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Functional Regulator Therapy in Treatment of Skeletal Open-bite

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Abstract

A study was performed on the functional regulator, Fränkel appliance (FR4) in order to test its efficiency in the treatment of patients with skeletal open-bite. Pretreatment and post-treatment cephalometric evaluation was done on 11 patients and 10 untreated patients with skeletal open-bite. The results showed that the FR4 appliance was mainly effective on changes in dentoalveolar structures and produced no significant skeletal changes. The degree of anterior open-bite was decreased significantly in the treatment group in comparison with the controls ($p<0.01$), due to vertical eruption of upper and lower incisors and retraction of maxillary incisors.

Introduction

Treatment of skeletal anterior open-bite deformity is one of the most difficult challenges for the orthodontist. The main cephalometric characteristics of this malocclusion are a decrease in the ratio of posterior to anterior face hight[1-5], an increase in anterior face height[1-8], due mainly to a rise in lower anterior face height and the mandibular plane angle as a result of backward rotation of the mandible, and a rise in the posterior and anterior maxillary and mandibular dental height[2,6,8,9]. Extraorally, affected patients have a narrow alar base and a parted lips posture which is a characteristic feature of their mouth breathing[10].

The etiology of this malocclusion may be multifactorial including heredity, sucking habits, mouth breathing with associated head-posture and some developmental anomalies[11]. Various methods of orthodontic treatment have been used with reference to the etiology of open-bite malocclusion[9,10,12-16]. Depending on the age of the patient, a functional therapy approach during the mixed dentition period or fixed appliance therapy after establishment of permanent dentition may be used.

Moss et al.[17] states that capsular functional matrices may play an important role in open-bite. Either the form of the oral functional space or its location may be abnormal relative to the nasal and pharyngeal functional spaces. On the basis of this concept, FRÄNKEL AND FRÄNKEL[18] developed a functional approach to

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orofacial orthopedics, and introduced the FR4 appliance for the treatment of skeletal open-bite malocclusion. This works by correcting the faulty postural activity of the orofacial musculature and helps to correct the associated skeletal deformity. It has also been claimed that this approach reverses the backward rotational growth pattern of the mandible.

The aim of the present study was to determine the effects of the FR4 appliance on the developing dentofacial skeletal structures in patients with skeletal open-bite. Cephalometric comparisons of the treated and control groups were made to evaluate the effects of the appliance.

Materials and Methods

Eleven patients in the mixed dentition period who had an anterior open-bite were treated with the FR4 appliance at the postgraduate orthodontic clinic of Hacettepe University. In addition, 10 children in the mixed dentition period with the same type of malocclusion were used as a control group. Average ages at the beginning and end of the observation period are shown in Table I. The patients were selected according to the following criteria: 1-Presence of anterior open-bite with a vertical growth pattern. 2-Lack of sucking habits. 3-Patients were in their mixed dentition period.

Table I
Average ages at the beginning of treatment and duration of treatment

	n	Average age	SD	Duration of treatment	SD
Treatment group	11	8.773	1.174	1.235	0.241
Control group	10	8.284	1.064	1.024	0.039

Lateral cephalograms of all patients were taken before and after the observation or treatment period. The FR4 appliance was constructed according to the methods described by FRÄNKEL AND FRÄNKEL[19] and GRABER et al.[20] (Fig. 1, a and b).

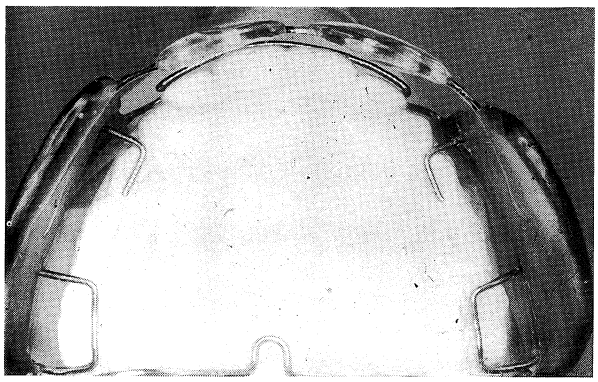

Fig. 1 a The FR 4 appliance on a maxillary model showing the occlusal rests on permanent and deciduous first molars

