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Effects of Four First Premolar Extraction on the Upper Airway Dimension in a Non-Growing Class I Skeletal Patients: A Systematic Review

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Abstract

Objective: Orthodontic treatment aims not only to treat one's malocclusion and facial aesthetics but also to maintain or improve the patient's airway patency. This review aims to evaluate post-treatment changes in the position of hyoid bone and oropharyngeal airway size and dimensions associated with fixed orthodontic treatment with four first bicuspid extractions in non-growing Class I skeletal bimaxillary protrusion individuals.

Methods: Electronic databases including Embase, Web of Science, PubMed, and Scopus were used to research published articles. Included studies assessed the post-treatment effects of four first bicuspid extractions with maximum anchorage on pharyngeal airway dimensions in non-growing patients. Relevant data were obtained, summarised, and analysed from the included studies.

Results: Six articles were selected in this systematic review after meeting the requirements of the inclusion criteria.

Conclusions: Four bicuspid extractions followed by maximum anchorage involves predominant retraction of the anterior segment of the arches in non-growing skeletal Class I bimaxillary protrusion cases. Extraction of four first premolars led to retraction of the anterior segment and the retroclination of anterior teeth, which narrowed the pharyngeal airway dimensions. After such treatment, the hyoid bone position changes remain inconclusive, which warrants further studies.

Keywords
Airway; Bicuspid extraction; Bimaxillary protrusion; Hyoid bone; Non-growing; Orthodontics.

Introduction

The airway, also known as the respiratory tract, is a vital anatomical structure responsible for airflow during ventilation [1]. The airway is subdivided into two zones: the upper airway and the lower airway [2]. Anatomically, the upper airway can be divided into three sections: nasopharynx, oropharynx, and laryngopharynx, which serve a vital function of human survival-breathing [3] (Figure 1). Among those, the oropharynx is the narrowest part of the airway. It is also the most predisposed to change during and or after the orthodontic treatment. Respiratory disorders such as obstructive sleep apnoea (OSA) can arise because of upper airway constriction.

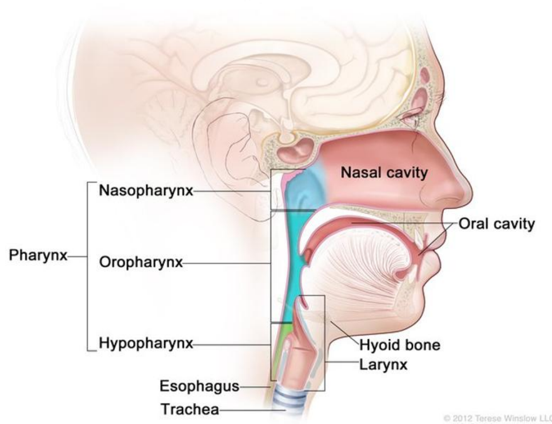

Figure 1: A diagram of the upper airway (pharynx). Three sections: nasopharynx, oropharynx, and laryngopharynx. The hyoid bone is also shown. ©2020 Terese Winslow LLC, U.S. Govt. has certain rights.

OSA is one of the sleep-breathing disturbances caused by collapsing of the upper airway during sleep, characterised by cessation of airflow with persistent respiratory effort, oxygen de-saturations, sleep arousals and sleep fragmentation [4]. Although OSA is a multifactorial disorder associated with obesity, age, facial morphology, airway collapsibility, and neuromuscular feedback, the size of the oropharyngeal airway is highly associated with OSA severity [5-12].

Recent research exhibited relationships between narrowed upper airway and obstructive sleep apnoea due to retrognathic mandible, high mandibular plane angle, and dorsally positioned tongue [13,14]. Although extraction orthodontic treatment is not limited to bicuspid extractions, it has been the choice for treating dental crowding cases for a long time. Since the birth of orthodontics, the extraction versus non-extraction orthodontic treatment method has been a long-discussed topic. However, over the last few decades, there has been a paradigm shift from extraction orthodontics, a traditional method of solving dental crowding, to a more functionally driven non-extraction approach. This emphasises the correction of malocclusion (how the study models occlude) and stability and the soft tissue profile aesthetics, the health of temporomandibular joints (TMJ), and the upper airway volumes [14,15].

