OROPHARYNGEAL AIRWAY CHANGES AFTER RAPID MAXILLARY EXPANSION ASSISTED BY LASER: A CEPHALOMETRIC STUDY

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Abstract

The objective of the present study was to evaluate the changes in the oropharyngeal airway depth, the hyoid bone, the tongue position and the head posture following rapid maxillary expansion assisted by laser in adult patients without any signs or symptoms of respiratory disturbances.

Adult subjects aged 16–24 years with maxillary constrictions and bilateral buccal crossbites were included in the treatment group (n = 12). A control group (n = 15) comprised subjects with normal dento-skeletal features. Expansion appliances were used in the treatment group. Lateral cephalometric radiographs were taken at two intervals: before treatment (T1) and after retention period at 3.22 months (T2). 14 linear and 5 angular measurements were made in all subjects. Paired and independent t-tests were conducted to evaluate changes within and between groups. The results were evaluated within a 95% interval. The statistical significance level was established as $p < 0.05$.

Results revealed significant increase in the length of each of the oropharynx and the tongue following treatment ($p < 0 .001$), but no statically significant changes were found in sagittal oropharyngeal dimensions, tongue height and head posture. Also, hyoid bone position according to mandible showed significant decrease following rapid maxillary expansion (RME) ($p < 0.5$). The nasal pharyngeal width, the middle and the inferior parts of the oropharynx were narrower in RME group either pre- or post-treatment.

RME helped the subject to increase vertical airway length by spontaneous movement of the mandible.

Keywords: Rapid maxillary expansion - oropharyngeal airway - sagittal airway dimension - laser in orthodontics.

IAJD 2016;7(1):109-117.

CHANGEMENT DES VOIES AÉRIENNES OROPHARYNGÉES APRÈS EXPANSION RAPIDE MAXILLAIRE ASSISTÉE PAR LE LASER: UNE ÉTUDE CÉPHALOMÉTRIQUE

Résumé

L'objectif de la présente étude était d'évaluer les changements de la profondeur des voies respiratoires oropharyngées, l'os hyoïde, la position de la langue et de la posture de la tête suite à l'expansion palatine rapide assistée par laser chez des patients adultes ne présentant aucun signe ou symptôme de troubles respiratoires.

12 sujets adultes, ayant 16-24 ans, avec constrictions maxillaires et articulés inversés bilatéraux ont été inclus dans le groupe de traitement. Un groupe témoin (n = 15) a compris des sujets présentant des caractéristiques dento-squelettiques normales. Les appareils d'expansion ont été utilisés dans le groupe de traitement. Des téléradiographies latérales ont été prises à deux intervalles: avant le traitement (T1) et après la période de maintenance à 3,22 mois (T2). 14 mesures linéaires et 5 mesures angulaires ont été réalisées. Les résultats ont révélé une augmentation significative de la longueur de l'oropharynx et de la langue après le traitement ($p < 0,001$). Des résultats non significatifs ont été trouvés dans les dimensions de l'oropharynx sagittal, la hauteur de la langue et de la posture de la tête. En outre, la position de l'os hyoïde selon la mandibule a montré une diminution significative suite à l'expansion rapide de maxillaires ($p < 0,5$). La largeur du nasopharynx, le milieu et les parties inférieures de l'oropharynx étaient plus étroites dans le groupe qui a reçu le traitement soit en pré- ou post-traitement. L'expansion rapide de maxillaires a permis une augmentation de la longueur verticale des voies aériennes par un mouvement spontané de la mandibule.

Mots-clés: expansion rapide de maxillaires – voie oropharyngée.

IAJD 2016;7(1):109-117.

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Introduction

The human facial form is determined largely by the relative positioning of the maxilla and mandible before, during, and after pubertal growth. Harmonious positioning of the maxilla and mandible relative to the cranium facilitates the ultimate function of the jaws and teeth. Also, it forms the anatomical basis of pleasing facial aesthetics. When the maxilla and mandible are not in proportion with each other or to the rest of the cranium, a dentofacial deformity is present [1].

