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Changes in soft tissue profile and electromyographic activity after activator treatment

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Background: To date, few studies have correlated the changes in muscle activity and specific soft tissue variables in adolescents with malocclusions.

Objective: To determine associations between the soft tissue profile and electromyographic activities in temporalis, masseter and orbicularis oris muscles in children with Class II division 1 malocclusions treated with activators.

Methods: For this prospective study, 25 subjects with Class II division 1 malocclusions were randomly assigned to either a Treatment group (N = 15) or a Control group (N = 10). The mean skeletal ages of the subjects in the Treatment and Control groups were 11.3 ± 1.1 and 11.0 ± 1.3 years, respectively. The subjects in the Treatment group were treated with activators and the subjects in the Control group were untreated. Lateral cephalometric radiographs and EMG recordings of the anterior temporalis and masseter muscles during clenching, chewing and swallowing and the orbicularis oris muscle during whistling were obtained at the start of the study and 12 months later. Changes in the soft tissue profile were correlated with changes in the EMG activities in anterior temporalis, superficial masseter and orbicularis oris muscles.

Results: The upper lip to E line distance (UL-E) decreased more in the Treatment group than the Control group ($p < 0.05$) and the H angle decreased in the Treatment group, but increased in the Control group ($p < 0.01$). The EMG activities of temporalis and masseter muscles increased significantly in both groups. All between-group EMG differences were statistically significant with the exception of the activities in the temporalis and masseter muscles during swallowing. In the Treatment group, a significant positive correlation (r = .57) was found between the changes in UL-E and anterior temporalis activity during swallowing, and significant negative correlations were observed between the EMG activity of masseter muscle during swallowing and changes in LL-E (r = -.54), OLp-UL (r = -.55) and OLp-LL (r = -.67).

Conclusions: Activator therapy is accompanied by changes in the lips and temporalis and masseter activities during swallowing.

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Introduction

The role of the orofacial musculature in determining facial morphology and tooth position has intrigued dental researchers for decades. Electromyographic (EMG) studies indicate that anterior temporalis, masseter and orbicularis oris muscles may play a part in the causation of malocclusion and relapse after orthodontic therapy.[1–15] Similar methods, which have been used to investigate the activity of the orofacial muscles during and following use of functional appliances, indicate that functional appliances modify the neuromuscular environment of the dentition and related bones.[16] However, the EMG evidence is by no means clear-cut: some investigators have reported reduced EMG activity in the temporalis and masseter muscles during maximal bite, chewing and at rest in patients treated with functional appliances, while other investigators have reported increased muscle activity during clenching, swallowing and at rest with these appliances.[9–12,17–19]

It would appear that the mechanisms of neuromuscular adaptation to functional appliance therapy are complex. Orthodontists have traditionally appraised the soft tissue profile on lateral cephalometric radiographs, but the information obtained from such investigations is limited as the observer has

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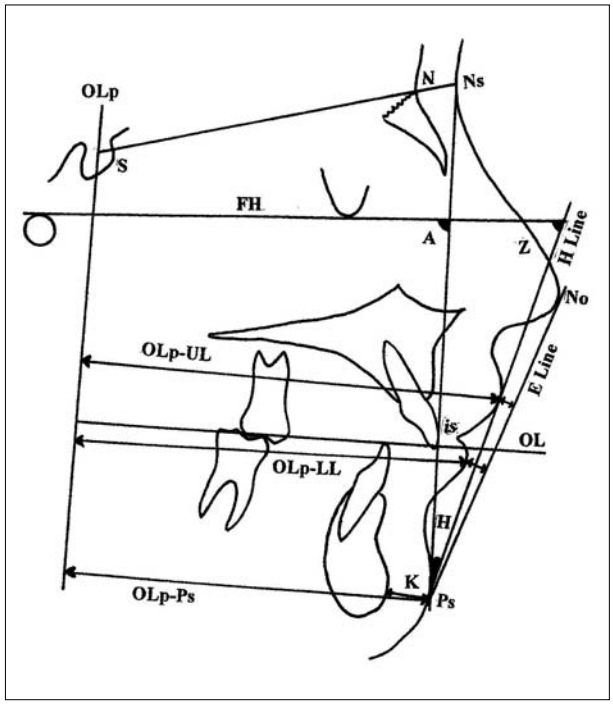


