Comparison between Effects of Butterfly Hyrax Versus Distalization with or without Expansion on The Nasal Airway in Adolescents after 6 Months

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Abstract

Objectives: The use of cone beam computed tomography (CBCT), to observe through retrospective study the alterations in the nasal airway following rapid maxillary expansion (RME) of butterfly hyrax versus distalization without or with expansion. **Material and Methods:** Data from 48 adolescent female patients were divided into three equal groups, depending on whether they had a constricted maxilla, reduced maxillary intermolar width. Group 1 was a conventional hyrax (E) with an average age of 13.27 years (Y), group 2 was a distalization assisted by expansion (DE) with an average age of 13.38 Y, and group 3 was a distalization without expansion (D) with mean age 13.25 Y. CBCT records were taken before and after six months of RME and/or distalization, so a total 48 CBCTs were analyzed. The airway was segmented and quantified using Romexis software (version 5.3.4.39 USA). **Results:** The intragroup difference between T1 and T2 showed that all groups showed a significant increase in total airway, nasopharynx, retropalatal airway, and nasal cavity, but that all groups showed a non-significant increase in SNA, or Position of maxilla, which was represented by A point to Nasion vertical (NV) in groups 1&3 but does not occur in group 2. The retroglossal airway, in group 3 exhibited a non-significant rise, whereas groups 1 and 2 showed a significant increase. **Conclusions:** Expansion and distalization can increase the total airway volume. Maxillary distalization assisted by expansion does not reduce the airway volume because pure backward skeletal action does not occur as what happens after a maxillary setback in orthognathic surgery.

Key Words: Nasal airway, Rapid Maxillary Expansion, Distalization, Hyrax expander, Miniplates, Cone beam computed tomography, CBCT.

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Introduction:

Maxillary arch constriction associated with Posterior crossbite can be treated using Rapid maxillary expansion (RME) through opening the mid palatal suture. [1, 2]

RME can split the maxilla into two parts which subsequently affect nasal airway hence, nasal cavity volume is increased leading to decreased nasal resistance and improved airflow. [3-5]

Previous studies reported that RME can improve the airway[6-8] on the other hand, other studies reported that RME does not affect oropharynx dimension.[9, 10]

It was mentioned that after distalization in upper arch the airway may be narrowed.[11] while another study reported that distalization might improve the pharyngeal air way after using carrier motion distalizer.[12] Others advocate that distalization has no effect on upper airway dimension and with the application of the skeletally assisted distalization resulted in a significant total arch distalization without a significant effect on the transverse dimensions or changes in the oropharynx airway space.[13-15]

Can RME facilitate the skeletal effects of distalization through disrupting the circum-maxillary sutures and subsequently narrowing the air way?

Objective:

The aim of this study was to compare volumetric changes in the nasal airway after conventional hyrax versus distalization with skeletally anchored appliances assisted by expansion or not using CBCT.

Material and Methods

This retrospective study was performed on records from previous study followed the requirements of the Consolidated Standards of Reporting Trials (CONSORT) (Figure 1) Patients were screened at the orthodontic department's outpatient clinic at Al-Azhar University in Cairo-boys faculty of dentistry. The Faculty Ethics Committee's guidelines for medical research involving persons were followed in conducting this study (approval number: #778/263).

The Egyptian Enhanced Research Ethics Committee, Standard Operating Procedure Guidelines, Monitor 2006, Declaration of Helsinki Guidelines, International Harmonized ICH Conference, and the United States Code of Federal Regulations are all followed by this ethics committee, which is a part of the IORG and has the Human Research Protection Agency number IORG #: IORG0010018

- **Sample size and factors influencing patient selection:**

According to the sample performance analysis of a prior research G-Power program, choose (version 3), a total sample of 51 young adolescent female orthodontic patients were included in the previous randomized controlled trial.

- **Inclusion criteria**

In group 1 Expansion only (class I, II or III presented with transverse maxillary deficiency, posterior crossbite with average or normal face height) does not need maxillary protraction or distalization. As regard for group 2 and 3 (class 2 molar relationship with decreased intermolar width before distalization without lower arch crowding).

