Effect of Premolar Extraction on the Upper Airway in Adult and Adolescent Orthodontic Patients: a Meta-analysis

Run Zhi GUO[1,#], Lin Wei LI[1,#], Li Wen ZHANG[2], Qian Yao YU[1], Yi Ping HUANG[1], Wei Ran LI[1]

Objective: *To analyse the effects of premolar extraction on the upper airway in adult and adolescent orthodontic patients using CBCT.*

Methods: *The Embase, Web of Science, Cochrane Library and Medline (via PubMed) databases were searched with no language restrictions. Longitudinal studies in which CBCT was applied to assess the effects of tooth extraction on the upper airway were included in the analysis. Two authors performed the study selection, methodological quality assessment, data extraction and data synthesis independently.*

Results: *A total of 12 studies were included, six of which were eligible for quantitative synthesis. In the adult group, the nasopharynx and oropharynx volume showed no significant change, and the minimum cross-sectional area of the upper airway demonstrated a non-significant decrease compared to the non-extraction group. In the adolescent group, the nasopharynx volume, oropharynx volume and minimum cross-sectional area of the upper airway increased in a non-significant manner.*

Conclusion: *The currently available evidence indicates that tooth extraction does not increase the risk of airway collapse in adult and adolescent patients. The present findings should be interpreted with caution and evaluated in further high-quality studies.*

Key words: *airway, extraction, meta-analysis, orthodontic*

Chin J Dent Res 2023;26(1):35–45; doi: 10.3290/j.cjdr.b3978679

The goals of orthodontic treatment are aesthetics, stability and function. An important concern in any orthodontic procedure is respiratory function, particularly in the upper airway, which includes the nasopharynx, oropharynx and hypopharynx. The oropharynx is surrounded by soft tissue (the soft palate, tongue and pharyngeal wall) and lacks skeletal support, and thus could be easily affected by orthodontic procedures. Changes in the upper airway dimensions have been reported following rapid maxillary expansion, the use of mandibular advancement appliances and orthognathic surgery[1-3].

Premolar extraction is performed to alleviate crowding, reduce facial convexity and correct anteroposterior discrepancies for orthodontic patients. The effect of premolar extraction on the upper airway has been investigated in previous studies. Some believe that it may predispose patients to oropharyngeal collapse, which is associated with a decreased oral cavity volume and posterior displacement of the tongue, especially for patients with protruding anterior teeth[4-6]. As such, an important concern is that the narrow airway caused by extraction may lead to obstructive sleep apnoea (OSA). The upper airway is a 3D structure, but the airway analyses in these studies were performed using a lateral cephalometric radiograph[4-6]. Because of the limitations of two-dimensional (2D) radiographs, lateral cephalometric radiographs yield only anteroposterior data and cannot be used to evaluate the upper airway volume.

1 Department of Orthodontics, Peking University School and Hospital of Stomatology, National Centre of Stomatology, National Clinical Research Centre for Oral Diseases, National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing, P.R. China.
2 Department of Stomatology Centre, China-Japan Friendship Hospital, Beijing, P.R. China.
# These two authors contributed equally to this work.

Corresponding authors: Dr Wei Ran LI and Dr Yi Ping HUANG, Department of Orthodontics, Peking University School and Hospital of Stomatology, #22 Zhongguancun South Avenue, Haidian District, Beijing 100081, P.R. China. Tel: 86-10-82195332; Fax:86-10-62173402. Email: weiranli@bjmu.edu.cn; yipinghuang@bjmu.edu.cn

Recently, CBCT has been used widely to evaluate the upper airway change, which enables 3D imaging of the upper airway and analysis of its morphology and volume[7]. Several studies reported the change in upper airway volume after premolar extraction treatment using CBCT[8-10]. Their results supported that extraction-induced reduction of the dental arch perimeter did not affect the upper airway volume and respiratory function, and extraction treatment was not an aetiology factor in the development of OSA[11]. At present, there is still no strong evidence for the effect of premolar extraction on the upper airway.

On the other hand, ageing has been found to influence the upper airway morphology[12,13]. As the upper airway undergoes growth during adolescence, the effects of extraction on the upper airway in adolescent and adult patients should be analysed separately, but are less reported. In this meta-analysis, we evaluated the effects of premolar extraction on this area in adult and adolescent orthodontic patients using CBCT.

Materials and methods

Protocol and registration

This meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[14] and was registered in the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) with registration number INPLASY202040175.

Eligibility criteria

The eligibility criteria were based on the participants, intervention, comparison, outcome and study (PICOS) criteria:

- Participants: Orthodontic patients with premolars extracted were included without age or sex restriction.
- Intervention: Orthodontic treatment with premolar extractions aiming to retract anterior teeth (moderate to maximum anchorage). The type of appliance, technique and treatment duration were not restricted.
- Comparison: Untreated patients or orthodontic patients without premolar extraction.
- Outcomes: The upper airway volume and minimum cross-sectional area analysed by CBCT were selected as the primary outcomes. To ensure comparability, the included patients should bite in centric occlusion and breathe normally without swallowing during CBCT scanning.
- Study: Randomised controlled trials (RCTs), controlled clinical trials (CCTs) and cohort studies were included. Considering the untreated patients were limited and the airway volume was relatively stable in adult patients, self-controlled studies, which could provide clinically beneficial information, were also included. Cross-sectional studies, case reports, animal studies and reviews were excluded.

