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AIRWAY DIMENSIONS, CRANIOFACIAL PATTERN, AND ORTHODONTIC INTERVENTION IN GROWING SAUDI PATIENTS: A DENTOFACIAL ORTHOPAEDIC PERSPECTIVE

DIMENSÕES DAS VIAS AÉREAS, PADRÃO CRANIOFACIAL E INTERVENÇÃO ORTODÔNTICA EM PACIENTES SAUDITAS EM FASE DE CRESCIMENTO: UMA PERSPECTIVA ORTOPÉDICA DENTOFACIAL

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Abstract
Airway assessment has become an important adjunct to orthodontic diagnosis in growing patients because transverse maxillary deficiency, mandibular retrognathia, vertical facial excess, and chronic mouth breathing may coexist with restricted nasal or pharyngeal dimensions. This review examines how airway dimensions, craniofacial pattern, and dentofacial orthopaedic intervention should be interpreted for Saudi children and adolescents. A structured evidence review was designed around three questions: which craniofacial patterns are most consistently associated with airway vulnerability; which orthodontic or orthopaedic interventions show favourable airway change; and how these findings can be translated into referral pathways suitable for Saudi practice. Literature from 2020 to 2025 was considered, with priority given to studies using cone-beam computed tomography, validated sleep or symptom questionnaires, growing samples, and clearly defined intervention groups. The synthesis indicates that maxillary expansion usually improves nasal or nasopharyngeal volume, mandibular advancement therapy may enlarge the oropharyngeal region in selected Class II patients, and maxillary protraction may benefit some Class III cases. However, airway volume alone cannot diagnose sleep-disordered breathing, and treatment should not be presented as a stand-alone respiratory cure. For Saudi patients, the most defensible model is integrated screening: history, clinical pattern recognition, justified imaging, risk stratification, and referral to paediatric, otolaryngology, or sleep-medicine services when symptoms exceed the orthodontic scope. The review concludes that airway-aware orthodontics is clinically valuable when it

Resumo
A avaliação das vias aéreas tornou-se um importante complemento ao diagnóstico ortodôntico em pacientes em crescimento, uma vez que a deficiência transversal da maxila, a retrognatia mandibular, o excesso facial vertical e a respiração bucal crônica podem coexistir com dimensões nasais ou faríngeas restritas. Esta revisão examina como as dimensões das vias aéreas, o padrão craniofacial e a intervenção ortopédica dentofacial devem ser interpretados em crianças e adolescentes sauditas. Uma revisão estruturada da evidência foi elaborada em torno de três questões: quais padrões craniofaciais estão mais consistentemente associados à vulnerabilidade das vias aéreas; quais intervenções ortodônticas ou ortopédicas apresentam alterações favoráveis nas vias aéreas; e como esses achados podem ser traduzidos em fluxos de encaminhamento adequados para a prática na Arábia Saudita. Foi considerada a literatura de 2020 a 2025, com prioridade para estudos que utilizaram tomografia computadorizada de feixe cônico, questionários validados sobre sono ou sintomas, amostras em crescimento e grupos de intervenção claramente definidos. A síntese indica que a expansão maxilar geralmente melhora o volume nasal ou nasofaríngeo, a terapia de avanço mandibular pode ampliar a região orofaríngea em pacientes selecionados de Classe II e a protração maxilar pode beneficiar alguns casos de Classe III. No entanto, o volume das vias aéreas por si só não permite diagnosticar distúrbios respiratórios do sono, e o tratamento não deve ser apresentado como uma cura respiratória isolada. Para pacientes sauditas, o modelo mais defensável é a triagem integrada: histórico, reconhecimento

remains growth-sensitive, evidence-based, and multidisciplinary.

Keywords: Airway Dimensions. Craniofacial Pattern. Saudi Children. Dentofacial Orthopaedics. Maxillary Expansion. Functional Appliance. CBCT.

de padrões clínicos, exames de imagem justificados, estratificação de risco e encaminhamento para serviços de pediatria, otorrinolaringologia ou medicina do sono quando os sintomas excedem o escopo ortodôntico. A revisão conclui que a ortodontia com atenção às vias aéreas é clinicamente valiosa quando permanece sensível ao crescimento, baseada em evidências e multidisciplinar.