When a skeletal constricted maxillary arch is diagnosed, orthopedic skeletal expansion involving separation of the midpalatal suture is the treatment of choice. Three treatment alternatives are available for this purpose: rapid maxillary expansion (RME), slow maxillary expansion (SME), and surgical-assisted RME (SARME) [2].

Rapid maxillary expansion (RME) is a clinically accepted treatment used by orthodontists for over 100 years, applicable for correcting posterior crossbites, narrow maxillary arches, mandibular functional shift, and dental crowding. RME is performed in two phases. The first phase is an active expansion of the maxilla by means of midpalatal sutural expansion. The second phase of retention allows for calcification of the midpalatal suture [3]. This procedure was first introduced by Angell in 1860, and since then, various appliances have been developed to expand the maxilla [3 - 5].

Since 1971, studies have evaluated the effect of laser on bone regeneration in clinical conditions or cell cultures. Healing is one of the implications of low-power laser therapy [6]. Regeneration is a complicated process and laser might accelerate it. Low-level laser irradiation can increase and accelerate bone regeneration in the midpalatal suture after rapid palatal expansion, hence, reduce retention time [6].

Transverse maxillary deficiency is commonly found in patients with sleep apnea and is also related to abnormal breathing patterns [7]. A reduced transverse dimension of the maxilla and a dental posterior crossbite are commonly associated with higher nasal resistance [8].

Respiratory function plays a significant role in the development of the face and occlusion. It has been hypothesized that chronic nasal obstruction causes hyper divergent facial growth. Evaluation of the pharyngeal airway space (PAS) thus has a very important role in diagnosis and treatment planning of patients with obstructive sleep apnea and dentofacial deformity [9]. The PAS significantly correlated with hyoid position, maxillary and mandibular size, maxillary and mandibular prognathism, and mandibular inclination [10]. Other factors that could influence the dimensions of the oropharynx are tongue position at the time of acquisition of the examination and repositioning of the tongue and the mandible due to the clinical procedure [11]. Pharyngeal size is very important for all subjects and especially for the patient with sleep apnea. The size of the nasopharynx may be of particular importance in determining whether the mode of breathing is predominantly nasal or oral [12]. The change in respiratory function induced by RPE has also been documented [13, 14]

The results of Charoenworaluck suggest that airway dimension and soft palate underwent noticeable changes after treatment with RME whereas the control group changed after growth factor event and changing environment. These changes are usually produced and may be compensated in time by natural growth. Thus RME has been shown to be capable of assisting nature in the process of growth [3], whereas Mucedero found that the favorable skeletal maxillary and mandibular changes produced by maxillary protraction with or without RME were not associated with significant changes in the sagittal oropharygeal and nasopharyngeal airway dimensions [15].

Due to the limited results of rapid maxillary expansion procedures in adults, whether in skeletal or soft tissues such as upper airway, and the development of laser efficiency in the field of orthodontics and maxillofacial structures, the aim of the present study was to determine the effects of RME assisted by laser on the oropharyngeal airway dimensions and the hyoid bone position in both sexes.

Materials and methods

Twelve adult patients (six females and six males), 16-24 years old were treated with rapid maxillary expansion assisted by laser at the Department of Orthodontics, Faculty of Dentistry, Hama University, Hama, Syria. Radiographs were taken in Al-Aswad X-Ray Center in Hama city, Syria. The first lateral radiograph (T1) was taken before expansion therapy and the second (T2) at the end of the retention phase. Mean duration from pretreatment (T1) to post-treatment (T2) was 1.35 year. A control group comprised of 15 subjects (eight females and seven males, 14-24 years old) with normal dentoskeletal features, and one lateral radiograph was taken for each subject (C0).

Treatment procedure

All the treatment procedures were performed by Dr. Shadi Moawad, a Master student in Orthodontics at the Department of Orthodontics, Faculty of Dentistry, Hama University, Hama, Syria.