Figure 1. Cephalometric variables.
UL-E: upper lip perpendicular to Esthetic line (mm)
LL-E: lower lip perpendicular to Esthetic line (mm)
OLp-UL: occlusal line perpendicular to upper lip (mm)
OLp-LL: occlusal line perpendicular to lower lip (mm)
OLp-Ps: occlusal line perpendicular to soft tissue pogonion (mm)
K: soft tissue chin thickness (mm)
No-Ps: distance between nose tip and soft tissue pogonion (mm)
H angle: angle between H line and Ns-Ps line (°)
A angle (Soft-tissue facial angle): angle formed by the intersection of Ns-Ps line and FH (°)
Z angle: angle formed by intersection of FH and H line (°)

no knowledge of activity of the muscles contributing to the profile changes.[19] Some clinicians have even asserted that diagnosis is incomplete without EMG data,[1–8,9–15,19] which is an extreme view as most orthodontic treatment is completed satisfactorily without EMG data.[20–25] Studies correlating changes in muscle activity with changes in the soft tissue profile during and following functional appliance treatment may throw some light on the mode of action of functional appliances.

The purpose of the present study was to investigate associations between the soft tissue profile and the electromyographic activity in temporalis, masseter and orbicularis oris muscles in children with Class II division 1 malocclusions treated with Andresen activators.

Material and methods

For this prospective study, 25 children with Class II division 1 malocclusions were selected from the patients referred to the Department of Orthodontics, Faculty of Dentistry, Atatürk University. The selection criteria were: no subjective neuromuscular or auditory symptoms, no symptoms of temporomandibular dysfunction, a full Class II relationship based on the position of the permanent canines, a skeletal II pattern (ANB angle > 5 degrees), retrognathic mandible based on subjective clinical and lateral cephalometric film assessments and deep anterior overbite i.e. greater than 4 mm. Subjects with a history of previous orthodontic treatment, subjective neuromuscular and/or auditory symptoms, symptoms of TMD, developmental and/or acquired craniofacial or neuromuscular deformities were excluded. Ethics approval was obtained from the Ethics Committee of the Faculty of Dentistry, Atatürk University.

The subjects were randomly assigned to the Treatment (9 girls, 6 boys) and Control groups (4 girls, 6 boys). The mean skeletal ages of the subjects in the Treatment and Control groups were 11.3 ± 1.1 years and 11.0 ± 1.3 years, respectively. Each subject in the Treatment group was asked to wear an Andresen activator for at least 16 hours a day and to keep their lips together to form a lip seal when the appliance was being worn. The construction bite for the activator was taken with the incisors in an edge-to-edge relationship and separated by 3 mm. The mean treatment/observation duration was 12 months. The subjects in the Control group were not treated during this period. At the start of the study the groups were matched for chronological age and observation period.

Cephalometric method

Lateral cephalometric radiographs were taken at the start of the study (T1) and, on average, 12 months later (T2). The radiographs were taken with the Frankfort plane parallel to the floor, the teeth in the intercuspal position and the lips in repose.

The radiographs were traced and measured by the same investigator. Soft tissue changes were assessed by seven linear and three angular measurements (Figure 1).[1,2,4,5,26–28] For the linear measurements, the occlusal line (OL) and the perpendicular to the occlusal line

(OLp) through sella (S) on the T1 radiograph was used as a reference grid. The grid was transferred from the first tracing to the second tracing by superimposing the grid on the N - S line (NSL) at S on each subject's T2 radiograph. The linear and angular measurements were made to the nearest 0.5 mm and 0.5 degree, respectively. The changes during treatment were the T2 measurements minus the T1 measurements.

To determine the errors associated with the radiographic tracings and measurements, 20 radiographs were randomly selected from the Treatment and Control groups, re-traced and remeasured one month after the first procedure. The variables were normally distributed, and there were no statistically significant differences between the first and second sets of measurements ($p > 0.05$).

