ECRONICON OPEN ACCESS

EC DENTAL SCIENCE

Research Article

Evaluation of Skeletal and Airway Volumetric Changes After Rapid Maxillary Expansion in Children Suffering from OSA - A Three-Dimensional Study

Kritika Kanwar Butta[1]*, Utsavraj Butta[2], Sanjeevani Ratti[3] and Priyanka Basu[4]

[1]*Department of Prosthodontics, TMJ and Dental Sleep Medicine, Dental World Superspeciality Clinics Pvt. Limited, West Bengal, India*

[2]*Department of Oral and Maxillofacial Surgery and Oral Implantology, Dental World Superspeciality Clinics Pvt. Limited, West Bengal, India*

[3]*Department of Orthodontics, Dental World Superspeciality Clinics Pvt. Limited, West Bengal, India*

[4]*Department of Periodontics, Dental World Superspeciality Clinics Pvt. Limited, West Bengal, India*

***Corresponding Author:** Kritika Kanwar Butta, Department of Prosthodontics, TMJ and Dental Sleep Medicine, Dental World Superspeciality Clinics Pvt. Limited, West Bengal, India.

Received: June 15, 2023; **Published:** June 28, 2023

Abstract

Introduction: Maxillary transverse deficiency (MTD) is a pathologic condition frequently seen associated with different malocclusions. Patients with MTD usually have increased nasal resistance, and unfavourable tongue and hyoid bone position, and are predisposed to breathing disorders. Rapid Maxillary Expansion (RME) may increase airway dimensions, and improve breathing and is an effective procedure to correct maxillary deficiency.

Aim: The aim of this study was to evaluate the changes in maxillary width and upper airway spaces in growing children with maxillary transverse deficiency (MTD) after rapid palatal expansion.

Materials and Methods: Five patients (1 male, 4 females; mean age 10.8) with maxillary transverse deficiency were recruited. An expander was placed on D, E and first permanent molars. Cone beam computed tomography was performed before treatment and at the end of the active expansion phase. Measurements were done on the basis of the cone beam computed tomography images by using Romexis 3-D software. Descriptive statistical analysis was performed to calculate the means with corresponding standard deviations (s.d.). t-test was used to compare means. Pearson's correlation coefficient was calculated to find the correlation between the two variables. $p < 0$.

Result: In all the cases the values of the parameters were increased after treatment as compared to before treatment but these were not significant ($p > 0.05$). After treatment, both Nasal Width and Transverse palatal width showed positive and significant correlations with airway volume. Thus, airway volume increased significantly with the increase in Nasal Width and Transverse palatal width ($p < 0.05$).

Conclusion: Widening of transverse maxillary deficiency after rapid palatal expansion with orthodontic therapy improves upper airway spaces in growing children.

Keywords: *Rapid Maxillary Expansion (RME); Obstructive Sleep Apnea (OSA); Sleep-Disordered Breathing (SDB); OSA-18 Quality of Life Survey; Pediatric Sleep Questionnaire; STOP-BANG Questionnaire; CBCT*

Abbreviations

MTD: Maxillary Transverse Deficiency; RME: Rapid Maxillary Expansion; RPE: Rapid Palatal Expansion; MCA: Minimum Cross-Sectional Area; OSA: Obstructive Sleep Apnea; UA: Upper Airway; PSG: Polysomnography; HSAT: Home Sleep Apnea Tests; AT: Adenotonsillectomy; SDB: Sleep-Disordered Breathing; 3D: Three-Dimensional; CBCT: Cone-Beam Computed Tomography; CT: Computerized Tomographic; OSAS: Obstructive Sleep Apnea Syndrome; AHI: Apnea Hypopnoea Index; BMI: Body Mass Index; NAR: Nasal Airway Resistance; TMCA: Total Minimum Cross-Sectional Areas; TNV: Total Nasal Volume; ENT: Ear Nose Throat; T0: Pre-Expansion Records; T1: Post-Expansion Records; OPD: Outpatient Department; PA: Posterioanterior; Z: Zygomatic Arch; N: Nasal Cavity; J: The Junction Between the Maxillary Tuberosity Outline and the Zygomatic Process; Ag: Ante Gonial Notch; N-N: Nasal Width; Z-Z: Facial Width; J-J: Maxillary Width; Ag-Ag: Mandibular Width; ANS: Anterior Nasal Spine; PNS: Posterior Nasal Spine; NS: Statistically Not Significant; S: Statistically Significant

