Open Access Library Journal
2024, Volume 11, e11783
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Valuation of the Effect of Premolar Extractions in the Context of Orthodontic Treatment on Vas: A Systematic Review of the Literature

Qaderi Mokhtar*, Traore Abdoul Aziz, Ousehal Lahcen

Department of Orthopaedics, Faculty of Dentistry, University Hassan II, Casablanca, Morocco
Email: *mokhtarqaderi13@gmail.com

How to cite this paper: Mokhtar, Q., Aziz, T.A. and Lahcen, O. (2024) Valuation of the Effect of Premolar Extractions in the Context of Orthodontic Treatment on Vas: A Systematic Review of the Literature. *Open Access Library Journal*, **11**: e11783.
https://doi.org/10.4236/oalib.1111783

Received: June 5, 2024
Accepted: July 14, 2024
Published: July 17, 2024

Abstract

Introduction: The extraction of premolars is now a procedure frequently practiced as part of orthodontic treatment although it is subject to controversy. Its main objective which is very often the repositioning of the incisors, considered a guarantee of stability of an orthodontic treatment, is likely to reduce the arch perimeter and therefore the space dedicated to the tongue resulting in a reduction in the dimensions of the upper airway (VAS). The aim of this study was to highlight the impact of premolar extractions for orthodontic treatment on the upper airway. **Methodology:** This was a systematic review of the literature including cohort studies, case-control studies and randomised clinical trials. The study population consisted of patients with malocclusion requiring extractions of 4 premolars for orthodontic purposes, without gender or age restriction. The intervention consisted of comparing changes in the dimensions of the VAS in patients who had undergone orthodontic treatment with extraction of 4 premolars, regardless of the orthodontic mechanics used, the type of appliance, the technique used and the duration of treatment, with patients before treatment, treated without extractions or not treated. To do this, the databases chosen for our bibliographic research are Medline, Science Direct, Scopus and Cochrane Library and during a period between 01/11/20015 and 01/11/2023. **Results:** The initial comprehensive literature search of databases using different Boolean keywords and equations resulted in a total of 930 titles. After deleting the duplications and critical reading of the abstracts, only 12 articles were selected that met the eligibility criteria of our study. The 12 studies that met the eligibility criteria for this study were included with a total of 758 patients, 547 women (72%) and 211 men (28%). **Conclusion:** It is difficult to draw definitive conclusions from this systematic review of retrospective clinical studies. The hypothesis is that premolar extraction reduces the arch perimeter, thereby restricting the space for the tongue and positioning it further back. This adaptation of the tongue to its new habitat would lead to constriction of the oropharyngeal airways. Several studies have been designed to test this hypothesis, but to date, solid evidence is lacking.

Subject Areas

Dentistry

Keywords

Extraction, Premolars, VAS, Orthodontics

1. Introduction

At present, the orthodontic paradigm has shifted to soft tissues, and orthodontists believe that soft tissue analysis, including facial contour evaluation, neuromuscular function, Language, tonsils and airways are integral to orthodontic diagnosis and treatment planning. The extraction of permanent teeth as part of orthodontic treatment has always been a controversial topic in clinical orthodontics.

One of the first orthodontists to indicate permanent tooth extractions to correct malocclusions was Charles Tweed, who found that only 20% of his clinical cases treated without extractions were successful. However, his ideas were considerably different from the non-extractionist theory supported by his professor, Edward Angle [1]. Extraction of the premolars is now a procedure frequently performed as part of orthodontic treatment.

The decision regarding dental extraction as part of an orthodontic treatment plan depends on a number of factors such as the age of the patient, the width of the dental arch, the dentoalveolar ratio, the profile of the face, the extent of the congestion, and the clinician's judgment and preferences. Depending on the diagnosis and treatment plan, 2 or 4 premolars are usually extracted. The repositioning of the incisors is considered a guarantee of stability of orthodontic treatment; however, it reduces the arch perimeter and therefore the space dedicated to the tongue. This can affect the dimensions of the upper airway (VAS).

The airways can be divided into two parts: the upper respiratory tract (VAS) which includes the nasal cavity, pharynx and larynx; and the lower respiratory tract (VAI) which corresponds to the trachea, bronchi and lungs. VAS is responsible for the physiological processes of swallowing, phonation and breathing.

