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Effect of functional appliances on the airway dimensions in patients with skeletal class II malocclusion: A systematic review

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Abstract:

OBJECTIVES: The aim of the present systematic review was to assess the effect of functional appliances on the airway dimensions in patients with skeletal Class II malocclusion.

MATERIALS AND METHODS: Articles were identified through a literature survey carried out through the following databases: (1) PUBMED, (2) Google Scholar, (3) The Cochrane Library, (4) Embase, (5) Lilac, and (6) Web of Scholars. The systematic review analyzed 12 articles comprising removable functional appliances, 3 articles with fixed functional appliances, and 2 articles having both fixed and removable functional appliances.

RESULTS: Qualitative assessment was done for all the 17 studies. The effect of functional appliances in the dimensions of three airway spaces – nasopharynx, oropharynx, and hypopharynx were analyzed.

CONCLUSIONS: Significant increase in the dimensions of nasopharynx and oropharynx was observed with Activator. Significant increase in the nasopharynx and hypopharynx (male patients) was observed with Bionator. Insignificant increase in the oropharynx was observed with the same. Significant increase in the oropharynx and hypopharynx was observed with Twin Block. Insignificant increase in the nasopharynx was observed with the same. Significant increase was observed only in the hypopharynx for Frankel II. Decreased or insignificant change was observed with FMA, MPA IV, and Herbst appliances.

Keywords:

Airway dimension, class II malocclusion, fixed functional appliances, removable functional appliances, retrognathic mandible

Introduction

Facial esthetics plays a pivotal role in the perception of beauty and is also the key reason for patients with skeletal Class II malocclusion to seek orthodontic treatment. This malocclusion is frequently caused by a mandibular deficiency. Mandibular deficiency can be attributed to a small or retruded mandible relative to the maxilla. From the days of Edward Angle, a frequently debated area in orthodontics has been the efficacy of various modalities in treating patients with Class II malocclusion with a retruded mandible. According to him, when a normal function is established, the adaptation of the craniofacial morphology subsequently follows it.[1] Growth modifications are attempted to alter a developing skeletal Class II relationship in young children, predominantly during the growth phase by modifying the patients' remaining facial growth to a favorable size or position of the jaws using functional appliances. Functional appliances enhance the proprioceptive sensory feedback mechanisms of various

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perioral musculatures that control the function and position of the mandible and transmit the generated forces to the dentition and basal bone.[2-5] This modifies the growth of the mandible and maxilla, guiding them into a favorable relationship.[4]

Severe mandibular deficiency has been linked to reduced oropharyngeal airway dimension increasing the chances of impaired respiratory function and possibly causing problems such as snoring, upper airway resistance syndrome, and obstructive sleep apnea-hypoapnea syndrome.

Harvold *et al*. suggested that in patients with skeletal Class II malocclusion caused by a retrognathic mandible, the reduced space present between the cervical column, and the mandibular body may lead to posterior positioning of the tongue and soft palate causing impairment in the airway.[6] This obstruction in the nasal airway can also lead to changes in the physiological rest position of the mandible.[7] Similarly, Linder-Aronson *et al*. and Quinn *et al*. have shown that, in children with decreased anterior facial height, retrognathism of mandible, and steeper mandibular planes, constriction is present in the nasopharyngeal region.[8,9] Further, airway disturbances can lead to a myriad of developmental deformities such as "long face syndrome," anterior and posterior open bites, and temporomandibular joint problems.[9]

Thus, it has been hypothesized that, as the mandible is repositioned forwards with the help of functional appliances, an increase in the airway space occurs indirectly. Graber *et al*. further added that, as the size and shape of the nasopharyngeal space enlarges, due to the usage of functional appliances, the effectiveness of these appliances also tends to improve simultaneously, which automatically results in improved respiration.[10]

However, contrary to these studies, Vig *et al*. and Horowitz *et al*. concluded that the mentioned interrelationship between the mandibular position and airway dimension is unproven.[11,12]

Zymperdikas *et al*. and Kevin O'Brien *et al*. have concluded that functional appliances do not have clinically significant skeletal effect on the mandible,[13,14] though other clinical studies proved functional appliances to be effective.[15-34] Hence, it can be inferred from their study that, through functional appliance therapy, no significant change occurs in the airway dimensions.