It is well known that the bicuspid extraction technique is used to solve dental crowding issues. It is also a well-known fact that bicuspid extractions can reduce dental arch lengths due to retraction mechanics resulting in retraction and retroclinication of lower incisors [14-16]. Williams et al. [17] reported that approximately 66.5% of the available premolar extraction spaces were taken up by anterior segment retraction with lower incisor retraction. The rest of the space was taken up by posterior segments drifting mesially [17]. An anchorage design must be established during the diagnosis when orthodontic treatment is planned with extractions. However, not all extraction orthodontic treatment is the same. Extraction space closing mechanics can be divided into different four types [18] (Figure 2).

1. Group A: anchorage technique involving 25% of anchorage loss from the posterior segment and 75% retraction of the anterior segment,
2. Group B: anchorage technique involving an approximately equal amount of posterior and anterior movements,
3. Group C: anchorage technique involving 75% of protraction of the posterior segment and 25% of retraction in the anterior segment,
4. Absolute: anchorage technique involving 100% retraction of the anterior segment, also known as the maximum anchorage.

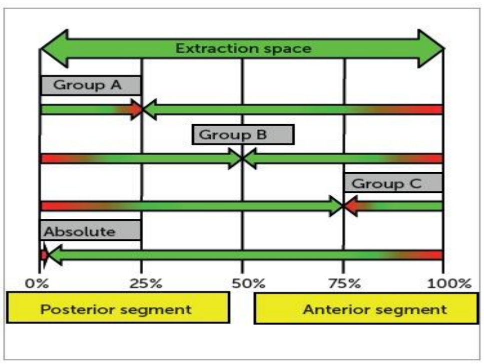

Figure 2: Anchorage classification: Group A space closure includes, on average, 25% of posterior anchorage loss and 75% of anterior retraction; Group B space closure includes more equal amounts of anterior and posterior tooth movement; Group C space closure includes, on average, 75% posterior protraction and 25% of anterior retraction. Absolute anchorage involves 100% retraction of the anterior segment [18].

It was shown that when maximum anchorage (absolute) mechanic design was used for the space closure, narrowing of the upper airway dimensions was resulted [19]. First bicuspid extractions with maximum anchorage design are commonly used in skeletal Class I bimaxillary protrusion cases to

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improve the soft-tissue protrusive profile. [20]. Some studies suggested that extraction orthodontics, which involved retraction of teeth, thus altered upper airway dimension, predisposed patients to sleep breathing disturbances such as obstructive sleep apnoea (OSA) [13-15]. The reduction in dental arch lengths in sagittal dimensions contributed to a decrease in airway volume and oral cavity dimension resulting in posterior displacement of the soft palate and the tongue.

Fukuda et al. [21] clinically found that orthodontic extraction patients displayed a higher Apnoea-Hypopnea Index (AHI) than untreated controls. On the other hand, Larsen et al. [19] showed no difference between patients who underwent extraction orthodontic treatment and the controls. While changes in hyoid bone position and decrease in airway dimension were reported after orthodontic extractions [20,22,23]. Other studies contradicted the findings where no changes were detected in hyoid bone position and the airway space following extraction orthodontic treatment [24-26].

Such inconsistent conclusions about whether extraction orthodontic impacts the upper airway may be due to natural craniofacial and pharyngeal growth that we see in growing patient samples. During this period, the rapid growth of the airway may partly disguise the effect of extraction on the changes in pharyngeal airway dimension. Varying growth rates in adolescent patients may lead to misinterpretation of the actual impact of dental extraction on the airway [27,28]. On the other hand, multiple studies reported that the upper airway ceased its growth in adult patients [19,24,29].

Objective

Above all, the most crucial aspect of the treatment objective should be improving or maintaining a patient's health. Each patient who will walk into our clinics will have their chief concerns that we will try to address and help. As treating orthodontic clinicians, we are trained and often hardwired to look at teeth only and undoubtedly, we straighten and solve malocclusion very well. However, we often forget about the possible negative impact our treatment may have on the patient's health, such as compromising one's airway, hence one's health. As doctors, we should never forget that, above all, we should avoid causing harm to our patients.

This systematic review attempted to explore the effects of maximum retraction of anterior teeth using maximum anchorage mechanics on pharyngeal airway space and hyoid bone position after four first bicuspid extractions with anterior incisor retractions in Class I skeletal bimaxillary protrusions non-growing individuals.

