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
periomusculatures 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]. 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.

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
• Insufficient 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 insufficient increase in one study
• Insufficient 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) | Class I control group |
| S. Han et al. (2014) | Class I control group |
| T. Iwasaki et al. (2014) | Class I control group |

Figure 1: Flow chart describing the search strategy
### Table 4: Summary of full text articles included in qualitative synthesis

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

"Contd..."
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. 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

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**Table 4: Contd...**

| Author                        | Sample | Appliances used                              | Control   | Study design |
|-------------------------------|--------|----------------------------------------------|-----------|--------------|
| G. Kinzinger et al. (2011)    | 43     | FMA-18 (10 girls, 8 boys)                    | Self      | Retrospective case control |
|                               |        | Herbst appliance - 25 (13 girls, 12 boys)    |           |              |
|                               |        | Treatment Duration: FMA: 18 months           |           |              |
|                               |        | Herbst: 19.5 months                         |           |              |
|                               |        | Treatment Duration:                         |           |              |
| F. Ozdemira et al. (2014)     | 23     | Farnand                                     | Self      | Retrospective case control |
|                               | (12 girls, 11 boys) | Treatment Duration: |           |              |
|                               |        | Forsus FRD                                  |           |              |
|                               |        | Treatment Duration:                         |           |              |
|                               |        | 5 months13 days±1 month 4 days               |           |              |
| G. Hui et al. (2003)          | 20     | Frankel II                                  | Self      | Retrospective case control |
|                               | (10 girls, 10 boys) | Treatment Duration: 7.4 months            |           |              |
|                               |        | Prepeak or peak pubertal growth stage      |           |              |
| B. Erbas et al. (2014)        | 25     | Xbow                                        | Self      | Retrospective case control |
|                               | (14 girls, 11 boys) | Treatment Duration: 6 months             |           |              |
| S. Yassaei et al. (2007)      | 28     | Farmand                                     | Self      | Retrospective case control |
|                               | (females 10, males 11) | Treatment Duration: 12 months          |           |              |
|                               |        | Active growth                               |           |              |
| S. Yassaei et al. (2012)      | 23     | Farmand                                     | Self      | Prospective case control |
|                               | (8 girls, 15 boys) | Treatment Duration: 12 months, follow up- 2 years |           |              |

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

| 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    | Low risk bias    |                |
| S. Ghodke et al. (2014)      | Definetely yes                                      | Definetely yes          | Probably yes                | Probably yes                          | Probably yes                                               | Definetely yes   | Definetely yes    | Low risk bias    |                |
| AK. Jenaa et al. (2013)      | Definetely yes                                      | Definetely yes          | Probably yes                | Probably yes                          | Probably yes                                               | Definetely yes   | Definetely yes    | Moderte risk bias|                |
| YC. Yen-Chun Lin et al. (2011) | Definetely yes                                    | Definetely yes          | Probably yes                | Probably no                           | Probably no                                                | Definetely yes   | Definetely yes    | Low risk bias    |                |
| S. Yassaei et al. (2007)     | Probably no                                         | Definetely yes          | Probably yes                | Probably yes                          | Probably yes                                               | Definetely yes   | Definetely yes    | Moderte risk bias|                |
| Quality Assessment                                                                 | Study Name |
|----------------------------------------------------------------------------------|------------|
|                                                                                  | C. Ulusoy et al. (2014) | 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        | No          | 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                      | No                   | 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                  | Good                    | Good                  | Good                     | Good                    | Good                  | Good                    | Good                    |