Palavras-chave: *Dimensões das Vias Aéreas. Padrão Craniofacial. Crianças Sauditas. Ortopedia Dentofacial. Expansão Maxilar. Aparelho Funcional. CBCT.*

1 INTRODUCTION

The relationship between craniofacial growth and the upper airway is clinically relevant because breathing pattern, facial development, dental occlusion, and sleep quality influence each other during childhood. In orthodontic clinics, this relationship is seen when a child presents with maxillary constriction, posterior crossbite, increased lower facial height, mandibular retrusion, lip incompetence, or a long-standing history of mouth breathing. These signs do not automatically prove airway disease, yet they raise the importance of looking beyond dental alignment. Recent reviews of cone-beam computed tomography indicate that several dentofacial orthopaedic interventions are followed by positive three-dimensional airway changes, particularly in growing patients, although the magnitude varies across protocols and the clinical meaning remains dependent on symptoms and medical findings (Steegman *et al*., 2023; Abdalla and Sonnesen, 2024). Saudi Arabia provides a distinctive context for this topic. Paediatric orthodontic demand is rising, mixed-dentition treatment need is high in regional samples, and sleep-disordered breathing symptoms are reported among Saudi children seeking orthodontic care (Al Ehaideb *et al*., 2021; Madiraju *et al*., 2024). General paediatric guidance in the Kingdom also recognises sleep-disordered breathing as a condition requiring structured recognition and referral, especially when snoring, witnessed apnoea, growth concerns, behavioural changes, or persistent nasal obstruction are present (Al-Shamrani and Alharbi, 2020). These findings justify a review focused on growing Saudi

patients rather than on airway volume as an isolated imaging variable. Orthodontic airway research is attractive because the jaws are modifiable during growth. Expansion can widen the maxillary arch and nasal floor region; mandibular advancement appliances can reposition the mandible and tongue base forward; maxillary protraction can alter the nasomaxillary complex in selected Class III patterns. Yet the evidence is not uniform. Changes may be small, measurement protocols vary, and cone-beam images are taken while the patient is awake and upright, not during sleep. A child may show a larger airway volume after expansion while still requiring medical treatment for adenoids, allergic rhinitis, obesity, neuromuscular problems, or sleep apnoea. Therefore, the airway-aware orthodontist must evaluate both skeletal opportunity and diagnostic boundaries (Sousa Melo *et al*., 2023; Piełunowicz *et al*., 2025). This review argues for a dentofacial orthopaedic perspective that is cautious but proactive. The relevant question is not whether orthodontics treats sleep apnoea in a universal way. Rather, the question is how orthodontists can identify craniofacial patterns that may contribute to airway vulnerability, apply growth modification when orthodontically indicated, monitor symptom change, and refer patients whose respiratory symptoms require medical confirmation. Such an approach is compatible with high-quality journal standards because it separates anatomical change, patient-centred outcomes, and disease diagnosis.

2 AIM AND OBJECTIVES

The aim of this review is to develop an evidence-informed framework for evaluating airway dimensions, craniofacial pattern, and orthodontic intervention in growing Saudi patients from a dentofacial orthopaedic perspective. The first objective is to summarise recent evidence linking maxillary constriction, sagittal jaw discrepancy, and vertical growth tendency with airway-related findings in children and adolescents. The second objective is to compare the reported airway effects of transverse expansion, Class II mandibular advancement, Class III maxillary protraction, and comprehensive orthodontic therapy. The third objective is to propose a Saudi referral pathway that distinguishes orthodontic screening from medical diagnosis. The fourth objective is to identify methodological limitations that should shape future Saudi research, including

standardised imaging, symptom questionnaires, sleep assessment, and long-term growth follow-up.

Table 1

Review objectives, operational definitions, and Saudi relevance

Review component	Operational definition	Relevance for growing Saudi patients
Population	Children and adolescents in active growth, with emphasis on mixed dentition and early permanent dentition.	Matches the period when maxillary expansion, mandibular advancement, and maxillary protraction are most biologically responsive.
Exposure or pattern	Maxillary constriction, Class II mandibular retrusion, Class III maxillary deficiency, vertical growth tendency, mouth breathing signs.	Allows clinicians to connect occlusion and facial pattern with symptoms rather than treating airway volume as an isolated number.
Interventions	Transverse expansion, functional mandibular advancement, maxillary protraction, comprehensive orthodontic therapy.	Supports treatment planning within accepted orthodontic indications and discourages appliance use as a stand-alone respiratory promise.
Primary outcomes	Airway volume, minimum cross-sectional area, nasal and pharyngeal segment changes, and symptom direction.	Encourages three-dimensional assessment only when justified and paired with clinical history.
Referral outcomes	Need for ENT, paediatric, allergy, or sleep-medicine evaluation.	Reflects Saudi care pathways in which dental clinics may be the first point of concern for snoring or mouth breathing.