Introduction

Pediatric obstructive sleep apnea (OSA) is described as a respiratory disorder characterized by prolonged partial (hypopnea) obstruction and/or intermittent complete (apnea) obstruction of the upper airway (UA) during sleep [1]. The OSA prevalence ranges between 1.2% and 5.8% in the general pediatric population [2]. It is commonly associated with conditions like neurocognitive deficits, cardiovascular diseases, and systemic inflammation [3]. These conditions adversely impact the child's health in the long run.

Adenotonsillar hypertrophy, obesity, craniofacial abnormalities, and neuromuscular disorders most commonly contribute to the development of pediatric OSA.

While planning a thorough orthodontic treatment in children, the presence of OSA is a hurdle in achieving control of the vertical aspect in hyper divergent malocclusions, which leads to an unsatisfactory improvement of the convex craniofacial profile. The gold standard in the diagnosis of pediatric OSA patients is essentially using polysomnography (PSG) however, home sleep apnea tests (HSAT) are increasingly getting accepted, especially when PSG is not available.

Common craniofacial characteristics in children suffering from OSA are a narrow palate, dental crowding, retrognathic mandible, steep occlusal plane, and high mandibular plane angle. On the other hand, craniofacial disharmony might predispose more severe sleep-disordered breathing (SDB) at a younger age [4].

Maxillary constriction, at first, was recognized and discussed extensively by Hippocrates in his 6th Book of Records over fifteen hundred years ago [5]. Rapid palatal expansion is a possible alternative to create space in the dental arches and address transverse discrepancies seen in constricted maxillary arches [6-9]. It is a routinely used technique and has grown popular over the last few decades [10]. It involves guided and controlled separation of the mid-palatal suture and circum-maxillary sutures by means of a screw application via orthopaedic forces to the hemi-maxillae. Following expansion there is an improvement in arch width, which facilitates the correction of malocclusion without the need for extraction in many patients, tongue space and position and width of the nasal floor, thus relieving upper airway obstruction.

Therefore, in this study, we assessed and compared the skeletal as well as airway changes caused by Rapid maxillary expansion (RME) in pediatric OSA patients before and after treatment using Cone beam computed tomography (CBCT).

Materials and Methods

This prospective study included a group of patients who received Rapid Palatal Expansion as part of their overall treatment protocol. All subjects were treated for constricted palatal arches. These subjects were chosen from the private orthodontic practice at the OPD of Dental World Super Speciality Clinics Pvt limited. CBCT records were taken pre (T0) and post-expansion (T1). Subjects were selected according to predetermined inclusion and exclusion criteria.

Inclusion criteria:

1. Orthodontically untreated subjects.
2. Growing subjects between the age group of 7 - 14 (preferably between 10 - 12 years if females; 12 - 14 years if males).
3. Mixed or early permanent dentition.
4. Non-syndromic children with a diagnosis of sleep disordered breathing, or obstructive sleep apnea by either a sleep disorders unit, screening questionnaires or polysomnography (PSG)
5. Studies with principal outcome measures of craniofacial and/or upper airway dimensions or proportions with various modalities of imaging for the craniofacial and neck region.

Exclusion criteria:

1. Syndromic children.
2. Children already wearing preventive or interceptive orthodontic appliances.

Patient records

Digital pre and post-lateral and PA cephalogram records (64 kV, 10 mA, 10.5s) comparing skeletal craniofacial dimensions and/or morphology of individuals and pre and post-airway parameter comparison utilizing low dose CBCT airway scans (90 kV, 6.3 mA, 0.04s) were taken before treatment (T0) and immediately after expansion (T1) for patients treated with RPE were collected using Planmeca unit (Planmeca Promax 3D classic, version 3.9.4) and measured using Planmeca Romexis version 4.6.2.R software. The airway parameters were measured for each CBCT record using Planmeca Romexis 4.6.2.R software. The relevant landmarks were identified in the lateral view and a posteroanterior view perpendicular to the mid-sagittal plane and measured. The total airway volume changes following expansion were measured.

Study selection criteria: Study selection criteria are given in table 1.

