left and right sides to test for any statistical significance between them (Table 1). The sample was used as a whole and not differentiated by sex or age.

A paired *t*-test was also applied to the pretreatment as well as the posttreatment left and right sides to test for any asymmetrical responses (Table 2).

Error study

For the error study, 14 pretreatment randomly selected tomograms (seven left and seven right, not necessarily belonging to the same person) and their posttreatment correspondings 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 using a paired *t*-test to check for 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 0.49 and 0.58.

RESULTS

All subjects were treated to a Class I dental arch relationship and the posttreatment records were taken two to three months after the Class I molar relationship was established. All 10 linear variables used in this study did not show any statistically significant difference between initial- and after-treatment measurements (Table 1). Similarly, no statistically significant differences were recorded when the left and right measurements were compared (Table 2).

DISCUSSION

Accurate (precise and unbiased) and valid (to reflect the biological parameter planned to be studied) measurements need to be secured to assure correct scientific interpretations and conclusions. It is generally accepted that the common radiographic images used in daily orthodontic treatment (cephalometric and panoramic images) do not offer a clear view of the temporomandibular joints. This is because of several reasons including (1) the two temporomandibular joints do not have the same angulation with the sagittal plane, (2) the two condyles may not be identical with regard to shape and size, (3) the articular eminence presents anatomical differences with respect to height and inclination, (4) the condylar position into the glenoid fossa may not be identical on the left and right side, (5) there may be a difference regarding the position in the frontal plane, meaning that one joint may be positioned mildly forward in comparison with the opposite joint, and (6) there is superimposition of the right and left sides in addition to image distortion. Taking all these factors into consideration, it appears that any attempt to use cephalograms or panoramic radiographs for studying temporomandibular joint morphology will have the disadvantage of a lack of accuracy and validity.

After a review of the literature, it is frankly surprising that lateral cephalograms have been used to study changes of glenoid fossa.[5,27] Because the fossa cannot be imaged on lateral cephalograms, one report used articulare[5] and the second used articulare and condylion[26] to draw conclusions regarding glenoid fossa displacement. However, such an approach presupposes a linear relationship regarding the fossa and articulare or condylion movement, a condition that is not an actual fact. It follows that their findings suffer from incorrect interpretation and thus should be considered with great reservation.

TABLE 1. Comparison of Before and After Treatment Values, for Both Left and Right Side[a]

		Left Side							
		Before			After				
Variables	n	X	SD	SEM	X	SD	SEM	*P*	Test
FossaPosterior–EminenceMiddlePoint	35	14.29	2.1	0.36	14.59	2.27	0.39	.191	NS
Porio–FossaPosterior	35	9.14	2.92	0.5	9.55	2.6	0.44	.185	NS
FossaPosterior–EminenceTop	35	20.1	2.46	0.42	20.61	2.46	0.42	.117	NS
FossaPosterior–FossaRoof	35	11.52	2.58	0.44	11.25	2.44	0.41	.284	NS
FossaRoof–EminenceTop	35	14.57	2.11	0.36	15.15	2.25	0.38	.091	NS
FossaRoof–Pt (ptm top)	35	51.04	3.19	0.54	51.4	3.5	0.61	.419	NS
Porio–Pt (ptm top)	35	65.02	3.29	0.56	65.19	3.55	0.6	.65	NS
Porio–EminenceTop	35	26.84	2.72	0.46	27.52	2.83	0.48	.077	NS
EminenceTop–Pt (ptm top)	35	42.64	3.48	0.58	42.4	3.48	0.58	.606	NS
Porio–FossaRoof	35	14.28	1.73	0.29	14.09	2.31	0.39	.486	NS

[a] X, indicates mean; SD, standard deviation; SEM, standard error of mean; and NS, no significance.

Linear laminagraphic exposures unequivocally offer a better image compared with cephalograms, but they were taken with a standard rotation of 40° and 44°, respectively, and their analysis suffered from inappropriate planes of reference.[25,26] Both studies concluded that in untreated Class II cases, the glenoid fossa is displaced backward and downward, whereas cases treated with an activator showed a forward and downward displacement.