The device used in the laser application was KaVo KEY Laser III 1243 in the laser unit, erbium lasers, erbiumdoped yttrium aluminum garnet (Er:YAG), at the Faculty of Dentistry, Hama University. It is equipped with four handpieces, each with its own use, namely: 2060, 2061, 2062 and 2063. The handpiece 2062 was used according to the program "Frectomy 2062 50 10" after modifying the program settings according to the followings: "Energy 400mj; Frequency 15hz". The aims of using this handpiece included: (1) causing injury surgery in order to make a deep revitalization of tourism phenomenon, (2) making a passage through

	Studied group	N	Mean ± SD
Age (in years)	RME	12	20.8 ± 3.5
	Control	15	17.7 ± 3.1
	All subjects	15	17.7 ± 3.1

SD: Standard deviation
Table 1: Mean age (in years) of the participants in the study.

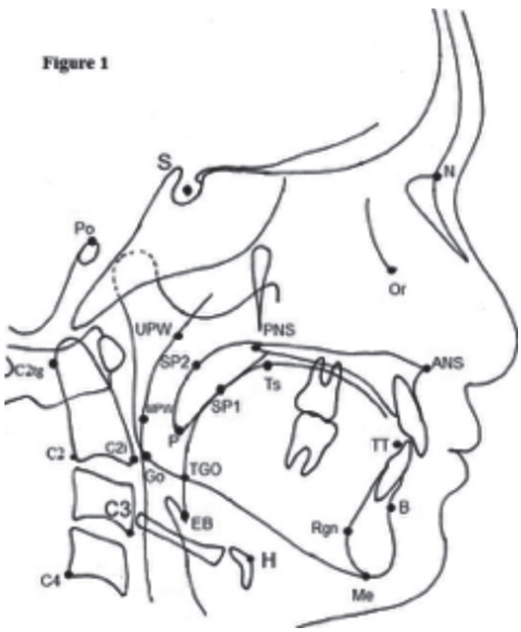

Fig. 1: Reference points used in the study: S: Sella; N: Nasion; ANS: Anterior nasal spine; PNS: Posterior nasal spine; B-point: Point B: The deepest (most posterior) midline point on the bony curvature of the anterior mandible; Go: Gonion; Me: Menton; Or: Orbital; Po: Porion (the most anteroinferior point of the third vertebra); H: Hyoid bone: most anterior superior point of the body of hyoid bone; Rgn: retrognathion: The most posterior point on the symphysis of the mandible.
UPW: Upper pharyngeal wall, a point on the posterior pharyngeal wall identified by an extension of the palatal (ANS-PNS) plane, presenting the width of the oropharynx at level of ANS-PNS; MPW: Middle pharyngeal wall: A point on the posterior pharyngeal wall identified by drawing a line from P to the posterior pharyngeal wall parallel to Go-B line; P: Tip of soft palate; Eb: Base of epiglottis: The deepest point of the epiglottis; TT: Tip of the tongue; TGO: Intersection of the mandible and the pharyngeal surface of the tongue; Ts: highest vertical point of the tongue; Sp1: Point on the oral surface of the soft palate where the thickness of the soft palate is greatest; Sp2: Point on the pharyngeal surface of the soft palate where the thickness of the soft palate is greatest; C3: The most antero-inferior point of the third vertebra [1, 3, 1618-].