Literature search strategy

An electronic search was performed of the Embase, Web of Science, Cochrane Library and Medline (via PubMed) databases from their inception up to 10 March 2022, with no language restrictions. The detailed search strategy for PubMed is illustrated in Table 1. Similar searches using a revised strategy were performed of the other databases with the assistance of a librarian, and the reference lists of the included studies were searched manually to identify relevant articles.

Study selection

The study selection was performed by two independent authors (Guo RZ and Li LW). After eliminating duplicate studies, the titles and abstracts of all the included studies were examined based on the eligibility criteria. The full texts were obtained and evaluated when the titles and abstracts provided insufficient information. Any conflicts regarding article selection were resolved by consultation and discussion with a third author (Li WR).

Data extraction

Two authors (Guo RZ and Li LW) independently extracted the following study characteristics: study design, sample size, patient age, diagnosis and treatment plan, radiographic method, airway measurements and outcomes. The upper airway volume and minimum cross-sectional area determined by CBCT were extracted for quantitative analysis. The reference line of airway volume and space in the individual studies was recorded due to the lack of a uniform definition of the upper airway. The treatment plan, including extraction sites, anchorage status and extent of incisor retraction, was recorded. Any disagreement between the two authors was resolved through discussion with a third author (Li WR).

Assessment of methodological quality

The quality of the included non-randomised studies was assessed using the Methodological Index for Non-

Table 1 Search strategy for Medline via PubMed.

Search terms		PubMed results
# 1	orthodontics [Mesh] OR orthodontic* OR tooth movement OR teeth movement	92229
# 2	airway OR oropharynx [Mesh] OR pharynx OR pharyngeal OR oropharyngeal	286313
# 3	Tooth extraction [Mesh] OR extract*	994460
# 4	computed tomography OR cone-beam computed tomography OR cbct	609996
# 5	#1 AND #2 AND #3 AND #4	24

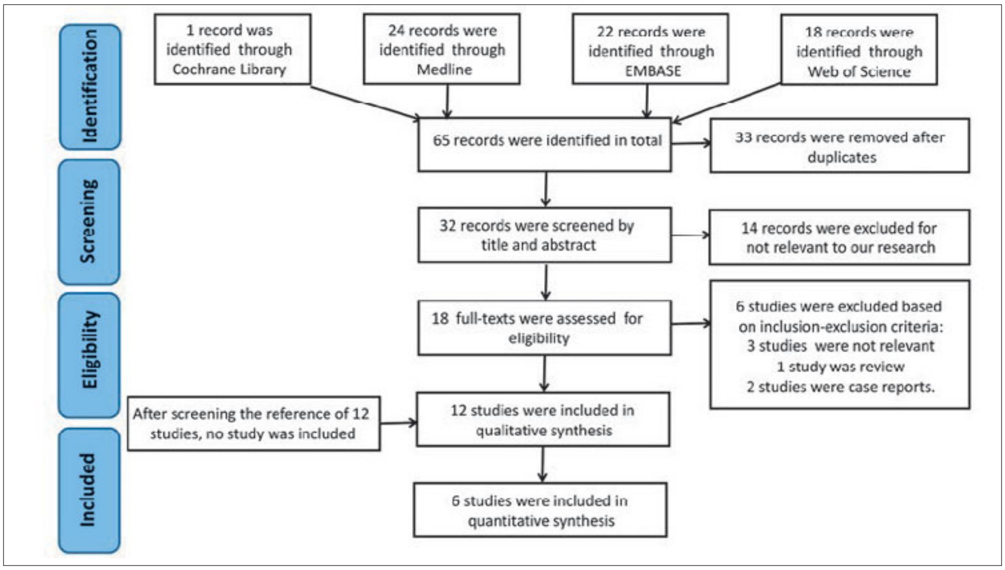

Fig 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

randomized Studies (MINORS). Only the first 8 of the 12 MINORS criteria were used to assess the quality of self-controlled studies. The overall quality of evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach[15]. Two authors (Zhang LW and Yu QY) independently evaluated the included studies, and any conflicts were resolved through consultation and discussion with a third author (Li WR).

Data synthesis

Review Manager 5.3 (Nordic Cochrane Centre, Cochrane Collaboration, Copenhagen, Denmark) was used for the meta-analysis. Heterogeneity was assessed using chi-square and I^2 tests. A random-effects model was used in cases of high heterogeneity ($I^2 > 50\%$); otherwise, the fixed-effects model was used. The level of statistical significance was set at $P \leq 0.05$. Studies with a high level of clinical heterogeneity such that data synthesis was not possible were described qualitatively.