- **Exclusion criteria**

Previous orthodontic treatment, previous upper airway surgery, class II mandibular deficiency and patient with periodontal defects.

- **Randomization:**

Using sequentially numbered opaque sealed envelopes (SNOSE), coded vehicles and assigned numbers were used in a prior research by **Park et al** [13] sample performance analysis. utilizing the G-Power program, choose (version 3).

- **Group allocation:**

The patients were divided into three equal groups based on the type of treatment.

- ***Group (1):*** The conventional hyrax (E)) (17 Females) with a mean age of 13.27 years (Y). **(Figure 2a).**
- ***Group (2):*** The distalization assisted by expansion (DE) (17 Females) with a mean age of 13.38 Y. **(Figure 2b).**
- ***Group (3):*** The distalization without expansion (D) (17 Females) with a mean age of 13.25 Y **(Figure 2c).**

A consent form for patient participation in the research project was obtained before commencing the study. Forty-eight records of young adult female orthodontic patients were chosen, categorized, and randomly divided into three equal groups (after exclusion of 3 patients from the original study one of each group).

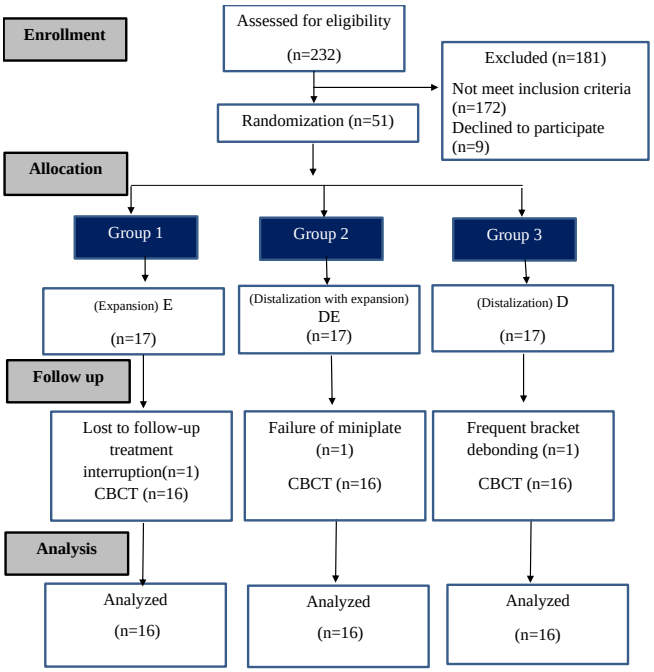


Figure (1): CONSORT flow diagram.

In group 1 two -banded Hyrax expanders(butterfly) 9mm screw length **(Figure 1 a)** was used and supported bilaterally by first permanent molars (16&26).

While in group 2 four-banded Hyrax expanders 9 mm screw length **(Figure 1 b)** were used and supported bilaterally by maxillary first premolars and permanent molars (14,24 &16,26). All appliances were activated 2 quarter turns at the time of delivery (0.25 mm per each) then they were activated quarter turn at the morning and another one at the evening by the patient or parents for 7-16 days reaching the total amount of expansion of about 8 mm (16 days) in expansion group while

only 7 days for the distalization with expansion group, thus reaching the total amount of expansion of about 3.5 mm in group 2.

In group 3, each patient received Roth's prescription edgewise brackets that had been pre-adjusted (*Ormco Mini 2000, Ormco Corporation, Glendora, California, USA*). Brackets were used on the first and second premolars, while bands were used on the first molars.

