Saudi Dental Journal (2021) 33, 860–868

King Saud University

Saudi Dental Journal

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ORIGINAL ARTICLE

Comparison of oropharyngeal airway dimensional changes in patients with skeletal Class II and Class III malocclusions after orthognathic surgery and functional appliance treatment: A systematic review

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Received 3 October 2020; revised 11 May 2021; accepted 5 September 2021
Available online 13 September 2021

KEYWORD

Airway dimension;
Class II skeletal malocclusion;
Class III skeletal malocclusion;
Functional appliance;
Orthognathic surgery;
Bimaxillary surgery

Abstract *Objective:* To compare the dimensional changes in the oropharyngeal airway in patients with skeletal Class II and Class III malocclusion before and after orthognathic surgery and treatment with a functional appliance.

Methods: The protocol was developed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P) and was registered to the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42020170901. Furthermore, the reporting of the present SR was performed based on the PRISMA checklist.

Results: The use of removable functional appliances increased the volume of the oropharyngeal airway in patients with skeletal Class II malocclusion. Furthermore, the increase in the volume of the oropharyngeal airway following the removable functional appliance treatment was more than that observed after fixed functional appliance treatment in growing patients. For patients with skeletal Class III malocclusion, who underwent the bimaxillary orthognathic surgery, resulted in no change in the dimensions of the oropharyngeal airway.

Conclusion: Growing patients who receive removable functional appliance treatment have a more favorable long-term prognosis with regard to the oropharyngeal airway when compared with

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sdentj.2021.09.013

those who receive fixed functional appliance. Alternatively, in patients aged from (18–22) years with skeletal class III malocclusion Bimaxillary orthognathic surgery was found to be the recomended and superior method of treatment.

1. Introduction

Dimensional changes in the oropharyngeal airway are a contentious issue examined by orthodontists, oral and maxillofacial surgeons, otolaryngologists, and others who are interested in the influence of the upper airway on growth and lifestyle. The morphometries of the upper airway vary in patients with different skeletal characteristics; in addition, an association between the airway space and skeletal growth pattern has been reported (Claudino et al., 2013; Pirilä-Parkkinen et al., 2011; Park et al., 2010).

Patients with retrognathic mandibles in Class II occlusion have the lowest oropharyngeal dimensions, whereas those with prognathic mandibles in Class III occlusion have the highest dimensions. Furthermore, a difference in the airway orientation in these skeletal deformities has been observed (Grauer et al., 2009). Patients with Class III skeletal issues have a vertical orientation, as opposed to the forward orientation in patients with Class II skeletal defects. The differences in these airway dimensions, among other related structural problems, could subsequently play a role in the development of breathing problems in these patients. Therefore, such patients require appropriate interception and early intervention.

However, multiple treatment modalities, including functional appliances, orthognathic surgery, or a combination of the two, are considered for patients with skeletal discrepancies, depending on the age and skeletal maturation. Currently, no study has compared the dimensional change in the oropharyngeal airway following these treatment modalities. Although, functional treatment might occasionally eliminate the need for surgery, whether the treatment outcome is equivalent to that obtained following orthognathic surgery remains unclear.

Therefore, the objective of this study was to compare the dimensional changes in the oropharyngeal airway in patients with skeletal Class II and Class III malocclusion before and after orthognathic surgery and functional appliance treatment.

2. Materials and Methods

2.1. Protocol and registration

The protocol was developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols (PRISMA-P) and was registered to the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42020170901. Furthermore, the reporting of the present SR was performed based on the PRISMA checklist.

2.2. Search strategy

The databases investigated were: PubMed/MEDLINE, Scopus, Google Scholar, and Web of Science. Additionally, the respective reference list of the journals included in the acquired research studies were hand searched. The terms in the Medical Subject Headings selected for this search included "Orthognathic Surgery," "Functional Appliance," "Class II, Class III," and/or "Skeletal Relationship." Based on the PICO framework, the current systematic review involved the Patient Population (males, females), Intervention (orthognathic surgery or functional appliances), Comparison (pharyngeal airway dimension), and Outcome (oropharynx dimension following orthognathic surgery and functional appliances). Studies that met our inclusion criteria were selected for analysis, However as the outcome variables were not homogenous, cumulative analysis could not be performed.

