TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2022.20141

Original Article

Does the Alternate Rapid Maxillary Expansion-Constriction/Reverse Headgear Therapy Enhance Pharyngeal Airway Dimensions?

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Cite this article as: Bhaskar N, Sundareswaran S, Vadakkeypeediakkal L, Santhakumar P, Sathyanathan S. Does the alternate rapid maxillary expansion-constriction/reverse headgear therapy enhance pharyngeal airway dimensions?. *Turk J Orthod.* 2022;35(1):7-15.

Main Points

- The Alternate Rapid Maxillary Expansion-Constriction/Reverse Headgear (AltRAMEC/RH) protocol produced more significant improvement in the nasopharyngeal airway dimensions as compared to the Rapid Maxillary Expansion/Reverse Headgear (RME/RH) protocol.
- Changes in the oropharyngeal airway were insignificant with both the protocols.
- Lateral cephalograms can serve as important tools in evaluating the airway, avoiding unnecessary additional radiation exposure.

ABSTRACT

Objective: The enhanced effect of maxillary protraction following the Alternate Rapid Maxillary Expansion-Constriction/Reverse Headgear (AltRAMEC/RH) protocol over the Rapid Maxillary Expansion/Reverse Headgear (RME/RH) protocol has been well documented. However, it is not known if the airway dimensions also follow a similar enhancement. This retrospective cohort study therefore aims to compare dimensional changes in the pharyngeal airway after maxillary protraction following RME/RH, versus AltRAMEC/RH.

Methods: Pre- and post-treatment lateral cephalograms of 46 skeletal Class III patients with maxillary retrusion, who had undergone maxillary protraction using the AltRAMEC/RH or RME/RH protocol were compared for 20 dentoskeletal and airway variables. The waiting period of 6-8 months before initiating treatment served as the control period. The results were statistically evaluated using the paired *t*-test, the independent *t*-test, and the intraclass correlation coefficient.

Results: The nasopharyngeal airway indicators in the AltRAMEC/RH group (PNS-ad1, PNS-ad2, UPD) showed a statistically significant mean increase of 2.09 mm, 2.74 mm, and 1.30 mm respectively. This was significantly more pronounced than the RME/RH group ($P < .001$). The control period did not show any significant change, thus showing the negligible effect of growth on the airway dimension. No significant changes were observed in the oropharyngeal airway indicators for both groups ($P > .001$).

Conclusions: The AltRAMEC/RH protocol produced more significant improvement in the nasopharyngeal airway dimensions as compared to the RME/RH protocol. The changes in the oropharyngeal airway were insignificant with both the protocols.

Keywords: Skeletal Class III, maxillary protraction, pharyngeal airway, nasopharynx, rapid maxillary expansion

INTRODUCTION

Rapid maxillary expansion (RME) along with reverse headgear (RH) therapy is accepted as the cornerstone of early orthopedic interception in developing skeletal Class III malocclusions.[1] Maxillary expansion is an important part of protraction with facemask (FM) as it disarticulates the circummaxillary suture, which is postulated to prime the sutures for more pronounced orthopedic effects.[2] The average protraction by using rapid maxillary expansion/reverse headgear (RME/RH) is reported to be 1.5-3 mm in 10-12 months.[3]

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Received: November 10, 2020
Accepted: July 4, 2021

To open the circummaxillary sutures more extensively and to improve the effectiveness of maxillary protraction, another novel breakthrough protocol was presented by Eric Jein-Wein Liou, which consisted of repetitive maxillary expansion and constriction (Alternate Rapid Maxillary Expansion-Constriction/Reverse Headgear (AltRAMEC) protocol) for a period of 7 weeks followed by maxillary protraction. The amount of maxillary protraction achieved thus was 5-6 mm.[3]

The benefits of these 2 protocols on dentoskeletal and soft tissue structures is now well documented.[4-6] The changes in the nasopharyngeal and oropharyngeal airway following the RME/RH protocol have also been studied, but with conflicting results.[6] Many of them have reported short-term improvement in airway dimensions—the majority of which have reported nasopharyngeal improvement following protraction using FM therapy.[7-11] However, there are reports which do not support the above findings, reporting no significant changes in sagittal nasopharyngeal and oropharyngeal dimensions, with or without RME.[12,13]

Two recent investigations on the effect of the AltRAMEC protocol have reported both dimensional and volumetric increase in the upper pharyngeal airway. One assessed volumetric changes after AltRAMEC without maxillary protraction, while the other used cephalograms to compare dimensional changes in the pharyngeal airway between 2 groups, after undergoing 5 and 9 weeks of the AltRAMEC protocol, followed by maxillary protraction.[6,14] Increase in dimension of the upper airway was reported in both groups, without any significant difference.

The enhanced effect of the AltRAMEC/RH protocol over the RME/RH protocol in improving maxillary protraction has been well documented in various investigations.[4-6] Do the airway dimensions also follow the same improvement? This has not been investigated so far. This study intends to address this lacuna.

The null hypothesis generated was that the dimensional changes in airway occurring as a result of RME/RH or the AltRAMEC/RH protocols may not be different. Thus, the aim of this study was to compare sagittal dimensional changes in the upper and lower airway following treatment with AltRAMEC /RH therapy, versus RME/RH therapy.