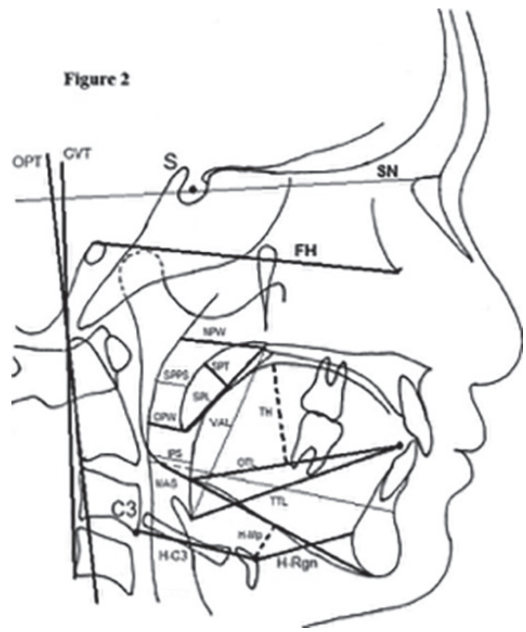

Fig. 2: Diagrammatic representation of airway variables, head posture, hyoid position and tongue position.

Oropharyngel Airway	NPW	Distance between PNS - UPW nasopharyngeal width
	OPW	Representing the width of the oropharynx at the tip of the uvula along parallel line to Go-B line.
	SPPS	The anteroposterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the soft palate on a line parallel to the Frankfort horizontal plane that runs through the middle of the line from PNS to P
	MAS	Middle airway space. The width of airway behind the tongue along line to the Go-B line to the posterior pharyngeal wall; representing the middle airway space
	IPS	Anteroposterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the tongue on a line parallel to the FH plane that runs through C2i
	VAL	PNS-EB: Vertical airway length: Distance between PNS and Eb
Soft Palate	SPL	Soft palate length: The distance from the uvula tip (p) to PNS
	SPT	The maximum thickness of the soft palate, The linear distance between Sp1 and Sp2
Tongue	OTL	TT-TGO: Oral length of the tongue
	TTL	TT-Eb: Total length of the tongue
	TH	Ts/Tt–Tgo: Height of the tongue
Hyoid bone	H–Rgn	Distance from H to Rgn
	H-MP	The perpendicular distance from hyoid bone to the mandibular plane
	H-C3	Distance from hyoid bone to the third vertebra

Table 2: Reference lines and angles used in the study [1, 3, 16-18].

the gingiva toward bone for using the following hold (2060).

"2060" handpiece was used (Laser Handpiece 2060 – Caries therapy / surgical) in order to make osteal perforation in mild palatal suture through the selection of the program (27.apictomy 2060 (with cooling, program settings were modified according to the following: Energy 400mj; Frequency 15 Hz. Finally, a palatal expansion device was activated directly after the completion of laser application. Laser has been applied in the study group once a month, until obtaining the desired result.

A hyrax type expander (DENTARUM®) was used in this study. Semi rapid maxillary expansion (SRME) was performed by activating the palatal screw two-quarter turns per day for the first week, followed by one-quarter turn every two days. The purpose was to cause sutural disarticulation by achieving contact between upper lingual cusps and lower buccal cusps; clinically, a diastema between the upper central incisors occured. Then the expander was used as a retention appliance for 3.22 months.

Cephalometric measurements

All the lateral cephalometric radiographs were taken using a standardized technique, with the tooth in centric occlusion and the lips relaxed. The subjects stood with the sagittal plane parallel to the film and the bilateral ear rods gently inserted into the external auditory meatus to stabilize the head position during exposure. The head was adjusted so that the Frankfurt horizontal plane was parallel to the floor.

All the lateral cephalometric radiographs were hand-traced using 0.5 mm lead 2H pencil on 0.003 mm matte acetate tracing paper in a darkened room with extraneous light from the viewing box blocked out. All tracings were performed by one investigator.

The values at T1 and T2 and the differences between the two values were evaluated for each variable. 24 landmarks were identified (Fig. 1), which were used to perform 15 linear and 5 angular measurements (Table 2). There were 5 linear items for the pharyngeal airway depth and one for its length , 4 linear items for the hyoid bone position.3 linear items for tongue position, 2 linear items for uvula and 5 angular items for head posture (Fig. 2): SN–OPT, SN–CVT, ANS-PNS/ OPT, ANS -PNS/CVT, and OPT–CVT angles [1, 3, 16 -18].