3 METHODOLOGY OF THE REVIEW

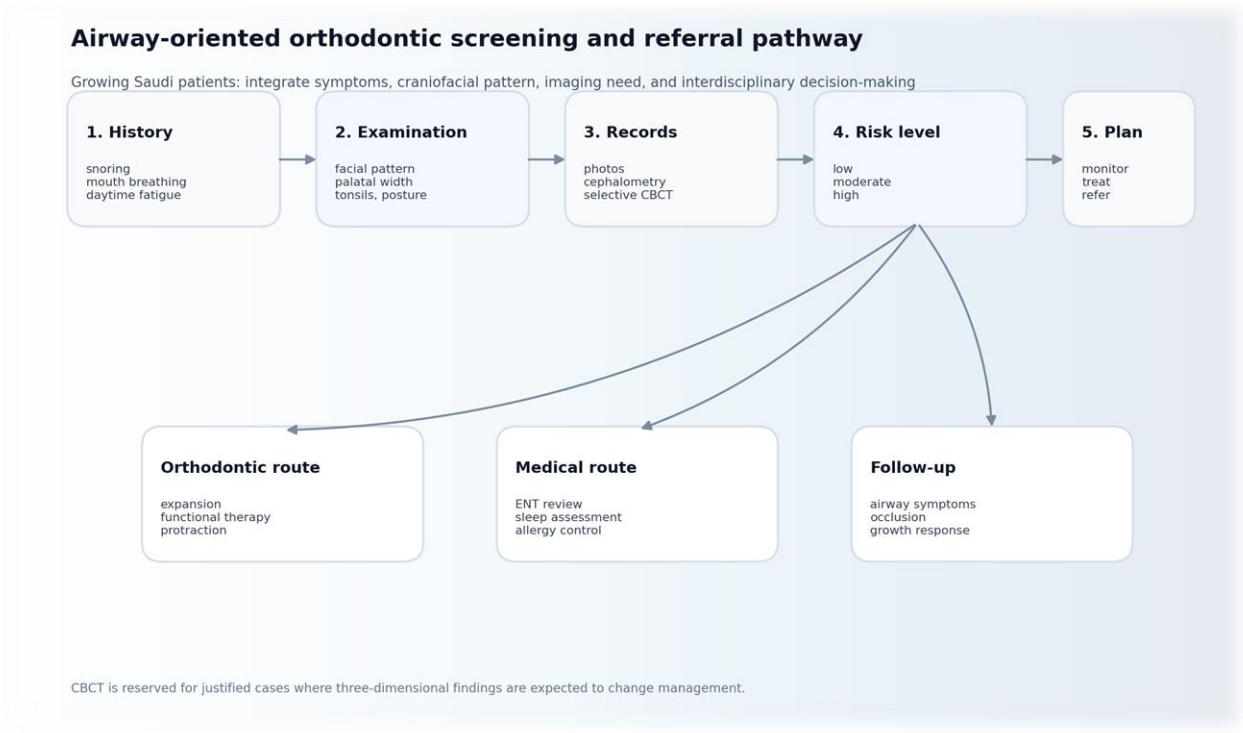
A structured narrative review method was adopted because the topic combines anatomical imaging, growth modification, orthodontic diagnosis, and paediatric respiratory symptoms. The review question was framed as follows: in growing patients, how do airway dimensions and craniofacial pattern influence orthodontic assessment and intervention, and how should this evidence be applied to Saudi clinical pathways? The population of interest was children and adolescents in active growth, with emphasis on Saudi relevance. The interventions were maxillary expansion, mandibular advancement functional appliances, maxillary protraction, and comprehensive fixed or aligner treatment when airway outcomes were reported. The outcomes were airway volume,

minimum cross-sectional area, nasal or pharyngeal segment change, symptom improvement, treatment need, and referral implications. Search terms combined orthodontics, dentofacial orthopaedics, airway, pharynx, nasopharynx, CBCT, maxillary expansion, functional appliance, Class II, Class III, sleep-disordered breathing, Saudi children, and mixed dentition. Evidence from 2020 to 2025 was prioritised to meet the recency requirement. Studies were considered more relevant when they included growing participants, three-dimensional airway measurement, clearly described appliance protocols, pre-treatment and post-treatment records, or Saudi epidemiological data. Reviews were used to identify consensus patterns and inconsistencies, while clinical studies were used to clarify mechanisms and limitations. Papers focused solely on adults, surgical airway management, syndromic conditions, or cleft patients were considered only when they clarified a methodological point rather than as direct evidence for healthy growing Saudi patients.

Data were extracted narratively under five themes: airway assessment methodology, craniofacial risk pattern, transverse intervention, sagittal intervention, and Saudi implementation. Methodological quality was judged by sample definition, presence of a comparator, imaging standardisation, follow-up duration, and whether airway findings were connected to clinical symptoms. A formal pooled estimate was not attempted because recent reviews show substantial heterogeneity in airway landmarks, segmentation boundaries, scanner settings, patient posture, respiratory phase, and intervention timing (Steegman *et al*., 2023; Sousa Melo *et al*., 2023). This choice is important: presenting a single pooled number would imply a level of comparability that current evidence does not support. The review therefore uses thematic synthesis. Findings are discussed as probable directions of effect, not as universal treatment promises. The synthesis also separates airway volume from respiratory diagnosis. Cone-beam imaging can describe anatomy but cannot diagnose obstructive sleep apnoea, which requires medical evaluation and, when indicated, sleep testing. This distinction protects patients from over-treatment and protects orthodontic planning from unsupported claims. The proposed pathway is intended for screening, communication, and referral, not for replacing otolaryngology or sleep-medicine assessment.