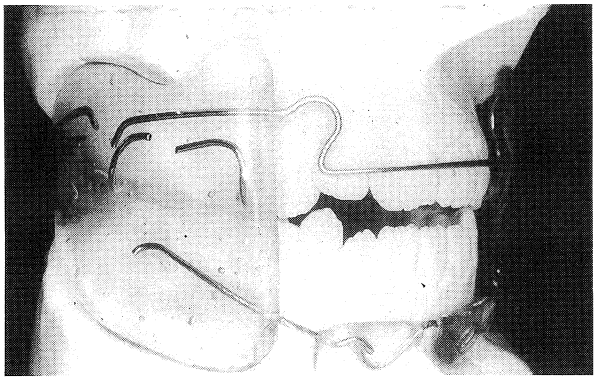

Fig. 1 b Finished appliance tested on mounted models before applying to the mouth

The patients were instructed to wear the appliance for 3 h on the first day and add one hour each day for the first ten days. After this period the patients were instructed to wear the appliance full-time (at least 20 h per day) except during eating or sports activity. They were advised not to wear the appliance during sleeping hours during the first 10 days. The importance of lip seal exercises were explained to the patients, and they were instructed to keep their lips together as much as possible. The patients were instructed to perform lip seal exercises such as holding a coin between the lips, blowing up a balloon or whistling.

Patients with upper airway problems were told to consult an ear-nose-throat (ENT) specialist, and adequate treatment measures were taken whenever necessary.

The pre- and post-treatment lateral cephalograms were traced, and 21 anatomic landmarks were used; 35 parameters—16 angular and 19 linear—were used to evaluate the effects of the FR4 appliance. Cephalometric evaluation was carried out on maxillary and mandibular skeletal and dental structures and also on vertical changes.

Statistical evaluation was made by Wilcoxon signed-rank test for longitudinal changes and Mann-Whitney U test for comparison of two groups.

Findings

The data showed that before treatment the FR4 group had more retroclined maxillary incisors than the controls (U1-SN° $p<0.05$, U1-NA° $p<0.05$) (Table II). In addition the FR4 group displayed higher U1-PP(mm) and U6-FH(mm) values ($p<0.05$) (Table II).

Maxillary skeletal and dental changes (Tables III, IV, V)

The Fränkel appliance appeared to restrain maxillary growth slightly. Maxillay length (Harvold) increased 1.227 mm in the treatment group ($p<0.05$) and 2.250 mm in the control group ($p<0.01$).

Maxillary incisors showed a significant amount of angular retraction (U1-SN°: -3.864° $p<0.05$, U1-NA: -3.091° $p<0.05$) and bodily retraction (U1-NAmm: -1.136 $p<0.05$). Upon comparison of these changes with the control group, only the decrease in the U1-NAmm measurement was found to be significant ($p<0.05$).

Table II
Pretreatment comparison of FR4 and control groups

Parameter	Experimental ($\bar{x}\pm SD$)	Control ($\bar{x}\pm SD$)	U	p value
Maxillary skeletal and dental				
SNA (°)	74.864±12.339	78.450±7.065	49	0.671
N. perpendicular-A (mm)	−0.136± 2.226	−1.800±3.450	69	0.339
Maxillary length(mm) (Cd-A)	78.500± 2.377	75.150±4.710	82	0.061
Convexity (mm)	5.409± 1.985	3.700±1.874	82	0.053
SN-PP (°)	10.045± 3.275	8.900±4.683	66	0.459
PP-MP (°)	34.000± 4.764	32.600±4.142	68	0.377
Occ-PP (°)	20.500± 4.806	17.450±3.715	79	0.097
Occ-MP (°)	13.500± 2.898	15.150±2.161	33	0.119
U1-SN (°)	98.591+ 6.587	104.050±5.718	21	0.016*
U1-NA (°)	21.045± 3.971	25.900±6.887	27	0.048*
U1-NA (mm)	2.727± 1.348	2.850±1.415	51	0.774
U1-FH (mm)(dental height)	46.818± 3.364	43.150±4.177	81	0.071
U1-PP (mm) (dental height)	26.818± 1.793	24.100±3.035	86	0.031*
U6-FH (mm) (dental height)	42.045± 2.945	34.450±2.477	90	0.014*
U6-PP (mm) (dental height)	20.955± 2.173	19.400±1.524	79	0.089
Mandibular skeletal and dental				
SNB (°)	71.909± 4.493	74.350±6.223	39	0.259
Facial angle (°)	84.045± 3.602	83.700±2.965	55	0.972
N. perpendicular-Pog (mm)	11.139± 5.595	11.000±5.533	58	0.832
Mandibular lenth(mm)(Cd-Gn)	102.364± 4.348	98.750±5.633	80	0.078
Ramus height (mm)	50.864± 3.661	48.000±5.121	74	0.180
Gonial angle (°)	127.273± 4.239	127.400±4.458	51	0.777
L1-MP (°)	91.773± 5.183	92.900±5.806	50	0.698
L1-NB (°)	26.682± 3.723	28.100±5.705	50	0.723
L1-NB (mm)	4.727± 1.403	5.150±2.334	53	0.887
L1-MP (mm) (dental height)	38.000± 2.280	36.500±2.582	81	0.070
L6-MP (mm) (dental height)	31.182± 1.820	29.750±2.276	77	0.118
Vertical				
Facial axis (°)	79.045± 4.156	80.950±3.166	39	0.244
FMA (°)	31.636± 5.745	32.150±3.266	52	0.804
Facial height(%)(UFH/LFH)	0.751± 0.049	0.766±0.081	53	0.858
Lower face height (°)	49.045± 3.984	48.400±3.017	61	0.696
Posterior face height(mm)(S-Go)	68.045± 4.569	66.850±5.011	64	0.549
Anterior face height(mm)(N-Me)	115.500± 6.961	111.100±3.872	76	0.147
Jarabak ratio (%)	58.900± 4.400	59.900±4.500	45	0.479
Mandibular arc (°)	34.955± 3.236	33.250±4.316	64	0.524
Anterior open-bite (mm)	2.636± 1.675	3.800±1.317	80	0.072