	Variable	Pre-treatment	Post treatment	
		Mean ± SD	Mean ± SD	p
Oropharyngeal airway (mm)	NPD	23.29 ± 2.14	23.56 ± 2.26	0.570
	OPW	11.81 ± 2.26	11.83 ± 1.62	0.972
	SPPS	12.00 ± 1.34	11.94 ± 1.68	0.839
	MAS	10.42 ± 1.46	9.90 ± 1.64	0.198
	IPS	10.08 ± 0.81	9.50 ± 1.70	0.282
	VAL	63.29 ± 7.13	67.29 ± 6.37	0.000**
Soft palate (mm)	SPL	31.63 ± 4.08	31.92 ± 3.60	0.557
	SPT	8.54 ± 1.19	9.04 ± 1.12	0.060
Tongue position (mm)	OTL	64.46 ± 5.54	67.65 ± 6.21	0.003**
	TTL	71.83 ± 4.32	74.79 ± 5.38	0.002**
	TH	19.96 ± 3.50	20.81 ± 2.69	0.136
Hyoid position (mm)	H-C3	34.19± 2.49	34.54 ± 2.73	0.490
	H - RGN	39.90 ± 3.95	38.23 ± 3.89	0.041*
	H - MP	20.21 ± 2.16	19.23 ± 1.61	0.048*
Head posture (Degree)	CVT -SN	110.79 ± 7.13	111.25 ± 6.98	0.623
	OPT - SN	107.96 ± 7.49	107.83 ± 7.34	0.885
	CVT -OPT	2.75 ± 0.89	2.77 ± 1.10	0.923
	CVT -SPP	100.67 ± 4.77	100.90 ± 5.46	0.803
	OPT - SPP	96.69 ± 4.53	97.10 ± 5.21	0.602

*: Significant at $p < 0.05$; **: Significant at $p < 0.01$.
Table 3: Comparison of pre- and post-treatment values of the RME assisted by laser.

Statistical analysis

The results were calculated using SPSS® statistical software (version 11.0 for windows, SPSS Inc., Chicago, Illinois, USA).

The statistical analyze was performed to analyze and compare the changes in the cephalometric variables pre- and post-treatment with laser assisted rapid maxillary expansion using paired sample t-test. Independent t-tests were conducted to evaluate changes between groups. The results were evaluated within a 95% interval. The statistical significance level was established as $p < 0.05$.

Descriptive statistics, including mean and standard deviation values were calculated for each of the cephalometric sets of measurements.

Results

To know if there are significant differences in mean values of each variable between pretreatment and post-treatment period, a paired sample t- test was used.

Changes in treatment group

While sagittal measurements of the oropharynx (NPW, OPW, SPPS, MAS, IPS) did not show significant differences due to treatment (Table 3), the oropharyngeal length VAL (PNS - Eb) showed significant increase ($p<0.001$, table 3). There were no statistically significant differences in soft palate between pre and post-treatment (table 3).

As for the tongue length (OTL), TTL distances showed significant increase after treatment ($p< 0.05$; table 3), but no change in tongue height TH.

Although the hyoid bone position according to cervical vertebrae was not affected by treatment, the sagittal position showed forward movement demonstrated by the decrease in H–Rgm distance 38.23 mm ($p < 0.05$; table 3). Hyoid bone-to-mandibular plane distance (H-MP) decreased significantly from pre-treatment to post-treatment: 20.21 and 19.23 mm, respectively ($p< 0.05$).

No patients showed any significant change in head posture (CVT –SN, OPT – SN, CVT –OPT, CVT –SPP, OPT – SPP) during active treatment (Table 3).