For both groups 2&3 after application of local anesthesia, the miniplates were attached to the zygomatico-maxillary buttress (16, 17) and modified to fit the form of each zygomatic process's lower face. The miniplates were secured with three self-drilling titanium bone screws after creating a vertical flap in that area to expose the zygomatic process (length, 5.0 mm; diameter, 2.0 mm). Single interrupted 4-0 polypropylene sutures were then used to reposition the whole thickness mucoperiosteal flap. Patients were told to rinse twice a day for two weeks, commencing 24 hours following surgery. During the first seven days, the patient was administered analgesic (Brufen 400 mm gm) orally as needed. After 7 days, the patients were summoned back for suture removal. The maxillary buccal segments were distalized bilaterally using a NiTi closed coil spring attached to a power hook on 0.018 0.025-inch stainless steel arch wire stepped on the six anterior teeth mesial to the maxillary 1st premolar and the hook of a miniplate supported to the Zygomatic buttress on each side. The spring delivered 450 gm continuous force, which was identical to the force employed for distalization in a previous investigation,[16] as measured by a correx tension gauge. Because the force level during distalization can drop below 450 gm, the springs were revived every three weeks with 0.01-inch stainless steel ligature wire, and the force was evaluated and calibrated with a gram-force gauge during initial activation and at 3-week intervals. The hook on the miniplates was placed approximately at the upper first molar bifurcation in the current study (by measuring the distance between the occlusal surface of each upper 1st molar and the bifurcation of its buccal roots on the CBCT), which placed the hook at approximately the center of resistance of molars, allowing for bodily distal movement of molars. After debonding, to enable enough time for healing, distalization began at least two weeks after the miniplates were surgically implanted. Fixed appliances were bonded to the anterior teeth for the second phase of orthodontic treatment when the super Class I correction was attained.

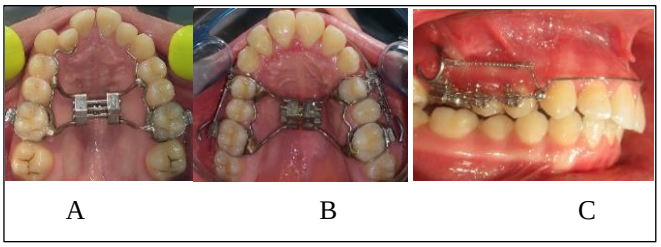


Figure (2): Three Different types of appliances (A) butterfly hyrax (B) dstalization assisted by expansion (C) distalization without expansion.

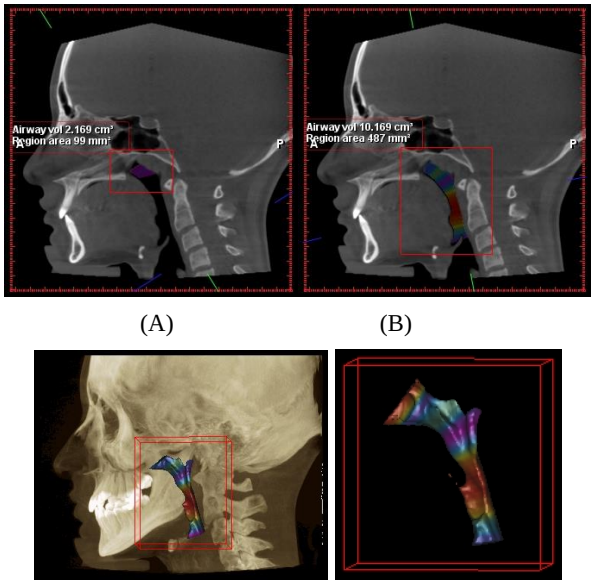
The CBCT was taken before beginning of orthodontic treatment (T1), six months after the last hyrax activation, or roughly six months after miniplate insertion (T2) **(Figure 3).** A Planmeca ProMax 3D Mid (at T1 and T2) Time of exposure: 6.22 seconds at 194 degrees, scan time: 18 seconds, 90 kV, 12.5 mAs, 20 x 17 mm field of view, the voxel size was 200 mm.

Each participant was instructed to hold her breath after expiration ended without swallowing, as this results in narrowing pharyngeal airway. [17, 18]

CBCT were reconstructed in 0.3 mm increments on a computer as DICOM (digital imaging and communications in medicine) data files before being evaluated with Romexis software (version 5.3.4.39USA). The patients were positioned according to natural head position. The nasal cavity (NC) and nasopharynx (NP) were traced layer by layer in the coronal cross section until the last layer, while the oropharynx (OP) was traced layer by layer in the axial cross section until the last layer, using the manual segmentation tool in the software. The Sagittal view validated the volume segmentation's completeness and volume in cubic mm. The nasopharynx was drawn from a line anteriorly from Posterior nasal spine (PNS) to Sella (S) point extended posteriorly to the posterior wall of the pharynx above the line uniting Anterior nasal spine (ANS) and PNS, and the nasal cavity was measured in 3D volume from (ANS) to (PNS).