The factors influencing the morphology of VAS are the size of the tongue and soft palate, the position of the lateral pharyngeal wall and the position of the maxilla and mandible [2]. In addition, patients with malocclusions have been reported in the literature to have differences in the size and position of soft tissue structures and airways [3]. The pharynx bike is the narrowest part of the respiratory tract which is therefore the most sensitive to stenosis and obstruction; it has been described that it may be affected by orthodontic treatment [4].

Evidence showed that significant dentofacial changes occurred after orthodontic treatment with extraction; these changes concerned skeletal structures, the soft tissue profile and the position of the incisors and have the potential to affect the position of the tongue and pharyngeal space [5]. The main concern regarding changes in VAS dimensions after orthodontic extraction of premolars is related to its adverse effects on sleep quality. Several studies have shown that upper airway stenosis leads to respiratory disorders such as snoring and obstructive sleep apnoea (OSA), which negatively affect quality of life [6] [7].

The orthodontist is faced with a clinical dilemma: should the incisors be extracted and repositioned or should the VAS and the impact of extractions on their permeability be considered? The question that each practitioner asks is: What is the effect of premolar extractions and therefore the lingual repositioning of the incisors on the permeability of VAS? It is to try to answer this question that we conducted this systematic review of the literature whose objective was to highlight the impact of premolar extractions for orthodontic treatment on the upper airways.

2. Materials and Methods

This is a systematic review of the literature including cohort studies, case-control studies and randomized clinical trials.

The protocol for this review was registered on 12/25/23 on the INPLASY platform (International Platform of Registered Systematic Review and Meta-analysis Protocols) under the following registration number: INPLASY2023120099 and under the DOI: 10.37766/in plasy 2023.12.0099.

The databases chosen to carry out our bibliographic search are the following: Medline, Science Direct, Scopus and Cochrane Library during the period between 01/11/2015 and 01/11/23.

The 4 main concepts of our research topic were: "Orthodontic treatment, Premolar's extractions, and Upper airways".

Study population consisted of patients with malocclusion requiring extractions of 4 premolars for orthodontic purposes, without gender or age restrictions. The intervention consisted of comparing the changes in the dimension of the VAS (total volume, and/or volume of the nasopharynx, oropharynx and hypopharynx) in patients who had benefited from orthodontic treatment with extraction of 4 premolars regardless of the orthodontic mechanics used. (Maximum/reciprocal/minimal anchorage/absolute anchorage by miniscrew), the type of device, the technique used and the duration of treatment with patients before treatment, treated without extractions or not treated.

The criteria for inclusion in this work were as follows:

Studies dealing with the effects of orthodontic extractions of premolars on VAS;

Randomized and non-randomized clinical trials;

Descriptive and analytical observational studies: case control study, cohort and cross-sectional study as well as retrospective studies;

Articles published between 2015 and 2023;

The Criteria for Exclusion were:

1) Articles judged as case studies, expert reports, letters, comments, and editorials.

2) Articles that do not meet the objectives of our work on the basis of the reading of abstracts and the critical reading of the full text.

3) Articles dealing with the effects of orthodontic treatment without extraction on VAS.

4) Articles with a publication date prior to 2015.

5) Articles in a language other than French and English.

After reading the titles of 685 articles, we kept 122 articles (563 articles were eliminated). After reading the summaries of the 122 articles, we kept 35 articles (87 articles were eliminated according to the exclusion criteria). The final number of validated publications is 12 articles and represents a database for systematic analysis that will be explored in the results and discussions section. All studies selected were observational studies and the quality assessment of these studies is carried out by STROBE ("Strengthening the Reporting of Observational studies in Epidemiology").