Criteria	Definition
Patient characteristics	Non-syndromic children of 7 - 12 years of age with a diagnosis of sleep disordered breathing, or obstructive sleep apnoea by either a sleep disorders unit, screening questionnaires or polysomnography. Medically compromised patients will be excluded.
Study method characteristics	Studies with various modalities of imaging for the craniofacial and neck region in children will be included.
Outcome characteristics	Trials reporting outcome measures as below: • Skeletal Craniofacial dimensions and/or morphology • Oropharyngeal airway dimensions and/or morphology

Table 1: *Selection criteria for this study.*

This study recruited 5 non-syndromic children between 7 - 14 years of age with a diagnosis of Sleep Disordered Breathing, or Obstructive Sleep Apnoea with transverse maxillary deficiency. Lateral cephalogram, Postero-anterior cephalogram (64 kV 10 mA 10.5s) and Low-dose cone-beam computed tomography CBCT airway scans (90 kV, 6.3 mA, 0.04s) were taken before treatment (T0) and immediately after expansion (T1). The primary outcome of this study comprised the assessment of skeletal, dentoalveolar, and airway measurements, which were performed at each time point.

Measurements

Skeletal parameters

Postero-anterior cephalometric parameters

The following variables (Figure 1) were identified and used in children with OSA:

- Nasal width (N-N): The width of the nasal cavity between the most lateral points on the nasal aperture.
- Facial width (Z-Z): The width of the zygomatic arch between the most lateral points.
- Maxillary width (J-J): The width of the maxilla from bilateral points on the jugal process at the intersection of the outline of the maxillary tuberosity and zygomatic buttress.
- Mandibular width (Ag-Ag): The width of the mandible from points at the ante gonial notch.

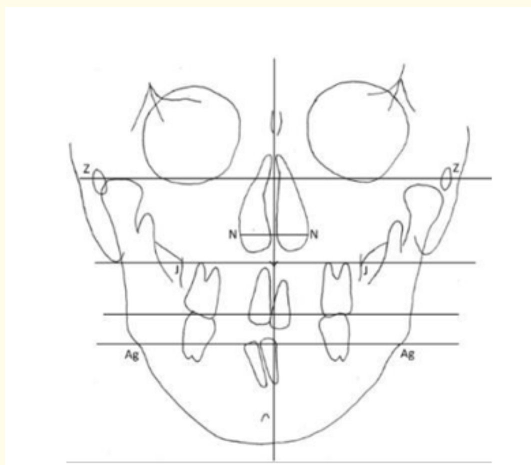

Figure 1: *Cephalometric references and landmarks used: a) Z-The most lateral point of the zygomatic arch, b) N-The most lateral wall of the nasal cavity, c) J-The junction between the maxillary tuberosity outline and the zygomatic process, d) Ag - The deepest point on the ante gonial notch.*

CBCT parameters

The following variables (Figure 2a-2c) were identified and used in children with OSA:

- Palatal depth
- Intermolar width
- Transverse palatal width
- Intercanine width.

Airway parameters

Airway measurement

The first step was to define and select an area containing the entire airway on an axial view. All axial views were checked to ensure that the airway was included in the selected area. Subsequently, the upper and lower borders in the airway volume area of interest were

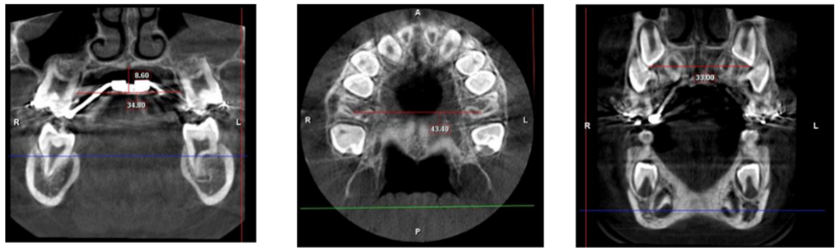

Figure 2a Figure 2b Figure 2c

Figure 2: *CBCT references and landmarks used: A) Intermolar width and the palatal depth, B) Transverse palatal width, C) Inter canine width.*

determined, and the specific borders of the segmented airway were defined manually by tracing the soft tissue-air interface at each 1-mm axial slice with the segmentation tool:

- Upper border- A horizontal line passing through the anterior and posterior nasal spine (ANS-PNS) extending back to the posterior pharyngeal wall.
- Lower border- A horizontal line parallel to the upper border passing through the superior point of the epiglottis.