METHODS

This was a retrospective cohort study based on data collected from departmental treatment records, including lateral cephalograms of skeletal Class III patients with retrusive maxilla treated with protraction FM, at the Department of Orthodontics, Government Dental College, after obtaining approval from the Institutional Ethics Committee (IEC number: 65/15/DC 28/12/15). A consent waiver was obtained from the IEC Board, as patients who had completed treatment were unavailable and the identity of the patients in the records was not disclosed to the researcher analyzing the cephalograms.

Data from a previous study formed the basis for calculating the sample size.[10] The standard deviation for the change in the nasopharyngeal airway parameter before and after treatment by maxillary protraction was 3.35.

Sample size calculation was done by the formula

$$n = \frac{(Z_\alpha + Z_\beta)^2 s}{d^2}$$

Where, n = sample size

σ = Standard deviation

$Z_\alpha = 1.96$ for $\alpha = 0.05$ (α = type I error)

$Z_\beta = 0.84$ for (1- β) power = 0.20 (β = type II error)

d = difference in mean

To detect a difference in mean of 2 mm (d), a sample size of 23 was deemed necessary to be able to reject the null hypothesis that the means of the 2 groups are equal.

Accordingly, the records of patients with developing skeletal Class III malocclusions who had received dentofacial orthopedic therapy were examined by 2 clinicians (V.P. and P.S.). The pre- and post-treatment cephalograms of patients with skeletal Class III malocclusion due to retrognathic maxilla (CVMI $\leq$ CS3), who had undergone either RME/RH or AltRAMEC/RH therapy, were selected. The records of patients with craniofacial deformities and endocrine problems were excluded.

The study involved 2 groups. Group 1 comprised 23 patients (10 females and 13 males; mean age 10.27 $\pm$ 1.26 years) treated using the AltRAMEC protocol for 5 weeks, using a bonded RME appliance followed by protraction of maxilla. Group 2 consisted of 23 patients (12 females and 11 males; mean age 9.53 $\pm$ 1.50 years) who had undergone maxillary protraction after RME. Hyrax RME screws (A2620 rapid expander, Leone Orthodontic Products, Sesto Fiorentino, Firenze, Italy) and Petit-type FM (Leone Facemask-Dynamic Vertical Adjustable, Leone Orthodontic Products, Sesto Fiorentino, Firenze, Italy) had been used in this study.

A modified acrylic-bonded RME was constructed for each patient. In group 1, the screw of the RME appliance was activated/deactivated twice daily (0.20 mm per turn) during alternate weeks for constriction/expansion respectively over a course of 5 weeks. In group 2, the screw was activated twice daily (0.20 mm per turn) for 2 weeks and then sealed with acrylic after maximum activation.

In both groups, a Petit-type FM was used simultaneously with a maxillary protraction force of 500 g per side with an antero-inferior force vector of approximately 30° to the occlusal plane, applied from the hooks placed in the canine region on the buccal sides of the expanders. The patients were instructed to wear the appliances for at least 15-16 hours per day until a 2-mm positive overjet was achieved as per the institutional protocol. The parents were asked to replace the elastics at least once a day and to record the daily use of the appliances.

At the time of first visit, all patients were routinely registered and records including lateral cephalograms were taken as per institutional protocol (T0). This being a government institution, it caters to the oral health needs of 4 thickly populated districts. Despite early scheduling of appointments for patients needing interceptive treatment, this leads to a delay of 6-8 months for initiation of treatment, at which time the second cephalogram was taken (T1). The third cephalogram was taken at the end of therapy (T2). Accordingly, T1-T0 represented the effect of normal growth and T2-T1 represented the effect produced as a result of appliance therapy. Thus the period from T1-T0 served as a control period and T2-T1, the active treatment period. All lateral cephalometric radiographs of patients had been taken by the same institutional technician using standard operating protocols (PlanMeca2002 CC Proline Cephalostat) and the treatment results were evaluated cephalometrically.

Cephalometric tracings were done on 0.003-inch matte acetate paper by 1 investigator (N.B.) under optimal illumination, and identification of landmarks by another (S.S.) who was unaware of the group to which the radiograph belonged. A digital Vernier caliper was used for recording linear measurements (6-inch, 0.01 mm accuracy, 506-196-20 Absolute Digimatic Digital Caliper, Mitutoyo) and the angular measurement was obtained with a semi-circular protractor to the nearest 0.5°. Structures were retraced in the event of any disparity. A total of 20 parameters were evaluated of which 9 were airway parameters. (Tables 1 and 2, Figure 1) The tracings were done randomly, and later reassembled in the specific groups. After 2 weeks, 15 radiographs were randomly selected and all procedures repeated by the same researcher.

Statistical Analysis

All the statistical analyses were performed by investigator N.B., using the SPSS statistical package (version 18 SPSS Inc., Chicago, IL, USA) for Windows. The analyses performed were the paired *t*-test (to quantify the treatment changes within each group), and the independent *t*-test (to compare the treatment changes between groups 1 and 2). Intra-examiner reliability was tested using the intraclass correlation coefficient (ICC) (Table 3).