*$p<0.05$

Although significant extrusion of the upper incisors was found (U1-FHmm: 3.227 mm $p<0.01$, U1-PP mm: 1.864 mm $p<0.01$), these changes were not significant when compared with the control ($p>0.05$). Similarly, upper 1. molars showed a noticeable increase in vertical height ($p<0.05$), but this was not found to be significant when compared with the control ($p>0.05$).

Mandibular skeletal and dental changes (Tables III, IV, V)

No measurements in these groups were found to be significantly noteworthy when the two groups were compared.

Although significant increases in the mandibular length and ramus height

Table III
Longitudinal changes in the treatment group

Parameter	Pretreatment ($\bar{x}\pm$SD)	Post-treatment ($\bar{x}\pm$SD)	Difference	p value
Maxillary skeletal and dental				
SNA (°)	74.864±12.339	77.409±4.421	−0.455	0.477
N. perpendicular-A (mm)	−0.136± 2.226	−0.955±3.150	−0.818	0.051
Maxillary length(mm) (Cd-A)	78.500± 2.377	79.727±2.494	1.227	0.032*
Convexity (mm)	5.409± 1.985	4.636±2.146	−0.773	0.262
SN-PP (°)	10.045± 3.275	9.545±3.602	0.500	0.093
PP-MP (°)	34.000± 4.764	34.727±4.390	0.727	0.091
Occ-PP (°)	20.500± 4.806	19.500±4.935	−1.000	0.139
Occ-MP (°)	13.500± 2.898	15.318±2.648	1.818	0.041*
U1-SN (°)	98.591± 6.587	94.727±5.106	−3.864	0.028*
U-NA (°)	21.045± 3.971	17.955±4.497	−3.091	0.033*
U1-NA (mm)	2.727± 1.348	1.591±1.562	−1.136	0.017*
U1-FH (mm) (dental height)	46.818± 3.364	50.045±3.876	3.227	0.003**
U1-PP (mm) (dental height)	26.818± 1.793	28.682±1.722	1.864	0.003**
U6-FH (mm) (dental height)	42.045± 2.945	43.591±3.590	1.545	0.011**
U6-PP (mm) (dental height)	20.955± 2.173	21.500±2.439	0.545	0.041*
Mandibular skeletal and dental				
SNB (°)	71.909± 4.493	72.273±4.297	0.364	0.109
Facial angle (°)	84.045± 3.602	84.045±3.395	0.000	0.079
N. perpendicular-Pog (mm)	11.139± 5.595	11.364±6.265	0.227	0.646
Mandibular lenth(mm)(Cd-Gn)	102.364± 4.348	105.545±4.942	3.182	0.005**
Ramus height (mm)	50.864± 3.661	52.409±3.056	1.545	0.018*
Gonial angle (°)	127.273± 4.239	127.364±4.267	0.091	0.657
L1-MP (°)	91.773± 5.183	92.091±4.505	0.318	0.767
L1-NB (°)	26.682± 3.723	27.636±4.154	0.955	0.508
L1-NB (mm)	4.727± 1.403	5.409±1.338	0.682	0.091
L1-MP (mm) (dental height)	38.000± 2.280	39.682±2.542	1.682	0.003**
L6-MP (mm) (dental height)	31.182± 1.820	31.500±1.987	0.318	0.308
Vertical				
Facial axis (°)	79.045± 4.156	79.773±3.573	0.727	0.097
FMA (°)	31.636± 5.745	32.682±4.771	1.045	0.053
Facial height(%)(UFH/LFH)	0.751± 0.049	0.765±0.059	0.014	0.028*
Lower face height (°)	49.045± 3.984	48.227±3.228	−0.818	0.080
Posterior face height(mm)(S-Go)	68.045± 4.569	69.500±5.153	1.455	0.051
Anterior face height(mm)(N-Me)	115.500± 6.961	118.182±7.561	2.682	0.003**
Jarabak ratio (%)	58.900± 4.400	58.600±3.900	−0.300	0.944
Mandibular arc (°)	34.955± 3.236	34.682±3.282	−0.273	0.906
Anterior open-bite (mm)	2.636± 1.675	0.000±1.265	2.636	0.003**