Once segmentation was performed, the software automatically computed the total airway volumes in cubic millimetres. The total airway volume was measured at the midsagittal section of the airway by using the linear-measurement tool.

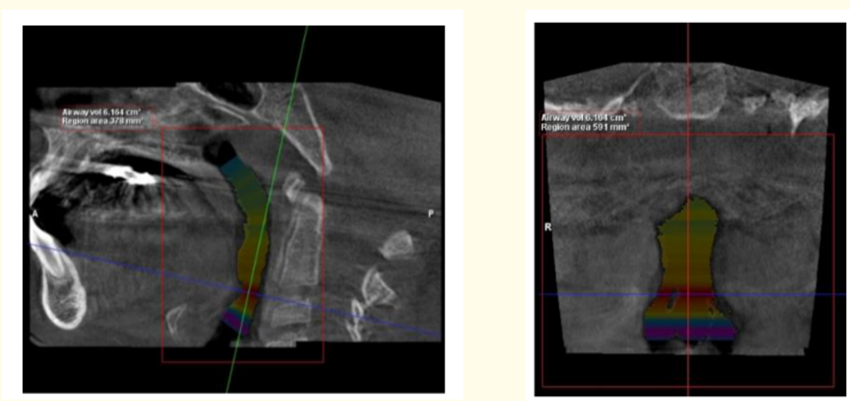

Figure 3: *CBCT references and landmarks used for oropharyngeal airway - superior border (ANS-PNS plane), inferior border (A line passing through the tip of the epiglottis parallel to ANS-PNS plane).*

Statistical Analysis was performed with the help of Epi Info (TM) 7.2.2.2 EPI INFO is a trademark of the Centers for Disease Control and Prevention (CDC). Descriptive statistical analysis was performed to calculate the means with corresponding standard deviations (s.d.).

t-test was used to compare means. Pearson's correlation coefficient was calculated to find the correlation between the two variables. $p < 0.05$ was taken to be statistically significant.

Result

Comparison of nasal width (N-N) before and after RPE

The mean nasal width before and after rapid palatal expansion was 27.11 mm and 30.26 mm respectively and the change in the nasal width between both groups was found to be statistically insignificant after treatment with RPE (p-value = 0.217).

Comparison of facial width (Z-Z) before and after RPE

The mean facial width before and after rapid palatal expansion was 106.4 mm and 110.22 mm respectively and the difference was found to be statistically insignificant after treatment with RPE (p-value = 0.660).

Comparison of maxillary width (J-J) before and after RPE

The mean maxillary width before and after rapid palatal expansion was 68.38 mm and 71.84 mm respectively. By applying Paired t-test, the change in the maxillary between both groups was found to be statistically insignificant after treatment with RPE (p-value = 0.528).

Comparison of mandibular width (Ag-Ag) before and after RPE

The mean mandibular width before and after rapid palatal expansion was 75.64 mm and 77.88 mm respectively. The change in the mandibular width between both groups was found to be statistically insignificant after treatment with RPE (p-value = 0.561).

Comparison of transverse palatal width before and after RPE

The mean transverse palatal width before and after rapid palatal expansion was 43.68 mm and 44.90 respectively and the difference between both groups was found to be statistically insignificant after treatment with RPE (p-value = 0.110).

Comparison of intermolar width before and after RPE

The mean intermolar width before and after rapid palatal expansion was 32.32 mm and 33.91 mm respectively. By applying Paired t-test, the change in the intermolar width between both groups was found to be statistically insignificant after treatment with RPE (p-value = 0.491).

Comparison of palatal depth before and after RPE

The mean palatal depth before and after rapid palatal expansion was 8.21 mm and 8.27 mm respectively. By applying Paired t-test, the change in the palatal width between both groups was found to be statistically insignificant after treatment with RPE (p-value = 0.972).

Comparison of inter canine width before and after RPE

The mean intercanine width before and after rapid palatal expansion was 30.232 mm and 31.68 mm respectively. By applying Paired t-test, the change in the intercanine width between both groups was found to be statistically insignificant after treatment with RPE (p-value = 0.488).