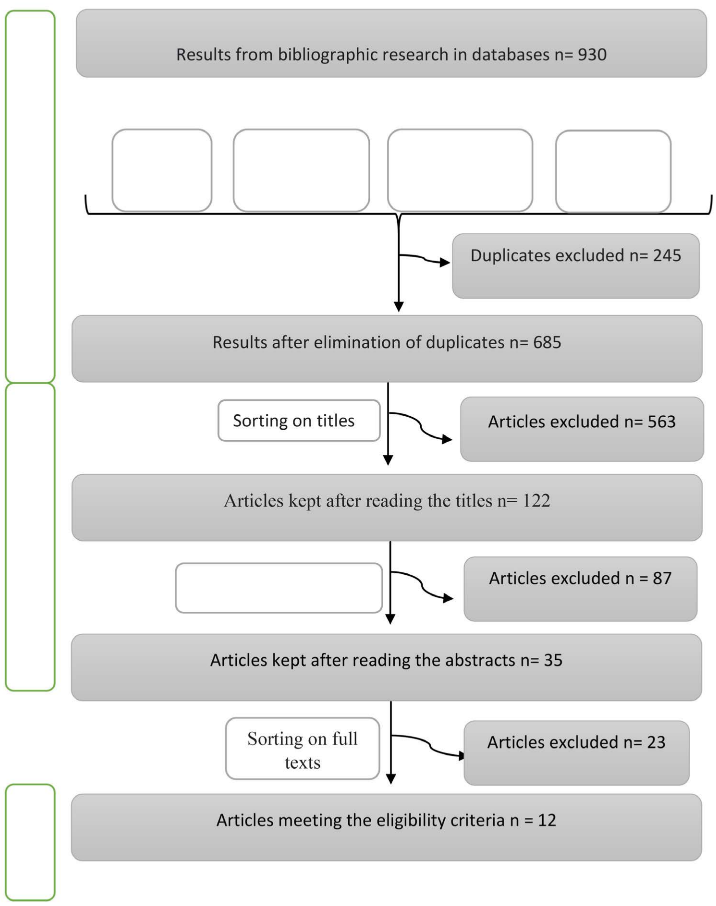

Figure 1. Flowchart of the relevant item selection process.

The following data were extracted from the included studies: title and name of authors, year of publication, study types, sample, diagnosis, means of measurement and finally conclusion.

Figure 1 summarizes the sequence of literature searches on the different databases using the different keywords and Boolean equations mentioned above, according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram. The initial exhaustive search resulted in a total of 930 titles, 245 were eliminated due to duplications. The remaining 685 were examined by titles and abstracts and 650 studies were excluded. The analysis of the full text of the remaining 35 articles led to the exclusion of 23 other publications. 12 articles therefore met the eligibility criteria.

3. Results

A total of 758 patients were included in the selected studies with 547 women (72%) and 211 men (28%). All the characteristics of the 12 selected studies were described in the table below (Table 1).

Table 1. Summary table of the characteristics of selected studies.

Authors, Reference Years	Title	Type of study and Sample	Diagnosis and Means of measurement	Conclusion
Cho HN *et al.* [2] 2021	Effect of extraction treatment on upper airway dimensions in patients with bimaxillary skeletal protrusion relative to their vertical skeletal pattern	Retrospective study 55 patients (10 Men and 45 Women) 23.4 5.21 years	Biprognathia Profile teleradiography	The size of the pharynx remains stable with sagittal changes. The oropharynx may be sensitive to vertical changes after extractions
Jena AK *et al.* [3] 2022	Adaptive changes in the posterior pharyngeal wall following large retraction of incisors during comprehensive orthodontic treatment	Retrospective study 61 patients Group I without extractions: 27 (21.04 ± 2.08) Group II with extraction : 34 (22.50 ± 3.53)	Skeletal class I with a biproalveolia Profile teleradiography	No change was observed in the dimension of the VAS after incisor retraction.
Bhatia Lt C *et al.* [4] 2016	Effect of retraction of anterior teeth on pharyngeal airway and hyoid bone position in Class I bimaxillary dentoalveolar protrusion	Retrospective study 22 patients (9 men and 13 women): 22.52 years old	Skeletal Class I Biproalveolia Profile teleradiography	Incisor repositioning influences the size of the airway as well as the position of the hyoid bone which becomes more posterior.
Shi X *et al.* [5] 2021	Effects of miniscrew-assisted orthodontic treatment with premolar extractions on upper airway dimensions in adult patients with Class II high-angle malocclusion	Retrospective study 18 patients 21.2 ± 2.9 years	Hyperdivergent Class II.1 CBCT (Cone beam computed tomography) Profile teleradiography	The use of miniscrews for the intrusion of the molars allows anterior rotation of the mandible which allows the increase in the size of the airway despite the extractions of premolars