Figure 1

Airway-oriented screening and referral pathway for growing Saudi orthodontic patients.



4 AIRWAY DIMENSIONS AND IMAGING INTERPRETATION

Three-dimensional imaging has changed airway research because it allows the nasal cavity, nasopharynx, oropharynx, hypopharynx, volume, and minimum cross-sectional area to be assessed more completely than a lateral cephalogram. Recent evidence, however, repeatedly warns that measurement reliability depends on landmarks, software, thresholding, head posture, tongue position, and breathing phase. The same child may show different airway measurements if the head is extended, if the tongue is low, if the child swallows, or if segmentation thresholds change (Diaconu *et al*., 2022; Sousa Melo *et al*., 2023). For this reason, airway CBCT should be justified by expected diagnostic benefit and interpreted as an anatomical record rather than a sleep test.

In growing Saudi patients, three-dimensional imaging is most defensible when it is already required for orthodontic reasons or when two-dimensional records are insufficient for a complex skeletal discrepancy. The orthodontist should document patient positioning, occlusion, lip posture, and instructions during scanning. The minimum cross-

sectional area may be more clinically meaningful than total volume when a focal narrowing is present, while segmental analysis may clarify whether the restriction is predominantly nasal, nasopharyngeal, or oropharyngeal. Even then, imaging results should be integrated with history: snoring, observed apnoea, restless sleep, morning headaches, daytime sleepiness, attention problems, nasal obstruction, allergic rhinitis, and recurrent tonsillar symptoms carry essential diagnostic information.

The literature also supports caution in terminology. An increased volume after orthodontic treatment does not necessarily mean that airflow resistance has normalised. Computational modelling after maxillary expansion suggests that anatomical widening may alter pressure gradients and airflow behaviour, but these models require careful validation against clinical breathing outcomes (Feng *et al*., 2021). Therefore, airway dimensions should be presented to families as one component of a broader assessment. This is particularly important in Saudi practice, where families may seek orthodontic care before medical sleep assessment and where clear referral language can prevent unrealistic expectations.

5 CRANIOFACIAL PATTERN IN GROWING SAUDI PATIENTS

A craniofacial pattern becomes clinically important when it creates a plausible pathway from form to function. Maxillary constriction may reduce nasal floor width and is frequently associated with posterior crossbite, high palatal vault, and mouth-breathing history. Class II mandibular retrusion may place the tongue base and soft tissues in a more posterior relationship, particularly when combined with vertical facial growth. Class III maxillary deficiency may affect nasomaxillary dimensions, while long-face patterns may coexist with lip incompetence, low tongue posture, and altered oral function. These patterns are not diagnostic of respiratory disease, but they should trigger careful questioning and examination.

Saudi studies strengthen the need for early detection. Mixed-dentition samples from Eastern Saudi Arabia show a high proportion of children with moderate or definite early orthodontic treatment need, and occlusal traits such as crowding, increased overjet, and crossbite are clinically common (Madiraju *et al*., 2021; Madiraju *et al*., 2024). Sleep-disordered breathing symptoms have also been identified among Saudi children in

orthodontic or primary school settings, suggesting that dental clinics may encounter children whose first visible signs are occlusal or facial rather than medical (Al Ehaideb *et al*., 2021; Alwadei *et al*., 2023). These findings do not prove causation, but they support routine airway-oriented screening during mixed dentition.

The most practical risk profile is cumulative. A child with mild crowding alone may require ordinary orthodontic monitoring. A child with maxillary constriction, habitual mouth breathing, snoring, enlarged tonsils, allergic rhinitis, and daytime behavioural concerns requires a different response. In such cases, orthodontic expansion may be indicated for transverse correction, but referral for medical evaluation is also appropriate. Likewise, a retrognathic Class II child with snoring and excessive daytime sleepiness should not receive a functional appliance as a substitute for sleep assessment. The airway-oriented orthodontic role is to recognise risk, correct relevant dentofacial problems within accepted indications, and coordinate care.

6 TRANSVERSE ORTHOPAEDIC INTERVENTION

Maxillary expansion is the most discussed orthopaedic intervention in airway literature. Recent reviews generally report positive effects on nasal or nasopharyngeal dimensions in growing patients, with less consistent oropharyngeal change (Steegman *et al*., 2023; Abdalla and Sonnesen, 2024). Slow expansion, rapid expansion, hybrid tooth-bone-borne expansion, and bone-borne designs differ in anchorage, skeletal effect, dental tipping, comfort, and retention demands. A case-control study comparing slow and rapid expansion reported volumetric airway gains in growing patients, while randomised and comparative studies have shown that skeletal anchorage can reduce unwanted dental effects in selected patients (Lanteri *et al*., 2020; Pasqua *et al*., 2022).