2.3. Eligibility criteria

The eligibility criteria used to acquire the data that were related directly to the core of this study were as follows: Published articles, articles available as full-text and not in the abstarct form; have a systematic review or systematic review and *meta*-analysis design; and have a prospective or retrospective design that focuses on all age groups. From each of the studies included, a data collection form was used to collect data regarding the surgical or functional appliance used, Class II or III skeletal relationship, study interval, number of patients, aim of the study, quality assessment, and conclusion of the study. The exclusion criteria were as follows: non-English language studies, those involving Class II or Class III dental relationship, and those aimed to assess any other airways apart from the oropharynx.

2.4. Quality of the studies

Two independent authors (FQ and KB), assessed the quality of the included studies. The weighted kappa statistic value between author agreements was 91%. The authors independently extracted the data and entered them into a prespecified data sheet in Microsoft Excel after confirming the quality of each study. From each eligible study the variables extracted included the name of the first author, year of publication, duration of the study, location of the study, design of the study, median follow-up time, data source, and size of the sample. The recommended checklist used was of STrengthening the Reporting of Observational Studies in Epidemiology (STROBE) (Rizk et al., 2016) to assess the risk of bias in all the full text articles that were identified and collected, which

had the following characteristics: (a) clear definition of the source of participant selection; (b) clear definition of the eligibility criteria; (c) explanation about the method used to measure the exposure; (d) explanation about the method used to measure the outcomes; (e) appropriate information about the follow-up; (f) definition of the sample sizes; and (g) clearly defined aims and objectives. All studies were reported to have a low risk of bias.

3. Results

Examination of five databases, along with additional hand searching, was performed, resulting in the extraction of 58 articles; 57 articles were screened following the removal of duplicates. Among them, 23 were excluded as they did not satisfy our inclusion criteria and the remaining 34 articles were assessed for eligibility. Subsequently, 13 studies were excluded as they were not relevant to our search question, and a total of 21 articles were finally used for quality assessment. All 21 articles published from 2007 to 2018 presented with a low risk of bias (Fig. 1).

A total of 806 patients with skeletal Class II and Class III malocclusion were included in the analysis. Among them, 472 received functional appliance therapy, whereas 334 underwent orthognathic surgery (Tables 1 and 2).

a. Outcome of oropharyngeal airway following orthognathic surgery in patients with Class II skeletal malocclusion

The total number of patients with skeletal Class II malocclusion who had undergone orthognathic surgery was 141; 106 of them received mandibular advancement surgery, and 35 patients underwent bi-maxillary orthognathic surgery (Table 1).

Mandibular advancement surgery alone exhibited an increase in the volume of the oropharyngeal airway. Likewise, skeletal Class II patients who underwent bi-maxillary surgery exhibited an increase in the volume of the oropharyngeal airway; however, the amount of increase was less than that observed in patients who underwent the mandibular advancement procedure (Table 1).

b. Outcome of the oropharyngeal airway following fixed and removable functional appliance therapy in patients with Class II skeletal malocclusion

A total of 472 patients used orthodontic functional appliances to correct Class II skeletal malocclusion. Different functional appliances were used, such as Mandibular Anterior Repositioning Appliance (MARA), headgear, twin block, cervical headgear, Mandibular Protraction Appliance (MPA-IV), Anderson appliance, Activator, and Herbst appliances (Table 2).

The use of removable functional appliances increased the volume of the oropharyngeal airway in patients with skeletal Class II malocclusion. Furthermore, the increase in the volume of the oropharyngeal airway following the removable functional appliance treatment was more than that observed after fixed functional appliance treatment (Table 2).

Among the functional appliances used, the Mandibular Anterior Repositioning Appliance (MARA) appliance presented with the highest amount of increase in the oropharyngeal airway volume, followed by the twin block and Herbst appliances (Table 2).

c. Outcome of oropharyngeal airway following orthognathic surgery in patients with Class III skeletal malocclusion

A total of 417 patients had skeletal Class III malocclusion and underwent surgical correction *via* bi-maxillary surgery and mandibular setback. None of them received functional appliance therapy to correct the malocclusion. The mandibular setback procedure resulted in a marked decrease in the volume of the oropharyngeal airway, whereas no change was observed following the bi-maxillary surgery (Table 1).

4. Discussion

The oropharyngeal airway has been an area of interest for otolaryngologists and orthodontists ever since craniofacial growth and development were known to be affected by respiratory functions (Claudino et al., 2013; Sheng et al., 2009; Oh et al., 2011). A particular concern would be a decrease in the airway dimension that can lead to obstructive sleep apnea or snoring. What would be important is that the treatment of these skeletal malocclusion can affect the size of the airway and thereby change the quality of life of the individual. Most of these functional problems are seen in skeletal Class II malocclusions.

