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Evaluation the effect of maxillary protraction on the airway dimensions: A review

Seyyed Amirhossein Mirhashemi, Hannaneh Ghadirian, Rashin Bahrami *

Department of Orthodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

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***Corresponding author:**
Rashin Bahrami

Departments of Orthodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran.

Tel: +98-937-0053618
Fax: +98-21-84902473
Email: bahramirashin@Yahoo.com

ABSTRACT

Aim and Objective: The aim of this study was to evaluate the effect of maxillary protraction on airway dimensions in growing patients.

Materials and Methods: The research was conducted using literature reviews. Articles included in databases such as PubMed, Embase, Google Scholar and Cochrane were reviewed via inputting keywords such as maxillary protraction, maxilla retrusion, retrognathic, class III malocclusion, face mask, reverse head gear, Delaire, protraction head gear, reverse occlusion, anterior crossbite, growing patient, bone anchorage, dental anchorage. The search period for articles ranged from January 2005 to April 2021.

Results: 7 articles with inclusion criteria were included in the study; the results of the studies showed the effectiveness of maxillary protraction on increasing the dimensions of the airway. Studies have shown a significant increase in the size of the upper airway, especially the nasopharynx, following maxillary protraction with tooth-borne and bone-borne appliances.

Conclusion: Maxillary protraction can increase the size of the upper airway in growing patients. However, further studies are needed to elucidate the effects on changes in the pharyngeal airway, respiratory indicators (such as the apnea-hypopnea index), and its long-term effects.

Keywords: Maxillary protraction; Maxilla retrusion; Retrognathic; Class III malocclusion; Face mask; Reverse head gear; Delaire; Protraction head gear; Reverse occlusion; Anterior crossbite; growing patient; Bone anchorage; Dental anchorage.

Introduction

Maxillary protraction has the potential to improve the dimensions of the airway [1]. A systematic study by Ming et al. Showed that the effects of skeletal correction resulting from the use of a face mask stimulated the maxilla to grow forward with clockwise rotation for the palatal plane and rotation clockwise for the mandible [2]. These orthopedic effects lead to the widening of the oral-pharyngeal airway by moving the PNS forward and downward, resulting in the soft palate growing as the velopharyngeal space increases [3]. Although lymphatic tissue growth is increasing until the age of 10-12 years, stimulation of stunted maxillary growth by functional therapy under the age of 9-10 years, when circum maxillary suture are still responsive, can expand the airway [4]. Ensure the upper by removing the soft palate from the posterior wall of the throat in children who show normal growth [5]. It is useful maxillary protraction using a face mask under the age of 9 due to the lower resistance of the seam around the maxilla; but at older ages, mini-plates placed in the zygomatic bone to preserve bone anchorage can replace intraoral devices to apply orthopedic force directly to the nasomaxillary [6]. For this, mini-plates can be used to connect the face mask on the upper jaw or mini-plates on the lower and upper jaws for elastic connection [7]. The best time to implant this mini-plate with surgery in the permanent dental period and in Teenagers is 12 years or older, when bone support with appropriate density is available [8]. Bringing forward of the maxilla, by spreading to the nasopharynx and increasing nasal breathing, eliminates snoring during sleep and improves the patient's quality of life [9].

But maxillary protraction, on the one hand, increases the oral-pharyngeal airway after the maxillary protraction, and this is due to the combined effects between the increased space of the tongue due to the protraction of the maxilla [10]. On the other hand, due to the rotation of the mandible in a clockwise direction (down and back) and according to the position of the tongue, which is probably facing backwards, they should not show a significant change in the pharyngeal-oral space [11]. Based on the information obtained from previous studies and the combined effect of maxillary protraction on mandibular and maxillary position, the aim of this study was to evaluate the effect of maxillary protraction on airway dimensions in growing patients.

Materials and Methods

1. Protocol and registration

The analysis method and inclusion criteria were determined before, which were based on a PRISMA-based guideline [12].