For Saudi children, the key clinical indication remains transverse maxillary deficiency, not airway enlargement alone. Expansion is most defensible when there is posterior crossbite, functional mandibular shift, constricted maxillary arch, high palatal vault, crowding related to transverse deficiency, or an orthopaedic need to coordinate the arches. When such findings coexist with nasal obstruction or mouth breathing, the orthodontist can explain that expansion may improve nasal or nasopharyngeal dimensions in some children but that adenoids, tonsils, rhinitis, turbinate hypertrophy, and sleep

disorders require medical assessment. This balanced explanation aligns treatment with evidence and avoids overclaiming.

The respiratory significance of expansion is still under investigation. A 2024 CBCT study in children with obstructive sleep apnoea and maxillary restriction reported improvement in upper-airway parameters after rapid maxillary expansion, and a 2025 review of children with sleep-disordered breathing found potential benefits of expansion and functional treatment when malocclusion and breathing symptoms coexist (Zreaqat *et al*., 2024; Piełunowicz *et al*., 2025). These findings are encouraging but should be interpreted through patient selection. Children with enlarged adenoids, severe obesity, craniofacial syndromes, or neuromuscular conditions may not respond to dental orthopaedics alone.

7 SAGITTAL ORTHOPAEDIC INTERVENTION

Class II mandibular retrusion is relevant to airway assessment because the mandible, hyoid region, tongue posture, and oropharyngeal space are anatomically linked. Recent evidence on functional appliances suggests that mandibular advancement can increase selected upper-airway dimensions, particularly in the oropharyngeal region, but the strength of evidence remains limited by sample size, growth confounding, and variation in appliance design (Bidjan *et al*., 2020; Steegman *et al*., 2023). A CBCT study of children with obstructive sleep apnoea, Class II malocclusion, and mandibular retrognathia reported favourable airway parameter changes after Twin-block treatment, supporting the biological plausibility of mandibular advancement in selected cases (Zreaqat *et al*., 2023).

The clinical interpretation is straightforward: functional appliances should be used when there is an orthodontic indication for growth modification, such as a growing Class II patient with mandibular retrusion and favourable timing. When the patient also has snoring or suspected sleep-disordered breathing, the appliance may contribute to a wider functional environment, but it does not remove the need for medical assessment. Compliance also matters. A removable functional appliance has limited value if the child does not wear it, and families should understand that airway-related expectations depend on growth, skeletal response, and respiratory diagnosis.

Class III maxillary deficiency creates a different airway question. Maxillary protraction aims to improve midfacial growth and anterior maxillary position. A randomised study of miniscrew-anchored maxillary protraction with hybrid and hyrax expanders reported airway changes in Class III patients, indicating that protraction protocols can influence the nasomaxillary and pharyngeal environment (Miranda *et al*., 2022). For Saudi children with early Class III tendency, the priority is early skeletal assessment because treatment timing strongly affects orthopaedic response. Airway findings may support comprehensive planning, but the primary indication remains correction of maxillary deficiency and occlusal development.

8 COMPREHENSIVE ORTHODONTIC TREATMENT AND EXTRACTION DECISIONS

Comprehensive fixed appliances or aligners may influence airway dimensions indirectly through arch coordination, incisor movement, mandibular rotation, and soft-tissue adaptation. Recent reviews suggest that non-extraction treatment in growing patients usually does not reduce airway volume and may show increases related to growth and dental alignment (Steegman *et al*., 2023). Extraction therapy is more complex. Modern evidence does not support a simple claim that premolar extraction universally damages the airway, but adult hyperdivergent patients and cases requiring substantial anterior retraction deserve careful assessment (Shi *et al*., 2021; Ning *et al*., 2022).

For growing Saudi patients, extraction decisions should therefore be diagnosis-led rather than airway-anxious. Severe crowding, protrusion, periodontal limits, facial profile, vertical control, and stability must be considered. The airway perspective adds one more question: will the plan reduce oral cavity volume, retract incisors substantially, or worsen mandibular posture in a patient already showing airway risk? If the answer is uncertain, the clinician should document the rationale, consider alternative mechanics, and coordinate with medical colleagues when symptoms are present. Miniscrew-supported mechanics, arch development, molar distalisation, and growth modification can sometimes reduce the need for extraction, but they are not universally superior.

Patient-centred outcomes are also relevant. Orthodontic treatment affects discomfort, quality of life, speech, eating, and compliance, and these factors may

influence long-term adherence to removable appliances or retention (Alajmi *et al*., 2020; Baseer *et al*., 2021; Li *et al*., 2023). In airway-aware practice, a child who sleeps poorly may also struggle with cooperation, oral hygiene, and appointment tolerance. Treatment efficiency therefore depends not only on skeletal diagnosis but also on family education, symptom management, and interdisciplinary support.