Intergroup differences at T1/C0 and T2/C0

Nasal pharyngeal width, middle airway and inferior pharyngeal spaces (NPW, MAS, IPS) were significantly greater in the normal subjects (Table 4). VAL was significantly longer in RME

	Variable	Control group				
		C0 (Mean ± SD)	T1-C0	P	T2-C0	P
Oropharyngeal airway (mm)	NPD	23.56 ±4.65	-3.23	0.036*	-2.95	0.055
	OPW	11.83 ±3.34	-0.57	0.618	-0.55	0.606
	SPPS	12.67 ±2.37	-0.67	0.394	-0.73	0.377
	MAS	12.77 ±3.53	-2.35	0.041*	-2.87	0.016*
	IPS	13.15 ± 3.58	-3.07	0.008**	-3.65	0.003**
	VAL	66.27 ± 10.12	-2.98	0.398	1.03	0.763
Soft palate (mm)	SPL	31.52 ± 2.63	0.11	0.934	0.40	0.741
	SPT	7.65 ± 1.14	0.89	0.058	1.39	0.004**
Tongue position (mm)	OTL	68.88 ±80	-4.43	0.059	-1.24	0.603
	TTL	72.42 ± 80.5	-0.58	0.766	2.38	0.271
	TH	22.40 ± 31.5	-2.44	0.099	-1.59	0.234
Hyoid position (mm)	H-C3	33.38 ± 4.86	0.80	0.608	1.16	0.468
	H - RGN	37.60 ± 3.15	2.30	0.105	0.63	0.646
	H - MP	14.78 ± 3.97	5.43	0.000**	4.45	0.001**
Head posture (Degree)	CVT -SN	111.52 ±6.18	-0.72	0.780	-0.27	0.917
	OPT - SN	106.42±7.24	1.54	0.593	1.42	0.620
	CVT -OPT	4.75±2.77	-2.00	0.025*	-1.98	0.029*
	CVT -SPP	101.47±6.86	-0.80	0.735	-0.57	0.816
	OPT - SPP	95.58±6.44	1.10	0.620	1.52	0.514

*: Significant at $p < 0.05$;
**: Significant at $p < 0.01$.
Table 4 :Statistical comparison between the treated (n = 12) and control (n = 15) groups at the start (T1/C0) and end (T2/C0) of treatment.

group compared with control subjects. Oral and total lengths of the tongue were significantly shorter in subjects with maxillary constriction when compared to subjects in the control group (Table 4). H -MP distance in normal subjects was significantly smaller in patients either pre- or post-treatment, although the treatment caused a significant decrease which indicates a low position of hyoid bone associated with narrowing of the maxilla.

No differences occurred between groups with regard to head posture except (CVT/OPT) which was significantly smaller in the treatment group.

Intergroup differences according to gender (Table 5)

No statistically significant differences were observed in all dimensions between males and females whether pre- or post-treatment except:

-Inferior pharyngeal space (IPS) was significantly narrower in females at the pretreatment stage.

-Vertical airway length (VAL) was significantly longer in males at post-treatment stage.

- Soft palate thickness (SPT) which was thicker in males compared to females at the two stages.

Discussion

There are contrasting findings in the literature regarding the possibility of improving sagittal airway dimensions. In the present study, changes in the upper airway dimensions in patients with maxillary constriction treated with rapid maxillary expansion assisted by laser were analyzed. The treatment changes that occurred in this group were evaluated at two times interval: pretreatment (T1) and post-treatment (T2).

Many studies analyzed the changes of the pharyngeal airway by RME [3, 5], by means of maxillary protraction (da Silva Filho et al. [19]; kilinic et al. [20];