EMG method

The EMG activities of the left anterior temporalis muscle, the left masseter muscle and the left orbicularis oris muscle were recorded in the same shielded room before treatment (T1) and, on average, 12 months later (T2). Before each recording session, the EMG recording procedure was explained in detail to the subjects and their parents to allay anxiety. The subjects were requested to wash their face with soap and water and the skin over the desired muscles was cleaned with alcohol, dried thoroughly and smeared with electrode jelly. Each subject was then comfortably seated with the head in natural head posture. The subjects were asked to practise habitual chewing, swallowing and whistling. Rectangular, unipolar surface electrodes were used for EMG recordings. The electrodes were taped in the main direction of the muscle fibres. The tip of the active electrode was placed on the contracted part of the muscle, while the tip of the passive electrode was placed 3 cm from the active electrode. The active regions of the anterior temporalis and masseter muscles were determined by palpation. A ground electrode was attached to the wrist of the subject.

The EMG recordings were made with a Disa Neuromatic 2000 electromyograph device (Dantec DISA, Scovlunde, Denmark). The sweep speed and sensitivity of the device were 100 mm/sec and 1–10 mV/cm, respectively. A few trial recordings were obtained to familiarise each subject with the recording procedure. EMG recordings of the anterior temporalis and superficial masseter muscles were obtained during maximal clenching, chewing and swallowing of nuts. For the latter, a readily available round hazelnut was used. The activity in the superior orbicularis oris muscle was recorded during whistling an habitual and constant tone. Two digital EMG recordings of each muscle were obtained at the same session and the mean of the recordings of each muscle have been used in all subsequent calculations. All recordings were obtained by the same operator.

EMG recordings were taken before treatment/observation (T1) and approximately 12 months later (T2). The differences were calculated by subtracting the T1 values from the T2 values. The measurement unit was in microvolts (μV), and the equipment was calibrated manually, according to the recording sensitivity for each functional activity, range 100–1000 μV. The sweep speed was set 10 msec/cm.

Statistical methods

A paired *t*-test was applied to determine the within-group changes in the cephalometric and electromyographic variables. Student's *t*-test was used to compare the changes between the Treatment and Control groups. In addition, Pearson's correlation analysis was used to disclose associations between the changes in the cephalometric and electromyographic variables. All statistical analyses were performed using the SPSS software program (SPSS for Windows 98, version 10.0, SPSS Inc, Chicago, IL, USA).

Results

There were statistically significant within-group changes in eight parameters in the Treatment group and five parameters in the Control group (Table I). There were, however, only two statistically significant between-group T1-T2 changes: the upper lip to E distance and the H angle. The upper lip to E distance decreased 1.53 mm in the Treatment group, but only 0.35 mm in the Control group ($p < 0.05$). The H angle decreased in the Treatment group by 1.23 degrees, but increased in the Control group by 1.65 degrees ($p < 0.01$).

The activity of temporalis and masseter muscles during clenching, chewing and swallowing increased significantly in both groups, particularly in the Treatment group where the EMG activity in the

Table I. Comparison of the cephalometric changes (T2-T1) in the Treatment and Control groups.

	Treatment group (N=15)		Within-group comparison	Control group (N=10)		Within-group comparison	Between-group
Parameters	Mean change	SD	*t*	Mean change	SD	*t*	*t*
Upper lip to E	-1.53	1.61	-3.69**	-0.35	1.06	-1.05	-2.04*
Lower lip to E	-1.23	1.71	-2.79*	0.00	2.64	0.00	-1.42
OLp-Upper lip	2.47	2.46	3.88***	2.00	1.67	3.79***	0.53
OLp-Lower lip	2.90	3.49	3.22**	2.25	2.06	3.46**	0.53
OLp-Ps	3.87	4.61	3.25**	1.65	1.75	2.98**	1.45
K	0.93	1.33	2.71*	0.45	0.96	1.49	0.98
No-Ps	3.73	1.55	9.36***	3.20	1.89	5.36***	0.77
H (angle)	-1.23	2.08	-2.30*	1.65	1.76	2.96**	-3.60**
A (angle)	-0.17	3.87	-0.17	0.15	1.84	0.26	0.27
Z (angle)	1.37	3.72	1.51	-0.15	2.98	-0.48	1.08

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table II. Comparison of the electromyographic differences (T2-T1) in the Treatment and Control groups.