Materials and Methods

This systematic review was conducted with a study design including comparative studies analysing the association between four bicuspid extractions with maximum anchorage involving anterior incisor retractions and upper airway dimension in skeletal Class I bimaxillary protrusive non-growing patients. Participants included in this review included patients with extractions and non-extraction orthodontic treatment. Eligible selected studies assessed the changes in the hyoid bone position and upper airway dimension as outcome measures.

Search Strategy

This systematic review was conducted using relevant publications from January 2006 to November 2021, from the following electronic databases: PubMed, Web of Science, Scopus and Embase. The keywords used to search these following databases are outlined in Table 1. The reference lists from included articles were manually searched using their full titles.

	Database	Search strategy used	Extent of search	Citations found
1	PubMed	orthod* AND (tooth OR teeth OR bicuspid OR premolar) AND airway* AND (extraction OR extract*)	In all fields	52
2	EMBASE	orthod* AND (tooth OR teeth OR bicuspid OR premolar) AND airway* AND (extraction OR extract*)	In all fields	50
3	Web of Science	orthod* AND (tooth OR teeth OR bicuspid OR premolar) AND airway* AND (extraction OR extract*)	In all fields	43
4	Scopus	orthod* AND (tooth OR teeth OR bicuspid OR premolar) AND airway* AND (extraction OR extract*)	In all fields	49
	TOTAL			194

Table 1: Search strategies for each database.

Study Selection

All articles searched were reviewed by reading titles and abstracts to eliminate and exclude irrelevant articles.

Selection Criteria

The inclusion criteria are as follows:

1. Human Studies
2. Study Type: retrospective clinical studies or randomised controlled trials
3. Research Sample: late adolescents and adults with skeletal Class I bimaxillary protrusion without limitation to gender or race.
4. Intervention: fixed orthodontic treatment involving four first bicuspid extractions with maximum anchorage and retraction of anterior incisors. The method used to achieve the maximum anchorage was not a critical factor in decision making. The intervention must include either two-dimensional or three-dimensional pre-treatment and post-treatment radiographic evaluations.
5. Comparator: Non-extraction or no treatment.
6. Outcome: soft tissue changes in linear and angular measurements in lateral cephalogram and soft tissue changes measured in 3D using computer tomography (CBCT).

The exclusion criteria are as follows:

1. Animal Studies
2. Study Type: case reports, editorials, opinions, letters
3. Research Sample: orthodontic treatments other than interventions mentioned in the inclusion criteria, including orthopaedic treatment, mandibular advancement, bimaxillary

protraction, orthognathic surgery and patients undergoing growth modification were excluded.

4. Patients with previous orthodontic treatment history.
5. Patients with medical histories including pharyngeal pathology, pre-existing OSA, craniofacial deformities, adenoidectomy, tonsillectomy, allergies, nasal obstructions, and chronic mouth breathing.

Data Collection and Analysis

Data Collection

The following data were collected: author, year of publication, study design type, imaging modality, participant information including sample size, gender and age, skeletal and dental malocclusion, teeth extracted, anchorage design (mechanics), outcome and conclusion. Dimensional measurement changes in any region of the pharyngeal airway, which included nasopharynx, oropharynx, and laryngopharynx, were collected. Only measurements from immediate pre-treatment and immediately post-treatment were accepted.

Quality Assessment

This systematic review used the Joanna Briggs Institute's Critical Appraisal Checklist to assess a study's methodological quality and address any possible bias in its study design, conduct, and analysis. The result of the checklist is described in Table 2, with each question answered as either "yes", "no", or "unclear".

	Bhatia[50] (2016)	Chen[22] (2012)	Cho[51] (2021)	Germec-Cakan[19] (2011)	Nasser[52] (2019)	Wang[21] (2012)
Is the review question clearly and explicitly stated?	Y	Y	Y	Y	Y	Y
Were the inclusion criteria appropriate for the review question?	Y	Y	Y	Y	Y	Y
Was the search strategy appropriate?	Y	Y	Y	Y	Y	Y
Were the sources and resources used to search for studies adequate?	Y	Y	Y	Y	Y	Y
Were the criteria for appraising studies appropriate?	Y	Y	Y	Y	Y	Y
Was critical appraisal conducted by two or more reviewers independently?	Y	Y	Y	Y	Y	Y
Were there methods to minimize errors in data extraction?	Y	Y	Y	Y	Y	Y
Were the methods used to combine studies appropriate?	Y	Y	Y	Y	Y	Y
Was the likelihood of publication bias assessed	Y	Y	Y	Y	Y	Y
Were recommendations for policy and/or practice supported by the reported data?	Y	Y	Y	Y	Y	Y
Were the specific directives for new research appropriate?	Y	Y	Y	Y	Y	Y

Abbreviations: Y, yes; N, no; U, unclear

Table 2: Assessment of methodological quality.