Lateral cephalograms and cone beam computer tomography (CBCT) have been used often in evaluating the airway dimensions in several airway spaces. Whether the three-dimensional measurements obtained using a CBCT will be able to make a significant difference to the assessment of the airway over the linear measurements acquired with lateral cephalograms is debatable with no consensus.

Research question

With the current controversy in the literature regarding the relationship between the airway dimension and functional appliances, a systematic review is needed to assess the changes seen in different airway spaces using functional appliances; no systematic review exists that provides this information.

Objectives

The aim of the present systematic review was to assess the effect of functional appliances on the airway dimension in patients with skeletal Class II malocclusion.

Materials and Methods

Search method

Articles were identified through a literature survey carried out through the following databases: (1) PUBMED, (2) Google Scholar, (3) The Cochrane Library, (4) Embase, (5) Lilac, and (6) Web of Scholars. The search algorithms used in each database are given in Table 1. A manual search was also performed by reviewing the references within the studies examined and the titles of the papers published over the last twenty years in various journals.

As this research was a systematic review, the institutional ethics committee was not required to approve the data abstraction.

Data abstraction

The selection process was done by two authors. The data extracted from each article was compared and discussed to resolve any discrepancies to reach a unanimous consensus.

Inclusion criteria

- Randomized controlled trials (RCTs), prospective, or retrospective case control studies

Table 1: Summary of the search database

Key words	Database	No. of articles
Functional appliances and airway	PUBMED	298
Activator, orthodontics, Airway	PUBMED	19
Bionator and airway	PUBMED	20
Twin Block and airway	PUBMED	10
Functional appliances, airway, Class II, orthodontics	Google Scholar	4910
Bionator, airway, orthodontics	Google Scholar	263
Airway , Class II , Orthodontics	PUBMED	81

- Healthy growing patients with skeletal Class II malocclusion without any systemic diseases treated with functional appliances
- Studies with a comparable control group.

Exclusion criteria

- Case reports, case series with no statistical analysis, comments, letters to the editor, and reviews
- Studies using functional appliances for the treatment of obstructive sleep apnea
- Studies using headgear as treatment modality in Class II patients and other functional appliances in treating patients' with Class III malocclusion
- Class I control groups.

The selected and rejected articles, after assessment of the full text articles, are listed in Tables 2 and 3, respectively; Figure 1 describes the search strategy. A summary of the articles included in this systematic review is presented in Table 4.

Quality assessment

The selected articles were graded based on the criteria proposed by the Cochrane Collaboration for Prospective Case- Control studies [Table 5] and the National Institutes of Health, Department of Health and Human Services, U.S.A for Retrospective Case-Control studies [Table 6].[35,36] The risk of bias within studies was assessed independently by the two authors and across studies by an independent reviewer. Any disagreement was resolved by discussion with the reviewer.

Results

The results were analyzed based upon the effect of functional appliances in the dimensions of three airway spaces – the nasopharynx, oropharynx, and hypopharynx.