2. Eligibility criteria

Is maxillary protraction effect on airway dimension?

- Patients (P). Individuals of both sexes, Growing patient, without restriction on ethnic or socioeconomic group, whose treatment with bone anchorage or conventional dental anchorage maxillary protraction, who with maxillary retrusion and class III malocclusion.

- Intervention (I). Application of bone anchorage or conventional dental anchorage maxillary protraction.

- Control (C). Patients who received placebo or no treatment or Between bone anchorage appliance-treated patients anddental anchorage appliance-treated.

- Outcome (O). Airway volume change.

- Study design (S). Randomized clinical trials (RCTs) or non-randomized clinical trials (Non-RCTs).

Animal and laboratory studies, technical and case reports, and opinion and review articles were excluded.

3. Inclusion and Exclusion criteria

Inclusion criteria for this review were: 1) Growing patients whose treatment with bone anchorage or conventional dental anchorage maxillary protraction and who with maxillary retrusion and class III malocclusion. 2) all languages, 3) Randomized clinical trials (RCTs) or non-randomized clinical trials (Non-RCTs) studies were considered, 4) January 2005 to April 2021, and 5) both published and unpublished data were sought out.

Exclusion criteria were: 1) studies that are not about maxillary protraction or do expansion before protraction, 2) studies that do not provide quantitative data, 3) animal and laboratory studies, technical and case reports, and opinion and review articles, and 4) children with previous orthodontic treatment, cleft palate, other craniofacial syndrome, temporomandibular joint disorders, OSAS due to tonsil and adenoid hypertrophy or nasal obstructive problems.

4. Search strategy

Using the keywords maxillary protraction, maxilla retrusion, retrognathic, class III malocclusion, face mask, reverse head gear, Delaire, protraction head gear, reverse occlusion, anterior crossbite, growing patient, bone anchorage, dental anchorage, for review in PubMed and Embase, Google Scholar, Cochrane and Scopus database. The article search range was from January 2005 to April 2021.