The oropharynx was divided into two sections: retropalatal (RP) extended inferiorly to the uvula and superiorly just below the ANS-PNS line, and retroglossal (RG) which reach inferiorly the epiglottis roughly at the same level as the antero-inferior point of the third cervical vertebrae (C3).[19]

The sum of the nasopharynx, retropalatal, and retroglossal airways give the total airway volume (TAV). **(Figure 3)**



(A) (B)

(C) (D)

Figure (3): Airway volumetric segmentation on CBCT
A- Nasopharyngeal airway B- Total airway
C- 3D rendering D-Isolated total airway

Statistical Analysis

All measurements for 15 randomly selected CBCT were done twice at 2 weeks' interval by the same examiner to determine the intra-examiner error.

Data was fed to the computer and analyzed using IBM SPSS software package version 20 (Armonk, NY: IBM Corp). For continuous data, they were tested for normality by the Shapiro-Wilk test. Distributed data were expressed as mean, standard deviation and standard error of mean. Descriptive statistic, paired t-test for comparing between pre-treatment and post-treatment was used. One-way ANOVA test was used for comparing the three studied groups and followed by Post Hoc test (Bonferroni) for pairwise comparison. On the other hand, Kruskal Wallis test was used to compare different groups for not normally distributed quantitative variables. Significance of the obtained results was judged at the 5% level

The total number of records became 48 CBCT of adolescent females after drop out of 3 patients one from each group from the original study.

Intra-groups

The intragroup difference between T1 and T2, all groups showed a significant increase in the total airway, nasopharynx, retropalatal airway, nasal cavity, all groups showed a non-significant increase in SNA, or Position of maxilla which represented by ANV in group 1&3 while in group 2 showed non-significant decrease.

As regards Retroglossal airway, group 3 showed a non-significant increase while group 1 &2 showed significant increase. For SNB group 1 showed a significant decrease while group 2&3 showed non-significant decrease. The ANB angle group 1&3 showed significant increase while group2 showed non-significant increase.

The mandibular position showed a significant increase in group 3 while group 1&2 showed non-significant increase. The maxillary first molar position showed significant increase in group 2 &3 to Nasion vertical while to pterygoid vertical the vice versa, as regard to group 1 showed non-significant difference to both.

Inter-group

Comparison among the three studied groups showed non statistical significance in all measurements except in the total airway mean difference change, since there was a statistically significant difference between group 1 and 2 **(Table 1. Figure 4).**

Discussion

In the functional matrix theory, the pneumatization of MS might affect the growth of maxilla [20, 21] but in the present study the process is reversed, i.e., does the RME can affect the MSV and or the airway?

The lumen of the upper airway is uneven, since narrowing in one or more segments of the upper airway can cause breathing problems and vice versa.[22]

The velopharynx was discovered to be the narrowest region just behind the soft palate. [23, 24]

The Airway resistance may be altered by volumetric changes, depending on the alteration.[25]

Although the fact that there were three different groups, the mean age of butterfly hyrax (E) (group 1) was 13.27 Y, compared to 13.38 Y in distalization assisted by expansion (DE) (group 2) and group 3 was a distalization without expansion (D) with mean age 13.25 Y. with no significant difference between groups even in the gender type (only females), indicating that all groups were homogeneous.

Table (1): Comparison among the three studied groups according to age and change in different measurements; N= (48)