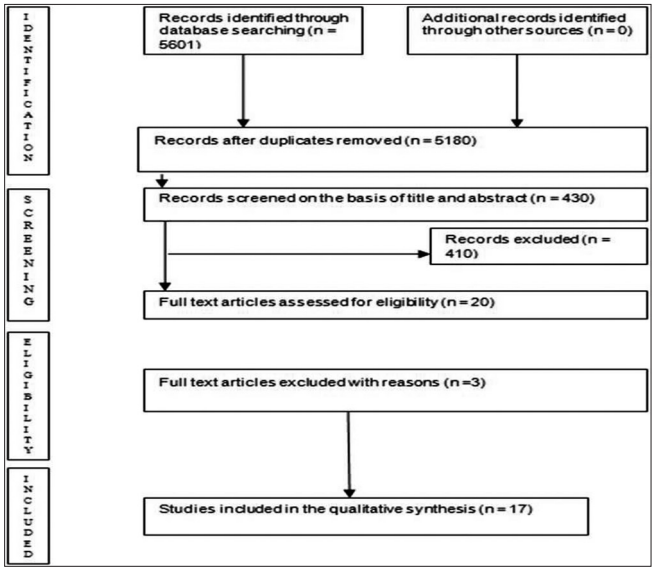

Figure 1: Flow chart describing the search strategy

Nasopharynx

- Significant increase in the dimension was observed with Activator, Bionator, Bite jumping appliance, and Farmand appliance
- Significant increase was observed with Twin Block in two studies, whereas three studies did not show any significant change
- Insignificant increase was observed with Frankel II and Herbst appliance
- A decrease was observed with MPA IV and FMA appliances [Table 7].

Oropharynx

- Significant increase was measured with Twin block, Bite jumping appliance, MPA IV, and X bow
- Significant increase was measured with Activator in four studies and insignificant increase in one study
- Insignificant increase was measured with Bionator, Forsus, and Herbst appliance
- Significant increase was measured with Farmand appliance, although 2 years after treatment, a decrease in the airway, when compared to the posttreatment values, were measured with this appliance
- A decrease was measured with FMA appliance [Table 7].

Table 2: Selected articles based on title and abstract

Key words	Database	No. of articles selected based on title and abstract, exclusion of repetition
Functional appliances and airway	PUBMED	7
Activator, orthodontics, Airway	PUBMED	4
Bionator and airway	PUBMED	1
Twin Block and airway	PUBMED	4
Functional appliances, airway, Class II orthodontics	Google Scholar	1
Bionator, airway, orthodontics	Google Scholar	1
Airway and Class II and Orthodontics	PUBMED	1
Similar articles	PUBMED	1

Table 3: Rejected articles after full text assessment

Name of the article	Reason for rejection
A. Horitata *et al*. (2013)[15]	Class I control group
S. Han *et al*. (2014)[16]	Class I control group
T. Iwasaki *et al*. (2014)[17]	Class I control group