		Pretreatment			Post-treatment		
		F	M		F	M	
Oropharyngeal airway (mm)	Variable	Mean ± SD	Mean ± SD	p	Mean ± SD	Mean ± SD	p
	NPD	22.42 ± 1.97	31.96 ± 5.09	0.165	23.25 ± 1.95	23.88 ± 2.68	0.654
	OPW	10.88 ± 1.30	9.58 ± 0.56	0.160	11.50 ± 1.13	12.17 ± 2.06	0.503
	SPPS	11.92 ± 1.55	12.08 ± 1.23	0.841	12.00 ± 2.09	11.88 ± 1.36	0.905
	MAS	9.79 ± 1.12	11.04 ± 1.58	0.146	9.75 ± 1.66	10.04 ± 1.76	0.774
	IPS	9.46 ± 0.58	10.71 ± 0.40	0.001**	9.25 ± 0.94	9.75 ± 2.31	0.634
	VAL	58.63 ± 6.91	67.96 ± 3.43	0.014	62.58 ± 5.13	72.00 ± 3.11	0.003**
Soft palate (mm)	SPL	31.29 ± 3.22	31.96 ± 5.09	0.792	31.88 ± 3.87	31.96 ± 31.96	0.970
	SPT	7.50 ± 0.45	9.58 ± 0.56	0.000**	8.38 ± 0.54	9.71 ± 9.71	0.031*
Tongue position (mm)	OTL	62.00 ± 3.21	66.92 ± 6.53	0.129	65.46 ± 3.16	69.83 ± 69.83	0.240
	TTL	69.79 ± 2.19	73.88 ± 5.12	0.103	72.21 ± 3.37	77.38 ± 77.38	0.097
	TH	19.96 ± 2.29	19.96 ± 4.66	1.000	20.38 ± 2.11	21.25 ± 21.25	0.597
Hyoid position (mm)	H-C3	33.38 ± 2.38	35.00 ± 2.53	0.279	33.58 ± 1.66	35.50 ± 3.38	0.241
	H - RGN	38.13 ± 4.01	41.67 ± 3.28	0.125	37.13 ± 4.71	39.33 ± 2.86	0.349
	H - MP	19.83 ± 1.75	20.58 ± 2.62	0.572	18.92 ± 1.36	19.54 ± 1.91	0.529
Head posture (Degree)	CVT -SN	108.88 ± 5.44	112.71 ± 8.57	0.377	110.88 ± 5.13	111.63 ± 8.97	0.862
	OPT - SN	106.04 ± 6.22	109.88 ± 8.71	0.401	107.54 ± 5.95	108.13 ± 9.11	0.898
	CVT-OPT	2.71 ± 0.95	2.79 ± 0.91	0.880	3.00 ± 0.63	2.54 ± 1.46	0.497
	CVT -SPP	99.75 ± 3.88	101.58 ± 5.75	0.532	100.71 ± 4.38	101.08 ± 6.80	0.912
	OPT - SPP	95.83 ± 2.80	97.54 ± 5.95	0.539	97.08 ± 3.92	97.13 ± 6.67	0.990

*: Significant at $p < 0.05$; **: Significant at $p < 0.01$.
Table 5: Statistical comparison of the changes between males and females, pre- and post-treatment in the treatment group.

Sayinsu et al. [16]) or by SARME (Vinha et al. [21]).

Considering the fact that mandibular growth has a definite influence on the upper airway dimension, it can be speculated that maxillary growth could also have beneficial effects on the upper airway [22]

Concerning the airway measurements, Özbek et al. [24] showed that only negligible changes occurred in the upper airway during their 1.8 year observation period. The present study did not found any changes in sagittal dimensions of oropharyngeal space after laser- assisted RME. NPD, MAS and IPS were smaller in the treatment group compared with controls. No significant differences were observed between the two groups according to the pharyngeal width posterior to the soft palate: SPPS and OPW. These results demonstrated that the superior and inferior parts of the oropharynx were slightly wider in normal subjects. Charoenworaluck [3] compared the RME group with a control group with normal transversal maxilla. Orthodontic treatment was started with RME, followed by conventional orthodontic treatment. The results suggested that airway dimension and soft palate underwent noticeable changes after treatment with RME.

Mucedero et al. [15] found that the favorable skeletal maxillary and mandibular changes produced by maxillary protraction with or without RME were not associated with significant changes in the sagittal oropharygeal and nasopharyngeal airway dimensions. This contradicted Baccetti et al. [25] who found no significant short- or long-term changes in the sagittal oropharyngeal airway dimension. Kilinc et al. [20] studied demonstration of RPE together with protraction of the maxilla; an improvement of the naso- and oropharyngeal airway dimensions was observed in the short term.