Continued

Aldosari MA *et al.* [6] 2019	Evaluation of the airway space changes after extraction of four second premolars and orthodontic space closure in adult female patients with bimaxillary protrusion	Retrospective study 29 patients Ages 18 to 30 years	Class I Biproalveolism Profile teleradiography	Extraction of the 4 second premolars does not affect the size of the VAS
Zhang J *et al.* [7] 2015	Upper airway changes after orthodontic extraction treatment in adults: A preliminary study using cone beam computed tomography	Retrospective study 18 patients (5 males and 13 females) 24.1 ± 3.8 years old	Hyperdivergent skeletal Class II CBCT	No significant differences in VAS volume and height after extraction of the first 4 premolars. The sagittal dimensions of the VAS are narrowed in the middle and lower parts
Mortezai O *et al.* [8] 2023	Effect of premolar extraction and anchorage type for orthodontic space closure on upper airway dimensions and position of hyoid bone in adults: A retrospective cephalometric assessment	Retrospective study 142 patients 40 cases of Class I biproalveolism 40 cases	Class I with moderate congestion 40 cases Class II 22 cases Classe III Profile teleradiography	Variations in the dimensions of the VAS and the position of the hyoid bone are affected by the type of anchor used to close the extraction spaces of the first 4 premolars.
Zheng Z *et al.* [9] 2017	Computational fluid dynamics simulation of the upper airway response to large incisor retraction in adult class I bimaxillary protrusion patients	Retrospective study 30 patients 19 females 11 males 25.87 ± 0.78 years old	Class I Biproalveolism Computational fluid dynamics (CFD)	CFD is a validated method for accurately calculating the aerodynamic flow characteristics of the VAS, enabling flow and regional pressure to be described. After extraction, the oropharynx and hypopharynx increase resistance to flow pressure, and the risk of pharyngeal collapse increases after incisor retraction with maximum anchorage
Guo R *et al.* [10] 2022	Oropharynx and hyoid bone changes in female extraction patients with distinct sagittal and vertical skeletal patterns: A retrospective study	Retrospective study Group I 40 patients without extractions Group 2 120 patients with extractions	Class I Normo (30 patients) Class I Hyper (30) Class II Normo (30) Class II Hyper (30) CBCT	The oropharynx increases in volume after extractions, more so in Class I than Class II patients. The hyoid bone is displaced posteriorly.
Joy A *et al.* [11] 2020	Airway and cephalometric changes in orthodontic patients after premolar extractions	Retrospective study Group I 42 patients without extractions (22 M + 20 F) 26 ± 8.0 years old Group 2 41 patients with extractions (20 M + 21 F) 26.1 ± 7.1 years	Classe I DDM Classe II DDM Classe III DDM CBCT	No significant differences in sagittal and transverse VAS dimen-sions

Continued

Al Kawari HM *et al.* [12] 2018	Pharyngeal airway dimensional changes after premolar extraction in skeletal class II and class III orthodontic patients	Retrospective study 60 patients Group I 10 M + 22 F 17±5 years old Group II 12 M + 16 F 18 ± 4 years	Group I = Skeletal Class II Group II = Skeletal Class III Profile teleradio-graphy	Increased rhinopharyngeal volume in Class II and Class III patients. Changes in the dimensions of the hypopharynx and oropharynx are not significant.
Fang MR *et al.* [13] 2022	Study of pharyngeal airway morphology with CBCT: Benefits of four premolar extraction orthodontic treatments	Retrospective study 80 patients Class I: 30 (5 H + 25F) 15.7 ± 4.48 Class II : 35 (8 H + 27 F) 18.1 ± 5.41 Class III: 15 (3 H + 12F) 18.9 ± 4.45	Classe I Squel Classe II Squel Classe III Squel CBCT	Premolar extractions do not affect VAS dimensions

4. Discussion

There is no real consensus in the literature on this subject; the methods of evaluating this probable restriction of the airways also vary from one author to another. Half of the authors retained in our study stated that orthodontic extractions of the 4 premolars did not affect the size of the VAS while the other half stated that a change could occur in the direction of a reduction in the volume of VAS the following premolar extractions.