Results

Study selection

Initially, 32 studies were identified using the search strategy. After title and abstract review, 18 were considered potentially eligible for full-text evaluation. Based on the eligibility criteria, 12 studies were included in the review, and six of these were eligible for quantitative synthesis. A flowchart of the study selection process is shown in Fig 1.

Study characteristics

The 12 studies comprised 8 cohort studies[8-10,16-20] and 4 self-controlled studies[21-24]. As for cohort studies, six studies included a non-extraction group[8-10,16-18] and two included an untreated control group[19,20]. In all studies, the premolars were extracted to retract the anterior teeth. Of these, five studies reported that maximum anchorage (miniscrew) was used to retract the anterior teeth[8,17,19,21,22], and the remaining studies did not report the anchorage characteristics. The characteristics of the included studies are summarised in Table 2.

Assessment of methodological quality

The risk of bias for the included studies is shown in Table 3. The MINORS score for the eight cohort studies ranged from 14 to 19, and for the four self-controlled studies it ranged from 8 to 11. All the included studies were retrospective. Among the MINORS criteria, the inclusion of consecutive patients, prospective collection of data, loss to follow-up less than 5% and prospective calculation of the study size were the main items that posed a potentially high risk of bias. The high clinical heterogeneity of the included studies was a methodological limitation.

3D airway analyses

The nasopharynx (from the top of the airway to the palatal plane level) and oropharynx (from the palatal plane to the uvula level) volumes and the minimum cross-sectional area analysed by CBCT were extracted for data synthesis. Based on age, the included patients were divided further into the adult group (aged > 18 years) and adolescent group (aged < 18 years) for assessment. There were seven studies in the adult group and five in the adolescent group. The adult and adolescent subjects were analysed separately, both quantitatively and qualitatively.

In the adult group, three studies quantitatively evaluated the nasopharynx and oropharynx volume and the minimum cross-sectional area of the upper airway[8,9,16]. After extraction, the nasopharynx (mean difference 0.07cm^3; 95% confidence interval [CI] −0.58 to 0.73cm^3; P = 0.82) and oropharynx (mean difference 0.21cm^3; 95% CI −0.76 to 1.19cm^3; P = 0.67) volumes showed no significant change (Fig 2). A quantitative synthesis of three studies[8,9,16] indicated that there were no significant differences in nasopharynx and oropharynx volume between extraction and nonextraction (Fig 3). The nonsignificant decrease in the minimum cross-sectional area of the upper airway (mean difference 0.37cm^2; 95% CI 0.06 to 0.68cm^2; P = 0.11) also did not differ significantly compared to the nonextraction group. Considering the extraction site and anchorage type among these three studies, two studies reported that at least two premolars were extracted, but the anchorage types were not stated[9,16]. One study included patients with extraction of four premolars and retracted the anterior teeth with miniscrews[8]. Zhang et al[19] found that extraction caused mainly morphological changes rather than a decrease in size in the upper airway. In contrast to our findings, Sun et al[21] and Zheng et al[22] reported a high risk of oropharyngeal collapse after maximum extraction of anterior teeth in adult patients.

In the adolescent group, three studies quantitatively evaluated the nasopharynx[10,17,20] and five quantitatively evaluated oropharynx volumes and the minimum cross-sectional area of the upper airway[10,17,18,20,21]. Unlike in the adult group, the nasopharynx volume (mean difference −0.10 cm^3; 95% CI −0.38 to 0.18 m^3; P = 0.48), oropharynx volume (mean difference −1.01 cm^3; 95% CI −2.48 to 0.47 cm^3; P = 0.18) and minimum cross-sectional area of the upper airway (mean difference −0.17 cm^3; 95% CI −0.49 to 0.14 cm^3; P = 0.29) increased in a non-significant manner (Fig 4). These changes were not significantly different from those in the non-extraction group (Fig 5). Considering the extraction site and anchorage type, all patients in the five included studies had their four first premolars extracted. Among these, one study reported that miniscrews were used[17]; the others did not report the anchorage type[10,18,20,21].

Risk of bias across studies and additional analyses

Due to the limited number of included studies, it was not possible to assess publication bias. The quality of evidence of the outcome was low in the adult group and very low in the adolescent group. The overall quality of evidence for each outcome assessed by GRADE is shown in Table 4.

Discussion

Effects on the airway are a concern in orthodontics. Rapid maxillary expansion, mandibular advancement appliances and orthognathic surgery increase the dimensions of the upper airway and alleviate the symptoms of OSA. At present, there is no strong evidence for the influence of extraction treatment on the upper airway. In this meta-analysis, we analysed the effects of premolar extraction on the upper airway in adult and adolescent orthodontic patients using CBCT.