Results

The article selection process is depicted in Figure 3. The initial total number of citations found was 196 from PubMed, EMBASE, Web of Science and Scopus electronic databases. A total of 115 duplicates were removed. Further exclusion of 46 articles was completed after screening the titles and abstracts. Thirty-three articles were then selected for full-text assessment. After the full-text appraisal, 26 articles were excluded due to the following reasons:

Article in a different language [30], sample age below 16 years old [24,31-34], Different premolar extractions [35,36], Different anchorage designs [25,37-43], Different malocclusion [44], non-retrospective studies [16,19,22,45-50].

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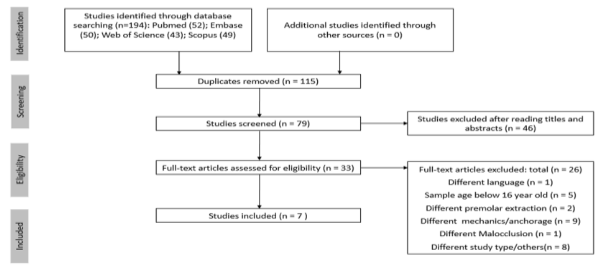

Figure 3: Flow Diagram for systematic search and article selection process.

Six eligible retrospective study articles were selected in this systematic review [20,22,23,51-53]. Table 2 summarises the quality assessment of the selected eligible articles. Table 3 outlines the characteristics of the included studies. The primary outcomes and conclusions from selected articles are summarised in Table 4. All six articles studied skeletal Class I bimaxillary protrusion cases involving four first bicuspid extraction using maximum anchorage mechanics, which resulted in retraction and retroclination of maxillary and mandibular incisors. Extraction indications were identical in these studies [20,22,23,51-53].

Authors	Year	Study Design	Imaging modality	Sample size	Gender (M/F)	Age (year)	Malocclusion	Teeth extracted	Extraction indication	Mechanics (Anchorage Design)
Bhatia, S.	2016	RS	Lateral Cephalograms	22	9/13	22.52 (19-29)	Class I bimaxillary protrusion	Four First Bicuspids	Anteroposterior discrepancy	Maximum anchorage
Chen et al	2012	RS	Cone Beam Computed Tomography	30	NS	Adults	Class I bimaxillary protrusion	Four First Bicuspids	Anteroposterior discrepancy	Maximum Anchorage
Cho, H. N.	2021	RS	Lateral Cephalograms	55	10/45	23.4±5.21	Class I bimaxillary protrusion	Four First Bicuspids	Arch length discrepancy ≤4mm)	Maximum Anchorage with microimplant
Germec-Cakan, D.	2011	RS	Lateral Cephalograms	13	2/11	15.5 ± 0.88	Class I bimaxillary protrusion	Four First Bicuspids	Anteroposterior discrepancy	Maximum Anchorage
				13	2/11	17.8 ± 2.4	Skeletal class I	Non-Extraction		Air-rotor stripping
				13	2/11	18.1 ± 3.7	Class I excessive crowding	Four First Bicuspids	Excessive dental crowding	Minimum Anchorage
Nasser, A.	2019	RS	Lateral Cephalograms	46	16/30	18-30	Class I bimaxillary protrusion	Four First Bicuspids	Anteroposterior discrepancy	Maximum Anchorage + Nance appliance
Wang et al	2012	RS	Lateral Cephalograms	44	8/36	21.19 (16-34)	Class I bimaxillary protrusion	Four First Bicuspids	Anteroposterior discrepancy	Maximum Anchorage

RS retrospective study, *NS* not specified

Table 3: Characteristics of selected articles.