VAS is composed of the nasopharynx, oropharynx and laryngopharynx, among which the oropharynx is the narrowest and potentially the most sensitive to adverse effects after orthodontic treatment [14]. The base of the tongue, soft palate and posterior and lateral pharyngeal walls form the boundary of the oropharynx. A large incisive repositioning results in a reduction in the volume of the oral cavity, which can affect the position of the tongue and soft palate and thus lead to a narrowing of the VAS [15] [16]. According to Guo R *et al.*, nasopharynx and hypopharynx are supported by bone and cartilage and are located far from the oral cavity; they are not easily influenced by extractions. In contrast, the oropharynx includes soft tissues and tongue; it is directly connected to the oral cavity and therefore more sensitive to changes [10].

The main concern about the impaired pharyngeal dimension caused by orthodontic extraction is the quality of sleep of patients. Constriction of the VAS can lead to respiratory disorders, such as snoring and obstructive sleep apnea (OSA), which can significantly degrade the quality of life of patients. OSA is a chronic sleep-related respiratory dysfunction, defined by the cessation of airflow accompanied by persistent respiratory stress due to the collapse of the VAS [17] [18]. Recently, there has been increasing evidence that patients with OSA have dento-facial morphological features associated with narrowing of the upper respiratory tract [19] [20]. The etiopathogenesis of OSA is still uncertain and several factors are implicated, including anatomical factors leading to VAS narrowing and obesity [21].

Several studies have been conducted by the authors to identify the real impact of orthodontic therapy on the upper airways.

Thus, Cho HN *et al.* [2] in their retrospective study of 55 patients treating biprognathia cases noted that pharynx size remains stable at sagittal changes. Oropharynx, on the other hand, may be sensitive to vertical changes after extractions.

Similarly, Jena AK *et al.* [3] in their study of 61 subjects with a skeletal class I associated with biproalveolie noted that no change was observed in the VAS dimension after incisive retraction as Aldosari M *et al.* [6] in their study of 29 patients who had a skeletal class I associated with biproalveolie. These authors used profile teleradiography as a means of evaluating changes in VAS dimensions.

Other authors have used CBCT as a means of assessment in pre and post orthodontic treatment. Thus, Zhang *et al.* [7] reported in their study of 18 subjects with skeletal class II associated with facial hyperdivergence that there are no significant differences in the volume and height of VAS after extractions of the first 4 premolars. According to the latter, the sagittal dimensions of VAS are narrowed in the middle and lower parts. Joy A *et al.* [11] and Fang MR *et al.* [13] also reported in their CBCT study that premolar extractions did not affect VAS dimensions.

As for Zheng Z *et al.* [9], they used a specific means of evaluation, computational fluid dynamics (CFD). This is a validated method to accurately calculate the aerodynamic characteristics of the VAS flow, thus describing the flow rate and regional pressure. In their study of 30 patients of class I biproalveolie, they noted that after extraction, oropharynx and hypopharynx increased the resistance to flow pressure and the risk of collapsing pharynx thus increased after incisive retraction with maximum anchoring.

Among the possible factors involved in the modification of VAS dimensions after extraction and incisive repositioning has been mentioned by some authors in the literature, the posterior-inferior movement of the hyoid bone. However, this posterior-inferior repositioning of this bone remains controversial. Chen *et al.* [15] showed that there was a significant correlation between the degree of retraction of the hyoid bone in the horizontal direction and the decrease in VAS, while Bhatia Lt *et al.* [4] revealed in their study of 22 class I biproalveolie patients that incisive repositioning influenced the size of the airway as well as the position of the hyoid bone that became more posterior using profile teleradiography.

As for the loss of anchorage of the molars, it seems to increase the space behind the tongue, which can play an essential role in improving the dimensions of the VAS. In the study of Germec-Cakan *et al.* [16], the average increase in VAS space was about 1.5 mm after treatment. The author attributed this increase to a mesial movement of 3 mm of the molars after resolution of the anterior clutter in cases by reduced anchoring.

However, Zhang *et al.* reported that the effect of extractions on the upper respiratory tract during orthodontic treatment appears to be an adaptive change in respiratory tract morphology, rather than a decrease in respiratory tract size [7].