RESULTS

Table 4 shows the measurements taken at 2 time periods T0 and T1. The airway variables were not seen to be significantly different. The maxillary skeletal parameters A-Np and ANB had become more negative (−3.46 to −4.20 and −2.17 to −2.93 respectively). The mandibular parameters SNB and Co-Gn showed statistically significant increase ($P < .001$).

Presented in Table 5 is the baseline comparison of cephalometric variables for the skeletal and airway parameters between group 1 and group 2 at the start of treatment. No significant differences were observed.

Table 1. Cephalometric landmarks

S	Sella: The point representing the midpoint of the pituitary fossa (Sella Turcica).
N	Nasion: The most anterior point on the fronto-nasal suture in the mid-sagittal plane.
A	A point: The deepest point of the curve of the maxilla between the anterior nasal spine and the dental alveolus.
B	B point: The deepest point on the bony curvature between the crest of the alveolus and pogonion.
Po	Porion: The most superior point of the outline of the external auditory meatus (“anatomic porion”).
Or	Orbitale: The lowest point on the inferior orbital margin.
ANS	Anterior nasal spine: The tip of the anterior nasal spine.
PNS	Posterior nasal spine: The tip of the posterior nasal spine.
Co	Condylion: The most superior point on the head of the condylar head.
Go	Gonion: The midpoint at the angle of the mandible.
Pog	Pogonion: The most anterior point on the mandibular symphisis.
Gn	Gnathion: The most posterior-inferior point on the outline of the mandible, lies on the contour of the chin at the point of intersection of the facial axis.
Me	Menton: The most inferior point on the symphyseal outline.
Ba	Basion: The most posteroinferior point on the anterior margin of the Foramen magnum.
ad1	Lower adenoid tissue: The point where posterior nasal spine (PNS) – basion (Ba) line intersects the posterior pharyngeal wall.
ad2	Upper adenoid tissue: The point where a line perpendicular to sella (S) – Ba plane passing through PNS intersects the posterior pharyngeal wall.
H	Hormion: The point located at the intersection between the perpendicular line to S–Ba from PNS and the cranial base.
C4	The most infero-posterior point on the corpus of the fourth cervical vertebra.

Table 2. Cephalometric parameters

Head Posture	1	SN-CVT (°)	Downward angle between SN (sella-nasion) and CVT (cervical vertebral tangent).
Maxillary Skeletal	2	Point A to Np (mm)	Point A to a line drawn perpendicular to Frankfort horizontal from nasion.
	3	Co-A (mm)	Effective midfacial length: Distance between condylion and subspinale.
	4	SNA (°)	The angle between the anterior cranial base (SN) and NA line.
Mandibular Skeletal	5	Pog to Np (mm)	Point Pog to a line drawn perpendicular to Frankfort horizontal from nasion.
	6	Co-Gn	Effective mandibular length: Distance between condylion and gnathion.
	7	SNB (°)	The angle between the anterior cranial base (SN) and NB line.
Anteroposterior Relationship	8	ANB (°)	The angle between the NA line and NB line
	9	Wits (mm)	Distance between the two points of intersection of the two perpendicular lines from points A and B to the functional occlusal plane.
Vertical Relationship	10	SN to Go-Gn (°)	Mandibular plane angle: Angle between SN plane and the mandibular plane (between Go-Gn).
	11	Jarabak ratio (%)	Percentage of the anterior and posterior facial proportions: This ratio is obtained by the formula posterior facial height/anterior facial height x 100. Anterior facial height is measured from nasion to menton and the posterior facial height is measured from sella to gonion.
Nasopharynx	12	PNS-ad1 (mm)	Upper airway thickness: The distance from PNS to the pharyngeal wall along the line from basion Ba to PNS.
	13	ad1-Ba (mm)	Upper adenoid thickness: The soft tissue thickness at the posterior nasopharynx wall through the PNS-Ba line.
	14	PNS-ad2 (mm)	Lower airway thickness: The distance from PNS to the adenoid tissue along the line from PNS to the midpoint of the line intersecting Ba to sellaturcica.
	15	Ad2-H (mm)	Lower adenoid thickness: Soft tissue thickness at the posterior nasopharynx wall through the PNS-H line.
	16	UPD (mm)	McNamara's upper pharynx dimension: The minimum distance between the upper soft palate and the nearest point on the posterior pharynx wall.
Oropharynx	17	SPAS (mm)	Superior posterior airway space: 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 FH plane (the line through Po and Or).
	18	MAS (mm)	Middle airway space: The 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.
	19	IAS (mm)	Inferior airway space: The 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. (inferior-most point on posterior border of C2 vertebra).
	20	LPD (mm)	McNamara's lower pharynx dimension: The minimum distance between the point where the posterior tongue contour crosses the mandible and the nearest point on the posterior pharynx wall.

Table 6 shows the results of the analysis of changes within each group and between the 2 groups. Significant maxillary advancement ($P < .001$) and mandibular restriction ($P < .001$) were seen in both groups, leading to improvement in the sagittal discrepancy ($P < .001$).

A comparison of the 2 groups showed the changes in group 1 to be more pronounced, as evidenced by the A-Np, Co-A, SNA, SNB, Pog-Np, ANB, and Wits values ($P < .001$, $=P < .01$). The nasopharyngeal airway also followed the same improvement but only in group 1, as evidenced by the statistically significant increase in PNS-ad1, PNS-ad2, and UPD. There were no significant changes in nasopharyngeal airway in group 2. The oropharyngeal airway dimensions did not show significant changes in either of the groups.