Table 4: Summary of full text articles included in qualitative synthesis

Author	Sample	Appliances used	Control	Study design
C .Ulusoy *et al*. (2014)[18]	16 (8 girls, 8 boys) Growth Period: Prepubertal	Activator Treatment Duration: 11±3.4 months Retention Phase: 29.75±5.17 months	19 (11 girls, 8 boys) Observation period: 11.37±1.2 months	Retrospective case control
MP. Hänggi *et al*. (2008)[19]	32 (16 girls, 16 boys) Growth Period: Not Mentioned	Activator-headgear appliance Treatment Duration: 17±6.5 months (range 9-32 months), followed by fixed orthodontic treatment in 27 patients	32 (16 girls, 16 boys)	Prospective case control
MM. Ozbek *et al*. (1998)[20]	26 (15 girls, 11 boys) Growth Period: Significant growth potential	14: Harvold Type activator 12: Harvold type activator with occipital headgear Treatment Duration: Not mentioned	15 (8 girls, 7 boys)	Retrospective case control
A. Godta *et al*. (2011)[21]	308 Growth Period: Not Mentioned	Headgear :209 (m/f%: 47/53), Activator: 50 (m/f%: 45/55), BJA: 49(m/f%: 44/56) Treatment Duration: Duration of first phase Bite jumping appliance: 2.9±1.15 years Duration of overall treatment Activator: 6.24±1.67 years Bite jumping appliance: 6.42±1.14 years	Self	Retrospective case control
C. Restrepo *et al*. (2011)[22]	50 (28 girls, 22 boys) Growth Period: Pre- Pubertal	Klammt activator (n=31) or a Bionator (n=19) Treatment Duration: 1 year	Self	Retrospective case control
YC. Yen-Chun Lin *et al*. (2011)[23]	86 (35 girls, 51 boys) Growth Period: Pubertal growth phase	Modified Bionator Treatment Duration: Treatment time: 1.86 years 56 patients: 2 years follow-up 22 patients: 4 years follow-up	Self	Prospective case control
S. Ghodke *et al*. (2014)[24]	20 (9 girls, 11 boys) Growth Period: Not Mentioned	Twin-block appliance Treatment Duration: Twin Block Group: 244.63±35.58 days Control Group: 222.80±32.91 days	18 (9 girls, 9 boys)	Prospective case control
L. Li *et al*. (2014) [25]	30 (17 girls, 13 boys) Growth Period: Not Mentioned	Twin-block appliance Treatment Duration: Twin Block Group: 13.67±1.51 months	30 (17 girls, 13 boys)	Retrospective case control
AK. Jenaa *et al*. (2013)[26]	37 Growth Period: Not Mentioned	16- MPA-IV (girls - 7, boys - 9), 21- twin-block (girls - 10, boys - 11) Treatment Duration: Twin Block: 9.38±1.68 MPA IV: 6.8±1.20 Control Group: 9.86±1.79	46 : 30 Class I malocclusion subjects (girls – 17, boys-13), 16 Class II malocclusion subjects (girls – 7, boys -9)	Prospective case control
SK. Vinoth *et al*. (2013)[27]	25 (13 girls, 12 females) Growth Period: Before peak mandibular growth	Twin Block Treatment Duration: Not mentioned	Self	Retrospective case control
G. Verma *et al*. (2012)[28]	40 (22 girls, 18 boys) Growth Period: Not assessed	Twin block Treatment Duration: Not mentioned	Self	Retrospective case control

Contd...

Table 4: Contd...

Author	Sample	Appliances used	Control	Study design
G. Kinzinger *et al*. (2011)[29]	43 Growth Period: Not Mentioned	FMA-18 (10 girls, 8 boys) Herbst appliance - 25 (13 girls, 12 boys) Treatment Duration: FMA: 18 months Herbst: 19.5 months	Self	Retrospective case control
F. Ozdemira *et al*. (2014)[30]	23 (12 girls, 11 boys) Growth Period: Post-peak growth stage	Forsus FRD Treatment Duration: 5 months13 days±1 month 4 days	Self	Retrospective case control
G. Hui *et al*. (2003)[31]	20 (10 girls, 10 boys) Growth Period: Growth phase or early peak stage	Frankel II Treatment Duration: 7.4 months	Self	Retrospective case control
B. Erbas *et al*. (2014)[32]	25 (14 girls, 11 boys) Growth Period: Prepeak or peak pubertal growth stage	Xbow Treatment Duration: 6 months	Self	Retrospective case control
S. Yassaei *et al*. (2007)[33]	28 (females 10, males 11) Growth Period: Active growth	Farmand Treatment Duration: 12 months	Self	Retrospective case control
S. Yassaei *et al*. (2012)[34]	23 (8 girls, 15 boys) Growth Period: Not mentioned	Farmand Treatment Duration: 12 months, follow up- 2 years	Self	Prospective case control

Table 5: Summary of the quality assessment of prospective case control studies

Quality Assessment	Study Name								
	Exposed and Nonexposed Cohorts From Same Population	Assessment of Exposure	Absence of Outcome Interest	Matching of variables during sampling	Assessment of the presence or absence of prognostic factors	Outcome assessment	Follow up of cohort	Co-intervention	Quality of study
M P. Hänggi *et al*. (2008)	Definetely yes	Definetely yes	Probably yes	Probably yes	Probably yes	Definetely yes	Definetely yes	Definetely yes	Low risk bias
S. Ghodke *et al*. (2014)	Definetely yes	Definetely yes	Probably yes	Probably yes	Probably yes	Definetely yes	Probably yes	Definetely yes	Low risk bias
AK. Jenaa *et al*. (2013)	Definetely yes	Definetely yes	Probably yes	Probably no	Probably yes	Definetely yes	Definetely yes	Definetely yes	Moderte risk bias
YC. Yen-Chun Lin *et al*.(2011)	Definetely yes	Definetely yes	Probably yes	Probably yes	Probably yes	Definetely yes	Definetely yes	Definetely yes	Low risk bias
S. Yassaei *et al*. (2007)	Probably no	Definetely yes	Probably yes	Probably no	Probably yes	Definetely yes	Definetely yes	Definetely yes	Moderte risk bias