In this study, the large variation between studies in the age of recruited subjects reduced comparability. In adolescents, the volume of VAS increases rapidly due to craniofacial growth. However, VAS is mature and stops growing in adult patients. Thus, the growth potential should be considered when evaluating the effect of orthodontic extraction treatment on VAS in adolescents [22] [23].

Malocclusion is another factor to consider. Different types of malocclusions have their own treatment protocols and extraction indications. In studies involving patients diagnosed with Class I bi-maxillary protrusion, the indication for extraction of the 4 premolars was incisive repositioning. After extensive retraction of the anterior teeth, a reduction in the volume of EVA was observed. In contrast, an increase in the volume of VAS was observed in patients diagnosed with Class I crowding and treated by extracting four premolars to eliminate crowding. The remaining extraction space after resolution of the MDD was used for closing the space by molar anchoring loss. Four premolars were extracted in both groups of subjects, but the treatment protocol was different. As a result, extractions affected the VAS in the opposite way [24] [25].

Three methods for assessing the dimensions of VAS (cephalometry, CT, and CFD) were used in the included studies, which could also affect the reliability and comparability of the results. High correlations were reported between the use of profile X-rays and CBCT imaging acquisitions to assess the pharyngeal airway [26]. However, the pharynx is a three-dimensional tubular structure and two-dimensional imaging can easily lose some dimensional information [27]. The American Association of Orthodontists on Obstructive Sleep Apnea and Orthodontics suggests that the 3D evaluation is ideal for evaluating the dimensions of the VAS [28].

The results of this systematic review showed that, during orthodontic treatment with extraction of the premolars, significant retraction of anterior teeth and loss of anchorage of molars were the two main factors that could affect the dimensions of the upper airways. However, the lack of consensus of the authors on the question tends to show that the morphology and initial pharyngeal dimensions are likely to respond differently to dento-skeletal changes in orthodontic treatment.

1) Limitations of the study: It should be noted that at the end of this systematic review, we found no randomized or non-randomized clinical trials, no case-control or prospective studies. The subject was treated in the literature only by retrospective studies based on the examination of orthodontic records of already treated patients. Also, efforts by researchers are requested on this subject to carry out more serious studies, with good quality and high reliability in terms of scientific evidence.

2) Conflicts of interest: There is no conflict of interest.

3) Financial support: There was no financial support for this study.

5. Conclusions

It is difficult to draw definitive conclusions based on this systematic review of retrospective clinical studies concerning the effects of premolar extraction on the VAS dimension. The hypothesis is that the premolar extraction decreases the arch perimeter and the size of the oral cavity thus restricting the tongue space and positioning it later.

This adaptation of the tongue to its new interior would cause a constriction of the oropharyngeal airways. Several studies have been designed to test this hypothesis, but so far, solid evidence is lacking.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Tweed, C.H. (1944) Indications for the Extraction of Teeth in Orthodontic Procedure. *American Journal of Orthodontics and Oral Surgery*, **30**, 405-428. https://doi.org/10.1016/S0096-6347(44)90038-4

[2] Cho, H., Yoon, H.J., Park, J.H., Park, Y. and Kim, S. (2021) Effect of Extraction Treatment on Upper Airway Dimensions in Patients with Bimaxillary Skeletal Protrusion Relative to Their Vertical Skeletal Pattern. *Korean Journal of Orthodontics*, **51**, 166-178. https://doi.org/10.4041/kjod.2021.51.3.166

[3] Jena, A.K., Anusuya, V. and Sharan, J. (2022) Adaptive Changes in the Posterior Pharyngeal Wall Following Large Retraction of Incisors during Comprehensive Orthodontic Treatment. *Turkish Journal of Orthodontics*, **35**, 248-254. https://doi.org/10.5152/turkjorthod.2022.21157

[4] Bhatia, S., Jayan, B. and Chopra, S.S. (2016) Effect of Retraction of Anterior Teeth on Pharyngeal Airway and Hyoid Bone Position in Class I Bimaxillary Dentoalveolar Protrusion. *Medical Journal Armed Forces India*, **72**, S17-S23. https://doi.org/10.1016/j.mjafi.2016.06.006