Contrarily, Sayinsu et al. [16] and Cakirer et al. [1] evaluated the effect of using maxillary disarticulation and protraction by face mask on the sagittal airway dimensions; they found amelioration in naso- but not oropharyngeal airways. However, these results should be interpreted with caution because of the small sample size and the lack of a control group.

Tongue posture and habits related to tongue function have been associated with the etiology of malocclusions as well as post-treatment stability [26]. Our results confirm that OTL and TTL are smaller in subjects with narrow maxillae and posterior crossbites. No changes were observed in tongue height versus the same distances in subjects with normal dentoskeletal characteristics. That could be explained by the functional matrix theory which suggests that the width of the maxillary palatal complex is influenced by the location of the tongue [27]. Low tongue posture has also been associated with chronic upper airway obstruction [24]. However, no changes were found in the present study in respect of vertical tongue position into the mouth, which indicates a lack of clear respiratory disorders among the patients.

All of these results clearly showed that RME treatment could change the position of the mandible and tongue length so that they affect the oropharyngeal airway, which is closely related to these structures.

Ozbek et al. [18] confirmed that H-MP is larger in subjects with narrow maxillae and posterior crossbites, but found that maxillary expansion caused a significant decrease in hyoid bone position according to the mandibular plane from pretreatment to post-treatment time intervals. The hyoid bone position remained constant throughout the fixed appliance phase.

Upper airway dimension and head posture were found to be strongly correlated with previous research (Spann and Hyatt [28]; Thach and Stark [29]; Hiyama et al. [22]). Although the head position has been found to be more extended after maxillary protraction [16, 20], head posture and RME assisted by laser were not found to be correlated in the current study. This result is in agreement with the findings of Cakirer et al. [1] who found no statistically significant differences in head posture.

The comparison of the different sex groups didn't show any difference between them, except for soft palate thickness (SPT) and vertical oropharyngeal length (VAL) at T1 and T2 (Table 5). Malhotra et al. [30] found increasing pharyngeal length, size of soft palate, and airway volume in the males when compared to the females. They suggested that these differences were sex-specific and not a function of the body size. So it could be considered that these differences were related to the sex differences and were not the result of treatment.

In the present study, IPS was slightly larger in males only before treatment, but this difference (1.25 mm) did not reflect essential clinical significance. In the previous studies on the effects of RME, there were important differences between the sexes. It is known that the facial skeletal structure significantly increases its resistance to expansion with increasing age and maturity [31]. As girls reach puberty earlier than boys, this may affect resistance to the forces of expansion.

The control group in the present study comprised normal subjects. In many studies, the participants in the control group were Class I occlusion. However, the dentoalveolar and skeletal growth trends in subjects with a narrowed maxillary and posterior crossbite may differ from those of normal subjects. The need to use a maxillary-deficient adequately matched control sample to make valid comparisons is therefore essential [16, 23]. Another limitation of the present study was the two-dimensional airway measurements. Accurate measurements with lateral cephalometric radiographs are very difficult to analyze since the anatomy is different between patients and the superposition of structures and images amplifications do not allow sensitive quantifications of the changes.

Computed tomography and magnetic resonance imaging are able to depict the correct three-dimensional morphology of the airway. However, their use is limited due to high irradiation, cost, and restricted accessibility. Cone beam computed tomography (CBCT), with its low effective radiation dose, represents an alternative technique for comprehensive head and neck evaluation [1].

Conclusion

Several authors have reported changes in the oropharyngeal region when using RME, assessed by 3-dimensional CBCT or 2-dimensional cephalometric analysis.

Within the limitations of the present study, the main conclusions are:

- -RME increased airway and tongue length by spontaneous movement of the mandible.
- -Hyoid bone has a low position in patients with narrowed maxillae.
- -Rapid maxillary expansion assisted by laser didn't yield different results compared to other types of RME.

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