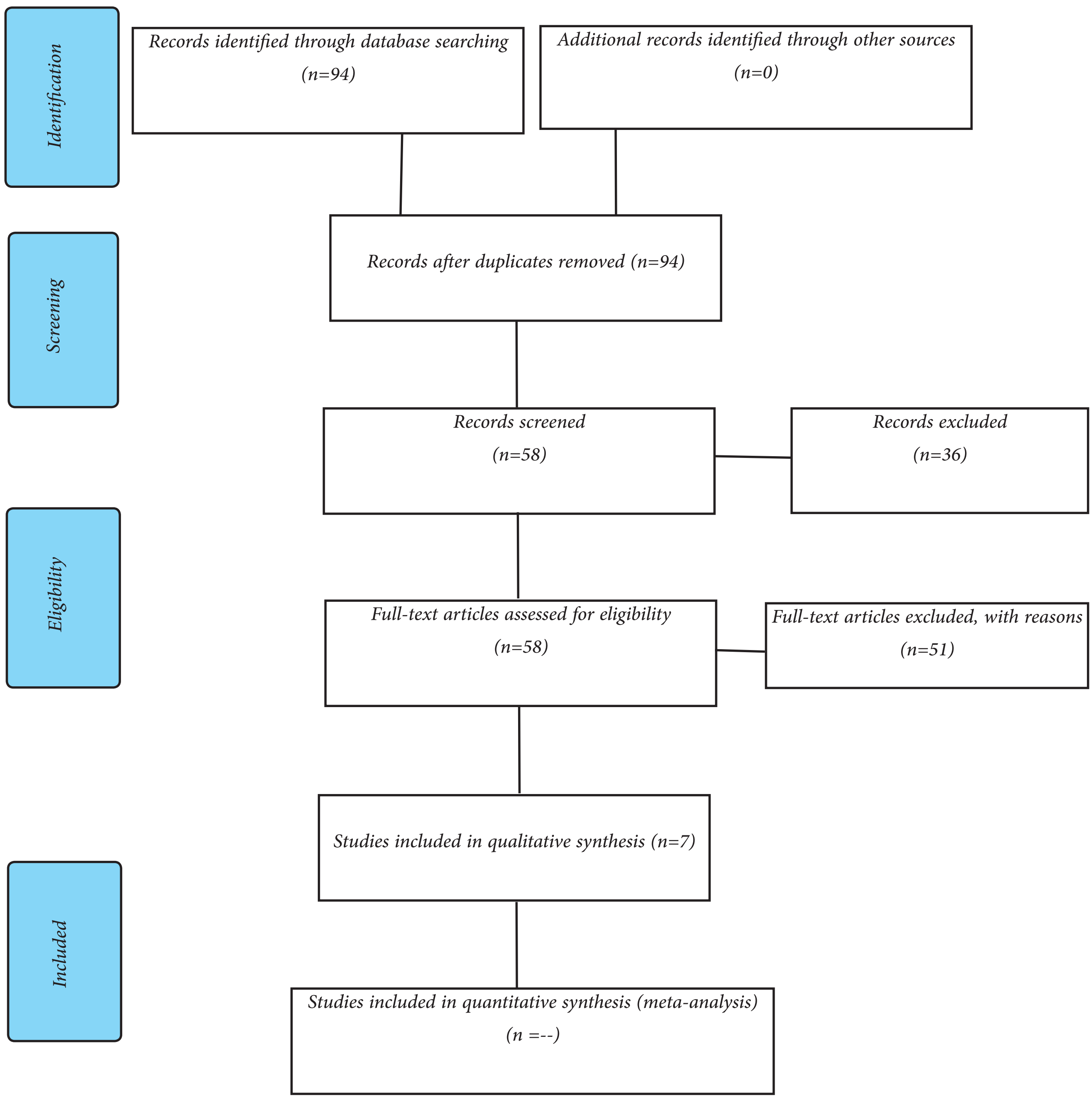
5. Search

Searches were tailored to the specific databases. Anexample of a search on PubMed is: (((“maxillary retrusion”) OR (“retrognathic”) OR (“class III maloclussion”) OR (“, anterior crossbite”) OR (“reverse occlusion”)) AND ((“growing patient”)) AND ((“maxillary protraction”) OR (“face mask”)OR (“reverse head gear”) OR (“bone anchorage”) OR (“ dental anchorage”) OR (“Delaire)) AND ((“airway”) OR (“airway dimension”) OR (“airway volume”) OR (“‘posterior airway space”)) OR (“‘pharyngeal space”))).

6. Study selection

To select papers and data collection, the subjects of all articles reached by two of author to the study and repetitive papers were omitted initially; so the subject and abstract of the remaining articles were carefully examined and papers with no criteria for entering this structured review were omitted. Finally, the full text of the probably associated papers was investigated; eligible papers were chosen and omitted from the non-relevant ones. Finally, associated with the inclusion and exclusion criteria 7 papers were found and analyzed. The PRISMA guidelines were followed in performing this systematic review (Figure1).

Figure 1. PRISMA flow-chart of selected criteria for the included article reports.



7. Type of studies

Randomized clinical trials (RCTs) or non-randomized clinical trials (Non-RCTs) studies were considered, both published and unpublished data.

8. Participants

Growing patients whose treatment with bone ancho age or dental anchorage maxillary protraction and who with maxillary retrusion and class III malocclusion.

9. Data extraction

Studies with inclusion criteria were reviewed by two authors; Collected data include study characteristics (such as The first author's name, year of publication, type of study, interventions, treatment/observation time, method examination), population characteristics (such as characteristics of subjects, sample size and age of subjects), results and outcome. Data from the treated and control groups (untreated or otherwise treated) were evaluated.