Table 2

Clinical synthesis by craniofacial pattern and intervention type

Clinical pattern	Orthodontic concern	Possible intervention	Airway-related interpretation	Referral trigger
Maxillary constriction with crossbite	Narrow upper arch, functional shift, high palate.	Slow or rapid maxillary expansion; skeletal anchorage when indicated.	Most consistent evidence for nasal or nasopharyngeal dimensional gain.	Habitual snoring, persistent nasal obstruction, suspected adenoids or tonsils.
Class II mandibular retrusion	Increased overjet, convex profile, retruded chin.	Functional appliance during growth; fixed correction when growth is limited.	May improve oropharyngeal dimensions in selected compliant patients.	Witnessed apnoea, daytime sleepiness, behavioural concerns.
Class III maxillary deficiency	Anterior crossbite, midface deficiency, early skeletal discrepancy.	Maxillary protraction with expansion or skeletal anchorage where suitable.	Can influence nasomaxillary and pharyngeal dimensions; timing is critical.	Nasal obstruction, syndromic concern, severe asymmetry, or speech/feeding concerns.
Vertical growth tendency	Long lower face, lip incompetence, low tongue posture.	Vertical control mechanics, habit management, arch coordination.	Airway risk is often multifactorial; volume alone is insufficient.	Mouth breathing with poor sleep, allergic rhinitis, or recurrent ENT history.
Crowding requiring extraction consideration	Space deficiency, protrusion, periodontal limits.	Diagnosis-led extraction or non-extraction alternatives.	Avoid simplistic claims; assess retraction amount and baseline airway risk.	Existing sleep symptoms or major planned incisor retraction in high-risk pattern.

9 PROPOSED SAUDI SCREENING AND REFERRAL PATHWAY

A practical pathway begins with history. Every growing orthodontic patient should be asked about snoring, mouth breathing, restless sleep, witnessed pauses in breathing, morning tiredness, school concentration, nasal allergy, recurrent tonsillitis, and previous ENT care. The second step is clinical examination: facial pattern, lip

competence, mandibular position, vertical proportions, palatal vault, transverse arch width, crossbite, overjet, tonsillar visibility, tongue posture, and nasal breathing ability. The third step is record selection. Standard orthodontic records are sufficient for many children; CBCT should be reserved for justified cases where three-dimensional information will change diagnosis or management.

Risk stratification can be simple. Low-risk patients have no airway symptoms and ordinary dental concerns. Moderate-risk patients have a craniofacial pattern that may affect airway function but no major sleep symptoms; they require monitoring and family education. High-risk patients have symptoms such as habitual snoring, witnessed apnoea, significant daytime sleepiness, behavioural concerns, growth concerns, or persistent nasal obstruction; they require referral while orthodontic planning continues. This pathway supports safe practice because it does not delay medical diagnosis and does not force unnecessary imaging.

Interdisciplinary communication is essential. The orthodontist should write referral letters that describe craniofacial findings, occlusion, airway-related history, and planned orthopaedic intervention. The ENT or paediatric physician should be asked to evaluate nasal obstruction, adenoids, tonsils, rhinitis, and sleep-disordered breathing. When sleep testing is indicated, the results should be integrated into orthodontic goals. This approach respects professional boundaries while making orthodontic care more comprehensive. It also matches Saudi healthcare realities, where families may access private orthodontic clinics, university centres, or public hospitals through different pathways.

10 CLINICAL SYNTHESIS AND IMPLICATIONS

The evidence supports four clinical messages. First, airway-oriented orthodontics is not a separate specialty built on appliance promotion; it is a diagnostic discipline that integrates growth, occlusion, function, and referral. Second, maxillary expansion in growing patients has the most consistent anatomical support, particularly for nasal and nasopharyngeal dimensions, but its respiratory benefit depends on patient selection and medical status (Kalaskar *et al.*, 2023; Zreaqat *et al.*, 2024). Third, mandibular advancement can be relevant in retrognathic Class II patients, yet it should be timed to