Author	Main Outcomes			Conclusion
	Incisors	Hyoid	Changes in upper airway	
Bhatia (2016)	The amount of upper and lower incisor retraction was 2.2mm (P<0.0001) and 5.4mm (P<0.00001) respectively. The mean decrease in the U1/FH angle was 118 (P < 0.0001), and for L1/MP, it was 11.98 (P < 0.0001). The tip of the upper incisor was retracted by 7.75 mm (P < 0.0001) and the tip of the lower incisor was retracted by 7.15 mm (P < 0.0001)	The mean percentage posterior movement of hyoid bone after retraction of lower incisor was found to be 11.64%	The mean percentage reduction of pharyngeal airway size was found to be – SPP-SPPW (16.72%), TB-TPPW (19.56%), and U-MPW (22.27%)	1. The pharyngeal airway dimensions reduced after retraction of anterior teeth especially at two levels – velopharynx and glossopharynx 2. The hyoid bone tends to move in the posterior direction 3.A significant correlation was observed between retraction of lower incisors and reduction of pharyngeal airway dimensions.
Chen (2012)	The amounts of upper incisor retraction at the incisal edge and apex were 7.64±1.68 and 3.9±2.10 mm, respectively. (P<0.05)	The hyoid retraction was 2.96±0.54 mm in horizontal direction and 9.87±2.92 mm in vertical direction. (P<0.05)	The reduction in mean cross-sectional areas of the palatopharynx, glossopharynx, and hypopharynx were 21.02±7.89, 25.18±13.51, and 38.19±5.51 %, respectively. (P<0.05)	1. Large incisor retraction leads to narrowing of the upper airway in adult bimaxillary protrusion patients 2. There is a significant correlation among the retraction distance of the upper incisor, then retraction distance of the hyoid in the horizontal direction, and the decrease of the hypopharynx
Cho (2021)	The mean change of U1-FH(°) was -12.00° (p<0.0001), L1-MP(°) was -9.27°(p<0.0001),	The mean decrease of hyoid position was -0.83mm (Distance between hyoid bone and the most protrusive point of retrognathion: H-RGN) (p<0.186)	The mean decreases in pharyngeal airways: PNS-Ad1 (-0.36mm) [p<0.344], PNS-Ad2 (-0.11mm) [p<0.632], SPAS (-1.96mm) [p<0.001], MAS (-1.95mm)[p<0.001], IAS (-1.74mm)[p<0.001], VAL (1.09mm) [p<0.058]	1. The BSP patients showed significant reductions in the velopharyngeal and glossopharyngeal airway spaces after extraction treatment; however, the reduced pos treatment dimensions corresponded to the normal dimensions in the control samples. 2. The glossopharyngeal space might be susceptible after treatment in the hyperdivergent BSP group, especially when the mandibular plane angle is increased during treatment. 3. Control of the vertical dimensions during maximum anterior retraction would be important to achieve both aesthetic and respiratory functional improvements in BSP patients.
Germec-Cakan (2011)	(1) In minimum anchorage group, the average upper and lower incisor retraction was 1.6±2.4 and 1.9±1.9 mm, respectively. The average mesial molar movement was 3 mm. (P<0.05) (2) In ARS group, mesial movement of upper and lower incisor was approximately 0.7 mm after treatment. (P<0.05) (3) In maximum anchorage group, the average upper and lower incisor retraction was 12.4±3.5 and 9.6±2.9 mm, respectively. (P<0.05)	Hyoid position has no significant change	(1) In minimum anchorage group, increase of superior and middle oropharynx size was 1.7±2.4 and 1.0±2.2 mm, respectively. (P<0.05) (2) In ARS group, no significant was observed in airway dimension (3) In maximum anchorage group, decrease of superior and middle oropharynx size was 2.1±1.5 and 3.8±3.3 mm, respectively. (P<0.05)	1. Superior and middle airway size increased in subjects treated with extraction and minimum anchorage. 2. In patients treated non-extraction by ARS, no significant change was observed in airway dimensions. 3. Middle and inferior airway size narrowed in subjects treated with extraction and maximum anchorage.
Nasser (2019)	The mean values of upper incisor retroclination and retraction were 9.6° and 4.1mm respectively. The mean values of lower incisor retroclination and retraction were -9.65° and 4.1mm respectively.	No measurement	The mean decreases in pharyngeal airways: SPAS (-0.69mm) [p<0.001], MAS (-0.66mm) [p<0.001], IAS (+0.31mm)[p<0.19], VAL (+0.45mm) [p<0.11]	Based on this study, a statistically significant reduction in soft palate thickness (0.35 mm), superior (0.69 mm), and middle (0.66 mm) airway spaces is evident following first premolar extraction and orthodontic retraction of anterior teeth among class I BMP patients. Furthermore, regression analysis showed that, for every 1° of lower incisor retroclination, a 0.73 mm change in tongue length was evidenced.
Wang (2012)	The tips of upper and lower incisor were retracted by 6.84 and 4.95 mm, respectively. (P<0.05)	The hyoid retraction was 0.88±2.32 mm in horizontal direction and 1.24±3.42 mm in vertical direction. (P<0.05)	The hyoid retraction was 0.88±2.32 mm in horizontal direction and 1.24±3.42 mm in vertical direction. (P<0.05)	1. Following retraction of incisors, the pharyngeal airway became narrower 2. The changes of the pharyngeal airway size were no different between the hyperdivergent and non-hyperdivergent groups 3. The hyoid bone tends to move in a posterior and inferior direction 4. There was a significant correlation between the retraction distance of lower incisor and the airway behind the soft palate, uvula, and tongue