Comparison of airway volume before and after RPE

The mean airway volume before and after rapid palatal expansion was 9.6 cm^3 and 10.77 cm^3 respectively. By applying Paired t-test, the change between both groups was found to be statistically insignificant after treatment with RPE (p-value = 0.840).

Parameters	Group	n	Mean	s.d.	t	p-value
Nasal width	Pre-treatment	5	27.11	3.75	1.341	0.217 NS
	Post-treatment	5	30.26	3.68		
Facial width	Pre-treatment	5	106.40	4.49	0.944	0.380 NS
	Post-treatment	5	110.22	7.86		
Maxillary width	Pre-treatment	5	68.38	8.32	0.660	0.528 NS
	Post- treatment	5	71.84	8.25		
Mandibular width	Pre-treatment	5	75.64	5.62	0.606	0.561 NS
	Post-treatment	5	77.88	6.06		
Transverse palatal width	Pre-treatment	5	43.68	1.20	1.816	0.110 NS
	Post- treatment	5	44.90	0.90		
Inter-molar width	Pre-treatment	5	32.32	3.65	0.722	0.491 NS
	Post-treatment	5	33.91	3.29		
Palatal depth	Pre-treatment	5	8.20	3.07	0.037	0.972 NS
	Post-treatment	5	8.27	2.78		
Inter canine width	Pre-treatment	5	30.23	3.25	0.727	0.488 NS
	Post-treatment	5	31.68	3.05		
Airway Volume	Pre-treatment	5	9.60	9.19	0.208	0.840 NS
	Post-treatment	5	10.77	8.69		

Table 2: *Comparison of pre-treatment and post-treatment parameters in a single table.*
NS-Statistically Not Significant.

In all the cases the values of the parameters were increased after treatment as compared to before treatment but these were not significant ($p > 0.05$).

Correlation between airway volume with nasal width and transverse palatal width

All the correlations were positive. However, pre-treatment correlations were not significant but post-treatment correlations were significant.

Correlation of Airway Volume (cm^3) with	Pre-treatment		Post-treatment	
	Pearson Correlation (r)	p-value	Pearson Correlation (r)	p-value
Nasal Width (N-N)	0.594	0.290 NS	0.820	0.026 S
Transverse palatal width	0.188	0.761 NS	0.765	0.044 S

Table 3: *Correlation between airway volume with nasal width and transverse palatal width.*

After treatment for both Nasal Width and Transverse palatal width, the correlations with airway volume were positive and significant. Thus, airway volume increased significantly with the increase in Nasal Width and Transverse palatal width ($p < 0.05$).

Discussion

The association between pediatric sleep-disordered breathing caused by upper airway obstruction and craniofacial morphology is poorly understood and contradictory. The aims of this study were to evaluate and compare the skeletal and volumetric changes caused by rapid palatal expansion (RME) in addition to understanding the prevalence of children at risk for sleep-disordered breathing, as identified in an orthodontic setting by validated screening questionnaires, and to examine associations with their craniofacial and upper airway morphologies [24].

In this study, we evaluated the effect of rapid maxillary expansion (RME) in pediatric OSA subjects by comparing the nasal, maxillary, mandibular, facial, intermolar, inter-canine and transverse palatal widths in addition to the Palatal depth and the airway volume before and immediately after treatment using CBCT. The results of our study show a stable reduction in the clinical signs and symptoms of OSAS in the majority of the children treated. Since maxillary constriction is a feature of chronic nasorespiratory obstruction, RME plays an evident role as a preventive treatment in children with OSA, particularly during the prepubertal growth period [12].

Skeletal transverse changes with RME have remained controversial. In one study [25] reported that there were no significant changes while another [8] reported the existence of significant changes [11,26] which can be attributed to the application of orthopaedic force to the mid-palatal suture, anatomically comprising of mainly compact bone laterally and fibrous tissue with fibroblasts, collagen fibres, and blood vessels centrally resulting in maxillary widening by distraction osteogenesis, which was defined more than 100 years ago by Gavriel Ilizarov [27] vas "mechanical induction of new bone between two bony surfaces that are gradually distracted" [28].