DISCUSSION

A major drawback in most of the investigations on airway changes has been the lack of a control group.[8-11] A few studies have used age- and sex-matched Class III controls[7,12,13] and some have even used Class I as controls.[14,15] However, dentoalveolar and skeletal growth trends differ from person to person, making valid comparisons questionable.[16] To overcome this individual variability, this research used the same patients as the "delayed controls" group, on whom active treatment was administered after a waiting period of 6-8 months only. This made it possible to evaluate and make the comparisons of treatment results more valid. The results of this study showed no significant changes during the period when active treatment had not been started. Hence, the changes observed during treatment period may be attributed to therapy rather than growth.

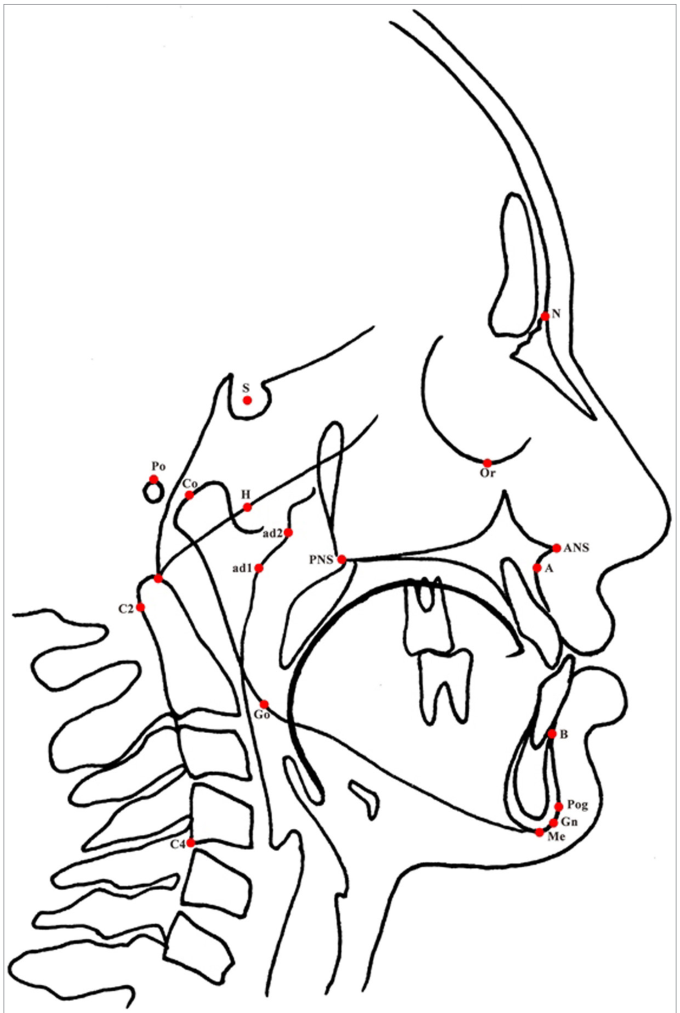

Figure 1. Cephalometric landmarks used (Table 1)

The increase in the anteroposterior dimensions of the nasopharyngeal airway was more significant in group 1 as compared to group 2. This is an important observation of this study. This may be attributed to the increased maxillary protraction obtained in the AltRAMEC protocol being reflected in the pharyngeal structures. Though there are studies proving the efficacy of AltRAMEC/RH over RME/RH in improving skeletal parameters,[4,5] the literature is scant in regard to comparison of airway dimensional changes between these 2 protocols. Hence, a comparison with previous studies was not possible.

The significant increase in sagittal dimensions of upper airway in group 1 are comparable to the cephalometric study by Celikoglu which showed similar significant increase in the linear variables of the upper airway in both treated groups following a 5-week and 9- week AltRAMEC protocol.[17] They attributed the results to the anterior movement of the maxilla.

Table 3. Intraclass correlation coefficients showing the level of agreement

Cephalometric Parameter	ICC
SNA	.988
Pog-Np	.997
PNS-ad1	1.000
LPD	.993

This result also complies with a CBCT study reporting significant increase in nasopharyngeal volume following the AltRAMEC protocol. However, their study did not use an FM for maxillary protraction. They concluded that for retrognathic maxillae, the AltRAMEC protocol alone, without the use of a maxillary protraction device, could not be considered a treatment option.[6]

When analyzing the therapeutic effects of airway modifications, an important consideration is the lymphoid tissue located on the posterior pharyngeal wall.[12] The comparison of the lymphoid parameters ad1-Ba and ad2-H in this study did not show a significant change during the control and treatment periods, attributing the obtained increase in nasopharyngeal airway dimensions to active interventional therapy. This is contradictory to the results obtained by Bacetti et al.[13] who reported a decrease of lymphoid tissue in both treated and control groups. No significant changes in any of the airway variables were reported by Bacetti et al. This could probably be attributed to the younger age of the group in the study by Bacetti et al., when compared with the mean age of the patients in our study group.