Table 4: Main outcome and conclusion.

A study by Germec-Cakan et al. [20] was the only study that divided its subjects into three groups: group 1 (13 borderline cases treated with extraction of four premolars with minimum anchorage), group 2 (13 borderline cases treated without extraction but with air-rotor stripping technique) and group 3 (13

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bimaxillary protrusion cases treated with the extraction of four premolars with maximum anchorage). Only the data from group 3 were considered in this systematic review.

The relationship between the hyoid bone position and the sagittal position of the anterior teeth was also assessed in six of the articles. Germec-Cakan et al. [20] showed no significant change in the positioning of the hyoid bone after the treatment. In contrast, other studies by Bhatia et al. [51], Chen et al. [23], Cho et al. [52] and Wang et al. [22] demonstrated retraction of hyoid bone after retraction of lower incisors. A study by Nasser et al. [53] did not study hyoid bone changes.

All studies selected showed pharyngeal airway reduction at various anatomical levels. Bhatia et al. [51] concluded that there was a significant correlation between first bicuspid extractions with maximum anchorage, which resulted in incisor retraction and pharyngeal airway dimensions: SPP-SPPW (16.72%), TB-TPPW (19.56%), and U-MPW (22.27%). Figure 4 depicts cephalometric landmarks used by Bhatia et al. [51].

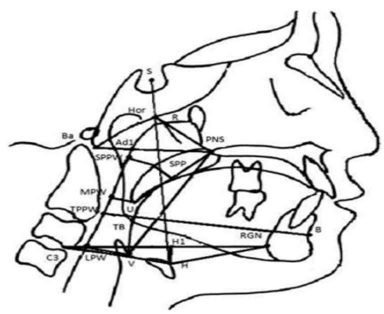

Figure 4: Cephalometric landmarks used in studies by Wang et al. [22] and Bhatia et al. [51] (Diagram from Wang et al. [22]).

Chen et al. [23] showed average cross-sectional area reductions inpalatopharynx (21.02±7.89%), glossopharynx (25.18%±13.51%), and hypopharynx (38.19±5.51%). The study by Chen et al. concluded upper airway dimension reduction was seen in bimaxillary protrusive adult patients with a significant incisor retraction. They have also concluded that there is a strong correlation between the amount of hyoid bone retraction, upper incisor retraction distance, and the hypopharyngeal dimension in the horizontal planes [23].

A significant decrease in glossopharyngeal and velopharyngeal airway dimensions was noted post-extraction orthodontic treatment with maximum anchorage from a study conducted by Cho et al. [52] The mean reduction in the Superior Posterior Airway Space (SPAS), the Middle Airway Space (MAS), and the Inferior Airway Space (IAS) were 1.96mm, 1.95mm and 1.74mm respectively. Different sections of pharyngeal spaces are depicted in Figure 5. Group 3 data from a study by Germec-Cakan et al. [20] showed a reduction in middle and inferior airway size in patients who went through first bicuspid extraction and maximum anchorage design. The average decreases in superior and middle oropharynx sizes were 2.1±1.5 and 3.8±3.3 mm, respectively. Nasser et al. [53] concluded a decrease in superior and middle airway space following first premolar extraction with maximum anchorage mechanics. He also

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concluded that every 1° of lower incisor retroclination reduced the tongue length by 0.73 mm.