		Treatment group (N=15)		Within-group comparison	Control group (N=10)		Within-group comparison	Between-group comparison
Muscle	Parameters	Mean	SD	*t*	Mean	SD	*t*	*t*
Temporal	Maximal clenching	554.1	276.0	7.76***	64.4	29.4	6.92***	5.55***
	Chewing	586.0	221.0	10.28***	130.5	56.1	7.35***	6.34***
	Swallowing	71.5	57.5	4.83***	51.6	54.6	2.99**	0.87
Masseter	Maximal clenching	334.0	146.2	8.84***	106.4	70.1	4.80***	4.56***
	Chewing	388.4	196.2	7.66***	85.1	74.5	3.61**	4.64***
	Swallowing	69.1	65.0	4.12***	45.4	30.0	4.78***	1.07
Orbicularis oris	Whistling	372.0	290.0	4.97***	111.8	203.6	1.82	2.46*

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

temporalis muscle during maximal clenching increased more than eight times the T1-T2 increase in the Control group (Table II). The activity in orbicularis oris during whistling increased significantly in the Treatment group, but not the Control group, but the standard deviations in both groups were large. All between-group differences were statistically significant with the exception of the activities in the temporalis and masseter muscles during swallowing.

In the Treatment group, four statistically significant coefficients occurred between the cephalometric and electromyographic changes (Table III). There was significant positive correlation of .57 between the changes in upper lip – E line distance (UL-E) and contraction in the anterior temporalis muscle during swallowing, and significant negative correlations between the changes in the lower lip – E distance (-.54), OLp to upper lip (-.55) and OLp to lower lip (-.67) and masseter muscle activity during swallowing.

Discussion

Functional appliances are thought to modify the neuromuscular environment of the dentition and related bones.[16] We investigated associations between the

Table III. Associations between the soft tissue and EMG changes in the activator group.

		UL-E	LL-E	OLp-UL	OLp-LL	OLp-Ps	K	No-Ps	H Angle	A Angle	Z Angle
Temporal	Maximal clenching	.295	.164	-.126	-.291	-.335	.016	-.202	.354	.043	-.206
	Chewing	.214	.045	.033	-.198	-.197	.145	.149	.163	-.120	-.115
	Swallowing	.574*	.088	.332	-.069	.089	.063	.538	-.218	.030	.334
Masseter	Maximal clenching	.116	.090	.282	.117	.197	-.048	.266	.023	.172	.039
	Chewing	.254	.125	-.164	-.306	-.122	-.324	.141	.192	-.064	-.005
	Swallowing	-.159	-.537*	-.554*	-.668**	-.305	.358	-.433	-.147	-.430	-.134
Orb. oris	Whistling	.316	.216	-.215	-.159	-.146	-.266	-.055	.156	.223	-.087

* $p < 0.05$, ** $p < 0.01$

changes in the soft tissue profile and changes in the activities of anterior temporalis, masseter and orbicularis oris muscles in children with Class II division 1 malocclusions treated with Andresen activators. At the start of the study, which ran for 12 months, the children were randomly assigned to either a Treatment or a Control group. The subjects in the Treatment group were closely matched for chronological age and observation period with the subjects in the Control group. We also took particular care to standardise our cephalometric and electromyographic methods. After 12 months treatment relatively weak, but statistically significant, associations occurred between the lips and temporalis and masseter activity during swallowing. The significant associations were attributed to changes in the positions of the lips, possibly due to overjet reduction, and changes in muscle activity during swallowing. In common with other studies, considerable variation in EMG activity was encountered, but less variation occurred during swallowing than during clenching and chewing.

The within-group cephalometric comparisons revealed eight significant changes (T1 to T2) in the Treatment group and five significant changes in the Control group. But when we compared the changes in the groups, only the upper lip to E distance (UL-E) and H angle were significantly different. The upper lip was 1.5 mm less protrusive (relative to the E line) in the group treated with activators, and less than 0.5 mm less protrusive in the untreated group. The H angle decreased in the Treatment group by almost 1.25 degrees, but increased in the Control group by more than 1.5 degrees. The H angle is not influenced by growth of the nose, but it is influenced by growth and treatment-induced changes in the upper lip and soft tissue pogonion. Others have attributed the changes in functional appliance groups to an appliance-induced retrusive force on maxilla and protrusive force on mandible,[29–32] but our evidence does not support this conclusion. Soft tissue pogonion (OLp-Ps) increased significantly in the Treatment group and Control groups, but the between-group difference was not statistically significant. It is unlikely that this measurement (OLp-Ps) was affected by growth changes in sella in the 12 months of our study. The wide variation in the Treatment group is probably the reason we failed to find a significant between-group difference for this measurement, and for OLp-UL and OLp-LL. Our findings emphasise the importance of using anatomically stable landmarks, such as the cranial base, rather than reference lines that may be affected by growth.