In growing children with skeletal Class II malocclusion, functional appliances are used primarily to cause a change in the position of the mandible (Isidor et al., 2018; Rizk et al., 2016; Ghodke et al., 2014; Jena et al., 2013; Han et al., 2014; Maspero et al., 2015; Ulusoy et al., 2014; Elfeky and Fayed, 2015; Iwasaki et al., 2014; Yassaei et al., 2007). Whereas, in adult patients, a skeletal Class II or Class III malocclusion is corrected by orthognathic surgery that may involve one or both jaws (Gokce et al., 2012; Tepecik et al., 2018). In a skeletal Class II malocclusion, an anterior repositioning of the mandible can increase the volume of the posterior airway. In patients with skeletal Class III malocclusion and a prognathic mandible, mandibular setback alone decreases the volume of the posterior pharyngeal space; however, the dimensions may remain the same or increase when bi-maxillary surgery is performed (Aydemir et al., 2012; Efendiyeva et al., 2014). Therefore, we wanted to analyse if functional treatment would eliminate the need for surgery or whether the treatment outcome is equivalent to that obtained following orthognathic surgery or otherwise.

4.1. Effect of removable and fixed functional appliance

Our observation showed that the outcomes of functional appliance treatment with regard to changes in the dimension of the oropharyngeal airway are inconsistent (de Almeida et al., 2006; Battagel et al., 1999) and this may be due to the position of the tongue following the treatment wherein the length, height, and position of the tongue were changed following treatment with a functional appliance (Ulusoy et al., 2014; de Almeida et al., 2006). Likewise, another study demonstrated changes in the position of the tongue following functional appliance correction (Battagel et al., 1999).

However, in the current study, most of the growing patients with Class II malocclusion underwent functional appliance treatment to correct the malocclusion, with a resultant increase in the dimensions of the oropharyngeal airway (Isidor et al., 2018; Rizk et al., 2016; Ozdemir et al., 2014; Restrepo et al., 2011; Yassaei et al., 2012; Ghodke et al., 2014; Jena et al., 2013; Han et al., 2014; Maspero et al., 2015; Ulusoy et al., 2014; Elfeky and Fayed, 2015; Iwasaki et al., 2014; Yassaei et al., 2007). This finding is not in accordance with those reported by Zymperdikas et al. and Kevin O'Brien et al. wherein functional appliances did not appear to have a impor-