Group 2 also showed an increase in the nasopharyngeal airway measurements but this increase was not statistically significant. This is in agreement with previous studies which showed an increase only in upper airway but not in the lower airway.[9-11] A longitudinal follow-up study of 5 years has demonstrated that the changes in the nasopharyngeal airway remained more pronounced and stable during the follow-up period as compared to the treatment period.[11]

The observations made by Kilinç et al.[7] (2006) who studied the effect of RME/RH in 18 patients with Class III malocclusion reported short-term improvement in both nasopharyngeal and oropharyngeal airway dimensions. Later investigations have, however, contradicted these findings.[12,13] This increase in nasopharyngeal airway also complies with the reported improvement in nasopharyngeal airway due to maxillary advancement by other surgical methods of treating skeletal Class III malocclusion, such as conventional LeFort I advancement or anterior maxillary segmental distraction for cleft patients.[18]

The findings of this study indicate that facilitation of maxillary protraction in growing patients with an orthopedic appliance could contribute to enhancement in upper-airway dimensions, thus improving respiratory function in patients with maxillary hypoplasia. This increase is found to be more significant in protraction following AltRAMEC therapy over protraction following the RME protocol. Thus, the early airway improvement reported in our study coheres with the evidence, stressing the importance of stable skeletal changes obtained via early orthopedic intervention in skeletal Class III over later surgical intervention.[19] The advantage of early intervention in skeletal

Table 4. Comparison of changes at first visit (T0) and start of treatment (T1)

		T0		T1		
Variable		**Mean**	**SD**	**Mean**	**SD**	***P***
Head Posture	SN–CVT (°)	102.46	8.26	100.46	7.66	.146
Maxillary Skeletal	A-Np (mm)	−3.46	2.84	−4.20	2.82	.006†
	Co-A (mm)	84.28	4.10	84.41	4.07	.011‡
	SNA (°)	79.46	4.57	79.59	4.56	.030 ‡
Mandibular Skeletal	Pog-Np (mm)	−2.23	5.15	−2.43	5.71	.737
	Co-Gn (mm)	113.52	5.76	115.43	5.72	.000*
	SNB (°)	81.63	4.61	82.52	4.38	.000*
Antero Posterior	ANB (°)	−2.17	2.99	−2.93	2.59	.001‡
	Wits (mm)	−8.71	3.40	−9.07	3.50	.370
Vertical	Sn to Go-Gn (°)	34.28	5.24	33.83	5.49	.397
	Jarabak (%)	62.62	4.52	62.69	4.64	.794
Nasopharynx	PNS-ad1 (mm)	20.74	3.45	20.61	2.95	.695
	ad1-Ba (mm)	22.28	3.90	22.17	3.16	.846
	PNS-ad2 (mm)	17.33	2.23	16.87	2.40	.076
	ad2-H (mm)	17.00	5.05	17.39	4.53	.464
	UPD (mm)	11.65	1.82	12.00	1.73	.088
Oropharynx	SPAS (mm)	14.41	3.42	14.48	2.56	.919
	MAS (mm)	11.71	3.10	11.30	2.23	.464
	IAS (mm)	12.20	4.00	11.41	3.36	.266
	LPD (mm)	11.90	2.44	11.46	2.77	.343

*$P < .001$, †$P < .01$, ‡$P < .05$.

Table 5. Comparison of baseline parameters between the 2 groups: Group 1 (alternate rapid maxillary expansion-constriction/reverse headgear) and group 2 (rapid maxillary expansion/reverse headgear) before treatment

		Group 1 (T1)		Group 2 (T1)		
Variable		**Mean**	**SD**	**Mean**	**SD**	***P***
Head Posture	SN–CVT (°)	100.46	7.66	99.87	10.55	.830
Maxillary Skeletal	A-Np (mm)	−4.20	2.82	−3.11	2.34	.162
	Co-A (mm)	84.41	4.07	83.96	4.58	.723
	SNA (°)	79.59	4.56	80.02	3.54	.720
Mandibular Skeletal	Pog- Np (mm)	−2.44	5.72	−2.59	4.44	.920
	Co-Gn (mm)	115.43	5.73	113.09	5.02	.146
	SNB (°)	82.52	4.38	82.52	3.72	1.000
Antero Posterior	ANB (°)	−2.94	2.59	−2.50	1.64	.500
	Wits (mm)	−9.06	3.50	−6.65	6.03	.104
Vertical	Sn to Go-Gn (°)	33.83	5.94	33.39	5.74	.802
	Jarabak (%)	62.69	4.64	62.48	4.27	.874
Nasopharynx	PNS-ad1 (mm)	20.22	1.57	20.74	1.51	.257
	ad1-Ba (mm)	22.17	3.16	22.39	4.52	.851
	PNS-ad2 (mm)	16.87	2.40	15.35	3.16	.072
	ad2-H (mm)	17.39	4.53	17.61	4.22	.867
	UPD (mm)	12.00	1.73	12.67	3.05	.362
Oropharynx	SPAS (mm)	14.48	2.56	15.13	2.81	.415
	MAS (mm)	11.30	2.23	13.13	2.56	.013
	IAS (mm)	11.41	3.63	14.13	3.33	.011
	LPD (mm)	11.46	2.77	10.37	3.08	.214

*$P < .001$, †$P < .01$, ‡$P < .05$.