Hypopharynx

- Significant increase was observed with Twin block and Frankel II
- Significant increase was observed in male patients with Bionator, and an insignificant increase was observed in female patients
- Significant increase was observed with Farmand appliance, although 2 years after treatment, a decrease in the airway, when compared to the posttreatment values, were seen with the same
- Insignificant increase was observed with Herbst appliance, FMA, and MPA IV [Table 7].

Discussion

Functional appliances are primarily used in growing children to bring about a change in the position of the mandible.[12] As the mandible moves forward, it is said to cause an indirect increase in the airway size. Although the restricting effect on the airway caused by the retrognathic mandible is no longer present, variable results are seen with the airway space dimensions.

Though the articles studied in this systematic review support the view of functional appliances bringing about a clinically significant skeletal change to the

Table 6: Summary of the quality assessment of retrospective case control studies

Quality Assessment	Study Name											
	C. Ulusoy *et al.* (2014)	M M. Ozbek *et al.* (1998)	A.Godta *et al.* (2011)	C. Restrepo *et al.* (2011)	L. Li *et al.* (2014)	SK.Vinoth *et al.* (2013)	G .Verma *et al.* (2012)	G. Kinzinger *et al.* (2011)	F.Ozdemira *et al.* (2014)	G.Hui *et al.* (2003)	B.Erbas *et al.* (2014)	S .Yassaei *et al.* (2007)
Appropriate research question	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Defined study population	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Target population and case representation	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size justification	Yes	No	No	Yes	No	No	No	No	No	No	No	No
Recruited groups from same population	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inclusion and exclusion criteria prespecified and applied uniformly	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Defined case and control	Yes	Yes	No	No	Yes	No	No	No	No	No	No	No
Random selection of study participants	No	No	No	No	No	No	No	No	No	No	No	No
Concurrent controls	No	No	No	No	No	No	No	No	No	No	No	No
Exposure assessed prior to outcome measurement	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exposure measures and assessment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Blinding of exposure assessors	No	No	No	No	No	No	No	No	No	No	No	No
Statistical analysis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quality assessment	Good	Good	Fair	Good	Good	Fair	Fair	Fair	Fair	Fair	Fair	Fair

(1-5: Poor; 6-8: Fair; 9-13: Good)