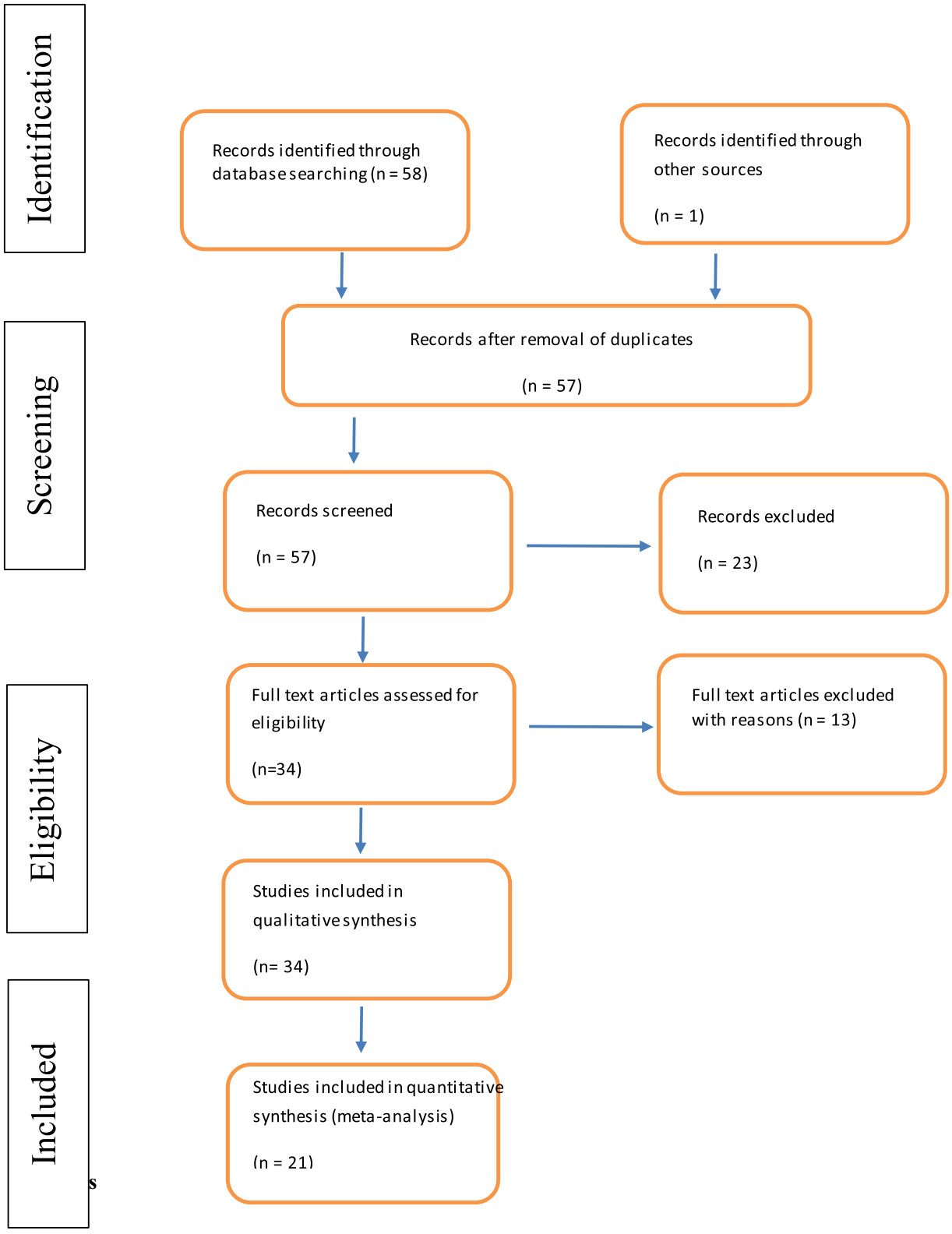

Fig. 1 Prisma chart.

tant influence on the skeletal position (Zymperdikas et al., 2016; O'Brien et al., 2003).

The use of the twin block appliance resulted in an increase in the oropharyngeal airway size in the current study. This finding is in line with those reported by Ghodke et al., Jena et al., and Elfeky et al., but contrary to that reported by O'Brien et al. (Isidor et al., 2018; Rizk et al., 2016; Ozdemir et al., 2014; Restrepo et al., 2011; Yassaei et al., 2012; Ghodke et al., 2014;

Table 1 Summary of Patients with Class II and Class III Malocclusion Treated Surgically.

Author/ Year	Number of Patients	Mean Age	Skeletal Relationship	Treatment	Outcome
Panouet al., 2013	17 Patients	22.59 Years	Class III	Bi-maxillary orthognathic surgery	Decrease in the lower pharyngeal airway – 4196.27 mm^3 Decrease in total pharyngeal airway volumes – 3375.53 mm^3
Hartet al., 2015	71 Patients	18.8 Years	Class II and Class III	Bi-maxillary orthognathic surgery	Class II – increase in oropharyngeal volume 383.9 ± 127.9 mm^3 Class III – decrease in oropharyngeal volume – 648.2 ± 270.4 mm^3
Aydemir et al., 2012	48 patients	*	Class III	1.Mandibular setback 2.Maxillary advancement and bi-maxillary surgery	Oropharyngeal area was decreased following mandibular setback only and exhibited no change after bi-maxillary or maxillary advancement procedures Maxillary advancement Posterior Phayrngeal Space – increased by 5.3 mm Middle Pharyngeal Space – increased by 0.9 mm Mandibular setback Posterior Phayrngeal Space – increased by 0.6 mm Middle Pharyngeal Space – decreased by 1.8 mm Bi-maxillary surgery Posterior Phayrngeal Space – increased by 2.2 mm Middle Pharyngeal Space – decreased by 0.8 mm
Chen et al., 2007	66 Patients	*	Class III	Mandibular setback surgery and bi-maxillary surgery	Airway was constricted after mandibular setback T1 – T2 = 4.26 mm T1 – T3 = 2.85 mm (T1 = 13.01 ± 3.71 T2 = 8.75 ± 2.17 T3 = 10.16 ± 3.51) No change in airway after bi-maxillary surgery T1 – T2 = 2.95 mm T1 – T3 = 1.5 mm (T1 = 14.46 ± 4.19 T2 = 11.51 ± 3.58 T3 = 12.96 ± 3.51)
Torre et al., 2017	20 Patients	*	Class II	Mandibular advancement	Increase in airway = 4.2235 cm^2
Jiang et al., 2017	50 Patients	21 Years	Class II	Mandibular advancement alone or mandibular advancement with maxillary setback	Increase in oropharyngeal airway Mandibular advancement T2 – T1 = 839 ± 168.2 mm^2 T3 – T1 = 80.44 ± 249.5 mm^2 Mandibular advancement + Maxillary setback T2 – T1 = 694.1 ± 170.4 mm^2 T3 – T1 = 859 ± 222.9 mm^2
Efendiyeva R., et al., 2014	26 Patients	21.88 Years	Class III	Bi-maxillary surgery	Posterior Pharyngeal Space – increased by 2.2 mm Middle Pharyngeal Space – decreased by 0.8 mm
Park et al., 2012	36 Patients	22 Years	Class III	Mandibular setback and bi-maxillary surgery	Decreased oropharyngeal airway Anteroposterior length decreased: Mandibular setback T1 – T0 = 1.61 mm T2 – T0 = 3.13 mm (T0 = 18.15 ± 5.26 T1 = 16.54 ± 5.67 T2 = 15.02 ± 2.82 Maxillary advancement + Mandibular setback T1 – T0 = 2.59 mm T2 – T0 = 2.44 mm (T0 = 18.56 ± 4.38 T1 = 15.97 ± 4.42 T2 = 16.12 ± 4.56

