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Stability of Pharyngeal Airway Dimensions, Tongue and Hyoid Changes after Treatment with a Functional Appliance

By S Yassaei, Z Tabatabaei, R Ghafurifard

Abstract: *Because stability is known as the fundamental key of the successful outcomes of orthodontics treatment, this study investigated the stability of tongue, hyoid bone and airway dimensions at least two years after active treatment with Farmand functional appliance in patients with class II div1 malocclusion.*

Conclusion: *The present findings indicate that treatment with functional appliance has the potential to increase pharyngeal airway dimensions and changes in tongue and Hyoid position. Importantly, these achieved changes seemed to be maintained in long term, up to 4 years on average.*

Key words: *stability, functional, tongue, hyoid*

Introduction

Functional appliances are mostly used in treatment of class II malocclusion and lead to improve malocclusion by stimulating mandibular growth through its anterior displacement.[1,2] Specially functional appliances result in anterior displacement of the tongue, as a result, the pharyngeal airway is broadened and also they can be used in treatment of Obstructive Sleep Apnea (OSA).[3-5] Obstructive Sleep Apnea (OSA) is a problem resulting from repeated obstruction of the upper respiratory tract during sleep. Even though the exact pathology of OSA is not recognized completely, but mandibular reterognatism is one of proposed causes.[6-9] Various researchers have reported the effect of mandibular advancement on improving the condition of adult OSA patients.[10-17] Similarly, it has been determined that treatment of mandibular deficiency with functional appliances results in positional changes of the tongue and hyoid bone and thus increase the diameter of the airway during treatment.[18-21] If these reported effects are stable, functional therapy can be very important. Hanggi et al [21] studied the long term changes in pharyngeal air pathways following treatment with headgear activator and fixed orthodontic treatment in Class II skeletal malocclusion and concluded that ANB angle decreased and pharyngeal region, length of the pharynx and the shortest distance between the tongue and the posterior wall of the pharynx increased significantly during treatment and remained stable on long term follow up. The present study evaluated the changes in the tongue position, hyoid bone and the airway dimensions following treatment with Faramand functional Appliance (Figure 1) and stability of these changes at least 2 years after completion of treatment.

Several types of functional appliances currently used for treatment of class II malocclusion with mandibular deficiency are prepared for improving skeletal imbalances, arch form, and orofacial function. Farmand is a kind of functional appliance that was designed and introduced in 1972 by Farmand S.M. and registered in Loyola University.[22] This appliance is used by most Iranian orthodontists. This appliance consists of flexible arches, tongue bow and stop bow at mesial of first molars.

Materials and Methods

This was a descriptive analytical study done by the historical cohort method. Of the 35 patients of the previous study who were treated by Farmand appliance

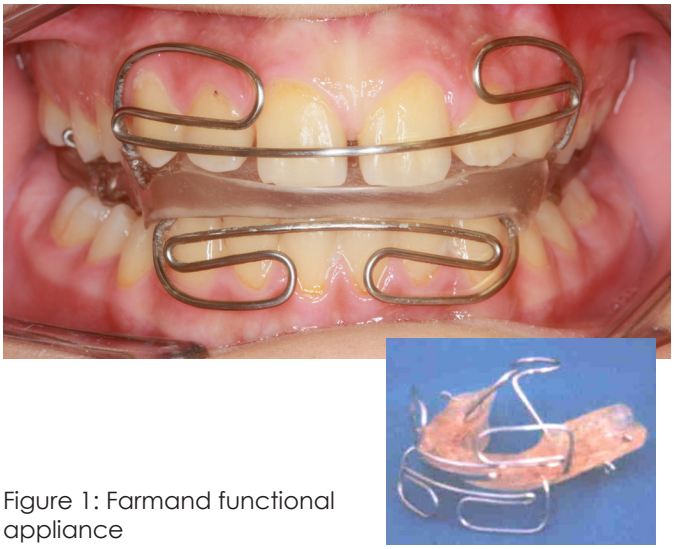

Figure 1: Farmand functional appliance

Figure 2: Pretreatment photographs of frontal, profile and intra oral view of a patient.

Figure 3: Post treatment photographs of frontal, profile and intra oral view of the patient.

(Figures 2,3) and their cephalometries had been traced.[23, 24] Only 23 were of the patients with Class II malocclusions due to mandibular deficiency were available at 2 years (Mean of 4 years with a range of 2 to 8 years). Their active treatment with Faramand functional appliance was studied.The population under study included 15 girls and 8 boys with age range of 15 to 21 years (Mean of 16.5 years).