One of the challenges in many orthodontic practices is the successful treatment of Class II division 1 malocclusions. Some orthodontists routinely use functional appliances, either alone or in combination with some other form of appliance, to treat these malocclusions. Conflicting results have been reported in the literature regarding the EMG changes in the muscles during functional therapy. We found significant EMG changes in the temporalis and masseter muscles during maximal clenching, chewing and swallowing in both groups, and a significant EMG change in the orbicularis oris muscle during whistling in the Treatment group, but not in the Control group. We also found significant between-group changes in the three muscles during clenching, chewing and whistling, but not during swallowing. The EMG patterns during swallowing were not only the smallest changes recorded, but also the least variable changes.

Swallowing is an oral function with a consistent pattern of muscle activity, which does not appear to be influenced by functional appliance treatment.

Whistling and swallowing require strong contractions in the same circumoral musculature. During whistling there was a marked increase in EMG activity at the end of 12 months treatment and the difference (T2 minus T1) was statistically significant. The reduction in overjet may have contributed to this finding. In the Control group, however, the change in the EMG activity in orbicularis oris was less marked, presumably because no additional effort was required (the subjects had an increased overjet on both occasions) and the change was not statistically significant. When we tested for between-group differences there was a small, but statistically significant finding.

Several investigators have reported that the EMG activities in temporalis and masseter muscles increased in subjects treated with functional appliances,[5,11,12,18] and other investigators have reported that the EMG activities in these muscles decreased.[9,10,19,33] We attribute this disagreement to the different functional appliances and treatment approaches used, occlusal instability during functional appliance treatment and to the different methods used to record EMG patterns. For example, several investigators have used hook electrodes, which are unreliable and give limited EMG data of a muscle.[9,10,34] Needle electrodes also have disadvantages: they markedly reduce intramuscular crosstalk and are rejected by patients and clinicians because of the need for specialised personnel to acquire data.[35,36] We used surface electrodes because they are noninvasive, allow recording over a large area and are reliable.[34,37]

A statistically significant positive correlation was found between the change in the upper lip to E line distance (UL-E) and the change in anterior temporalis activity during swallowing. This means that the EMG activity in the temporalis muscle increased during swallowing when the upper lip to E line distance increased. However, measurements to the E line give an unreliable indication of change in the lips because of the confounding effect of nasal growth. Three statistically significant negative correlations were found between masseter activity during swallowing and LL-E, OLp-UL, and OLp-LL. In general, these significant correlations indicate that the more retrusive the soft tissue profile, the greater the masseter muscle activity during swallowing.

Associations have been reported between the craniofacial morphology and muscle activity during rest,[2,3,38,39] maximum intercuspation,[2,3] clenching,[2,3,8,13,14] chewing,[6,39] and swallowing.[3,6,8,39] The significant associations we found between the changes in EMG activity in masseter and temporal muscles during swallowing and sagittal movements of upper and lower lips may be due to the combined effects of forward growth of the face, treatment-induced changes in the lips due to overjet reduction and age-related postural changes in the lips. Although special attention was given to the EMG and cephalometric methods, the findings should be interpreted with care due to the small sample sizes.

Conclusions

After 12 months treatment with Andresen activators, statistically significant associations occurred between the sagittal changes in the lips and temporalis and masseter muscles during swallowing. In general, the more retrusive the soft tissue profile, the greater the masseter muscle activity during swallowing.

Significant sagittal changes in the positions of the lips may have been due to the reduction in overjet.

Considerable variation in the EMG activity of temporalis, masseter and orbicularis muscles was encountered during clenching, chewing and whistling. Less variation in EMG activity occurred in the temporalis and masseter muscles during swallowing.

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