* = Data Not Available.

Table 2 Summary of Patients with Class II Malocclusion Treated with Functional Appliances.

Author/year	Number of patients	Skeletal relationship	Mean Age	Type of Treatment	Results
Isidor et al., 2018	20 patients	Class II	11 Years	Functional appliance	Oropharyngeal airway was increased by 1167 mm^3
Rizk et al., 2016	20 patients	Class II	11 Years	Mandibular Anterior Repositioning Appliance (MARA) followed by fixed appliances	Oropharyngeal airway increased by 5537.4 mm^3
Ozdemir et al., 2014	23 patients	Class II	17 Years	Fixed functional appliance	No statistically significant change in the oropharyngeal area – 0.16 mm^2
Restrepo et al., 2011	50 Patients (19 Bionator Appliance) (31 Klammt Appliance)	Class II	6–8 Years	Bionator Appliance Klammt Appliance	Significant increase in airway dimensions Bionator by 2.06 mm Klammt activator by 1.31 mm
Yassaei et al., 2012	23 patients	Class II	13 Years	Headgear activator and fixed orthodontic treatment	Increase in oropharyngeal airway by 2 mm
Ghodke et al., 2014	20 patients	Class II	8–14 Years	Twin block appliance	Depth of the oropharynx was increased significantly by 1.54 mm
Jena et al., 2013	83 patients	Class II	8–14 Years	Mandibular Protraction Appliance (MPA-IV) & twin block appliance	Mandibular Protraction Appliance (MPA– IV) Increase in oropharyngeal airway by 0.85 mm Twin block increased oropharyngeal airway by 2.12 mm
Han et al., 2014	48 patients	Class II	11.5 Years	Functional appliance	Increase in pharyngeal airway dimensions by T1-T0 – 105.9 mm^2 T2-T0 – 142.9 mm^2
Maspero et al., 2015	40 patients	Class II	9–14 Years	Activator	Increase in oropharyngeal airway by 2.43 mm
Ulusoy et al., 2014	37 patients	Class II	11 Years	Activator	Oropharyngeal area increased T2-T1 Superior Pharyngeal Space – 0.47 mm Middle Pharyngeal Space – −0.56 mm Inferior Pharnygeal Space – −0.34 mm T3-T1 Superior Pharnygeal Space – 1.34 mm Middle Pharyngeal Space – 0.65 mm Inferior Pharyngeal Space – 1.62 mm
Elfeky and Fayed, 2015	36 patients	Class II	8–12 Years	Twin block	Oropharyngeal airway increased by 3052.45 mm^3
Iwasaki et al., 2014	44 patients	Class II	11.5 Years	Herbst	Increased oropharyngeal airway depth by 4.16 mm Increase in oropharyngeal airway width by 7.72 mm Increase in oropharyngeal airway volume by 5000.2 mm
Yassaei et al., 2007	28 patients	Class II	10–14 Years	Functional appliance	Oropharyngeal airway increased by 1.49 mm

* = Data Not Available.