Table 7: Summary of the influence of the appliance on the airway spaces

Author	Investigating method	Nasopharynx	Oropharynx	Hypopharynx
C. Ulusoy *et al*. (2014)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: Control- *P* value: Not Significant Activator- *P* value: Significant Comparison between the groups: *P* value: Not significant	Comparison between pretreatment and posttreatment: Control- *P* value: Not Significant Activator- *P* value: Not Significant; End of retention: Significant Comparison between the groups: *P* value: Not significant	Not Assessed
M P. Hänggi *et al*. (2008)	Lateral Cephalogram	Comparison between pretreatment, posttreatment and end of retention: Control- *P* value: Significant Activator-Headgear- *P* value: Significant	Comparison between pretreatment, posttreatment and end of retention: Activator-Headgear- *P* value: Significant Comparison between the groups: *P* value: Significant	Not Assessed
M.M. Ozbek *et al*. (1998)	Lateral Cephalogram	Not Assessed	Comparison between pretreatment and posttreatment: Control- *P* value: Significant Activator-Headgear- *P* value: Significant	Not Assessed
A. Godta *et al*. (2011)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: BJA- *P* value: Significant Activator-Headgear- *P* value: Significant	Comparison between pretreatment and posttreatment: BJA- *P* value: Significant Activator-Headgear- *P* value: Significant	Not Assessed
C. Restrepo *et al*. (2011)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: Bionator- *P* value: Significant Klammt Activator- *P* value: Significant	Comparison between pretreatment and posttreatment: Bionator- *P* value: Not Significant Klammt Activator- *P* value: Not Significant	Not Assessed
YC. Yen-Chun Lin *et al*. (2011)	Lateral Cephalogram	Female: Comparison between pretreatment, posttreatment, 2 years after Retention and 4 year follow-up : Modified Bionator - *P* value: Significant Male : Comparison between pretreatment, posttreatment, 2 years after Retention and 4 year follow-up: Modified Bionator- *P* value: Significant	Female & Male: Comparison between pretreatment, posttreatment, 2 years after Retention and 4 year follow-up: Modified Bionator - *P* value=Not significant	Female: Comparison between pretreatment, posttreatment, 2 years after Retention and 4 year follow-up: Modified Bionator - *P* value=Not significant Male : Comparison between pretreatment, posttreatment, 2 years after Retention and 4 year follow-up: Modified Bionator- *P* value: Significant
S. Ghodke *et al*. (2014)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: Control- *P* value: Not Significant Twin Block- *P* value: Not Significant Comparison between treatment and control group *P* value: Not Significant	Comparison between pretreatment and posttreatment: Control- *P* value: Significant Twin Block- *P* value: Significant Comparison between treatment and control group: *P* value: Significant	Comparison between pretreatment and posttreatment: Control- *P* value: Not Significant Twin Block- *P* value: Significant Comparison between treatment and control group: *P* value: Not Significant

Contd...

Table 7: Contd...

Author	Investigating method	Nasopharynx	Oropharynx	Hypopharynx
L. Li *et al*. (2014)	Cone Beam Computed Tomography	Comparison between pretreatment and posttreatment: Control- *P* value: Not Significant Twin Block- *P* value: Significant Comparison between treatment and control group *P* value: Not Significant	Comparison between pretreatment and posttreatment: Control- *P* value: Significant Twin Block- *P* value: Significant Comparison between treatment and control group *P* value: Significant	Comparison between pretreatment and posttreatment: Control- *P* value: Significant Twin Block- *P* value: Significant Comparison between treatment and control group *P* value: Significant
AK. Jenaa *et al* (2013)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: Control- *P* value: Not Significant Twin Block- *P* value: Not Significant MPA IV- *P* value: Not Significant Comparison between Twin Block and control group- *P* value: Not Significant Comparison among MPA IV and control group *P* value: Not Significant	Comparison between pretreatment and posttreatment: Control- *P* value: Not Significant Twin Block- *P* value: Significant MPA IV- *P* value: Significant Comparison between Twin Block and control group- *P* value: Significant Comparison among MPA IV and control group *P* value: Not Significant	Comparison between pretreatment and posttreatment: Control- *P* value: Not Significant Twin Block- *P* value: Significant MPA IV- *P* value: Not Significant Comparison between Twin Block and control group- *P* value: Not Significant Comparison among MPA IV an control group *P* value: Not Significant
SK. Vinoth *et al*. (2013)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: Twin Block- *P* value: Significant	Not Assessed	Not Assessed
G .Verma *et al*. (2012)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: Twin Block- HYPODIVERGENT: *P* value: Significant NORMODIVERGENT: *P* value: Significant HYPERDIVERGENT: *P* value: Significant	Not Assessed	Not Assessed
G. Kinzinger *et al*. (2011)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: Herbst- *P* value: Not Significant FMA- *P* value: Not Significant Comparison between Herbst and FMA: *P* value: Not Significant	Comparison between pretreatment and posttreatment: Herbst- *P* value: Not Significant FMA- *P* value: Not Significant Comparison between Herbst and FMA: *P* value: Not Significant	Comparison between pretreatment and posttreatment: Herbst- *P* value: Not Significant FMA- *P* value: Not Significant Comparison between Herbst and FMA: *P* value: Not Significant
F. Ozdemira *et al*. (2014)	Lateral Cephalogram	Not Assessed	Comparison between pretreatment and posttreatment: Forsus- *P* value: Not Significant	Not Assessed
G. Hui *et al*. (2003)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: Frankel 2- *P* value: Significant	Not Assessed	Comparison between pretreatment and posttreatment: Frankel 2- *P* value: Significant
B. Erbas *et al*. (2014)	Cone Beam Computed Tomography	Not Assessed	Comparison between pretreatment and posttreatment: X- Bow- *P* value: Significant	Not Assessed
S. Yassaei *et al*. (2007)	Lateral Cephalogram	Not Assessed	Comparison between pretreatment and posttreatment: Farmand- *P* value: Significant	Not Assessed
S. Yassaei *et al*. (2012)	Lateral Cephalogram	Comparison between pretreatment and posttreatment: Farmand- *P* value: Significant 2 years after treatment: *P* value- Not Significant	Comparison between pretreatment and posttreatment: Farmand- *P* value: Significant 2 years after treatment: *P* value- Not Significant with decrease in mean value	Comparison between pretreatment and posttreatment: Farmand- *P* value: Significant 2 years after treatment: *P* value- Not Significant with decrease in mean value