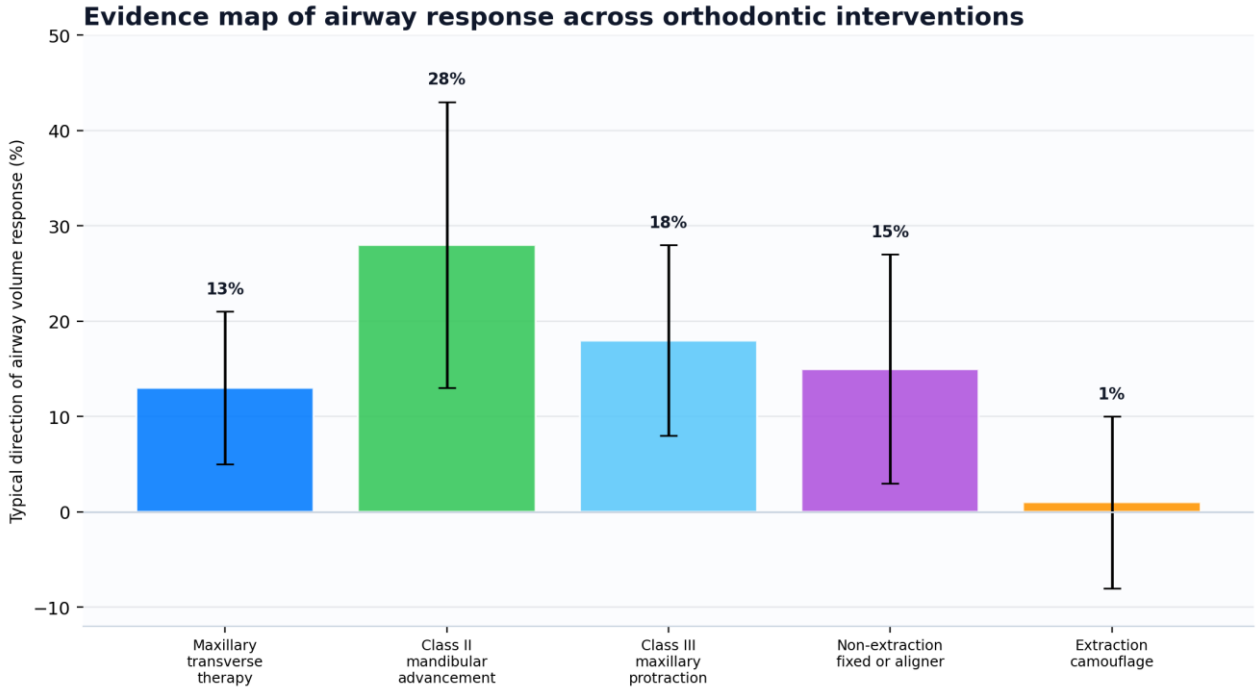
growth and supported by compliance monitoring. Fourth, airway measurement must be standardised before Saudi data can be compared internationally.

For Saudi orthodontic education, the curriculum should emphasise airway history, recognition of red flags, evidence-based imaging, and communication with medical colleagues. For clinics, intake forms should include sleep and nasal breathing questions. For research centres, future studies should include Saudi normative data on airway dimensions by age, sex, skeletal class, vertical pattern, body mass index, and nasal obstruction status. These studies should use consistent CBCT protocols, upright posture, defined tongue instructions, segmental airway boundaries, minimum cross-sectional area, and symptom questionnaires. When possible, sleep study outcomes should be included so that anatomical change can be linked to functional improvement.

The public-health implication is also important. If early orthodontic treatment need is high in Saudi mixed-dentition children, then screening programmes should not focus only on crowding and aesthetics. They should also identify mouth breathing, crossbite, severe overjet, mandibular retrusion, and sleep-related symptoms. Early recognition may reduce treatment complexity, support timely medical referral, and improve family understanding. However, public communication must avoid implying that expansion or functional appliances cure all breathing problems. The correct message is that certain dentofacial problems may contribute to airway vulnerability and are best managed early within a multidisciplinary system.

Figure 2

Evidence map showing the typical direction of airway response across orthodontic intervention groups.



11 SAUDI RESEARCH AGENDA AND CLINICAL GOVERNANCE

A Saudi airway-oriented orthodontic research agenda should begin with normative growth data. International airway measurements cannot be transferred directly to Saudi children without considering ethnicity, body size, environmental exposure, allergy prevalence, craniofacial morphology, and referral patterns. Multicentre studies from Riyadh, Jeddah, Dammam, Al-Ahsa, Qassim, Madinah, and the southern regions would allow researchers to define normal ranges for nasal cavity volume, nasopharyngeal volume, oropharyngeal volume, minimum cross-sectional area, maxillary width, palatal height, mandibular position, and vertical facial proportions. Such data should be stratified by age, sex, dentition stage, skeletal class, body mass index, and nasal obstruction history. Without these baseline ranges, clinicians may overinterpret a single airway measurement as abnormal when it may represent ordinary growth variation.

A second priority is linking anatomy to symptoms. Many studies report volume change after expansion or functional therapy, but fewer connect these changes to validated questionnaires, sleep measures, nasal airflow tests, or family-reported improvement. Saudi studies should therefore combine orthodontic records with paediatric sleep questionnaires, ENT findings, allergy status, tonsil and adenoid grading, and, where indicated, sleep testing. This design would allow researchers to determine whether a child with maxillary constriction and snoring improves because of expansion, medical management, growth, improved nasal allergy control, or a combination of factors. The result would be a more clinically honest model of response.

Third, future studies should compare intervention timing. The mixed dentition period may offer the strongest skeletal response for expansion and protraction, while early adolescence may be more appropriate for mandibular advancement in Class II cases. Saudi longitudinal cohorts could examine whether earlier referral reduces treatment complexity, improves transverse coordination, lowers extraction need, or improves patient-reported breathing. Outcomes should include occlusal correction, airway dimensions, symptoms, oral health-related quality of life, adverse effects, retention stability, and cost. Cost matters because families may access care through different public and private systems, and evidence-based timing can prevent both undertreatment and unnecessary early treatment.