Jena et al., 2013; Han et al., 2014; Maspero et al., 2015; Ulusoy et al., 2014; Elfeky and Fayed, 2015; Iwasaki et al., 2014; Yassaei et al., 2007). Aksu et al. concluded that the activator appliance increased the oropharyngeal airway dimension at the level of the middle pharyngeal space only (Aksu et al., 2017). Contrarily, Ozbek et al. recorded a total increase in all dimensions of the oropharyngeal airway following treatment with the activator appliance (Ozbek et al., 1998), as observed in two studies in the current systematic review. Alternatively, Ulusoy et al. reported no significant enhancement in the oropharyngeal airway dimension following treatment with activator appliance (Ulusoy et al., 2014).

In the present study, the removable functional appliance had the most reliable outcome on the oropharyngeal airway when compared with fixed functional appliances in growing patients (6–17 years). Removable functional appliances have been shown to increase the volume of the airway to a greater extent when compared with fixed functional appliances (Rizk et al., 2016; Jena et al., 2013; Elfeky and Fayed, 2015; Ghodke et al., 2014).

4.2. Effect of orthognathic surgery

Bi-maxillary surgery and mandibular advancement procedures have resulted in significant increase in the dimension of the oropharyngeal airway (Hart et al., 2015; Torre et al., 2017; Jiang et al., 2017). The findings of our study corresponded to those reported by Joao Roberto (Goncalves et al., 2004) and Jakobsone et al. wherein a considerable increase in the volume of the oropharyngeal airway was observed following bi-maxillary surgery (Jakobsone et al., 2010).

Minh Nguyen reported that mandibular advancement surgery improved the dimensions of the oropharyngeal airway, whereas bi-maxillary surgery decreased the dimensions of the airway (Nguyen et al., 2014). These findings were similar to that of another study where bi-maxillary surgery resulted in a decrease in the oropharyngeal airway (Mattos et al., 2011).

In skeletal Class III patients, mandibular setback surgery has been shown to decrease the dimensions of the oropharyngeal airway (Aydemir et al., 2012; Park et al., 2012). Liukkonen et al. reported a decrease in the volume of the oropharyngeal airway in patients with Class III skeletal relations, following mandibular setback surgery. This may be due to the counterclockwise rotation of the mandible during the setback surgery, which results in a reduction in the volume of the oropharyngeal airway, (de Haan et al., 2013; Liukkonen et al., 2002), or due to the posterior and inferior displacement of the hyoid bone, which results in the obstruction of the airway (Kawamata et al., 2000).

Maxillary advancement surgeries in the current study were found to have no effect on the dimensions of the oropharyngeal airway on grown patients. This may be due to the integration of the soft palate to maintain the velopharyngeal seal prior to maxillary advancement (Schendel et al., 1976; Aydemir et al., 2012). This finding was not in accordance with those of several other studies that recorded a decrease in the oropharyngeal airway dimension following the advancement surgery (Degerliyurt et al., 2008; Mehra et al., 2001; Samman et al., 2002).

In grown patients aged (18–22) years with skeletal class III malocclusion, bimaxillary orthognathic surgery was found to be the recommended and superior method of treatment due to its effect of reducing relapse in the oropharyngeal airway, its ability to correct and prevent obstructive sleep apnea in skeletal class III patients (Gokce et al., 2012; Tepecik et al., 2018) and due to a resultant increase in the airway space as reported by Santagata (Santagata et al., 2015). It is also observed that bimaxillary surgery can decrease the magnitude of the reduction of the airway space caused by mandibular setback (Lye, 2008).

5. Conclusion

The limitations of this study include the presence of incomplete records, missing patient information, inadequate documentation and the limited amount of studies with non-homogeneous variables among the included articles cumulative analysis could not be performed.

In patients with skeletal Class II malocclusion, removable functional appliances appear to increase the dimensions of the oropharyngeal airway to a greater extent when compared with the fixed functional appliances in growing patients (6–17) years. Therefore, patients who receive removable functional appliance treatment have a more favorable long-term prognosis with regard to the oropharyngeal airway when compared with those who receive fixed functional appliance. Alternatively, in patients aged from (18–22) years with skeletal class III malocclusion bimaxillary orthognathic surgery was found to be the recommended and superior method of treatment due to its effect of reducing relapse in the oropharyngeal airway and its ability to correct and prevent obstructive sleep apnea in skeletal class III patients.

CRediT authorship contribution statement

Feras Al Qahtani: Conceptualization, data curation, formal analysis, methodology, writing original draft. **Khalid Bishawi:** Conceptualization, data curation, formal analysis, methodology, writing original draft. **Jeny Mary George:** Conceptualization, methodology, project administration, supervision, writing - review and editing. **Sam Thomas:** Methodology, validation, Writing - review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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