In this study, we used corrected lateral tomograms taken at maximum intercuspation. The sections were 2.5 mm thick and taken at the middle of the condyle. It has been claimed that lateral tomography represents a more accurate image of the osseous anatomy when compared with magnetic resonance images.[31] The magnification in all exposures is the same and so linear measurements can be used without any correction.

Our results show that glenoid fossa morphology did not change, at least not to a statistically significant level, during treatment with mandibular protrusive appliances. We lack data showing glenoid fossa changes in untreated Class II cases for comparison. However, studies on dry skulls have shown that glenoid fossa length (distance between top of postglenoid process and middle of the top of articular eminence), a parameter that is the same as the distance Fp-Aetop (Fossa posterior-articular eminence top) measured in this study, attains 95% of its adult size by age nine to 10 years.[17,32,33] This is true for glenoid fossa width as well.[16] Taking this for granted and considering that 28 patients in this study were older than 10 years (Figure 1), it is not surprising that the results did not reveal any change of glenoid fossa morphology. However, considering that all cases were successfully treated, we concluded then that the source of the adaptations for clinical Class II corrections should be located somewhere outside the fossa.

Excluding studies based on cephalograms and laminograms, there is another group of studies in which magnetic resonance images have been used.[29,30] However, this technology has been applied almost exclusively in studies evaluating the effects of the Herbst appliance. According to the results of these studies, there is bone deposition on the anterior surface of the postglenoid process, a finding that has also been reported in monkeys,[22,23] rats,[24] and sheep.[34] It is obvious that this finding cannot be confirmed by this study because the distance porion-posterior fossa did not increase. If bone deposition was taking place at the postglenoid process, we should have found an increase in this distance. One may ask what is the reason for the differences between findings of this study and those of Ruf and Pancherz.[29,30] Although a definitive answer cannot be given we can, however, share some related thoughts.

Compared with our use of activators, Ruf and Pancherz used the Herbst appliance that not only holds the mandible in a protruded position but also forces the mandible to function at the height of the eminence and on the middle zone of the articular disk on a continuous basis. It follows that for as long as the appliance is in the mouth, the temporomandibular joint functions in an abnormal state outside of the glenoid fossa. On the other hand, the activator holds the mandible passively over the height of articular eminence with the middle zone of the disk interposed between the two bony structures. Furthermore, the horizontal forces developed by the activator do not exceed the range of light orthodontic forces.[35] In addition, this occurs during a time of decreased and not increased EMG muscle activity.[36–38]

Thus, the old and previously popular view over the past 30 years, as proposed by the experiments of Charlier et al[39] and supported by McNamara,[40] that mandibular protrusive appliances (activator) induce isometric contractions of the muscles of mastication (particularly the superior head of the lateral pterygoid muscles) and that this force is responsible for the activator's effects has been refuted. The lateral pterygoid muscle hyperactivity theory at the turn of the century was largely replaced by the growth relativity concept for functional appliances.[23] Activators appear to activate non-muscular soft tissues such as the retrodiskal tissues, fibrous capsule, synovial fluid lining, and fibrocartilagenous layer

TABLE 1. Extended

Right Side							
Before			After				
X	SD	SEM	X	SD	SEM	*P*	Test
14.42	2.22	0.38	14.73	2.3	0.39	.318	NS
9.58	2.42	0.41	10.26	2.69	0.46	.057	NS
20.45	2.18	0.37	20.87	2.5	0.42	.154	NS
11.08	2.26	0.38	11.28	2.4	0.41	.598	NS
15.09	1.65	0.28	15.68	2.1	0.36	.078	NS
51.32	4.18	0.71	51.82	4.03	0.69	.248	NS
65.31	4.46	0.76	65.54	3.78	0.64	.653	NS
27.7	2.64	0.45	28.24	2.9	0.49	.099	NS
42.29	4.48	0.76	42.38	3.8	0.65	.882	NS
14.38	2.05	0.35	14.2	1.6	0.27	.594	NS