Fourth, governance is required for imaging. Cone-beam scans should not be used as routine screening images for every child with snoring. Radiation exposure must be justified, the field of view should be limited to the diagnostic need, and repeated scans should be avoided unless they are necessary for treatment evaluation. When CBCT is justified, clinics should use written acquisition protocols: upright natural head position, teeth in intercuspation, lips relaxed, tongue instructions, avoidance of swallowing, and documentation of nasal breathing status. The same software, thresholding approach, and airway boundaries should be used for serial comparisons. These steps are simple but essential for credible data.

Finally, clinical governance should include language standards. Families deserve clear explanations that distinguish orthodontic indications from respiratory diagnosis. A suggested statement is: your child has a jaw or bite pattern that may be associated with reduced airway space, and orthodontic treatment may improve the dentofacial

environment; however, snoring or suspected sleep apnoea needs medical assessment. This wording is accurate, reassuring, and ethically safer than claiming that an appliance will cure breathing problems. It also supports collaboration rather than competition between orthodontists, paediatricians, otolaryngologists, allergists, and sleep physicians.

12 IMPLEMENTATION NOTE

Implementation should be deliberately simple. At the first visit, the clinician can use a short airway history form completed by the parent, followed by a focused examination of the face, lips, palate, dental arches, tonsillar region, mandibular posture, and nasal breathing. This adds only a few minutes to the consultation, but it changes the quality of the record because the treatment plan can explain why a child is monitored, treated, referred, or reassured. In mixed dentition, the same form can be repeated at review appointments, allowing the team to detect whether symptoms are improving, stable, or worsening during growth.

Record keeping should also be standardised. Photographs can document lip competence, facial proportions, and occlusal development. Study models or scans can document transverse change. Cephalometry can support sagittal and vertical diagnosis. Three-dimensional imaging should be reserved for cases in which the finding will influence management, and the report should describe the exact airway boundaries rather than giving a single unexplained volume. When families ask about breathing, the clinician should avoid dramatic language and should explain that the airway is dynamic, influenced by posture, inflammation, muscle tone, and sleep state.

Consent is another part of implementation. Parents should understand the orthodontic indication, expected dental and skeletal effects, possible airway-related benefits, limitations, discomfort, retention needs, and the possibility that medical treatment will still be required. Children should receive age-appropriate explanations because cooperation with expansion screws, functional appliances, elastics, oral hygiene, and retainers depends on trust. For high-risk patients, the plan should identify who is responsible for medical assessment and how orthodontic milestones will be coordinated with ENT or sleep-medicine findings.

Audit can make this pathway sustainable. Clinics can record the number of children screened, the number referred, the number receiving expansion or functional therapy, symptom direction after treatment, adverse effects, and parent satisfaction. These simple indicators would allow Saudi services to compare outcomes, refine referral thresholds, and develop stronger multicentre research. The result would be a model of care that is practical, cautious, and responsive to the needs of growing patients.

Training is the final requirement. Reception teams, dental assistants, general dentists, orthodontic residents, and consultants should use the same screening vocabulary so that important symptoms are not lost before the specialist appointment. Written referral templates and shared outcome forms can reduce variation between clinics and improve continuity when a child moves between public, private, and university services. This makes airway-aware care reproducible rather than personality dependent. Regular calibration meetings can review difficult cases, update evidence, and maintain a balance between early intervention and conservative monitoring for each child.

13 LIMITATIONS

The evidence base has several limitations. Many airway studies are retrospective, include small samples, use different anatomical borders, and lack untreated controls. Growth itself increases airway dimensions, making it difficult to separate treatment effect from normal development. CBCT records are static awake images, while obstructive breathing often occurs during sleep and involves neuromuscular tone, posture, inflammation, and obesity. Saudi-specific evidence is still limited, especially for longitudinal CBCT studies connecting malocclusion, airway morphology, symptoms, and treatment response. Another limitation is that patient-centred outcomes are inconsistently reported. Families care about breathing, sleep, school performance, comfort, and facial development, not only cubic millimetres of airway volume. Future research should therefore combine anatomical, functional, and quality-of-life outcomes.

14 CONCLUSION

Airway dimensions should be considered during orthodontic assessment of growing Saudi patients, especially when maxillary constriction, mandibular retrognathia, vertical facial excess, mouth breathing, or sleep-related symptoms are present. Recent evidence suggests that dentofacial orthopaedic interventions can produce favourable airway dimensional changes in selected growing patients, with the strongest support for maxillary expansion and promising findings for mandibular advancement and maxillary protraction. Nevertheless, airway volume is not a diagnosis, and orthodontic treatment should not be framed as an independent cure for sleep-disordered breathing. The most appropriate model is integrated care: systematic screening, justified imaging, growth-sensitive orthodontic intervention, medical referral when symptoms indicate risk, and outcome monitoring. This balanced framework can improve orthodontic decision-making in Saudi children while maintaining scientific accuracy and patient safety.

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