10. Duplicate data

Data that were published multiple times were considered duplicates. In case of any doubt or ambiguity, the original article was always considered as the final option for study.

11. Investigating the missing or defective data:

Strategies for missing and/or incomplete information in the studies included are as follows:
1- Contact the author, **2-** Analysis of existing data only (ignoring missing data) and finally, **3-** The possible effect of the lost data on the findings under consideration in the discussion section.

12. Intervention

Bone anchorage or conventional dental anchorage maxillary protraction (such as tooth-borne facemask, skeletal anchored facemask, intermaxillary elastics).

13. Evaluating the quality of studies

Evaluating the quality of studies was conducted independently by two authors. The national institute for health and clinical excellence (NICE) tool for quality assessment was used [13] (Table 1).

Figure 1. PRISMA flow-chart of selected criteria for the included article reports.

Study	*Quality Assessment**																								
	Population			*Method of allocation to intervention*									*Outcomes*						*Analyses*					*Overall assessment*	
	1	2	3	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	1	2	3	4	5	1	2
Lee et al.2011[14]	++	+	+	+	+	NA	+	NA	+	+	+	+	+	+	+	++	+	++	NA	NA	+	NR	++	+	+
Kaygısız et al.2009[15]	++	+	+	+	+	NA	+	NA	+	+	+	+	+	+	+	+	+	-	NA	NA	+	NR	+	+	+
Akin et al.2015[16]	+	+	+	+	+	NA	+	NA	+	+	+	+	+	+	+	+	+	-	NA	NA	+	NR	++	+	+
Oktay et al.2008[17]	-	+	+	+	+	NA	+	NA	+	+	+	+	+	+	+	+	+	-	NA	NA	+	NR	+	+	-
Baccetti et al.2010[18]	+	+	+	+	+	NA	+	NA	+	+	+	+	+	+	+	+	+	-	NA	NA	+	NR	+	+	+
Sayınsu et al.2006[19]	+	+	+	+	+	NA	+	NA	+	+	+	+	+	+	+	+	+	-	NA	NA	+	NR	+	+	+
Seo et al.2017[20]	+	+	+	+	+	NA	+	NA	+	+	+	+	+	+	+	+	+	-	NA	NA	+	NR	++	+	+

*Quality assessment of cases series studies checklist from National Institute for Health and Clinical Excellence: 1-Population: 1.Is the source population or source area well described? 2. Is the eligible population or area representative of the source population or area? 3. Do the selected participants or areas represent the eligible population or area? / 2- Method of allocation to intervention: 1. How was selection bias minimized? 2. Were interventions (and comparisons) well described and appropriate? 3. Were participants or investigators blind to exposure and comparison? 4. was the exposure to the intervention and comparison adequate? 5. Are the groups matched? 6. Were other interventions similar in both groups? 7. Were all participants accounted for at study conclusion? 8. Are the conditions provided in the study similar to the usual conditions of population? 9. Did the intervention or comparison differ significantly from usual practice in the population? / 3- Outcomes: 1. were outcome measures reliable? 2. Were all outcome measurements complete? 3. Were all important outcomes assessed? 4. Were outcomes relevant? 5. Were there similar follow-up times in exposure and comparison groups? 6. Was follow-up time meaningful? / 4- Analyses: 1. was exposure and comparison groups similar at baseline? If not, were these adjusted? 2. Was intention to treat (ITT) analysis conducted? 3. Was the study sufficiently powered to detect an intervention effect (if one exists)? 4. Were the estimates of effect size given or calculable? 5. Were the analytical methods appropriate? / 5- Overall assessment: 1. Are the study results internally valid (i.e. unbiased)? 2. Are the findings generalizable to the source population (i.e. externally valid)?