Our meta-analysis quantitatively analysed the upper airway change in adult and adolescent patients after tooth extraction. The upper airway was not affected in adult or adolescent extraction compared to nonextraction patients, which was consistent with the findings of Alswairki et al[25]. Hu et al[26]performed a systematic review to analyse the effect of extraction treatment on the upper airway and reported that the retraction of the anterior teeth might lead to a narrowing of the oropharynx. On the other hand, the present systematic review combined the results of studies using lateral cephalometric radiographs and CBCT, which could cause bias. The

Table 2 Characteristics of the included studies.

Author/Year	Study design	Sample size	Average age	Diagnosis	Treatment Plan	Airway measurements	Outcomes
Park et al[8]	Cohort study	Extraction group 16, non-extraction group 17	22.18±3.99 y for both groups	Dental Class II	Distalization with and without extraction (mini-screw anchorage)	Volume of oropharynx (velopharynx and glossopharynx); Minimum cross-section area (MCA)	There were no significant changes in the airway volume or the MCA of the oropharynx among two groups
Joy et al[9]	Cohort study	Extraction group 41, non-extraction Group 42	Extraction group 26.1±7.1 y, non-extraction Group 26.0±8.0 y	Dental Class I and Class II	Extraction group: at least two premolars extracted	Volume of nasopharynx, retropalatal and retroglossal; MCA	Extractions in nongrowing patients have no negative consequences on airway measurements
Stefanovic et al[10]	Cohort study	Extraction group 31, non-extraction group 31	Extraction group 12.97±1.15 y, nonextraction group: 12.86±0.74 y	Dental Class I and Class II	Extraction of four first premolars	Volume of nasopharynx and oropharynx	An extraction or non-extraction choice for orthodontic treatment would not affect the pharyngeal airway
Pliska et al[16]	Cohort study	Extraction group 26, non-extraction group 48	Extraction group 27.4±9.7 y, non-extraction group 31.9±12.0 y	Dental Class I and Class II	Extraction group: at least two premolars extracted	Volume of nasopharynx, retropalatal and retroglossal; MCA	Dental extractions in conjunction with orthodontic treatment have a negligible effect on the upper airway in adults
Chen et al[17]	Cohort study	Extraction group 25, non-extraction group 25	Extraction group 12.2±1.2 y, non-extraction group 12.4±1.5 y	Dental Class I	Extraction of four premolar (mini-screw anchorage)	Volume of nasopharynx, oropharynx and hypopharynx; MCA	The airway volume and MCA were significantly decreased after treatment
Valiathan et al[18]	Cohort study	Extraction group 20, non-extraction group 20	Extraction group 13.8±1.3 y, non-extraction group 13.8±1.2 y	Dental Class I	Extraction of four first premolars	Volume of oropharynx; MCA	Extraction of four premolars with retraction of incisors does not affect oropharynx airway volume
Zhang et al[19]	Cohort study	Extraction group 18, untreated group 18	Extraction group 24.1 ± 3.8 y	Dental Class II	Extraction of four premolar (mini-screw anchorage)	Volume of nasopharynx, velopharynx and hypopharynx	The airway changes after extraction in adults are mainly morphological changes, rather than a decrease in size
Lei et al[20]	Cohort study	Extraction group 27, untreated group 30	Extraction group 13.62±1.49 y, nontreatment group 13.21±1.73 y	Dental Class II	Extraction of four premolar	Volume of nasopharynx, oropharynx, and hypopharynx MCA	Extraction treatment can widen the airway in adolescent patients.
Sun et al[21]	Self-controlled study	30	31.6±3.9 y	Dental Class I with bimaxillary protrusion	Extraction of four premolar (mini-screw anchorage)	Volume of nasopharynx, oropharynx and hypopharynx	The oropharynx was constricted and the pharyngeal resistance was increased after incisor retraction in adult patients.
Zheng et al[22]	Self-controlled study	30	25.87±0.78 y	Dental Class I with bimaxillary protrusion	Extraction of four premolar (mini-screw anchorage)	Volume of nasopharynx, oropharynx and hypopharynx; MCA	The risk of pharyngeal collapsing become higher after extraction with maximum anchorage in adult patients with bimaxillary protrusion.
Shi et al[23]	Self-controlled study	18	21.2±2.9 y	Dental Class II	Extraction of maxillary first premolars and mandibular second premolars (maxilliary molar intrusion with mini-screw)	Volume of nasopharynx, oropharynx and hypopharynx; MCA	By using mini-screw to intrude maxillary molars, orthodontic premolar extraction treatment could increase the upper airway dimensions
Sun et al[24]	Self-controlled study	30	13.7±1. 5 y	Dental Class I	Extraction of four first premolars	Volume of nasopharynx, oropharynx and hypopharynx; MCA	The impact of orthodontic extraction treatment on oropharyngeal airway was generally small in skeletal class I adolescents.

Table 3 Methodological index for non-randomised studies (MINORS).