[5] Shi, X., Chen, H., Lobbezoo, F., Berkhout, E., de Lange, J., Guo, J., *et al.* (2021) Effects of Miniscrew-Assisted Orthodontic Treatment with Premolar Extractions on Upper Airway Dimensions in Adult Patients with Class II High-Angle Malocclusion. *American Journal of Orthodontics and Dentofacial Orthopedics*, **159**, 724-732. https://doi.org/10.1016/j.ajodo.2020.02.016

[6] Aldosari, M.A., Alqasir, A.M., Alqahtani, N.D., Almosa, N.A., Almoammar, K.A. and Albarakati, S.F. (2020) Evaluation of the Airway Space Changes after Extraction of Four Second Premolars and Orthodontic Space Closure in Adult Female Patients with Bimaxillary Protrusion—A Retrospective Study. *The Saudi Dental Journal*, **32**, 142-147. https://doi.org/10.1016/j.sdentj.2019.11.004

[7] Zhang, J., Chen, G., Li, W., Xu, T. and Gao, X. (2015) Upper Airway Changes after Orthodontic Extraction Treatment in Adults: A Preliminary Study Using Cone Beam Computed Tomography. *PLOS ONE*, **10**, e0143233. https://doi.org/10.1371/journal.pone.0143233

[8] Mortezai, O., Shalli, Z., Tofangchiha, M., Alizadeh, A., Pagnoni, F., Reda, R., *et al.*

(2023) Effect of Premolar Extraction and Anchorage Type for Orthodontic Space Closure on Upper Airway Dimensions and Position of Hyoid Bone in Adults: A Retrospective Cephalometric Assessment. *PeerJ*, **11**, e15960. https://doi.org/10.7717/peerj.15960

[9] Zheng, Z., Liu, H., Xu, Q., Wu, W., Du, L., Chen, H., *et al.* (2017) Computational Fluid Dynamics Simulation of the Upper Airway Response to Large Incisor Retraction in Adult Class I Bimaxillary Protrusion Patients. *Scientific Reports*, **7**, Article No. 45706. https://doi.org/10.1038/srep45706

[10] Guo, R., Wang, S., Zhang, L., Li, L., Yu, Q., Huang, Y., *et al.* (2022) Oropharynx and Hyoid Bone Changes in Female Extraction Patients with Distinct Sagittal and Vertical Skeletal Patterns: A Retrospective Study. *Head & Face Medicine*, **18**, Article No. 31. https://doi.org/10.1186/s13005-022-00334-1

[11] Joy, A., Park, J., Chambers, D.W. and Oh, H. (2019) Airway and Cephalometric Changes in Adult Orthodontic Patients after Premolar Extractions. *The Angle Orthodontist*, **90**, 39-46. https://doi.org/10.2319/021019-92.1

[12] AlKawari, H., AlBalbeesi, H., Alhendi, A., Alhuwaish, H., Al Jobair, A. and Baidas, L. (2018) Pharyngeal Airway Dimensional Changes after Premolar Extraction in Skeletal Class II and Class III Orthodontic Patients. *Journal of Orthodontic Science*, **7**, 10. https://doi.org/10.4103/jos.jos_140_17

[13] Zhang, Y., Guo, S., Fang, M., Yan, X., Ni, J., Gu, Y., *et al.* (2022) Study of Pharyngeal Airway Morphology with CBCT: Benefits of Four Premolar Extraction Orthodontic Treatments. *Nigerian Journal of Clinical Practice*, **25**, 1955-1962. https://doi.org/10.4103/njcp.njcp_1815_21

[14] Hwang, S., Chung, C.J., Choi, Y., Huh, J. and Kim, K. (2010) Changes of Hyoid, Tongue and Pharyngeal Airway after Mandibular Setback Surgery by Intraoral Vertical Ramus Osteotomy. *The Angle Orthodontist*, **80**, 302-308. https://doi.org/10.2319/040209-188.1

[15] Chen, Y., Hong, L., Wang, C., Zhang, S., Cao, C., Wei, F., *et al.* (2012) Effect of Large Incisor Retraction on Upper Airway Morphology in Adult Bimaxillary Protrusion Patients. *The Angle Orthodontist*, **82**, 964-970. https://doi.org/10.2319/110211-675.1