Parameter	Group I (n = 16)		Group II (n = 16)		Group III (n = 16)		Test of Sig.	p	Sig. bet. groups.		
	Mean	SD.	Mean	SD.	Mean	SD.			p_1	p_2	p_3
Age (years)	13.25	1.22	13.38	1.24	13.27	1.61	F=0.024	0.976	–	–	–
Total volume (cm^3)	1.88^b	1.72	4.36^a	2.25	3.16^{ab}	1.69	F=4.040*	0.030*	0.576	0.468	0.027*
Naso pharynx (cm^3)	0.61	0.41	1.73	1.71	0.78	0.48	F=3.134	0.061	–	–	–
Retro palatal (cm^3)	1.70	1.22	1.85	1.93	0.96	1.04	H=3.030	0.220	–	–	–
Retro glossal (cm^3)	0.74	0.64	1.19	1.07	0.81	1.28	H=0.972	0.615	–	–	–
Nasal Cavity (cm^3)	4.55	2.58	8.96	6.14	7.09	6.54	F=1.653	0.212	–	–	–
SNA (◦)	0.45	1.22	0.33	1.18	0.30	0.63	F=0.054	0.948	–	–	–
SNB (◦)	-0.82	0.81	-0.10	0.73	-0.64	1.27	F=1.416	0.262	–	–	–
ANB (◦)	1.47	1.31	0.71	1.43	0.98	1.09	F=0.855	0.437	–	–	–
A-Nv (mm)	2.02	3.67	-0.68	2.78	0.16	0.78	F=2.433	0.108	–	–	–
B-Nv (mm)	4.28	8.19	0.28	1.54	1.89	1.25	F=1.524	0.237	–	–	–
MBCU6-Nv (mm)	2.29	6.72	2.82	1.62	4.38	2.23	F=0.587	0.563	–	–	–
MBCU6-ptv (mm)	-1.43	4.45	-2.52	1.58	-3.94	2.89	F=1.418	0.261	–	–	–

SD: Standard deviation **N:** Number = (48) **H:** H for Kruskal Wallis test
F: F for One-way ANOVA test, Pairwise comparison bet. each 2 groups were done using Post Hoc Test (Bonferroni)
p: p value for comparing between the studied groups
p1: p value for comparing between Group III and Group II
p2: p value for comparing between Group III and Group I
p3: p value for comparing between Group II and Group I
*: Statistically significant at $p \leq 0.05$
Means with Common letters are not significant (i.e. Means with Different letters are significant)
Group I: Expansion only
Group II: Distalization with expansion
Group III: Distalization only

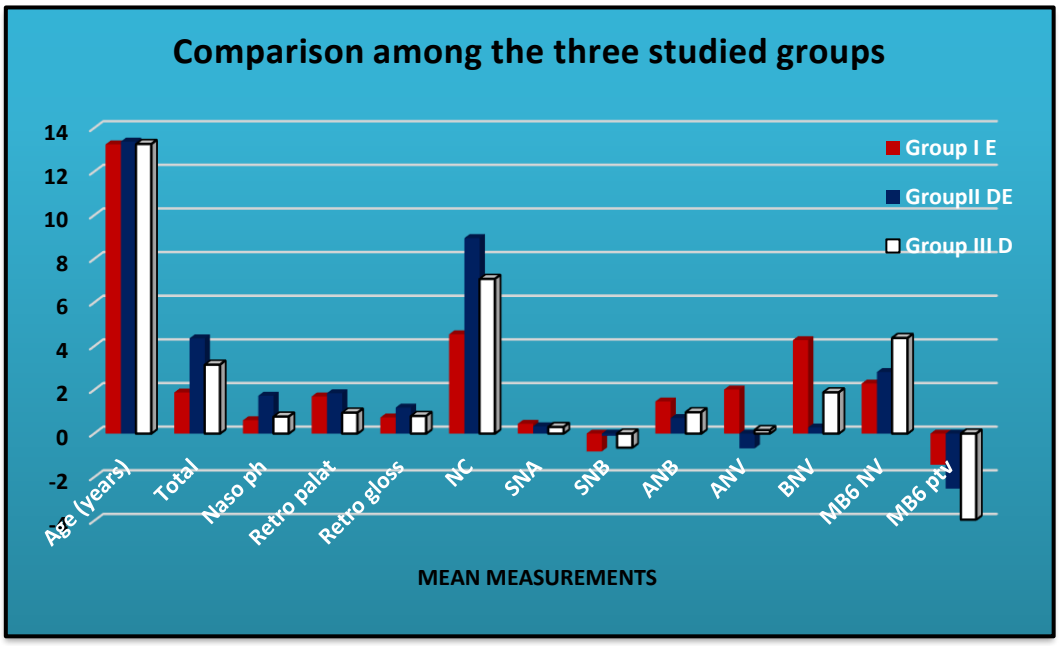


Figure (4): Bar chart shows comparison among the three studied groups according to age and change in different measurements.