Study	MINORS score												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Park et al[8]	2	2	1	2	2	2	0	0	2	2	2	2	19
Joy et al[9]	2	0	1	2	2	2	0	0	2	2	2	2	17
Stefanovic et al[10]	2	0	0	2	2	2	0	0	2	2	2	2	16
Pliska et al[16]	2	0	0	2	2	2	0	0	2	2	2	2	16
Chen et al[17]	2	0	0	2	2	2	0	0	2	2	2	2	16
Valiathan et al[18]	2	0	2	2	2	2	0	0	2	2	2	2	16
Zhang et al[19]	2	0	0	2	2	2	0	0	1	2	2	1	14
Lei et al[20]	2	0	1	2	2	2	0	0	2	2	2	2	17
Sun et al[21]	2	1	2	2	2	2	0	0					11
Zheng et al[22]	2	0	0	2	2	2	0	0					8
Shi et al[23]	2	0	0	2	2	2	0	0					8
Sun et al[24]	2	0	0	2	2	2	0	0					8

Items 1–12 represent: 1, a clearly stated aim; 2, inclusion of consecutive patients; 3, prospective collection of data; 4, endpoints appropriate to the aim of the study; 5, unbiased assessment of the study endpoint; 6, follow-up period appropriate to the aim of the study; 7, loss to follow-up less than 5%; 8, prospective calculation of the study size; 9, an adequate control group; 10, contemporary groups; 11, baseline equivalence of groups; and 12, adequate statistical analysis.

*Items scored 0 means not mentioned, 1 means reported but inadequate and 2 means reported and adequate. The total score was 24 for cohort studies and 16 for self-controlled studies.

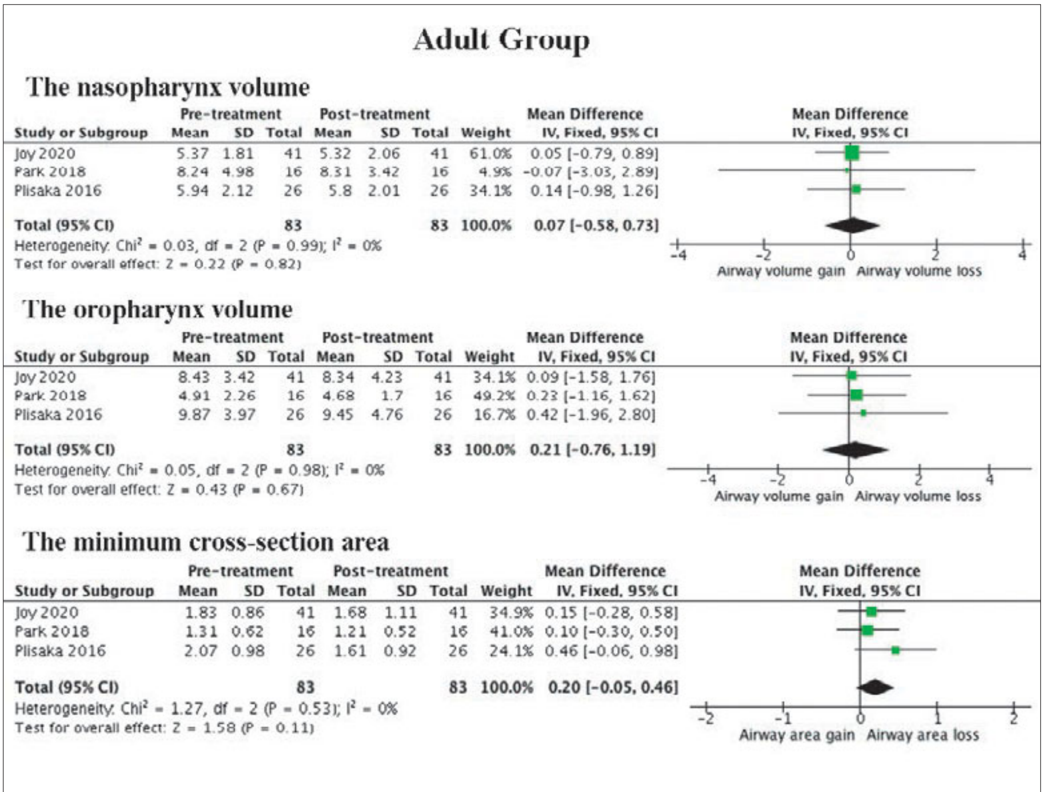

Fig 2 Forest plots of upper airway changes after extraction in the adult group.