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

were observed in the FR4 group (3.182 mm $p<0.01$, 1.545 mm $p<0.05$), these changes were considered to be non-significant when compared with the control.

Despite a higher incidence of vertical eruption of the lower incisors, comparison of the two groups showed no significant difference ($p>0.05$).

Vertical Changes (Tables III, IV, V)

The decrease in the amount of open-bite (mm) was found to be crucial when the groups were compared.

In the treatment and control groups the degree of open-bite was decreased by

Table IV
Longitudinal changes in the control group

Parameter	Preobservation ($\bar{x}\pm SD$)	Postobservation ($\bar{x}\pm SD$)	Difference	p value
Maxillary skeletal and dental				
SNA (°)	78.450±7.065	78.950±6.322	0.500	0.445
N. perpendicular-A (mm)	−1.800±3.450	−1.150±3.473	0.650	0.059
Maxillary length(mm) (Cd-A)	75.150±4.710	77.400±4.569	2.250	0.005**
Convexity (mm)	3.700±1.874	3.800±1.719	0.100	0.584
SN-PP (°)	8.900±4.683	8.350±4.755	−0.550	0.173
PP-MP (°)	32.600±4.142	32.350±4.217	−0.250	0.499
Occ-PP (°)	17.405±3.715	16.550±2.544	−0.900	0.554
Occ-MP (°)	15.150±2.161	15.800±4.780	0.650	0.859
U1-SN (°)	104.050±5.718	103.950±5.408	−0.100	0.722
U1-NA (°)	25.900±6.887	25.100±4.533	−0.800	0.554
U1-NA (mm)	2.850±1.415	2.850±1.765	0.000	0.636
U1-FH (mm) (dental height)	43.150±4.177	44.900±3.307	1.750	0.009**
U1-PP (mm) (dental height)	24.100±3.035	25.450±2.629	1.350	0.012*
U6-FH (mm) (dental height)	34.450±2.477	39.800±2.275	5.350	0.015*
U6-PP (mm) (dental height)	19.400±1.524	20.000±1.826	0.600	0.091
Mandibular skeletal and dental				
SNB (°)	74.350±6.223	74.850±5.845	0.500	0.236
Facial angle (°)	83.700±2.965	84.550±3.113	0.850	0.017*
N. perpendicular-Pog (mm)	11.000±5.533	10.100±4.971	−0.900	0.263
Mandibular length(mm)(Cd-Gn)	98.750±5.633	101.900±5.607	3.150	0.008**
Ramus height (mm)	48.000±5.121	49.200±4.803	1.200	0.012*
Gonial angle (°)	127.400±4.458	126.200±4.104	−1.200	0.041*
L1-MP (°)	92.900±5.806	92.900±6.471	0.000	0.953
L1-NB (°)	28.100±5.705	27.800±5.841	−0.300	0.813
L1-NB (mm)	5.150±2.334	5.500±2.369	0.350	0.080
L1-MP (mm) (dental height)	36.500±2.582	37.300±2.830	0.800	0.012*
L6-MP (mm) (dental height)	29.750±2.276	29.750±2.276	0.000	1.000
Vertical				
Facial axis (°)	80.950±3.166	81.550±3.387	0.600	0.401
FMA (°)	32.150±3.266	31.450±3.640	−0.700	0.107
Facial height(%)(UFH/LFH)	0.766±0.081	0.773±0.057	0.007	0.590
Lower face height (°)	48.400±3.017	48.100±3.026	−0.300	0.674
Posterior face height(mm)(S-Go)	66.850±5.011	68.550±4.884	1.700	0.008**
Anterior face height(mm)(N-Me)	111.100±3.872	112.600±4.427	1.500	0.008**
Jarabak ratio (%)	59.900±4.500	60.600±3.900	0.700	0.128
Mandibular arc (°)	33.250±4.316	33.200±3.584	−0.050	0.889
Anterior open-bite (mm)	3.800±1.317	2.700±1.567	1.100	0.024*