Lateral cephalometries of before and after treatment and at least 2 years follow up were traced (Figure 4). The variables obtained on previous tracing were compared with the variables obtained at least 2 years after completion of treatment in order to study the stability of the changes of the airway passages, tongue and hyoid bone due to treatment with Faramand appliance. All of the cephalometries were taken at the Sajjad Radiology Clinic with a PM_2002 model EC machine and Kodak film under standard conditions (teeth in occlusion, lips at rest position and natural head position) with no difference in magnification of the three-stage radiographs. The radiographs of each patient were hand-traced 2 times with one week interval by one person and in cases of difference; the mean value was calculated and recorded.

Table 1 presented definitions of cephalometric landmarks, linear and angular measurements used in this study.

Results

Table 2 shows the mean values of all cephalometric variables and the paired t-test results changes the occurred during treatment with Faramand functional appliance. Changes of all variables during treatment was significant except Pmp-u/NL. Table 3 shows the paired t-test results changes that occurred during the post treatment period. Table 4 shows that changes of all variables in immediately after treatment and at least 2 years after treatment.

Discussion

Tongue:

This study showed that the changes in length and height of the tongue after treatment with Faramand functional appliance were significant and this increase in height and length persisted years after completion of treatment. Similarly, tongue posture (V-T/FH) became flatter no significantly and remained stable in follow up period.

Similarly Almeida et al[12] and Battagel et al[10] reported that the length and height of the tongue increases after treatment with functional appliance.

Kollia et al[25] and Vig and Cohen[26] reported increases in tongue dimension with age. The present study showed increased dimensions of the tongue even after completion of treatment.

Table 1: Definitions of cephalometric landmarks, linear and angular measurements used in this study (figure 5).

Airway Passages and Tongue[12,24]

Valeculla (V) = Meeting point of tongue root and epiglottis
H = Most anterior point of tongue in relation to line joining V and T
Upper pharyngeal wall (UPW) = Intersection point of pmp_ba line and posterior wall of the pharynx
Middle pharyngeal wall (MPW) = Intersection point of perpendicular line from U and posterior wall of the pharynx
Lower pharyngeal wall (LPW) = Intersection point of perpendicular line from V and posterior wall of the pharynx
PMP = Perpendicular line from intersection point of anterior and posterior wall of pterygomaxillary fissure to palatal plane
Pmp-u = Distance between Pmp and U (Tip of the uvula) that depicts the long axis and length of the soft palate
V-T = Distance between V and T(Tongue tip) that depicts the length of the tongue
H'□VT = Perpendicular distance from H' to VT that depicts the height of the tongue
Pmp-upw = The shortest distance between Pmp and upw that depicts the nasopharyngeal airway
U-Mpw = Distance between U and mpw that depicts the oropharyngeal pathway
V-Lpw = Distance between V and Lpw that depicts the hypopharyngeal pathway
PAS min = The shortest distance between base of the tongue and the posterior wall of the pharynx
V- FH = Perpendicular distance from V to FH that depicts the perpendicular position of the vallecula
V-C3 = Distance between V and C3 that depicts the horizontal position of the vallecula
SPT = Maximum thickness of the soft palate that is measured by perpendicular plotting on the PMP-U line
Pmp-V = Distance between Pmp and V that depicts vertical airway length
Pmp-u/NL = Soft palate long axis in relation to the nasal line
V-T/FH = Long axis of the tongue in relation to the Frankfurt plane

Hyoid posiion[12]

C3 = Most anterior and the inferior point on the C3 cervical bone of the spinal column
H (Hyoid) = Most anterior-supperior point on the hyoid bone
Retrognathion (RGN) = Most posterior point on the posterior border of the mandibular synphysis
C3-RGN = Distance between C3 and most posterior point on the posterior border of the mandible
H□ C3-RGN = Perpendicular distance from H on the C3-RGN line that depicts the perpendicular position of the hyoid
C3-H and H-RGN = Depicts the horizontal position of the hyoid

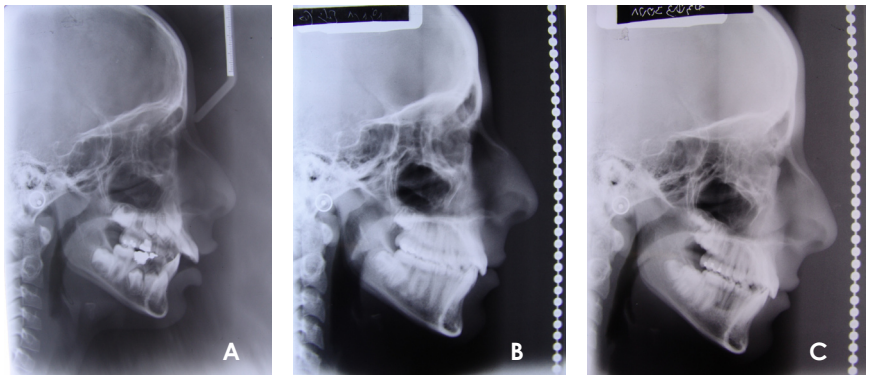

Figure 4: Lateral cephalometric radiographs of another patient. A: Before treatment B: with completion of active treatment C: 41 months after active treatment.