Cephalometry is insufficient to depict the actual change in airway since only linear data are recorded in 2D, whereas the cylindrical form of the upper airway is 3D. A CBCT gives a more detailed picture of the volume, which can help with diagnosis and total changes. [24, 26]

However, the real challenge with CBCT during airway assessment is that the patient should be in a supine position rather than an upright one,

Since **Ingman et al** [27] showed that a difference may occur on the oropharyngeal area, but not on the naso- or hypopharyngeal area due to bony and cartilaginous support, while According to **Zimmerman et al** [28] , the hypopharynx and nasopharynx volumes, as well as the overall minimal cross-sectional area, are unreliable when analyzed using CBCT. Oropharyngeal volume was the only criterion with high intra- and inter-

examiner reliability.

The volumetric evaluation of the airway was investigated. In this retrospective study, 3D CBCT analysis was used to compare tooth-borne expanders to maxillary distalization with or without expansion.

It was proved that all RME appliances, including tooth-borne, tooth-tissue-borne and bone-borne appliances almost generate considerable enlargement at the mid-palatal suture, according to moderate evidence. [8, 29, 30]

Rapid palatal expansion decrease nasal resistance, improve breathing in nasal stenosis patients and increase oxygen saturation [31-33]

In the present study the NC showed significant increase in all groups (4.55, 8.96 and 7.09) with highly significance in group 1 and 2 this might be due to expansion effect this was in accordance with previous studies [10, 31, 34-39]

Niu et al [40] in their meta-analysis showed no significant increase (1224 mm3) in NC volume (P=0.110) immediately after expansion, but after retention period the significant change (1604 mm3) (P=0.000) was reported.

Our study discovered an increase in NP in all groups (0.61, 1.73 and 0.78) this was in accordance with previous studies. [10, 17, 37, 41]

On the other side **Abdalla et al** [9] when compared to young controls, tooth-borne RME is not linked with a substantial change in upper airway volume or MCA in children. They urged the increase in airway volume and MCA over time in both groups was likely due to growth, they concluded that the younger the skeletal age before treatment, the better the effect on upper airway changes. [9]

Also, there was no change of airway volume or MCA after maxillary expansion and protraction treatment, since young cleft patients (8.4 ± 1.7 Y) treated for almost 2years and were assessed with different software [42, 43]

While **Yavan et al** [44] there was no significant change in nasopharyngeal area after treatment with an ARME due to different appliance with different software [44]

Niu et al [40] in their systematic review showed immediate significant increase (829 mm3) in NP volume (P=0.000) after expansion, but after T2 when compared to T0 the significant change (492 mm3) (P=0.022) was reported.

Park et al [13] did not evaluate the nasopharynx, since they considered it as a confounding factors because the treatment effect was related to the oral cavity mainly (OP). Previous studies mentioned a significant increase in the nasal cavity and nasopharynx, but no effect on the oropharynx. [10, 17, 35, 37, 41]

It was documented that removable functional appliance (RFA) can improve airway in class II division 1. [11, 45, 46] Also Fixed functional appliance (FFA) also can improve airway [18, 47, 48]

The evidence implies that forward mandibular repositioning alters the position of the hyoid bone, tongue and associated muscles resulting in increased OP and patent airway.[49]

Oliveira et al [50] showed that treatment with the Herbest appliance significantly increased oropharynx volume in people with Class II malocclusion and mandibular deficiency but no alteration in the nasal cavity and nasopharynx volume.

On the other hand, FFA may not boost air flow, it might be due to linear assessment on lateral cephalometry. [51]

After distalization in the current study both group 2 and 3 showed significant increase in the retropalatal volume (RPV), this was accompanied by previous studies. [12, 18] And was in disagreement with **Park et al** [13] who reported that the volume of the upper oropharynx was reduced by 0.5 to 1.5 cm3 and the minimum cross-sectional area (MCA) of the upper oropharynx was reduced by roughly 8% to 10%, according to; however, these reductions were not statistically significant and might be related to different appliance and this was true as regard to the extracted group after distalization as mentioned in previous study[52] and decreased the space available for tongue, while other retrospective study showed no effect on upper airway after orthodontic treatment[53].