Table 6. Comparison of the mean changes between group 1 (alternate rapid maxillary expansion-constriction/reverse headgear) and group 2 (rapid maxillary expansion/reverse headgear) group

Variable		AltRAMEC/RH Difference (T2-T1)			RME/RH Difference (T2-T1)			Unpaired *t*-Test
		Mean	SD	*P*	Mean	SD	*P*	*P*
Head Posture	SN–CVT (º)	1.15	5.78	.35	−2.22	5.25	.055	.044‡
Maxillary Skeletal	A-Np (mm)	2.37	1.38	.000*	1.43	0.53	.000*	.004†
	Co-A (mm)	2.72	1.16	.000*	1.57	0.51	.000*	.000*
	SNA (º)	2.33	1.24	.000*	1.68	2.04	.001*	.197
Mandibular Skeletal	Pog- Np (mm)	−2.85	1.82	.000*	−0.48	1.92	.244	.000*
	Co-Gn (mm)	1.83	1.47	.000*	1.91	1.31	.000*	.833
	SNB (º)	−2.17	1.61	.000*	−0.74	1.91	.077	.009†
Antero Posterior	ANB (º)	3.84	1.82	.000*	3.20	2.15	.000*	.272
	Wits (mm)	4.85	2.57	.000*	2.91	2.92	.000*	.021‡
Vertical	Sn to Go-Gn (º)	1.78	1.68	.000*	0.65	1.27	.022‡	.013‡
	Jarabak (%)	−1.11	1.45	.001*	−0.38	1.65	.281	.119
Nasopharynx	PNS-ad1 (mm)	2.09	1.83	.000*	0.00	0.45	.133	.000*
	ad1-Ba (mm)	0.61	1.50	.064	0.28	3.83	.727	.706
	PNS-ad2 (mm)	2.74	1.18	.000*	0.00	0.45	1.000	.000*
	ad2-H (mm)	0.09	2.86	.885	0.00	2.89	1.000	.919
	UPD (mm)	1.30	1.11	.000*	0.02	1.93	.957	.008†
Oropharynx	SPAS (mm)	0.74	2.38	.150	0.54	3.12	.413	.812
	MAS (mm)	0.43	2.19	.352	−0.13	1.84	.737	.349
	IAS (mm)	0.93	3.17	.170	−0.15	3.15	.819	249
	LPD (mm)	0.59	1.84	.140	0.09	2.81	.884	.479

*$P < .001$, †$P < .01$, ‡$P < .05$.
AltRAMEC, alternate rapid maxillary expansion/constriction; RME, rapid maxillary expansion; RH, reverse headgear.

Class III was highlighted in this interesting study which compared the long-term treatment effects produced by protraction FM therapy (followed later by a second phase of comprehensive fixed-appliance therapy), with untreated Class III controls and with subjects surgically treated with LeFort I maxillary advancement. They have reported that early treatment with orthopedic forces to advance the maxilla might reduce altogether the need for surgical intervention later. If surgery becomes necessary, it might be restricted to only 1 jaw, thereby minimizing complications.[19]

The oropharyngeal airway parameters SPAS, MPS, IAS, OAW, and LPD did not show any significant increase. This is in agreement with previous investigations which have reported an increase only in the nasopharyngeal airway dimensions.[10,11]

The post-treatment posture of the head was seen to be more extended with respect to the cervical vertebrae, as indicated by the mean increase of 1.15° in the SN–CVT angle in the AltRAMEC group. This could be attributed to the counter-clockwise rotation of the maxillary complex, reported in previous studies with maxillary protraction.[16] The upper-airway dimension and head posture observed in our study seem to be in accordance with the findings from previous investigations.[20]

The findings of the present investigation have demonstrated that the AltRAMEC/RH protocol showed significant favorable effects over the RME/RH therapy with respect to the skeletal components of Class III malocclusion, as reported in previous studies.[21-23] The nasopharyngeal airway dimensions also followed a similar improvement. Thus, the null hypothesis stands rejected.

The present study is based on two-dimensional cephalometric measurements of airway structures, and thus, has limitations. However, as lateral cephalograms are used as routine diagnostic aids in orthodontics, they may also serve as important tools in evaluating the airway, avoiding unnecessary radiation exposure when subjected to computed tomographic imaging. Although there are problems of superimposition and magnification in the lateral cephalogram due to the complex anatomy of the pharyngeal airway, there have been studies stating that lateral cephalometric films stand significantly reliable and reproducible in assessing airway dimensions on successive radiographs when attention is given to the reproducibility of head position during image acquisition.[24] A positive correlation between nasopharyngeal airway size on cephalometric films and its true volumetric size as assessed from CBCT scans has also been reported.[25]