Histologic investigation demonstrates that the application of strong forces, through an orthodontic device anchored to the teeth, rearranges the central zone, with the collagen fibres arranged in the direction of the distraction, and a progressive ossification occurs. A child can withstand up to 1 mm of expansion daily, but the speed of expansion varies. The bone distraction at the level of the suture causes an actual widening of the maxilla with increasing the cross-section as well as the volumetric space of the nasal cavity. The total expansion effect consists of a downward and forward movement of the maxillary complex with a resulting increase in the nasal canal and an improvement in the nasal airflow thereby alleviating symptoms of obstructive sleep apnea.

In our analysis, we identified the nasal, zygomatic or facial, maxillary, mandibular, intermolar, intercanine and transverse palatal width. However, these increases were around 2 to 3 mm, clearly indicating that a great portion of the true expansion was dental rather than skeletal [29]. Some studies have reported an indirect expansion occurring on the mandible after an RME treatment [9]. The results of our study, however, did not identify any statistically significant mandibular expansion. Future studies are needed concerning this parameter since this could be a temporary change that could relapse after a period.

Furthermore, when comparing the expansion increase on molars, canines and midline diastema, we found that the greatest expansion was at the molars with progressively reduced expansion in the anterior part of the arch. As the appliance used in this study was not anchored to canine teeth, this result was not a surprise and was in agreement with the findings of several studies [30,31]. The appliances used for RME exerted their force directly on the posterior teeth used for anchorage. This further supports the theory that a significant portion of the expansion is dental instead of solely skeletal.

Although clinically or statistically insignificant, increases in palatal depth were observed in 3 out of 5 of our patients which is in line with other studies [32,33] and contradict reports of palatal flattening, or lowering of the roof of the palatal vault [8] after RME [34,35]. Previous systematic reviews [36-38] regarding long-term changes after RME reported no clinically significant transverse, vertical and anteroposterior changes and were found to be more dental than skeletal in nature.

RME is a traditional orthodontic treatment for maxillary constriction and has been proposed as a treatment modality for OSA. It has been shown to increase the width of the maxilla, reduce nasal resistance and the apnea-hypopnea index of OSA patients in studies conducted by Pangrazio-Kulbersh., *et al*. [39], Caprioglio., *et al*. [40] and Fastuca., *et al* [41]. Our results are consistent with these. The airway volume increased considerably in our subjects post-expansion. The nasal cavity volume showed an increase after the use of RME with improvement in the breathing pattern seen in a study done by Gorgulu., *et al* [42]. An increase and widening of nasal cavity volume and nasal width were also demonstrated by El and Palomo [43], Pangrazio-Kulbersh., *et al*. [39] and Baratieri., *et al* [21]. In their studies, contradictory to the former, Zhao., *et al*. [33] found there were no differences between the untreated controls and treated in retroglossal and retropalatal airways following treatment with RME [36,44].

Although recent scientific literature shows that RME also affects the oropharyngeal airway in addition to causing dentoalveolar changes, it cannot be quantified in an objective way and there is a need for further well-controlled long-term clinical trials using the most precise methods to measure upper airway anatomy and its function and to look at the data for a longer observation period. There is also a need for long-term follow-up to access stability that results from rapid palatal expansion [45].

Conclusion

- Favourable changes were noted in upper airway space following RPE treatments in growing children.
- Rapid maxillary expansion may be a beneficial approach in growing children dealing with abnormal breathing patterns during sleep.
- Early orthopaedic treatment corrects the sagittal intermaxillary relation in Class II children, inducing significant pharyngeal changes that may benefit patients with mild to moderate obstructive sleep apnea syndrome.
- The forms/questionnaire utilized for childhood SRBDs, snoring, sleepiness, and behaviour is a valid and reliable tool that can be advantageous in identifying SRBDs or associated symptom as part of clinical research when polysomnography is not feasible.

Conflict of Interest

The author declares no financial interest and no conflict of interest exists.

Bibliography

1. Eckert DJ and Malhotra A. "Pathophysiology of adult obstructive sleep apnea". *Proceedings of the American Thoracic Society* 5.2 (2008): 144-153.
2. Cielo CM and Marcus CL. "Obstructive sleep apnoea in children with craniofacial syndromes". *Paediatric Respiratory Reviews* 16.3 (2015): 189-196.
3. Tsukada E., *et al*. "Prevalence of childhood obstructive sleep apnea syndrome and its role in daytime sleepiness". *PLoS One* 13.10 (2018): 0-12.
4. Lee YH., *et al*. "Craniofacial, dental arch morphology, and characteristics in preschool children with mild obstructive sleep apnea". *Journal of Dental Sciences* 15.2 (2020): 193-199.
5. Timms DJ. "The reduction of nasal airway resistance by rapid maxillary expansion and its effect on respiratory disease". *The Journal of Laryngology and Otology* 98.4 (1984): 357-362.
6. Haas AJ. "Palatal expansion: Just the beginning of dentofacial orthopedics". *American Journal of Orthodontics and Dentofacial Orthopedics* 57.3 (1970): 219-255.