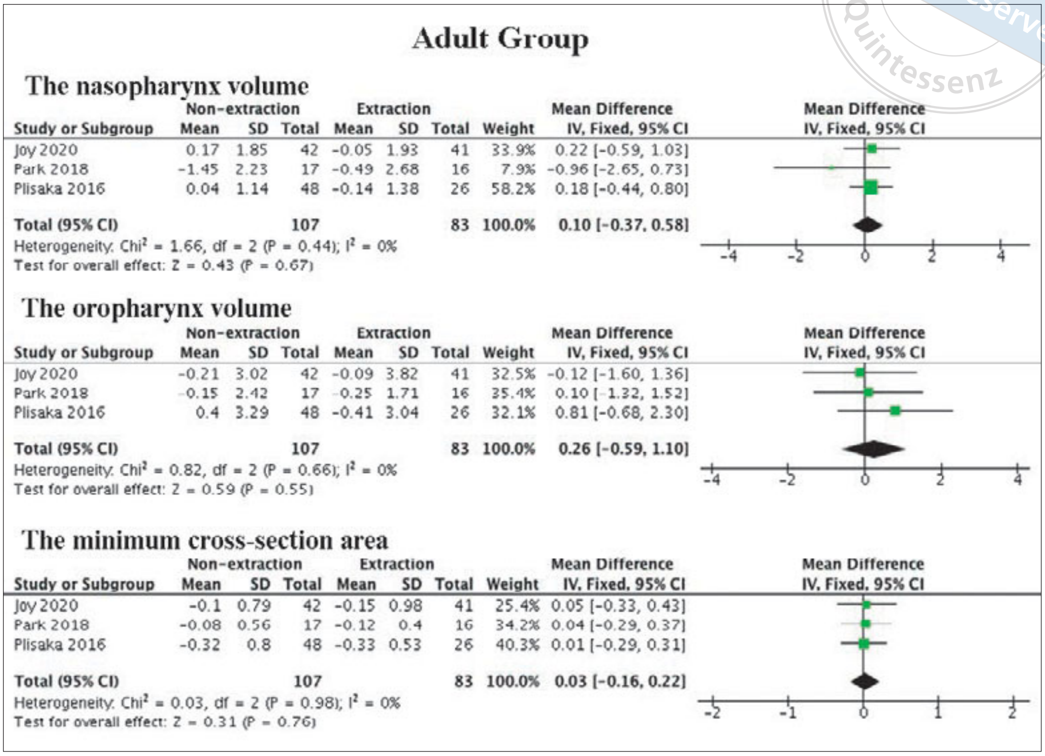

Fig 3 Forest plots of upper airway changes compared for extraction and nonextraction in the adult group.

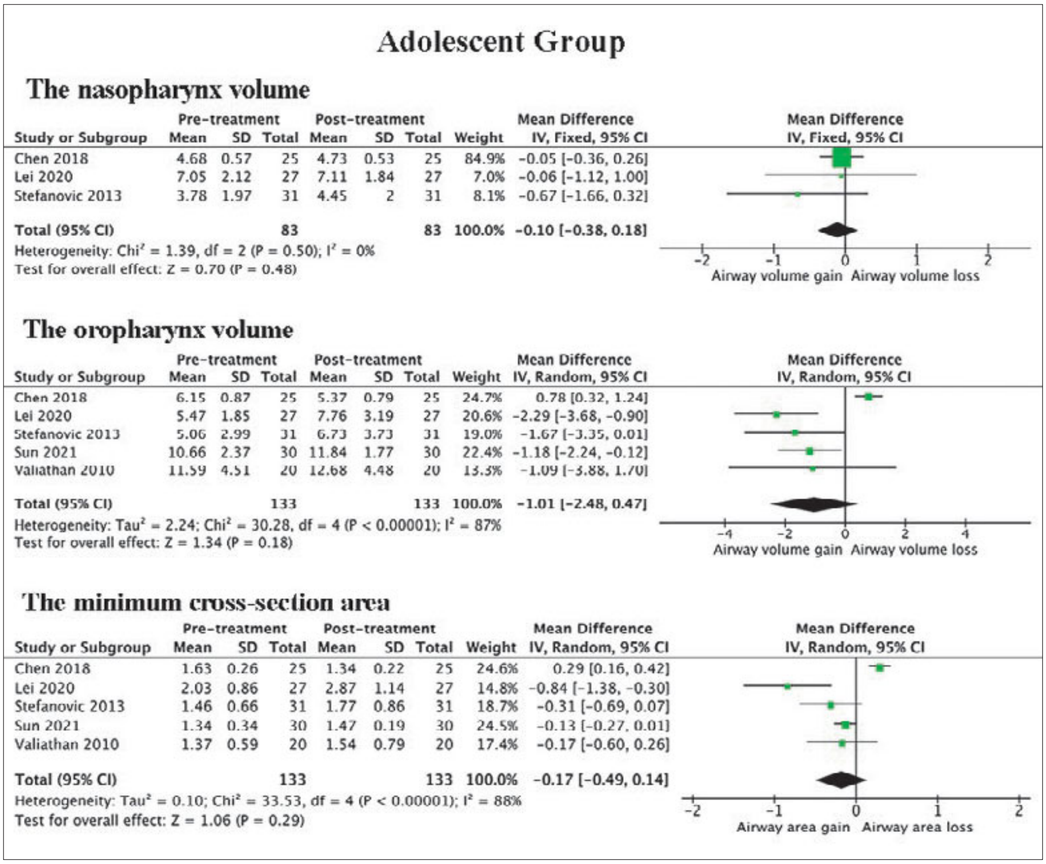

Fig 4 Forest plots of upper airway changes after extraction in the adolescent group.