++: Indicates that for that particular aspect of study design, the study has been designed or conducted in such a way as to minimize the risk of bias/ +: Indicates that either the answer to the checklist question is not clear from the way the study is reported, or that the study may not have addressed all potential sources of bias for that particular aspect of study design/ -: Should be reserved for those aspects of the study design in which significant sources of bias may persist/ NR: Not reported/ NA: Not applicable.

In overall assessment: ++: All or most of the checklist criteria have been fulfilled; where they have not been fulfilled the conclusions are very unlikely to alter. / +: Some of the checklist criteria have been fulfilled, where they have not been fulfilled, or not adequately described, the conclusions are unlikely to alter. /–: Few or no checklist criteria have been fulfilled and the conclusions are likely or very likely to alt.

Results

Following the initial search in the databases using keywords, 94 studies were obtained, and by the exclusion of the duplicates, 58 studies remained. Using the provided abstracts, irrelevant and unavailable studies were excluded. Then, the remaining studies were reviewed by the authors, and studies that were unable to fulfill the criteria were excluded. In this regard, studies with irrelevant participants (in terms of age), and studies that used other appliances along with maxillary protraction or studies that did not mention the evaluated landmarks also were excluded. Finally, 7 articles were selected for this study.

All of the studies had used lateral cephalometry radiography. Most of the studies had under 6-months follow-ups, and only two of the studies had follow-ups of 3-4 years. Most of the studies had examined the effect of maxillary protraction with tooth-borne appliances. Only one of the studies had compared the effect of maxillary protraction by tooth-borne appliances with maxillary protraction by bone-borne appliances. Table 2 summarizes these articles.

Table 2. Summary of articles from 2005 to 2021.

Author	Subject	Number of Partic-ipants	Gender	Mean Age (Year)	Evaluation Methods	Variable used in radiography analysis	Follow-up Periods (year/ month)	Results
Lee et al.2011[14]	Correlation between skeletal changes by maxillary protraction and upper airway dimensions	20	5 boys, 15 girls	9.4 ±1.8 years	Lateral cephalometry	PNS-ad[1] PNS-ad[2]	-----	The nasopharyngeal airway dimensions increased after maxillary protraction.
Kaygısız et al.2009[15]	Effects of Maxillary Protraction and Fixed Appliance Therapy on the Pharyngeal Airway	25	11 girls, 14 boys	11.32 years	Lateral cephalometry	S-PNS PNS-ad1 PNS-ad2 AA›-Pm›[3] Pm›-SPL[4]	4 years	The nasopharyngeal airway dimensions increased after maxillary protraction; and this change remained over the posttreatment period of 4 years
Akin et al.2015[16]	Effects of chincup or facemask therapies on the orofacial airway and hyoid position in Class III subjects	67	15 girls, 10 boys In face mask group	10.3±1.5 years	Lateral cephalometry	Head posture Pharyngeal width Nasopharyngeal area Hyoid-bone	6- months	Orofacial airway dimensions were enlarged significantly by facemask treatment.
Oktay et al.2008[17]	Maxillary Protraction Appliance Effect on the Size of the Upper Airway Passage	20	5 male, 15 female	11.5 years	Lateral cephalometry	PMV-A distance PMV-B distance PMV-Pg distance	---	The size of the upper airway (Significant increases in the width and area of the pharyngeal airway, also occurred in the sagittal growth of the maxilla, and inhibition of sagittal growth in the mandible) can be increased by means of MPA application.
Baccettiet al.2010[18]	Treatment and post-treatment effects of facemask therapy on the sagittal pharyngeal dimensions in Class III subjects	22	12 females, 10 males	8.9±1.5 years	Lateral cephalometry	PNS-AD [5] AD1-Ba [6] PNS-AD [7] AD2-H [8] Upper pharynx [9] Lower pharynx [10]	3 years	No signifcant changes for the oro- and nasopharyngeal sagittal airway dimensions were induced by facemask therapy.
Sayınsu et al.2006[19]	Sagittal airway dimensions following maxillary protraction: a pilot study	19	12 girls, 7 boys	10.51 ± 1.15 years	Lateral cephalometry	PNS-ad1 PNS-ad2	---	Maxillary protraction via facemask improve nasopharyngeal but not oropharyngeal airway dimensions.
Seo et al.2017[20]	Comparison of the effects on the pharyngeal airway space of maxillary protraction appliances according to the methods of anchorage	28 In tooth-borne face mask group	8 boys, 20 girls	10.3 years	Lateral cephalometry	SPPS [11] MPS [12] IPS [13] SPPA [14] MPA [15] IPA [16]	--	Skeletal anchored face mask is more effective than tooth- borne face mask in increasing upper airway dimensions.
		24 In skeletal Anchored face mask group	12 boys, 12 girls	11.2 years				