[16] Germec-Cakan, D., Taner, T. and Akan, S. (2010) Uvulo-glossopharyngeal Dimensions in Non-Extraction, Extraction with Minimum Anchorage, and Extraction with Maximum Anchorage. *The European Journal of Orthodontics*, **33**, 515-520. https://doi.org/10.1093/ejo/cjq109

[17] Svaza, J., Skagers, A., Cakarne, D. and Jankovska, I. (2011) Upper Airway Sagittal Dimensions in Obstructive Sleep Apnea (OSA) Patients and Severity of the Disease. *Stomatologija*, **13**, 123-127.

[18] Shigeta, Y., Ogawa, T., Tomoko, I., Clark, G.T. and Enciso, R. (2009) Soft Palate Length and Upper Airway Relationship in OSA and Non-OSA Subjects. *Sleep and Breathing*, **14**, 353-358. https://doi.org/10.1007/s11325-009-0318-7

[19] Kikuchi, M. (2005) Orthodontic Treatment in Children to Prevent Sleep-Disordered Breathing in Adulthood. *Sleep and Breathing*, **9**, 146-158. https://doi.org/10.1007/s11325-005-0028-8

[20] Bruyneel, M., Ameye, L. and Ninane, V. (2010) Sleep Apnea Syndrome in a Young Cosmopolite Urban Adult Population: Risk Factors for Disease Severity. *Sleep and Breathing*, **15**, 543-548. https://doi.org/10.1007/s11325-010-0398-4

[21] Morong, S., Benoist, L.B.L., Ravesloot, M.J.L., Laman, D.M. and de Vries, N. (2014) The Effect of Weight Loss on OSA Severity and Position Dependence in the Baria-

tric Population. *Sleep and Breathing*, **18**, 851-856. https://doi.org/10.1007/s11325-014-0955-3

[22] Valiathan, M., El, H., Hans, M.G. and Palomo, M.J. (2010) Effects of Extraction versus Non-Extraction Treatment on Oropharyngeal Airway Volume. *The Angle Orthodontist*, **80**, 1068-1074. https://doi.org/10.2319/010810-19.1

[23] Stefanovic, N., El, H., Chenin, D.L., Glisic, B. and Palomo, J.M. (2012) Three-Dimensional Pharyngeal Airway Changes in Orthodontic Patients Treated with and without Extractions. *Orthodontics & Craniofacial Research*, **16**, 87-96. https://doi.org/10.1111/ocr.12009

[24] Wang, Q., Jia, P., Anderson, N.K., Wang, L. and Lin, J. (2011) Changes of Pharyngeal Airway Size and Hyoid Bone Position Following Orthodontic Treatment of Class I Bimaxillary Protrusion. *The Angle Orthodontist*, **82**, 115-121. https://doi.org/10.2319/011011-13.1

[25] Schwab, R.J. (1998) Upper Airway Imaging. *Clinics in Chest Medicine*, **19**, 33-54. https://doi.org/10.1016/s0272-5231(05)70430-5

[26] Aboudara, C., Nielsen, I., Huang, J.C., Maki, K., Miller, A.J. and Hatcher, D. (2009) Comparison of Airway Space with Conventional Lateral Headfilms and 3-Dimensional Reconstruction from Cone-Beam Computed Tomography. *American Journal of Orthodontics and Dentofacial Orthopedics*, **135**, 468-479. https://doi.org/10.1016/j.ajodo.2007.04.043

[27] Behrents, R.G., Shelgikar, A.V., Conley, R.S., Flores-Mir, C., Hans, M., Levine, M., *et al*. (2019) Obstructive Sleep Apnea and Orthodontics: An American Association of Orthodontists White Paper. *American Journal of Orthodontics and Dentofacial Orthopedics*, **156**, 13-28.E1. https://doi.org/10.1016/j.ajodo.2019.04.009

[28] The Report of an American Academy of Sleep Medicine Task Force (1999) Sleep-Related Breathing Disorders in Adults: Recommendations for Syndrome Definition and Measurement Techniques in Clinical Research. *Sleep*, **22**, 667-689. https://doi.org/10.1093/sleep/22.5.667