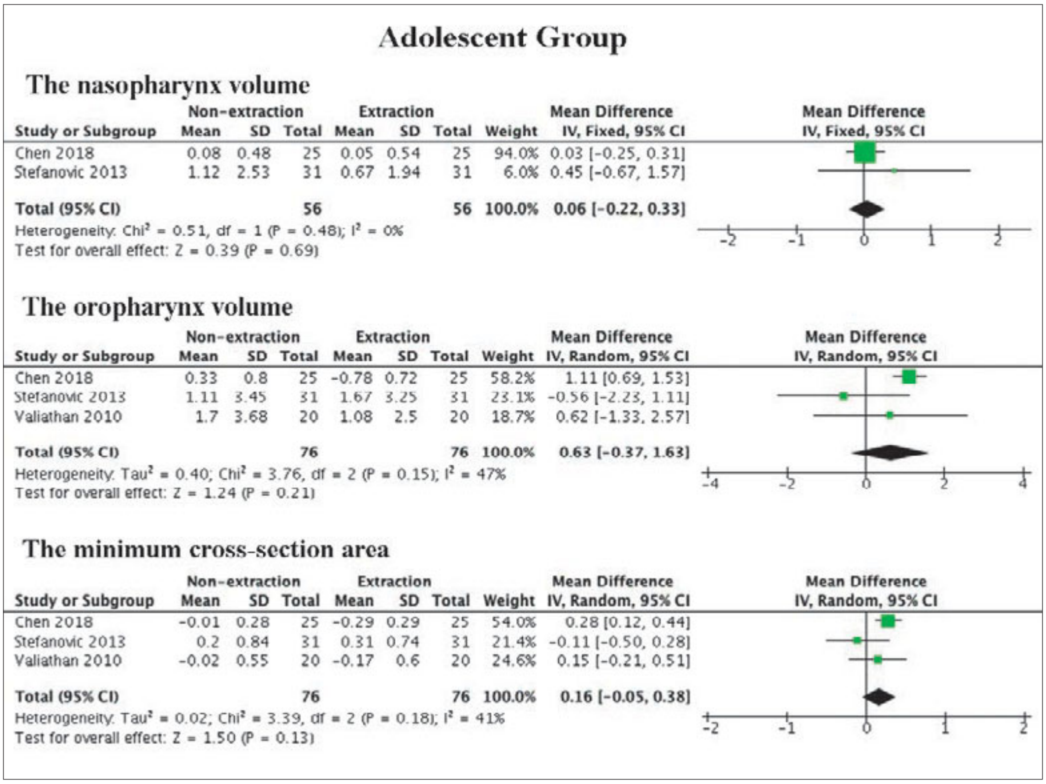

Fig 5 Forest plots of upper airway changes compared for extraction and nonextraction in the adolescent group.

Table 4 Quality of available evidence using GRADE.

Outcome	Downgrade					Upgrade	Overall quality
	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias		
Airway volume analysis in adult group	Serious[a]	Not serious	Not serious	Serious[c]	None	None	Low
Airway volume analysis in adolescent group	Serious[a]	Serious[b]	Not serious	Serious[c]	None	None	Very low

[a]All studies were retrospective with a high risk of bias.

[b]Higher statistical heterogeneity was involved.

[c]Participants included in the meta-analysis were limited, and 95% CIs were wide.

nasopharynx volume was stable, likely because it is supported by bone and cartilage. Indeed, although it is surrounded by soft tissue rather than bone, the oropharynx volume was also not significantly changed after extraction. The minimum cross-sectional area of the airway decreased in a non-significant manner in the adult group. Changes in the minimum cross-sectional area detected by CBCT are less reliable and more easily influenced by head position, tongue position and mode of breathing[27]. Other airway measurements reported in the included studies were analysed qualitatively. There was a close relationship between the upper airway and hyoid bone[6,28]. The latter was displaced posteriorly and inferiorly after retraction of the anterior teeth. Bhatia et al[4] suggested that posterior and inferior movement of the hyoid bone prevents encroachment of the tongue into the oropharynx. Zheng et al[22] assessed variation in airflow characteristics in the upper airway using computational fluid dynamics (CFD) and reported increased oropharynx resistance. One limitation of the CFD model is that the upper airway is assumed to have an inflexible wall; the adaptive ability of soft tissue is not considered.

In the adult group, the airway volume analysed using CBCT scans was not affected by extraction. Extraction treatment did not increase the risk of airway collapse in adult patients, while the anteroposterior airway space analysed using lateral cephalometric radiographs was mostly reported to decrease[4-6]. Lateral cephalometric radiographs typically show that after extraction, the upper airway narrows in the two-dimensional view, but the 3D airway volume is indeed not affected. We assumed that airway morphology might adapt to anteroposterior compression and transverse broadening; thus, the airway volume was maintained, which was consistent with Zhang et al[19]. Compared to lateral cephalometric radiographs, CBCT enables two- and 3D airway analyses, which could be more useful in airway morphology evaluation.