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

2.636 mm ($p<0.01$) and 1.100 mm ($p<0.05$), respectively, and the difference between the groups was found to be significant ($p<0.01$).

Anterior face height increased to 2.682 mm ($p<0.01$), which was significant in comparison with the control ($p<0.05$).

Table V
Comparison of treatment changes between FR4 and control groups

Parameter	Experimental ($\bar{x}\pm SD$)	Control ($\bar{x}\pm SD$)	U	p value
Maxillary skeletal and dental				
SNA (°)	−0.455±0.986	0.500±1.650	36	0.165
N. perpendicular-A (mm)	−0.818±1.210	0.650±0.973	15	0.004**
Maxillary length(mm) (Cd-A)	1.227±1.489	2.250±1.379	33	0.119
Convexity (mm)	−0.773±1.679	0.100±1.022	38	0.207
SN-PP (°)	−0.500±0.894	−0.550±1.117	54	0.943
PP-MP (°)	0.727±1.191	−0.250±1.137	81	0.061
Occ-PP (°)	−1.000±2.408	−0.900±3.703	48	0.621
Occ-MP (°)	1.818±2.272	0.650±4.110	73	0.203
U1-SN (°)	−3.864±4.050	−0.100±3.502	29	0.061
U1-NA (°)	−3.091±3.974	−0.800±4.917	41	0.329
U1-NA (mm)	−1.136±1.142	0.000±1.434	26	0.035*
U1-FH (mm) (dental height)	3.227±1.708	1.750±1.318	82	0.060
U1-PP (mm) (dental height)	1.864±1.185	1.350±1.156	69	0.318
U6-FH (mm) (dental height)	1.545±1.368	5.350±1.248	61	0.696
U6-PP (mm) (dental height)	0.545±0.611	0.600±0.937	58	0.827
Mandibular skeletal and dental				
SNB (°)	0.364±0.778	0.500±1.247	41	0.285
Facial angle (°)	0.000±1.871	0.850±0.784	35	0.155
N. perpendicular-Pog (mm)	0.227±2.805	−0.900±2.221	72	0.229
Mandibular length(mm)(Cd-Gn)	3.182±2.160	3.150±1.796	57	0.915
Ramus height (mm)	1.545±1.457	1.200±0.789	62	0.613
Gonial angle (°)	0.091±1.841	−1.200±1.585	80	0.081
L1-MP (°)	0.318±3.002	0.000±2.877	61	0.671
L1-NB (°)	0.955±3.402	−0.300±2.898	63	0.571
L1-NB (mm)	0.682±1.290	0.350±0.580	62	0.603
L1-MP (mm) (dental height)	1.682±1.210	0.800±0.587	81	0.062
L6-MP (mm) (dental height)	0.318±0.956	0.000±0.527	72	0.219
Vertical				
Facial axis (°)	0.727±1.367	0.600±1.792	62	0.644
FMA (°)	1.045±1.739	−0.700±1.229	87	0.023*
Facial height(%)(UFH/LFH)	0.014±0.018	0.007±0.034	67	0.369
Lower face height (°)	−0.818±1.505	−0.300±1.874	47	0.569
Posterior face height(mm)(S-Go)	1.455±2.006	1.700±1.438	56	0.972
Anterior face height(mm)(N-Me)	2.682±1.488	1.500±0.850	83	0.042*
Jarabak ratio (%)	−0.300±0.015	0.700±0.013	38	0.204
Mandibular arc (°)	−0.273±2.630	−0.050±2.409	56	0.972
Anterior open-bite (mm)	2.636±0.710	1.100±1.101	98	0.002**

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

Discussion

Although the treatment period used here of one year and two months was less than the proposed Fränkel treatment duration, the changes observed during this period gave sufficient information about the efficiency of FR4.

There has been only one study on the effects of the FR4 appliance since that of FRÄNKEL AND FRÄNKEL[18]. OWEN[21] reported the results of treatment of some open-bite patients using the FR4. Accordingly, we shall compare our results with those of FRÄNKEL AND FRÄNKEL[18,19].