7. Adkins MD., *et al*. "Arch perimeter changes on rapid palatal expansion". *American Journal of Orthodontics and Dentofacial Orthopedics* 97.3 (1990): 194-199.
8. Baccetti T., *et al*. "Treatment Timing for Rapid Maxillary Expansion". *The Angle Orthodontist* 71.5 (2001): 343-350.
9. Boucher G. "Book Reviews: Book Reviews". *Critical Sociology* 37.4 (2011): 493-497.
10. Los UMDECDE. No No Covariance structure analysis of health-related indicators in elderly people at home with a focus on subjective health.
11. Pirelli P., *et al*. "Rapid maxillary expansion (RME) for pediatric obstructive sleep apnea: A 12-year follow-up". *Sleep Medicine* 16.8 (2015): 933-935.
12. Villa MP., *et al*. "Efficacy of rapid maxillary expansion in children with obstructive sleep apnea syndrome: 36 months of follow-up". *Sleep Breath* 15.2 (2011): 179-184.
13. Marino A., *et al*. "Rapid maxillary expansion in children with Obstructive Sleep Apnoea Syndrome (OSAS)". *European Journal of Paediatric Dentistry: EJPD* 13.1 (2012): 57-63.
14. Villa MP., *et al*. "Adenotonsillectomy and orthodontic therapy in pediatric obstructive sleep apnea". *Sleep Breath* 18 (2014): 533-539.
15. Matsumoto MAN., *et al*. "Long-term effects of rapid maxillary expansion on nasal area and nasal airway resistance". *The American Journal of Rhinology and Allergy* 24.2 (2010): 161-165.
16. Abdalla Y., *et al*. "Effects of rapid maxillary expansion on upper airway volume: A three-dimensional cone-beam computed tomography study". *The Angle Orthodontist* 89.6 (2019): 917-923.
17. Ceroni Compadretti G., *et al*. "Acoustic rhinometric measurements in children undergoing rapid maxillary expansion". *International Journal of Pediatric Otorhinolaryngology* 70.1 (2006): 27-34.
18. Compadretti GC., *et al*. "Nasal airway measurements in children treated by rapid maxillary expansion". *American Journal of Rhinology and Allergy* 20.4 (2006): 385-393.
19. Langer MRE., *et al*. "Does rapid maxillary expansion increase nasopharyngeal space and improve nasal airway resistance?" *International Journal of Pediatric Otorhinolaryngology* 75.1 (2011): 122-125.
20. Iwasaki T., *et al*. "Tongue posture improvement and pharyngeal airway enlargement as secondary effects of rapid maxillary expansion: A cone-beam computed tomography study". *American Journal of Orthodontics and Dentofacial Orthopedics* 143.2 (2013): 235-245.
21. Baratieri C., *et al*. "Does rapid maxillary expansion have long-term effects on airway dimensions and breathing?" *American Journal of Orthodontics and Dentofacial Orthopedics* 140.2 (2011): 146-156.
22. Chervin RD., *et al*. "Pediatric sleep questionnaire (PSQ): Validity and reliability of scales for sleep-disordered breathing, snoring, sleepiness, and behavioral problems". *Sleep Medicine* 1.1 (2000): 21-32.
23. PSAAAV. "Age changes of jaws and soft tissue profile". *The Scientific World Journal* (2014).
24. Katyal V., *et al*. "Craniofacial and upper airway morphology in pediatric sleep-disordered breathing and changes in quality of life with rapid maxillary expansion". *American Journal of Orthodontics and Dentofacial Orthopedics* 144.6 (2013): 860-871.

25. Cozzani M., *et al*. "Deciduous dentition-anchored rapid maxillary expansion in crossbite and non-crossbite mixed dentition patients: reaction of the permanent first molar". *Progress in Orthodontics* 4 (2003): 15-22.