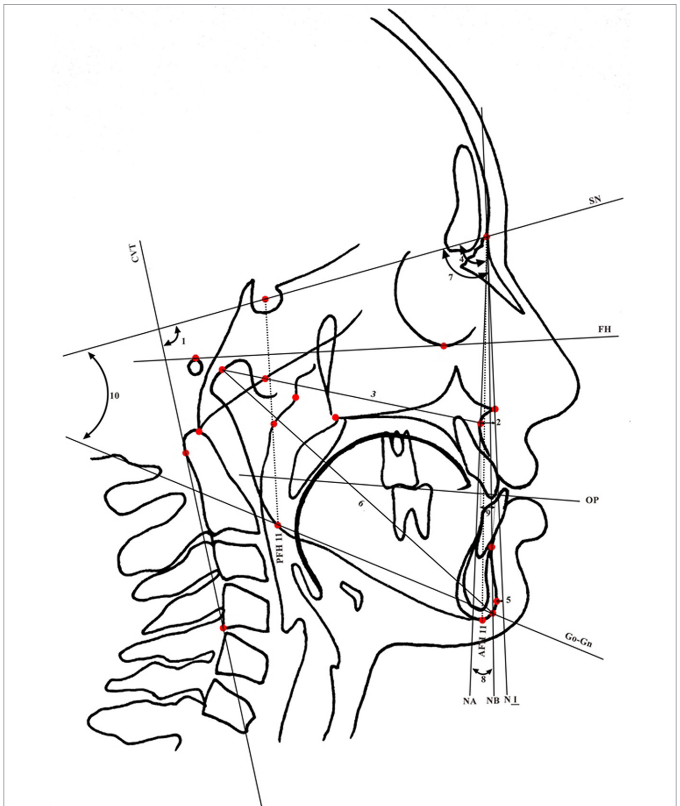

Figure 2. Skeletal parameters and planes used (Table 2)

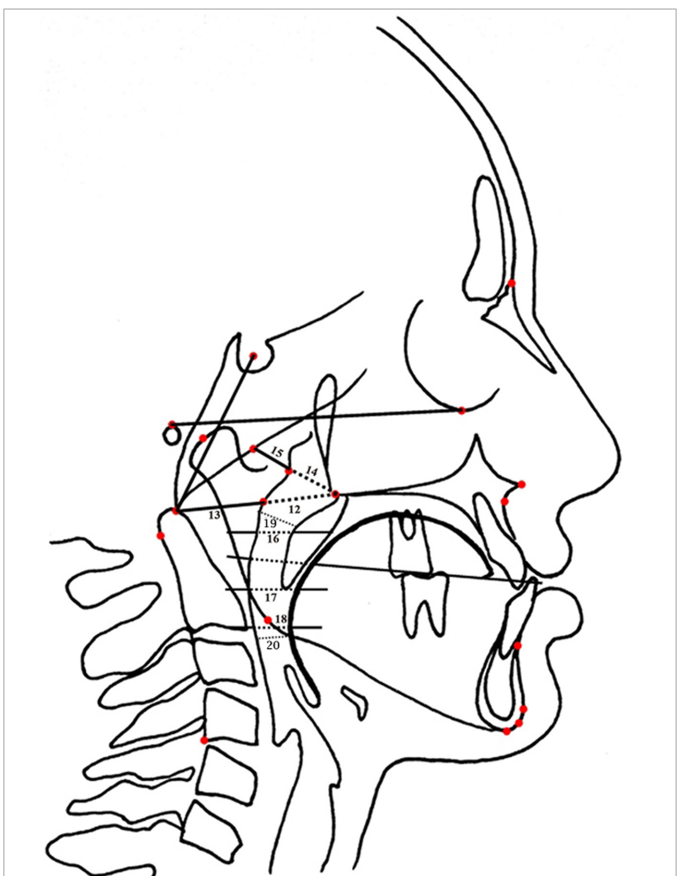

Figure 3. Airway parameters (Table 2)

CONCLUSION

The AltRAMEC/RH protocol produced more significant improvement in the nasopharyngeal airway dimensions as compared to the RME/RH protocol; whereas the changes in oropharyngeal airway were insignificant with both the protocols.

Ethics Committee Approval: Ethics committee approval was received for this study from the IEC number: 65/15/DC 28/12/15 of Government Dental College, Calicut, Kerala, India.