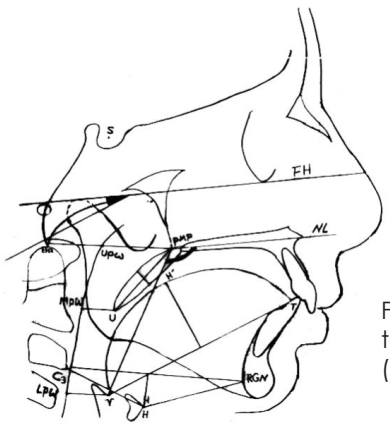

Figure 5: A sample tracing of airways, tongue and hyoid bone of one patient (post treatment)

Liu et al[11] reported a decrease in V-T/FH and position of the tongue in a more leveled plane. In the present study, there was no significant decrease. This can be explained by the statement of Kollia[25] that with an increase in age in both sexes, the tongue attains a more perpendicular position (increase in V-T/FH).

Vallecula position:

The results of the present study showed that the vallecula was displaced anteriorly in the perpendicular plane after treatment with Faramand functional appliance. Treatment with the Faramand appliance results in anterior displacement of the mandible by genioglossus muscle action and also base of the tongue anterior movement. Thus the intersection of the tongue base and epiglottis moves proportionately in the anterior direction. According to the results of the present study, the position of the vallecula was relatively stable at 2 years post treatment. It was also noticed that the vallecula moved significantly downwards during

Table 2: Mean and Standard Deviation of studied variables and their changes during treatment with Faramand functional appliance

Type of Variable	No. of Samples	Before Treatment		After Treatment		Changes*		Pvalue **
		Mean	SD	Mean	SD	Mean	SD	
V-T(mm)	23	69.78	7.16	76.24	5.89	6.46	4.85	0.000
H '□VT(mm)	23	31.43	3.06	35.29	2.87	3.86	3.52	0.000
V-T/FH (degrees)	23	22.96	5.34	21.85	6.01	-1.11	2.80	0.071
V□FH(mm)	23	73.67	6.04	79.65	6.32	5.98	3.67	0.000
V-C3(mm)	23	20.61	4.15	23.13	5.15	2.52	5.17	0.029
Pmp-U(mm)	23	32.83	3.47	35.44	2.80	2.61	2.29	0.000
SPT(mm)	23	8.04	1.02	8.67	1.14	0.63	1.00	0.006
Pmp-U/NL (degrees)	23	136.65	6.09	132.91	5.70	-1.74	5.89	0.171
H□C3-RGN (mm)	23	4.54	4.24	2.76	4.56	-1.78	3.32	0.017
H-RGN(mm)	23	35.15	6.19	37.41	5.87	2.26	4.96	0.040
H-C3(mm)	23	31.98	3.15	34.87	4.25	2.89	3.31	0.000
Pmp-UPW (mm)	23	22.15	4.61	24.46	4.80	2.31	4.45	0.021
U-MPW(mm)	23	9.06	2.75	11.06	3.58	2.00	2.39	0.001
V-LPW(mm)	23	15.21	2.53	17.54	4.61	2.33	3.87	0.009
PAS min (mm)	23	10.43	3.75	12.43	4.36	2.00	2.39	0.003
Pmp-V (mm)	23	57.96	5.32	62.70	5.03	4.74	3.53	0.000

* - Decreased values denoted by – sign and increased values by + sign
** - Paired t-test
(Variables with P < 0.05 considered statistically significant)

Table 3: Mean and Standard Deviation of studied variables and their changes immediately after treatment and at least 2 years after treatment with Faramand Type II functional appliance