26. Villa MP., *et al*. "Rapid maxillary expansion outcomes in treatment of obstructive sleep apnea in children". *Sleep Medicine* 16.6 (2015): 709- 716.

27. Ilizarov GA. "The Tension-Stress Effect on the Genesis and Growth of Tissues". *Clinical Orthopaedics and Related Research* 239 (1989): 263-285.

28. Lagravère MO., *et al*. "Rapid Maxillary Expansion Treatment". *Journal of the American Dental Association* 137.1 (2006): 44-53.

29. Greenlee GM. "Rapid Maxillary Expansion Results Primarily in Dental, not Skeletal, Changes". *Journal of Evidence-Based Dental Practice* 7.1 (2007): 17-18.

30. Akkaya S., *et al*. "A comparison of sagittal and vertical effects between bonded rapid and slow maxillary expansion procedures". *European Journal of Orthodontics* 21.2 (1999): 175-180.

31. Thiradilok S. Changes in Dental Arch Dimension among Dental Class II Patients after Rapid Maxillary Expansion Therapy (2008).

32. Oliveira De Felippe NL., *et al*. "Relationship between rapid maxillary expansion and nasal cavity size and airway resistance: Short- and long-term effects". *American Journal of Orthodontics and Dentofacial Orthopedics* 134.3 (2008): 370-382.

33. Zhao Y., *et al*. "Oropharyngeal airway changes after rapid palatal expansion evaluated with cone-beam computed tomography". *American Journal of Orthodontics and Dentofacial Orthopedics* . 137.4 (2010): S71-S78.

34. Chen G., *et al*. "Stable region for maxillary dental cast superimposition in adults, studied with the aid of stable miniscrews". *Orthodontics and Craniofacial Research* 14.2 (2011): 70-79.

35. Saadeh M., *et al*. "Instability of palatal rugae following rapid maxillary expansion". *European Journal of Orthodontics* 39.5 (2017): 474-481.

36. Parakkal T., *et al*. "Long-term Effects of Rapid Palatal Expansion on Airway and Nasal Cavity Using Three-dimensional Analysis: A Systematic Review". *World Journal of Dentistry* 14.2 (2023): 182-191.

37. Pia M., *et al*. "Rapid maxillary expansion in children with Obstructive Sleep Apnoea Syndrome (OSAS)". *Sleep Medicine* 10.1 (2017): 1053-1061.

38. Bahammam SA. "Rapid Maxillary Expansion for Obstructive Sleep Apnea among children - Systematic Review and Meta-analysis". *Sleep Science. Brazilian Association of Sleep and Latin American Federation of Sleep Societies* 13 (2020): 70-77.

39. Berger JL., *et al*. "Stability of orthopedic and surgically assisted rapid palatal expansion over time". *American Journal of Orthodontics and Dentofacial Orthopedics* 114.6 (1998): 638-645.

40. Cordasco G., *et al*. "Efficacy of orthopedic treatment with protraction facemask on skeletal Class III malocclusion: A systematic review and meta-analysis". *Orthodontics and Craniofacial Research* 17.3 (2014): 133-143.

41. Digregorio MV., *et al*. "Buccal bone plate thickness after rapid maxillary expansion in mixed and permanent dentitions". *American Journal of Orthodontics and Dentofacial Orthopedics* 155.2 (2019): 198-206.

42. Niu X., *et al*. "Three-dimensional analyses of short- and long-term effects of rapid maxillary expansion on nasal cavity and upper airway: A systematic review and meta-analysis". *Orthodontics and Craniofacial Research* 23.3 (2020): 250-276.

43. ElH and Palomo JM. "Three-dimensional evaluation of upper airway following rapid maxillary expansion A CBCT study". *The Angle Orthodontist* 84.2 (2014): 265-273.

44. Giannasi LC., *et al*. "Effect of a rapid maxillary expansion on snoring and sleep in children: A pilot study". *The Journal of Craniomandibular and Sleep Practice* 33.3 (2015): 169-173.

45. Ortu E., *et al*. "Oropharyngeal airway changes after rapid maxillary expansion: The state of the art". *International Journal of Clinical and Experimental Medicine* 7.7 (2014): 1632-1638.

Volume 22 Issue 7 July 2023