(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 | Comparison between pretreatment and posttreatment: Control - *P* value: Not Significant | Not Assessed                |
|                         |                      | Activator - *P* value: Significant                                         | Activator - *P* value: Significant; End of retention: Significant          |                              |
|                         |                      | Comparison between the groups: *P* value: Not significant                   | Comparison between the groups: *P* value: Not significant                  |                              |
| M P. Hänggi et al. (2008)| Lateral Cephalogram  | Comparison between pretreatment, posttreatment and end of retention:       | Comparison between pretreatment, posttreatment and end of retention:      | Not Assessed                |
|                         |                      | Control - *P* value: Significant                                            | Activator-Headgear - *P* value: Significant                              |                              |
|                         |                      | Activator-Headgear - *P* value: Significant                                | Comparison between the groups: *P* value: Significant                     |                              |
| M.M. Ozbek et al. (1998)| Lateral Cephalogram  | Not Assessed                                                                | Comparison between pretreatment and posttreatment: Control - *P* value:   | Not Assessed                |
|                         |                      |                                                                             | Significant                                                                |                              |
|                         |                      |                                                                             | Activator-Headgear - *P* value: Significant                              |                              |
|                         |                      |                                                                             | Comparison between the groups: *P* value: Significant                     |                              |
| A. Godta et al. (2011)  | Lateral Cephalogram  | Comparison between pretreatment and posttreatment: BJA - *P* value: Significant | Comparison between pretreatment and posttreatment: BJA- *P* value: Significant | Not Assessed                |
|                         |                      | Activator-Headgear - *P* value: Significant                                | Activator-Headgear - *P* value: Significant                              |                              |
|                         |                      |                                                                             | Comparison between the groups: *P* value: Significant                     |                              |
| C. Restrepo et al. (2011)| Lateral Cephalogram | Comparison between pretreatment and posttreatment: Bionator - *P* value: Significant | Comparison between pretreatment and posttreatment: Bionator- *P* value:   | Not Assessed                |
|                         |                      | Significant                                                                 | Not Significant                                                              |                              |
|                         |                      | Klammt Activator - *P* value: Significant                                   | Klammt Activator - *P* value: Not Significant                              |                              |
| 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 | Female: 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 | Male: 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: Not significant |
| S. Ghodke et al. (2014)  | Lateral Cephalogram  | Comparison between pretreatment and posttreatment: Control - *P* value: Not Significant | Comparison between pretreatment and posttreatment: Control- *P* value: Significant | Comparison between pretreatment and posttreatment: Control- *P* value: Significant |
|                         |                      | Twin Block - *P* value: Not Significant                                     | Twin Block- *P* value: Significant                                         | Comparison between pretreatment and control group: *P* value: Significant |
|                         |                      | Comparison between treatment and control group: *P* value: Not Significant  | Comparison between treatment and control group: *P* value: Significant     | Comparison between treatment and control group: *P* value: Not Significant |
| Author                  | Investigating method | Nasopharynx                                                                 | Oropharynx                                                                 | Hypopharynx                                                                 |
|------------------------|----------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| L. Li et al. (2014)    | Cone Beam Tomography | Comparison between pretreatment and posttreatment: Control- *P* value: Not Significant Twin Block- *P* value: Significant Control- *P* value: Significant Twin Block- *P* value: Significant | Comparison between pretreatment and posttreatment: Control- *P* value: Significant Twin Block- *P* value: Significant Control- *P* value: Significant Twin Block- *P* value: Significant | Comparison between pretreatment and posttreatment: Control- *P* value: Significant Twin Block- *P* value: Significant Control- *P* value: Significant Twin Block- *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: Not Significant MPA IV- *P* value: Not 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: 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 |
| SK. Vinoth et al. (2013)| Lateral Cephalogram  | Not Assessed                                                                 | Not Assessed                                                                 | Not Assessed                                                                 |
| G. Verma et al. (2012) | Lateral Cephalogram  | Comparison between pretreatment and posttreatment: Twin Block- *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                                                                 | Not Assessed                                                                 | 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 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.\textsuperscript{[15–34]} Zymperdikas \textit{et al.} and Kevin O’Brien \textit{et al.} concluded that functional appliances do not provide a clinically significant skeletal effect. Kevin O’Brien \textit{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.\textsuperscript{[15,14]}

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.\textsuperscript{[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.\textsuperscript{[19,29]}

The literature is divided about the effect of functional appliances on airway space sizes led to this systematic review. 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.\textsuperscript{[37–42]}

The literature search showed that Yassaei \textit{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.\textsuperscript{[10]}

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.

| Article | Oropharynx and hypopharynx | Nasopharynx, oropharynx, and hypopharynx | Nasopharynx, oropharynx, and hypopharynx | Nasopharynx, oropharynx, and hypopharynx | Nasopharynx, oropharynx, and hypopharynx | Nasopharynx, oropharynx, and hypopharynx | Nasopharynx, oropharynx, and hypopharynx |
|---------|---------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|
| Overall effect of appliance on airway | Increase in airway | Increase in airway | Increase in airway | Increase in airway | Increase in airway | Increase in airway | 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.[40] 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 stereomaging 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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