Type of Variable	No. of Samples	Immediately after Treatment		At least 2 years after Treatment		Changes*		Pvalue **
		Mean	SD	Mean	SD	Mean	SD	
V-T(mm)	23	76.24	5.89	80.11	5.78	3.87	7.05	0.0156
H'□VT(mm)	23	35.29	2.87	37.65	3.27	2.36	3.17	0.002
V-T/FH (degrees)	23	21.85	6.01	22.59	6.31	0.74	6.92	0.614
V□FH(mm)	23	79.65	6.32	84.00	6.80	4.35	6.69	0.005
V-C3(mm)	23	23.13	5.15	23.89	6.21	0.76	6.94	0.604
Pmp-U(mm)	23	35.44	2.80	36.61	3.54	1.17	3.72	0.145
SPT(mm)	23	8.67	1.14	8.87	1.16	0.20	1.10	0.405
Pmp-U/NL (degrees)	23	132.91	5.70	122.39	5.90	0.48	7.49	0.726
H□C3-RGN (mm)	23	2.76	4.56	3.50	5.39	0.74	4.39	0.428
H-RGN(mm)	23	37.41	5.87	39.43	5.18	2.02	5.50	0.092
H-C3(mm)	23	34.87	4.25	37.06	5.07	2.19	4.47	0.028
Pmp-UPW (mm)	23	24.46	4.80	25.89	4.26	1.43	4.54	0.144
U-MPW(mm)	23	11.06	3.58	10.15	3.14	-0.91	3.44	0.216
V-LPW(mm)	23	17.54	4.61	16.56	4.32	-0.98	4.57	0.316
PAS min (mm)	23	12.43	4.36	12.20	4.47	-0.24	4.10	0.782
Pmp-V (mm)	23	62.70	5.03	67.09	6.32	4.39	7.74	0.013

* - Decreased values denoted by – sign and increased values by + sign
** - Paired t-test
(Variables with P < 0.05 considered statistically significant)

treatment and even post treatment. This can be explained by the statement of Kollia[25] that the tongue mass expands in the downward direction (Caudally) with an increase in age.

Soft palate:

The results of the present study showed that the length and thickness of the soft palate increased significantly after treatment with Faramand appliance and there was no significant change at least 2 years post treatment. Similarly, angle of Pmpu/NL decreased by 1.74 degrees. In other words, the soft palate was placed more perpendicularly, but this was not significant (P = 0.171). This change was stable after completion of treatment.

Yahua Liu[11] reported that treatment of mandibular repositioning resulted in a significant increase in the length of the soft palate and decrease in the angle of Pmp-u/NL by 1.24 degrees that was not significant. This was in line with the results of the present study but unlike the present study, he did not report any changes in the thickness of the soft palate.

In the study by Poon et al[14] too, there was an insignificant decrease in the soft palate long axis angle that is in line with the results of the present study.

Hyoid position:

In the perpendicular plane it was noted in the present study that treatment of patients with Class II malocclusion by Faramand appliance resulted in displacement of hyoid bone in upward direction but it moved back in the downward direction at least 2 years post treatment. This was not significant.

The findings of Battagel et al,[10] Poon et al,[14] Almeida et al,[12] Liu et al[11] and Doff et al[13] that showed that the hyoid bone moved upwards after treatment with functional appliances. The Robertson[15] study did not show this.

The hyoid bone does not have any articulations with other bones and is held in position only by muscles and ligaments.[27] It can be said that the position of hyoid bone in rest position is affected by the balance between stretching of suprahyoid and infrahyoid muscles and any change in this balance will affect its position. There are two explanations for the upward displacement of hyoid bone.

First, the functional appliance places the mandible in a more anterior position because of the tongue attachment to the hyoid and mandible because it is pulled forwards along with the mandible. The force exerted by the activity of the hyoglossus muscle results in displacement of the hyoid bone.[11]

Second, the hyoid bone is attached by the geniohyoid, myelohyoid and anterior ventricle of the digastrics muscle to the mandible. These three muscles are also responsible for downward movement of the mandible. Therefore, during treatment with Faramand appliance, hyperactivity is created in these muscles placing the mandible in a downward position. As a result an imbalance is created between suprahyoid and infrahyoid muscles and the hyoid bone is displaced in the upward direction.

Horizontal plane: In the present study, the hyoid bone moved significantly in the anterior direction (P < 0.001) and the linear distance between the most anterior point on the hyoid and the most inferior-anterior point on third cervical spine increased significantly. The significant anterior displacement of the hyoid bone in the present study might be due to the functional therapy. Ordubazari et al[28] do not agree with our results. Others studies agree with our research (Zhou et al,[18] Battagel et al[10]). Due to tongue attachment, when the functional appliance places the mandible in a more forward position, the base of the tongue along with the hyoid bone is also pulled anteriorly by the muscles.

Two years post treatment, the hyoid bone continued to displace anteriorly. Considering the fact that the hyoid bone moves insignificantly in the anterior direction during growth period,[28] this anterior displacement could be due to the stability of the mandibular position and ANB changes after functional therapy and stretching of the genioglossus muscle.