In some previous studies, the negative effects of extraction on the upper airway were thought to be a result of retraction of the anterior teeth, causing posterior displacement of the tongue and compression of the soft tissue and leading to upper airway narrowing[4,17,21]. This theory fails to consider the adaptive ability of the upper airway to maintain the airflow. Besides, healthy individuals with a narrow airway reportedly maintain patency by dynamically dilating the airway during inspiration[29]. Among the three included studies, two reported the lower incisor was retracted approximately 3 mm[8,16]. The remaining study did not state the extent of incisor retraction but reported that there was no significant relationship between initial crowding and changes in airway volume in the extraction group[9]. Park et al[8] used a modified C-palatal plate to further retract the anterior teeth after extraction space closure; the airway volume was not significantly changed. Thus, retraction of the anterior teeth seems to have no negative effect on airway volume. Interestingly, Shi et al[23] extracted four premolars of Class II high-angle patients and used miniscrews to further intrude the maxillary molars and found that mandibular counterclockwise rotation could increase the upper airway dimension in extraction patients.

There was a tendency towards increased airway volume in the adolescent group, possibly because of growth. The growth of the skeletal structure and the shrinking of soft tissue (tonsils and adenoids) contribute to the increase in the upper airway volume from infants (0 to 5 years) to children (6 to 9 years) and adolescents (12 to 16 years)[30,31]. The patients in our adolescent group ranged from 12 to 16 years of age, and the use of age-matched controls precluded elimination of the influence of growth. The airway changes were not significantly different between the extraction and nonextraction group. In this study, we distinguished the effects of extraction and growth factors and found that the airway changes caused by growth exceeded the effects of extraction.

The relationship between airway dimensions and OSA is a concern of orthodontists. OSA is common in both adult and adolescent patients; the prevalence is 5% to 14% and 1% to 4%, respectively[11]. The role of the orthodontist in the management of OSA, as suggested by the American Association of Orthodontists, is to screen and refer at-risk patients to a physician[11]. At present, there are no cutoff airway volumes and cross-sectional areas that indicate a high risk of OSA. Lowe et al[32] reported that the mean airway volume in OSA patients was 13.9 cm^3. Although airway narrowing is important in the pathogenesis of OSA, other risk factors, such as craniofacial morphology, obesity, menopause, increasing age and male sex, are also involved[33,34]. As breathing is a dynamic process, CBCT scans provide information only on the static anatomy of the upper airway and do not reflect breathing. There is also no direct link between airway volume analyses and polysomnography (PSG) results[11]. To diagnose and monitor OSA, the radiographic measurement of the airway should be interpreted in combination with other clinical symptoms and PSG results. This meta-analysis evaluated the effects of extraction only on airway morphology; airway function should be assessed in further studies. At present, there is no evidence that extraction treatment will result in the development of OSA[11].

Compared with lateral cephalometric radiographs, CBCT scans enable 3D measurement of the upper airway, including morphology and volume. Although CBCT is superior to 2D measurements to analyse the upper airway, it still has some limitations. Firstly, the cost and radiation dose are relatively high. Secondly, the upper airway is easily affected by head position and respiratory status during the CBCT scanning; thus, the reliability of upper airway assessment using CBCT, especially nasopharynx and hypopharynx assessments, has been reported to be generally low[35]. Finally, CBCT images can only reflect the static images of a dynamic breathing process.

Limitations

The main limitation of this meta-analysis was the absence of high-quality studies. All the included studies were retrospective and so had a relatively high risk of bias. As a result of the varied landmarks and reference lines selected for measurements, relatively few studies could be analysed quantitatively. Moreover, there was a high level of clinical heterogeneity among the included studies. Several factors, such as extraction site, anchorage type, skeletal patterns and body mass index varied and were generally not well reported. Because of the lack of sufficient high-quality studies, the findings should be interpreted with caution and further evaluation is needed. Finally, more attention should be paid to the effects of extraction on airway function and long-term changes.

Conclusion

Within the limitations of this meta-analysis, the evidence indicates that premolar extraction does not elevate the risk of airway collapse in adult or adolescent orthodontic patients. The findings of this meta-analysis apply only to healthy patients without OSA. Further studies are required to evaluate the effect of extraction on the upper airway in patients with OSA.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Run Zhi GUO carried out the review and drafted the manuscript; Dr Lin Wei LI performed the study selection and data extraction; Drs Li Wen ZHANG and Qian Yao YU participated in the data synthesis and quality assessment; Drs Wei Ran LI and Yi Ping HUANG participated in the research design and revised the manuscript.

(Received Jul 14, 2022; accepted Sept 29, 2022)

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