Informed Consent: Departmental Treatment Records used. Consent Waiver obtained from IEC Board.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - S.Sundareswaran.; Design - N.B., S.Sundareswaran.; Supervision - S.Sundareswaran.; Fundings - N.B.; Materials - N.B., S.Sundareswaran.; Data Collection and/or Processing - N.B., L.V., P.S., S.Sathyanathan.; Analysis and/or Interpretation - N.B., S.Sundareswaran.; Literature Review - N.B., L.V., P.S., S.Sathyanathan.; Writing - N.B., S.Sundareswaran., L.V., P.S., S.Sathyanathan.; Critical Review - S.Sundareswaran., L.V.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. McNamara JAJ. An orthopedic approach to the treatment of Class III malocclusion in young patients. *J Clin Orthod*. 1987;21(9):598-608.
2. Vaughn GA, Mason B, Moon HB, Turley PK. The effects of maxillary protraction therapy with or without rapid palatal expansion: a prospective, randomized clinical trial. *Am J Orthod Dentofacial Orthop*. 2005;128(3):299-309. [CrossRef]
3. Liou EJW, Tsai WC. A new protocol for maxillary protraction in cleft patients: repetitive weekly protocol of alternate rapid maxillary expansions and constrictions. *Cleft Palate Craniofac J*. 2005;42(2):121-127. [CrossRef]
4. Isci D, Turk T, Elekdag-Turk S. Activation-deactivation rapid palatal expansion and reverse headgear in Class III cases. *Eur J Orthod*. 2010;32(6):706-715. [CrossRef]
5. Chang Y, Koenig LJ, Pruszynski JE, et al. Dimensional changes of upper airway after rapid maxillary expansion: a prospective cone-beam computed tomography study. *Am J Orthod Dentofacial Orthop*. 2013;143(4):462-470. [CrossRef]
6. Yilmaz BS, Kucukkeles N. Skeletal, soft tissue, and airway changes following the alternate maxillary expansions and constrictions protocol. *Angle Orthod*. 2015;85:117-126.
7. Kilinç AS, Arslan SG, Kama JD, Özer T, Dari O. Effects on the sagittal pharyngeal dimensions of protraction and rapid palatal expansion in Class III malocclusion subjects. *Eur J Orthod*. 2008;30(1):61-66. [CrossRef]
8. Tsai HH, Ho CY, Lee PL, Tan CT. Cephalometric analysis of non-obese snorers either with or without obstructive sleep apnea syndrome. *Angle Orthod*. 2007;77(6):1054-1061. [CrossRef]
9. Oktay H, Ulukaya E. Maxillary protraction appliance effect on the size of the upper airway passage. *Angle Orthod*. 2008;78(2):209-214. [CrossRef]
10. Sayinsu K, Isik F, Arun T. Sagittal airway dimensions following maxillary protraction: a pilot study. *Eur J Orthod*. 2006;28(2):184-189. [CrossRef]
11. Kaygisiz E, Tuncer BB, Yüksel S, Tuncer C, Yildiz C. Effects of maxillary protraction and fixed appliance therapy on the pharyngeal airway. *Angle Orthod*. 2009;79(4):660-667. [CrossRef]

12. Mucedero M, Baccetti T, Franchi L, Cozza P. Effects of maxillary protraction with or without expansion on the sagittal pharyngeal dimensions in Class III subjects. *Am J Orthod Dentofacial Orthop*. 2009;135(6):777-781. [CrossRef]
13. Baccetti T, Franchi L, Mucedero M, Cozza P. Treatment and post-treatment effects of facemask therapy on the sagittal pharyngeal dimensions in Class III subjects. *Eur J Orthod*. 2010;32(3):346-350. [CrossRef]
14. Takada K, Petdachai S, Sakuda M. Changes in dentofacial morphology in skeletal Class III children treated by a modified maxillary protraction headgear and a chin cup: a longitudinal cephalometric appraisal. *Eur J Orthod*. 1993;15(3):211-221. [CrossRef]
15. Tindlund RS. Orthopaedic protraction of the midface in the deciduous dentition: results covering 3 years out of treatment. *J Craniomaxillofac Surg*. 1989;17(suppl 1):17-19. [CrossRef]
16. Shanker S, Ngan P, Wade D, et al. Cephalometric A point changes during and after maxillary protraction and expansion. *Am J Orthod Dentofacial Orthop*. 1996;110(4):423-430. [CrossRef]
17. Celikoglu M, Buyukcavus MH. Changes in pharyngeal airway dimensions and hyoid bone position after maxillary protraction with different alternate rapid maxillary expansion and construction protocols: a prospective clinical study. *Angle Orthod*. 2017;87(4):519-525. [CrossRef]
18. Tahmasbi S, Jamilian A, Showkatbakhsh R, Pourdanesh F, Behnaz M. Cephalometric changes in nasopharyngeal area after anterior maxillary segmental distraction versus LeFort I osteotomy in patients with cleft lip and palate. *Eur J Dent*. 2018;12(3):393-397. [CrossRef]
19. Pangrazio-Kulbersh V, Berger JL, Janisse FN, Bayirli B. Long-term stability of Class III treatment: rapid palatal expansion and protraction facemask vs LeFort I maxillary advancement osteotomy. *Am J Orthod Dentofac Orthop*. 2007;131:9-19.
20. Hiyama S, Suda N, Ishii-Suzuki M, et al. Effects of maxillary protraction on craniofacial structures and upper-airway dimension. *Angle Orthod*. 2002;72(1):43-47. [CrossRef]
21. Baccetti T, McGill JS, Franchi L, McNamara JA, Tollaro I. Skeletal effects of early treatment of Class III malocclusion with maxillary expansion and face-mask therapy. *Am J Orthod Dentofacial Orthop*. 1998;113(3):333-343. [CrossRef]
22. Ngan P, Hägg U, Yiu C, Merwin D, Wei SH. Treatment response to maxillary expansion and protraction. *Eur J Orthod*. 1996;18(2):151-168. [CrossRef]
23. Ngan P, Wei SH, Hagg U, et al. Effect of protraction headgear on Class III malocclusion. *Quintessence Int*. 1992;23(3):197-207.
24. Malkoc S, Usumez S, Nur M, Donaghy CE. Reproducibility of airway dimensions and tongue and hyoid positions on lateral cephalograms. *Am J Orthod Dentofacial Orthop*. 2005;128(4):513-516. [CrossRef]
25. Aboudara C, Nielsen I, Huang JC, et al. Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2009;135(4):468-479. [CrossRef]