Finally, Wang et al. [22] found that the pharyngeal airway narrowed following incisor retraction. He also indicated a noticeable relationship between lower incisor retraction and a decrease in size of the airway posterior to the soft palate, uvula, and tongue. The mean reductions in pharyngeal space were 0.56±1.48mm (SPP-SPPW), 0.85±1.77mm (U-MPW), 1.63±1.80mm (TB-TPPW), and 1.54±2.90mm (V-LPW).

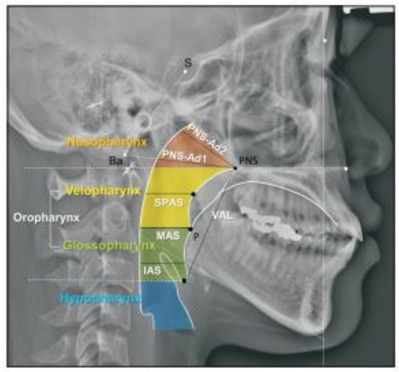

Figure 5: Cephalometric pharyngeal area map showing different sections of the pharyngeal airway: "PNS-Ad2 and PNS-Ad1 for the nasopharynx in orange; superior posterior airway space (SPAS) for the velopharynx behind the soft palate in yellow; middle airway space (MAS) and inferior airway space (IAS) for the glossopharynx behind the tongue base in green" [52]; and Hypopharynx in blue (Diagram from Cho et al. [52]).

Discussion

This systematic review analysed and investigated the effects of maximum retraction of anterior teeth using maximum anchorage mechanics on pharyngeal airway space and hyoid bone position after four first bicuspid extractions with anterior incisor retractions in Class I skeletal bimaxillary protrusions non-growing individuals. Every study selected in this systematic review established that when maximum anchorage mechanic was applied to four first bicuspid extractions, a large amount of anterior teeth retraction and retroclination occurred. Kalwitzki et al. [54] demonstrated a large amount of incisor retraction resulted in a "dorsal movement of the anterior border of the oral cavity" [54], which may cause a reduction in the upper airway dimension by affecting the position of the soft palate and the tongue [54]. Germec-Cakan et al. [20] concluded there was no significant correlation between four first bicuspid extractions orthodontic with maximum anchorage and hyoid position. Cho et al. [52] also demonstrated a minimal decrease in hyoid position, which seemed clinically insignificant.

On the contrary, Bhatia et al. [51] demonstrated that the mean percentage of posterior movement of hyoid bone after retraction of lower incisors was found to be 11.64%. Chen et al. [23] showed 2.96±0.54mm and 9.87±2.92 mm of hyoid retraction in the horizontal and vertical planes, respectively, demonstrating a significant narrowing in upper airway dimensions. From these studies, it was difficult to conclude the impact of hyoid position change on the upper airway due to contradicting results.

All six articles concluded a reduction in upper airways when maximum anchorage design was applied to

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four first bicuspid extractions in skeletal Class I bimaxillary protrusion cases. Not only did Germec-Cakan et al. [20] study maximum anchorage subjects, but they have also studied minimum anchorage. In contrast to the maximum anchorage, where the anterior arch segment is brought distally, minimum anchorage involves mesial movement of posterior teeth with minimum retraction of the anterior segment to fill in the premolar spaces created from the extractions. This resulted in a dimensional increase of 1.7±2.4mm and 1.0±2.2 mm in the superior and middle oropharynx, respectively. Such planned mesial movement of the posterior segment with minimum retraction of the anterior segment seemed to provide increased space behind the tongue, which may explain the improvement in pharyngeal dimension even after the extraction [45].

When the research criteria excluded the maximum anchorage from the inclusion criteria, there was a consensus from the literature reviews that there was no strong correlation between extraction orthodontic treatment and reduction of the pharyngeal airway space [25,35]. Al Maaitah et al. [25] was one of the articles which did not specify the type of mechanics used to close first premolar extraction spaces, which concluded there was no change in the upper airway space after the treatment. Studies that failed to specify the exact anchorage design used in their studies, including Stefanovic et al. [16], Valiathan et al. [24], Pliska et al. [26] and Joy et al. [37], concluded a negative association between airway space changes and dental extractions.