[1] The distance from PNS to the pharyngeal wall along the line from Basion toPNS.
[2] The distance from PNS to the adenoid tissue along the line from PNS to the midpoint of the line intersecting Ba to Sellaturcica.
[3] The distance between the perpendicular intersections of anterior atlas and pterygmaxillary line along palatal line.
[4] sphenoid line tangent to lower border of sphenoid registered on basion.
[5] Lower airway thickness; distance between the PNS and the nearest adenoid tissue measured through the PNS-Ba line (AD1).
[6] Lower adenoid thickness; defned as the soft tissue thickness at the posterior nasopharynx wall through the PNS-Ba line.
[7] Upper airway thickness; distance between the PNS and the nearest adenoid tissue measured through a perpendicular line to S–Ba from PNS (AD2).
[8] Upper adenoid thickness; defned as the soft tissue thickness at the posterior nasopharynx wall through the PNS-H line (H, Hormion, point located at the intersection between the perpendicular line to S–Ba from PNS and the cranial base).
[9] The minimum distance between the upper soft palate and the nearest point on the posterior pharynx wall.
[10] The minimum distance between the point where the posterior tongue contour crosses the mandible and the nearest point on the posterior pharynx wall.
[11] Superior pharyngeal space (SPPS): The 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) that runs through the middle of the line from PNS to P.
[12] Middle pharyngeal space (MPS): The 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 P.
13 Inferior pharyngeal space (IPS): The 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.
[14] Superior pharyngeal area (SPPA): The area of the pharynx with an inferior border on the ANS-PNS extension line and an anterior border on the line perpendicular to the ANS-PNS line that runs through the pterygoid.
[15] Middle pharyngeal area (MPA): The area of the pharynx with a superior border on the ANS-PNS extension line and an inferior border of the extended occlusal plane.
[16] Inferior pharyngeal area (IPA): The area of the pharynx with a superior border on the extended occlusal plane and an inferior border of the most anteroinferior point on the body of the third cervical vertebra (cv3i)—the most anterior point of the hyoid bone (hy) line.

Discussion

In the present research, 7 studies were reviewed. These studies examined the effects of maxillary protraction by tooth-borne and skeletal anchored appliances on the airway dimensions of patients with maxillary hypoplasia. Participants of this study mainly consisted of adolescents with ages ranging from 8.9 to 11.5 years and did not use other appliances for the expansion of the maxilla. Follow-up time was mainly under one year (results were provided immediately after the treatment); in 2 cases, long-term follow-up (3 to 4 years) was performed. In most of the studies, parameters obtained from the lateral cephalometric radiograph were examined to assess the changes in the airway and the upper respiratory tract. The findings of this study indicate that the maxillary protraction method was able to significantly increase the airway volume of the patients. Lee et. al., (2011) reviewed the literature related to the therapeutic effects of maxillary protraction, and their findings revealed that the application of a Delaire-type face mask can help to open the airway. In line with the findings, they compared the cephalometric radiographs before and after the treatment, and analysis of the data related to the dimensions of the airway indicated an increase in the dimensions of the upper airway following a maxillary protraction. The findings of their study revealed a statistically significant increase in the measurements of the PN-ad1 and PNS-ad2 as 1.40±2.28mm and 1.90±2.64mm, respectively. The increases noted in the measurements of superior posterior airway space (SPAS), vertical airway length (VAL), and OAW; and the reductions of the middle airway space (MAS) and inferior airway space (IAS) were not statistically significant [14].