Park et al [13] proved no significant change in OP airway volume after distalization with no risk to produce OSA especially in the non-extraction group. **Fastuca et al** [33] demonstrated no significant change in OPV after conventional expansion. **El and Palomo** [10] also reported that the RME group's oropharyngeal airway volume increased to 1273mm3, but there was no significant difference in oropharyngeal airway volume increments between the RME and control groups.

Ribeiro et al [54] discovered a significant change in the OP following RME.

Niu et al [40] in their review showed immediate significant increase (1424 mm3) in OP volume (P=0.023) after expansion, but after T2 when compared to T0 no significant change (P=0.198) was reported.

Yavan and colleagues [44] found in their study, that the modified ARME treatment resulted in a significant increase in OP volume of 1340 mm3.

Retropalatal changes in the current literature were (1.70, 1.85 and 0.96) this was in disagreement with **Chang et al** [17] who showed no significant change in RPV (P=0.1604) and **Niu et al** [40] in their meta-analysis reported no significant increase in RPV (P=0.393).

In accordance with the limited maxillary forward expansion, the retropalatal airway at the maxillary level did not change considerably.[18]

As regard to RGV result of **Niu et al** [40] in their meta-analysis showed No significant increase after expansion (P=0.087) or post retention (P=0.373).

The changes of RGV in this study were (0.74, 1.19 and 0.81) with no statistical significance in only group 3. This might be due to absence of expansion leading to no improvement in tongue position.

There was a significant increase (P= 0.030) in this study in TAV in group 1,2 and 3 (1.88, 4.56 and 3.16) respectively. This was in agreement with previous studies [12, 40, 41, 46, 54]

Chou et al [14] provided improvement in anteroposterior skeletal relationship After total maxillary arch distalization (SNA and ANB decreased by 1.23_ and 1.61_ respectively) [14].

Although **Chen et al** [14] clarified at the distal end of the tuberosity, a slight increase in bone size was noticed after extraction treatment, the air way in the current study did not decrease.

Despite the fact that **Eldawlatly et al** [55] discovered statistically significant point A retrusion (1.62±0.82 mm) during distalization, it might be due to different age and device, or the distal repositioning of the maxillary incisors after remodeling, as described by **Gandini et al** [56], could be the cause of this point A retrusion.

In our study we did not expect any retrusive position of point A due to the cessation of maxillary growth.

In the current study the ANB was increased in group 1 and 3 with no significant change in SNA that means minute backward and downward rotation of mandible which might lead to decrease in the retroglossal volume.

As regard to maxillary position, **Park et al** proved average amount of molar distalization 3.3 mm with no change in pharyngeal airway [13]

The amount of molar position in this study related to N. v Group1 (2.29), group2 2.82 and 4.38mm in group 3, while the amount in relation to pt.v was (-1.43, -2.52 and -3.94) in group1,2 and 3 respectively. This indicated that the large amount was found in group 3 (D) this might attributed to banded hyrax might restraint the molar position due to it is rigidity unless the actual skeletal movement occur.

Finally tongue posture is significant in assessing the retropalatal and retroglossal areas, as high tongue posture may be detected in patients with obstructive sleep apnea and low tongue posture may be noticed in individuals with a constricted maxilla and mouth breathing.

After RME, it's unclear whether low tongue posture will be improved or not, since the possibility of a persistent mouth breathing habit, less improvement in airway dimension or even a low hyoid bone position is possible.

Conclusions

- Expansion and distalization can increase the total airway volume.
- Maxillary distalization assisted by expansion does not reduce the airway volume because pure backward skeletal action does not occur as what happens after a maxillary setback in orthognathic surgery.

Limitations

Absence of a passive control group for ethical and medico-legal reasons, gender difference, absence of maxillary protraction, lack of a sleeping questionnaire, lack of ENT clinical examination of the airway, Oxygen saturations are an important first step in evaluating a patient with an airway narrowing, airway resistance and finally technical difficulty, due to CBCT collected in a standing position, which is less reliable in assessing the airway than supine posture.

Conflict of Interest:

The authors declare that they have no competing interest.

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