An article from Aldosari et al. [35] studied airway space changes after second premolar extractions. The study concluded an increase in the vertical airway length following extractions of second premolars but failed to describe the exact anchorage mechanics used in this study. Group 1 samples from a study by Germec-Cakan et al. [20] showed an increase in the upper airway dimension where minimum anchorage design was applied.

Growing patients, including young adolescents under 16 years of age, experience craniofacial growth, which leads to an upper airway volume increase [16,24,30]. A vast majority of articles published included growing individuals in their studies, which may explain the negative association between extraction orthodontic and pharyngeal size reduction. Rapid growth and different growth rates of the airway in growing individuals may have played a pivotal role in masking and confounding the effect on the upper airway following teeth extractions.45 On the other hand, the upper airway ceases its growth in adult patients [19,24,29]. Therefore, this systematic review excluded growing patients to assess and obtain results as accurately as possible.

There are many different types of malocclusions. Although it must be stressed that every case is different, each malocclusion type has its own treatment protocol, which may or may not involve extraction or extractions of teeth. To maintain strict research parameters, only one type of malocclusion and one method of teeth extractions were chosen in this systematic review: skeletal I bimaxillary protrusion and four first bicuspid extractions. Further studies are required to examine the effects of various extraction groups and mechanics designs in different skeletal and dental malocclusion settings. Articles that used both cone-beam computed tomography (CBCT) and the lateral cephalogram as imaging modalities were selected to measure and quantify in this systematic review. The pharyngeal airway is a three-dimensional structure. Hence, 3D imaging using CBCT would be the best method of obtaining true pharyngeal airway dimensions [55-58]. However, a two-dimensional lateral cephalogram has been proven to be an acceptable imaging modality in assessing pharyngeal airway changes in patients [59,60,61]. In fact, a high correlation was reported between the pharyngeal volume measured on CBCT and pharyngeal airway size seen on lateral cephalograms [62]. A high reliability of cephalometric landmarks and measurements was also reported by Miles et al. [61] Out of six eligible articles, one study by Chen et al. [23] utilised CBCT to measure the airway changes. The rest of the studies used lateral cephalograms for obtaining results [20,22,23,51-53].

Limitations

For research, a Randomised Controlled Trial (RCT) is the most controlled and least biased method for interventional research. However, the nature of orthodontic treatment will not allow RCT to be conducted easily because every case is individualised based on its diagnosis. Also, it is unethical to extract all four bicuspids or not extract them randomly, not considering their actual needs, particularly if it can harm the patient. All six articles chosen for this review were retrospective studies, and the value and quality of their research cannot be overlooked.

Unfortunately, the long-term stability of the measurements was unable to be obtained from all included studies. Therefore, further follow up research on the long-term effect of extraction orthodontic treatment on the pharyngeal airway would be required. Inconsistent study designs, research materials and methods were identified for this systematic review. Inconsistencies in age selection, skeletal and dental malocclusion type, selection of teeth being extracted, anchorage design and keeping the research parameters wide open may have led to many articles resulting in no correlation between extraction orthodontics and narrowing of the airway. Thus, results from articles with inconsistent research materials and methodologies may be questioned. For this reason, it is difficult to rationalise and make a conclusive statement that there is no association between extraction orthodontics and reduction of pharyngeal airway dimension. The result may depend heavily on the chosen study design. In the end, because each orthodontic treatment should be tailored to individual needs, further studies are required with strict research parameters to study the effects of orthodontic extractions on the upper airway with different skeletal pattern variations without various anchorage designs to avoid generalisation, which seems to be happening in the world of orthodontic.

Conclusions

Within the limitations of this systematic review, for non-growing Class I skeletal bimaxillary protrusion with four first bicuspid extractions, the following conclusions could be drawn when treated with maximum anchorage design:

1. Retraction and retroclination of the anterior incisors reduced oral cavity dimension, affecting soft palate and tongue position, consequently reducing the pharyngeal airway dimension.
2. The hyoid bone positional changes following extraction orthodontic and incisor retraction remain inconclusive. Further studies are warranted.

3. A significant correlation was observed between first four bicuspid extraction orthodontics with maximum anchorage and the pharyngeal airway dimension reduction.

Extraction orthodontic treatment should be considered as one of the treatment options, not a solution to every orthodontic problem. Every case should be carefully diagnosed and analysed for correct treatment planning and execution for optimal results without compromising our patient's airways hence their health.

Conflict of interest

The author has no conflict of interest to declare in this article.

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