mandible,[15-34] Zymperdikas *et al*. and Kevin O'Brien *et al*. concluded that functional appliances do not provide a clinically significant skeletal effect. Kevin O'Brien *et al*.'s study found that the Twin Block does not appreciably modify mandibular growth and that it is simply a tooth modifying appliance. Thus, it can be inferred from their results that no pharyngeal size modification occurs with functional treatments as the advancement of mandibular position is not significant enough to cause the change.[13,14]

The need for clarity regarding the effect of functional appliances on airway space sizes led to this systematic review.

The literature search revealed absence of RCTs in this area of research. RCTs are considered the gold standard among all research designs in the evidence pyramid. In orthodontics, a lacuna is present in this topic probably due to the ethical considerations in denying treatment to a patient with malocclusion. Absence of historic growth studies with untreated Class II subjects where airway was assessed was taken into account while contemplating the inclusion criteria. This led to the inclusion of both retrospective and prospective studies in this systematic review. Studies which had a comparable Class II control group, or those in which Class II patients were assessed pre and posttreatment, were included. Class I control groups were not taken into consideration due to difference in growth pattern between them and Class II patients.[37-42]

Case reports and case series were not taken into consideration due to the inadequacies in their study designs to address the objective of this systematic review. Studies involving functional appliances to treat obstructive sleep apnoea patients were not used as the patients have a pathological reason for decreased airway space.

The literature is divided about the accuracy in measuring airway spaces dimensions using lateral cephalograms, with the main concern being inadequacy to give a three-dimensional perspective.[43-46] Pirila-Parkkinen *et al*. and Vizzotto *et al*. concluded in their studies that lateral cephalograms can be used as a reliable method in assessing the airway.[43,44] Studies having both lateral cephalogram and CBCT imaging techniques have been included in this systematic review, although volumetric quantification is possible with CBCT. Linear measurements were taken in studies involving lateral cephalograms.

The literature search showed that Yassaei *et al*. had the same content published in two different journals. Their study dealt with the effect of the Farmund appliance on 28 Class II patients, namely in Arabic, in the Shiraz University Dental Journal, 2007, and in English, in the Journal of Clinical Paediatric Dentistry; the article, published in the English language, was taken into consideration.[33]

The present systematic review analyzed 12 articles comprising removable functional appliances, 3 articles with fixed functional appliances, and 2 articles having both fixed and removable functional appliances [Tables 8 and 9].

A significant number of selected studies appeared in the PUBMED database. A few of the studies did not specify the precise regions where the airway spaces were measured. Correlating with the anatomical structures, measurements of the airway dimensions were taken into consideration.