TABLE 2. Comparison of Left and Right Side Before and After Treatment

a/a	Variables	Before Treatment *P*	After Treatment *P*	Test
1	FossaPosterior–EminenceMiddle-Point	.55	.594	NS[a]
2	Porio–FossaPosterior	.297	.231	NS
3	FossaPosterior–Eminence Top	.275	.346	NS
4	FossaPosterior–FossaRoof	.337	.943	NS
5	FossaRoof–EminenceTop	.081	.159	NS
6	FossaRoof–Pt (ptm top)	.533	.515	NS
7	Porio–Pt (ptm top)	.551	.353	NS
8	Porio–EminenceTop	.116	.336	NS
9	EminenceTop–Pt (ptm top)	.606	.882	NS
10	Porio–FossaRoof	.594	.594	NS

[a] NS indicates no significance.

covering the fossa but not the neuromusculature. Consequently, in this downward and forward mandibular position, the superior as well the inferior retrodiscal tissue laminae are stretched reciprocally causing the blood vessels of the retrodiscal tissues to become engorged, bringing nutrients to both the condyle and fossa.[23,41]

The greatest difference between an activator and the Herbst appliance is that the activator acts only for part of the day, usually 12–14 hours, and of course there is no function during this period of wear. Whether these differences could account for the observed divergences is not known.

Another possibility with results stemming from magnetic resonance imaging could be incorrect interpretation. It is possible that some of the changes described as bone deposition may be artifacts.

Radiographic findings of this study have shown that glenoid fossa does not change its morphology as a result of treatment with mandibular protrusive appliances. However, this finding by no means excludes the relative contribution of the glenoid fossa to the resolution of a skeletal Class II problem treated with mandibular protrusive appliances. A possible explanation would be that, normally during craniofacial growth, it has been shown that the glenoid fossa is displaced downward and backward.[5,42] Popovich[42] has shown clearly from the serial Burlington Growth Center data that the condyle is displaced specifically in a downward and backward direction during natural facial growth and development.

Because our results found no statistically significant increase in the distance from porion to posterior glenoid fossa, this can at least be interpreted as a restriction of the glenoid fossa from continuing its natural downward and backward growth direction. This restriction of temporal bone (fossa) growth may assist the explanation of how unexpected Class II corrections occur in treatment. The reason is that the growing mandible is also not displaced normally downward and backward. This relative restriction of fossa growth is not readily visible radiographically in our standard orthodontic superimpositions on the cranial base, maxilla, or mandible. This investigation also does not eliminate the possibility that microscopic growth modifications may also be occurring at the anterior aspect of the postglenoid spine that are not visible radiographically.

As orthodontic clinicians, we tend to focus solely on the forward and downward growth changes of the face during functional appliance therapy often entirely ignoring the restriction of downward and backward growth of the face in general. It is recommended when superimposing on the cranial base structures to not only assess downward and forward mandibular growth changes that account for Class II corrections, but also to consider the actual restriction of downward and backward fossa growth.

This study has shown the difficulty often encountered with measuring fossa changes from lateral cephalograms. The use of current lateral cephalograms is not recommended because condylion is difficult to locate. Any posttreatment evaluation with a lateral cephalogram of fossa restriction is qualitative. In addition, using the condylion point for fossa evaluation assumes that the condyle is seated back in the fossa after treatment. However, it is well recognized that some functional appliance therapy may continue to displace the condylion point anteriorly immediately after treatment. Therefore, caution must be used because condylion in these circumstances does not necessarily indicate the true position of the fossa. Fossa changes from this investigation have been shown to be more ideally assessed using tomograms of the temporomandibular joints.

In summary, the findings of our work, contrary to current views, point to the absence of any contribution from the glenoid fossa during treatment of skeletal Class II malocclusions with functional appliances. However, because of the small size of our sample, and hence the possibility of type II error, we should be cautious until more information becomes available.

CONCLUSIONS

On the basis of the findings of this study the following conclusions can be drawn:

1. The glenoid fossa does not show change in morphology radiographically as result of treatment with mandibular protrusive appliances (activators).
2. Contrary to the common belief, the glenoid fossa does not appear radiographically to contribute positive growth modifications to the Class II correction by active bone modeling.

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