Furthermore, the results obtained from the analysis of the cephalometric landmarks of Sayinsuet. al, (2006) showed increases in both PN-ad1 and PNS-ad2 (2.71±3.35mm and 3.03± 2.37mm, respectively) which indicates an increase in the nasopharyngeal dimensions following a maxillary protraction [19]. As mentioned, maxillary protraction is a successful treatment which most of the studies have confirmed its efficacy and feasibility for increasing the volume of the airway. In line with this, Akin et. al., (2015) examined the effect of face mask on the dimensions of the airway in children (mean age of the female participants: 1.3±9.9 years, and mean age of the male participants: 1.7±10.8 years) and showed that face mask leads to a significant increase in the anteroposterior width of the pharynx and nasopharyngeal region. As a result of the changes in the position of the head, the position of the hyoid bone, and the dimensions of the airway in the nasopharynx and pharynx, the dimensions of the upper airway would be increased [16]. Oktayet. al., (2008) studied the effect of maxillary protraction by face mask on the dimensions of the airway. The results indicated a significant increase in the width of the upper and middle part of the pharyngeal airway along with a statistically significant increase in the nasopharynx and upper part of the oropharynx, but the changes of the dimensions of the lower part of the pharyngeal airway and oropharynx were not significant [17].

Long-lasting durability is another important variable to evaluate the efficiency of this method. Kaygisiz (2009) and Baccetti (2010) studied the long-term effects of this treatment on the dimensions of the airway [15,18]. Kaygisizet. al., (2009) stated that the increases of the dimensions of the airway by face mask lasted for 4 years after the treatment [15]. Baccettiet. al., (2010) examined the sagittal changes in pharyngeal dimensions following treatment with face masks on the class-III children at growth age. A 3-year follow-up revealed that the changes following a maxillary protraction would have long-lasting durability [18]. Maxillary protraction using skeletal anchored appliances is possible and based on the previous studies; in comparison to tooth-borne protraction it has higher efficiency in the midface area. The number of studies on the efficacy of this method which compared this method to the tooth-borne protraction is limited. The limitations of this method are including age indication (due to the required bone maturity for placement of the mini-plates), the cost of treatment, and invasive procedure. Seoet. al. compared the two therapeutic procedures and stated that both methods can increase the dimensions of the airway, but in comparison to the tooth-borne protraction, maxillary protraction using skeletal anchored appliances had higher efficiency. Especially, in measuring SPPA and IPA in which the greater skeletal effect of this method, and the direct application of force to the bone and the zygomaticofrontal and frontomaxillary lead to more protraction of the mid-face area and subsequently, more increase in the airway dimensions. This study proposed that maxillary protraction using skeletal anchored appliances is a suitable treatment for enhancing the respiration in patients with maxillary retrognathia along with patients with obstructive sleep apnea (OSA) [20].

Conclusion

The results of this study prove the efficiency of maxillary protraction to increase the volume of the airway. According to the available evidence, the superiority of neither of the methods cannot be confirmed, because the number of studies on this subject is limited. The period of follow-up in the studies on the effect of protraction on the dimensions of the airway was mainly short and long-term effects were not evaluated using scales such as AHI. Therefore, it is proposed that more studies should be performed on the effect of maxillary protraction using skeletal anchored appliances on the dimensions of the airway, and we suggest that in addition to the 2-dimensional lateral cephalometry, 3-dimensional CBCT and MRI to be used for more detailed examination of the airway.

Conflict of Interest

There is no conflict of interest to declare.

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