Table 8: Removable functional appliance

Appliance	Number of articles	Airway space analyzed	Overall effect of appliance on airway
Activator	5	Nasopharynx, oropharynx	Increase in airway
Bionator	2	1st Article- Nasopharynx, oropharynx 2nd Article- Nasopharynx, oropharynx, and hypopharynx	Increase in airway
Twin block	5	3 articles- Nasopharynx, oropharynx, and hypopharynx 2 articles- Nasopharynx	Increase in airway
Frankel 2	1	Nasopharynx and hypopharynx	Increase in airway
Farmand appliance		1st Article- Oropharynx 2nd Article- Nasopharynx, oropharynx, and hypopharynx	Increase in airway

Table 9: Fixed functional appliance

Appliance	Number of articles	Airway space analyzed	Overall effect on appliance
Herbst	1	Nasopharynx, oropharynx, and hypopharynx	Increase in airway
FMA	1	Nasopharynx, oropharynx, and hypopharynx	Decrease in airway
MPA IV	1	Nasopharynx, Oropharynx and Hypopharynx	Increase in oropharynx and hypopharynx, Decrease in nasopharynx
Bite jumping appliances	1	Nasopharynx, and Oropharynx	Increase in airway
X bow appliance	1	Oropharynx	Increase in airway
Forsus	1	Oropharynx	Increase in airway

An insignificant increase in the region of the nasopharynx with Twin Block was seen with three studies that have a higher rating in the quality of assessment scale than the two studies which show a significant increase.[24-28]

Lin *et al*. in 2011 reported an insignificant increase in the oropharyngeal region while using Bionator due to the connection of the lateral wall of the soft palate to the base of the tongue through the palatoglossus arch. In relation to the hypopharyngeal area, an insignificant increase was reported in the same study only in female patients.

Though Herbst and FMA appliances are known to have better patient compliance, Kinzinger *et al*. have shown them to have an insignificant or adverse effect, respectively, in the airway dimensions. Further, they have questioned the reliability of the assessment of posterior airway space with lateral cephalograms due to its limitations in studying three-dimensional structures.[29] Yassaei *et al*. in 2012 also found a decrease in the airway space in the long term with the usage of the Farmund appliance.[34]

The interrelationship present between the craniofacial form and the function of the airway gets established during the growth and development stage, making it vital to establish a good harmony between them as early as possible.[47] Future research is required to unearth the reasons behind the insignificant increase or decrease in a specific airway space with some appliances, though an increase is seen in other airway spaces.

Limitations of the study

- Many studies did not have a Class 2 untreated control group. Thus, quantification of the changes due to functional appliances alone, without the effect of growth changes, could not be assessed. Absence of blinding while analyzing cephalometric or CBCT values could have eliminated reviewer bias. All these point out the need for additional RCTs in this area
- Absence of a standard rating scale for quality assessment of retrospective studies.

Potential studies should consider analyzing the most proficient functional appliance using dynamic contrast magnetic resonance imaging as it provides stereoimaging of the airway region. Although a volumetric quantification is possible with CBCT imaging, a potential underestimation of the same is present when compared to that of MRI.[48]

Conclusions

Cephalometric and CBCT imaging provide sufficient data to analyze the airway dimension changes in the nasopharynx, oropharynx, and hypopharyngeal areas. A significant change was seen in the airway due to the repositioning of the mandible, especially with removable functional appliances.

- Significant increase in the nasopharynx and oropharynx was observed with Activator
- Significant increase in the nasopharynx and hypopharynx (male patients) was observed with Bionator. Insignificant increase in the oropharynx was observed with the same
- Significant increase in the oropharynx and hypopharynx was observed with Twin Block. Insignificant increase in the nasopharynx was observed with the same
- Significant increase was observed only in the hypopharynx with Frankel II
- Decrease or insignificant change was observed with FMA, MPA IV, and Herbst appliances.

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Conflicts of interest

There are no conflicts of interest.

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