The FR4 appliance was found to affect the changes in dental structures rather than skeletal configuration.

Although not significant when compared with the control, vertical eruption of the upper and lower incisors in the FR4 group was found more frequently. This vertical eruption of incisors in the FR4 group combined with the retraction of the upper incisors which would have affected the vertical height, were considered to be the main reasons for the decrease in open-bite. This change may have resulted from the lip seal exercises and the change from mouth breathing to nasal breathing, which in turn would have caused the tongue to alter its postural position backward, thus allowing the incisors to erupt freely.

Our findings show that the use of the FR4 appliance caused some backward rotation of the mandible (FMA: 1.045°), which was significant when compared with the control. However, this contradicts the findings of Fränkel's study, where appliance caused anterior rotation of the mandible, whereas backward rotation of the mandible continued in his control sample.

In addition, the fact that the increase in the anterior face height in our experimental group was significantly greater than in the control suggests that the appliance restricts the natural anterior rotation of the mandible, as seen in the control sample.

FRÄNKEL AND FRÄNKEL[18,19] explained the forward rotation of the mandible as an increase in posterior face height, which they attributed to compensatory growth at the condyle and raising of the anterior part of the mandible as a result of lip seal exercises. No such anterior rotation of the mandible was observed in our group, although they performed lip seal exercises throughout the treatment, and no significant increase in ramus height was observed in compaison with the controls.

FRÄNKEL AND FRÄNKEL[18,19] stated that in their experimental group, posterior maxillary and mandibular dentoalveolar growth was not inhibited by use of the appliance, although they did not believe that maxillary dentoalveolar excess was a factor causing open-bite. We also found that the use of FR4 did not change the normal eruption of the upper and lower first molars in compaison with the control. FRÄNKEL AND FRÄNKEL[18,19] set out from Nahoum's finding that the distance from the maxillary first molar to the palatal plane was not significantly different from that in normal subjects. More recent research has shown that posterior maxillary dentoalveolar excess is a significant finding in open-bite cases. From this viewpoint, this is one area that has to be controlled during the treatment of skeletal open-bite.

Importance of vertical control in the treatment of malocclusion has been stressed many times[1,8,15,21]. OWEN[21] stated that the FR4 appliance did not prove effective in his study, in agreement with our results. He modified the appliance by adding a posterior bite block and tubes for occipital-pull head-gear for positive control of the posterior maxilla.

McNAMARA[22] stated that patients with an excessive vertical dimension were least likely to benefit from the Fränkel treatment, and therefore he combined the FR4 appliance with a vertical-pull chin cap in patients with skeletal open-bite.

It is not clear why excessive eruption of posterior theeth, causing backward

rotation of the mandible, occurs in children with open-bite, although the occlusal forces are not low during this period in comparison with normal individuals. The findings of PROFFIT's group[23,24] suggest that the long face pattern present in children when occlusal forces are not low, is not a cause of, but rather an effect of this condition. INGERVALL et al.[25] in their study concluded that the long face morphology characterisitc of mouth-breathing children, is not due to weak muscles.

The theory of soft tissue stretching proposed by SOLOW et al.[26] states that in upper airway inadequacy a mouth breather will alter his head posture, and that this in turn will affect craniofacial morphology. This change in head posture may increase the interocclusal space, causing excessive eruption of posterior teeth.

Considering the results of these studies, it seems improbable that lip seal exercises, which are highly recommended by FRÄNKEL AND FRÄNKEL[18] can alter growth direction by strengthening the elevator muscles, which in any case are not weak during this period.

Further research on this subject may result in different conclusions, and by focusing treatment planning on the cause of the vertical excess, it should be possible to alter the direction of growth in the early mixed dentition period.

Summary and Conclusions

The effects of the FR4 appliance in cases of skeletal open-bite were evaluated cephalometrically and the following conclusions reached:

1-The FR4 appliance did not produce any skeletal changes.

2-No significant changes in facial proportions occurred.

3-The lack of any significant increase in ramus height and an unexpected slight posterior rotation of the mandible contradict the hypothesis on which this appliance is based.

4-The amount of open-bite decreased significantly in the FR4 group. Vertical eruption of the upper and lower incisors and retraction of the upper incisors are considered responsible for the closure of open-bite.

The FR4 appliance was found to affect dental structures rather than skeletal configuration, thus failing to improve the facial pattern, and merely masking the existing vertical problem.

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