Airway:

The results of the present study showed that functional therapy has the potential to increase the airway dimensions during treatment and it seems that the increase in airway dimensions remains stable over a long period (mean of 4 years with a range of 2 – 8 years). These changes can prevent Obstructive Sleep Apnea (OSA) as the soft tissue changes due to increasing age, obesity and genetic factors result in decrease in the primary oropharyngeal airway making the person more prone to OSA and snoring.[21] In this study the nasopharyngeal dimensions increased significantly after treatment(P = 0.021) and this change was stable at least 2 years post treatment.

In the study by Poon et al[14] and Tsuiki[16] functional appliance treatment was used for treatment of sleep obstructive apnea, in adult patients, with an increase in nasopharyngeal airspace dimensions.

The significant increase in the oropharyngeal airspace dimensions in the sagittal plane after treatment (P = 0.01) was also stable at least 2 years post treatment. The study by Ordubazari et al[27] showed that oropharyngeal space changes in the sagittal plane during the growth period are minimal, the significant changes depicted the effect of the functional appliance on the oropharynx.
The study of Ozbek et al[29] and Athanasiou et al[17] were also in accordance with our results. Similarly, in the studies

Table 4: Changes of all variables in immediately after Treatment and at least 2 years after Treatment.

Variables		Immediately after Treatment	At least 2 Years afer Treatment
Tongue	Length	Increase*	Increase*
	Height	Increase*	Increase*
	Posture	Flatter	Stable
	Vallecula	Shifted forward*-downward*	Shifted forward-downward*
Soft Palate	Length	Increase*	Stable
	Thickness	Increase*	Stable
	Posture	More upright	Stable
Hyoid bone	Hyoid bone	Shifted forward*- upward*	Shifted forward*- downward
Air way dimension	Nasopharyngeal	Increase*	Stable
	oropharyngeal	Increase*	Stable
	hypopharyngeal	Increase*	Stable
	Minimal pharyngeal space	Increase*	Stable

* Significant

by Battagel,[10] Doff,[13] Liu,[11] and Robertson,[15] functional appliances were used for the treatment of sleep apnea in adults and an increase in oropharyngeal space dimensions was reported in all of them.

As most of the respiratory associated problems are present in the velopharynx,[30] improvement of airways by use of Faramand appliance increases the importance of functional therapy. Though the effect of the forward displacement of the mandible on the velopharynx is complex, there are two possible mechanisms: the base of the tongue is situated in front of the anterior wall of the soft palate and the forward displacement of the tongue reduces its gravitational effect on the soft palate.[11] As the side wall of the soft palate is attached to the base of the tongue by the palatoglossal muscle, it is possible that the anterior displacement of the mandible results in decrease in the collapse of the velopharynx and possibly the anterior displacement of the mandible pulls the soft palate forwards via its connections and results in opening of the velopharynx.[11]

There was a significant increase in the hypopharyngeal airspace dimensions (V-Lpw) after treatment (P = 0.009) and this change was stable at least 2 years post treatment. The fact that following treatment the vallecula is displaced anteriorly during treatment can explain the increase in the hypopharyngeal airway dimensions and its stability. The our results are in accordance with studies by Poon et al[14] and Liu et al.[11]

Anterior displacement of the tongue with mandible by functional appliance increases airspace dimension behind it. Isono stated that increase in airway dimensions results from anterior displacement of the mandible even in obese individuals without failure.[31]

In the present study, the distance between the base of the tongue and posterior wall of the pharynx was also studied and it was observed that this space increased significantly and stable.

Ozbek et al[29] and Hanggi et al[21] reported the distance between the base of the tongue and the posterior wall increased significantly following treatment of Class II skeletal patients and in Hanggi study the changes remained stable after completion of treatment. Doff[12] and Battegel[10] also reported an increase in this variable in adult patients with OSA after treatment with mandibular advancement device. These results are in line with the results of the present study.

Another variable used to investigate the changes in airways in the present study was vertical airway length which increased after treatment (P < 0.001). This variable showed a significant increase at least 2 years post treatment and this showed that the vertical height of the airways increases with age. Nelson et al[30] and Hanggi et al[21] in their longitudinal studies realized that the vertical airway length increases between 20-50 years of age and this could be the reason for worsening of conditions of OSA patients with age.[12] This increase in the vertical airway length occurs even in those OSA patients in whom mandibular advancement devices have been used.[12]

Conclusion

Our results indicated that treatment with functional appliance has the potential to increase pharyngeal airway dimensions and changes in tongue and Hyoid position. Importantly, these achieved changes seemed to be maintained in long term, up to 4 years on average.

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