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Miniscrew-Assisted Rapid Palatal Expansion (MARPE) for Obstructive Sleep Apnoea: A Narrative Review

(Pengembangan Lelangit Pantas Berbantukan Skru Mini (MARPE) untuk Apnea Tidur Obstruktif: Satu Ulasan Naratif)

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ABSTRACT

Obstructive sleep apnoea (OSA) affects millions worldwide and significantly impacts cardiovascular health and quality of life. While continuous positive airway pressure remains the gold standard, poor compliance drives interest in alternative treatments. Miniscrew-assisted rapid palatal expansion (MARPE) has emerged as a promising non-surgical intervention for patients with OSA and transverse maxillary deficiency. This narrative review summarises the current literature on MARPE's biomechanical principles, reported clinical outcomes, and long-term considerations. Available studies suggest that MARPE may achieve meaningful skeletal expansion and may be associated with improvement in apnoea-hypopnoea index (AHI) in carefully selected patients. Compared with some alternative expansion approaches, MARPE has been reported to show favourable periodontal outcomes and encouraging long-term stability in selected studies, although these findings should be interpreted cautiously. Complications have been reported in some case series, but many are manageable with appropriate planning, appliance design, and follow-up. This narrative review provides a clinically oriented overview of current evidence on case selection, treatment planning, and complication management.

Keywords: Maxillary expansion; miniscrew anchorage; obstructive sleep apnea; rapid palatal expansion; sleep-disordered breathing

ABSTRAK

Apnea tidur obstruktif (OSA) menjejaskan berjuta-juta orang di seluruh dunia dan memberi kesan yang ketara terhadap kesihatan kardiovaskular dan kualiti hidup. Walaupun kaedah tekanan saluran udara positif berterusan kekal sebagai rawatan utama, pematuhan yang rendah telah mendorong kepada pilihan rawatan alternatif. Pengembangan aplians untuk meluaskan lelangit dengan sokongan skru mini (MARPE) telah muncul sebagai intervensi alternatif tanpa pembedahan bagi pesakit OSA dan mempunyai saiz maksila yang kecil. Ulasan naratif ini merumuskan kepustakaan semasa mengenai prinsip biomekanikal MARPE, hasil klinikal yang dilaporkan dan pertimbangan jangka panjang. Kajian yang tersedia menunjukkan bahawa MARPE berpotensi menghasilkan pengembangan skeletal yang bermakna dan mungkin dikaitkan dengan penambahbaikan dalam indeks apnea-hipopnea (AHI) dalam pesakit yang dipilih dengan teliti. Berbanding dengan beberapa pendekatan pengembangan alternatif, MARPE dilaporkan menunjukkan hasil periodontal yang memuaskan dan kestabilan jangka panjang yang menggalakkan dalam beberapa kajian terpilih, walaupun keputusan ini perlu ditafsirkan dengan berhati-hati. Komplikasi telah dilaporkan dalam beberapa siri kes, namun kebanyakkannya boleh diuruskan dengan perancangan yang sesuai, reka bentuk aplians yang baik dan susulan yang rapi. Ulasan naratif ini memberi gambaran keseluruhan yang berorientasikan klinikal terhadap bukti semasa berkaitan pemilihan kes, perancangan rawatan dan pengurusan komplikasi.

Kata kunci: Aplians pengembangan lelangit pantas; aplians sokongan skru mini; apnea tidur obstruktif; gangguan pernafasan tidur; pengembangan maksila

INTRODUCTION

Obstructive sleep apnoea (OSA) is a chronic sleep-related breathing disorder characterised by recurrent episodes of partial or complete collapse of the upper airway during sleep, resulting in oxygen desaturation, sleep fragmentation, and substantial long-term morbidity if left untreated (Alrumaih, Alterki & Qali 2025). The pathophysiology involves multiple mechanisms including compromised airway anatomy, altered muscle responsiveness, and impaired arousal thresholds that collectively reduce

respiratory drive and upper airway patency during sleep (Randerath et al. 2022). The clinical manifestations extend beyond nocturnal symptoms to encompass excessive daytime sleepiness, cognitive impairment, and morning headaches that significantly impact quality of life and work performance (Alrumaih, Alterki & Qali 2025). The long-term consequences of untreated OSA are devastating, including substantially increased risk of myocardial infarction, stroke, hypertension, sudden cardiac death, and cognitive decline (Inchingolo et al. 2025). Contemporary evidence shows that hypoxic burden, defined as the total area under desaturation curves divided by sleep time, is one of the strongest predictors of cardiovascular risk in OSA (Pinilla et al. 2023).

The prevalence of OSA has reached epidemic proportions globally, affecting approximately one-fifth of the adult population in developed nations, with even higher rates documented in older adults and patients with obesity or craniofacial abnormalities (Inchingolo et al. 2025). Paediatric OSA, affecting 2-3% of children with peak incidence between ages 2-8 years, carries particularly serious consequences due to the profound impact on neurocognitive development, behaviour, learning capacity, and metabolic function during critical developmental windows (Sood & Khilnani 2015). In syndromic populations, such as individuals with Down syndrome, OSA prevalence increases dramatically and the severity is often more pronounced, necessitating specialised diagnostic and management approaches (Simpson et al. 2018). Despite advances in awareness and diagnostic capabilities, significant underdiagnosis persists in the general population, with estimates suggesting that only 10-15% of individuals with clinically significant OSA receive appropriate diagnosis and treatment (Inchingolo et al. 2025).

Transverse maxillary deficiency, characterised by a narrowed palate and reduced dental arch width, is a significant anatomical factor predisposing to the development and persistence of OSA. This anatomical abnormality affects 8-22% of the general orthodontic population and can persist or progress into adulthood as the midpalatal suture progressively ossifies with advancing skeletal age. The narrowed maxillary structure reduces the cross-sectional area of the nasal cavity and contributes substantially to upper airway collapsibility during sleep, particularly in patients with concurrent retrognathic mandibles or other anatomical risk factors that compound the airway-restricting effects of transverse maxillary insufficiency (Memè et al. 2024). Current treatment options for OSA include continuous positive airway pressure (CPAP) as the first-line therapy, followed by mandibular advancement devices (MADs) for mild-to-moderate OSA in CPAP-intolerant patients, positional therapy, weight management, and various surgical interventions ranging from simple adenotonsillectomy to complex maxillomandibular advancement (Arachchige & Steier 2021). However, each modality has distinct limitations, as CPAP frequently faces long-term adherence challenges, MADs are associated with progressive dental side effects, and surgical interventions involve operative risks with variable outcomes (Sutherland & Cistulli 2011).

Rapid maxillary expansion (RME) using tooth-borne appliances has been the standard orthodontic treatment for transverse maxillary deficiency for decades. However, this approach is limited in skeletally mature patients due to progressive ossification of the midpalatal suture, which increases resistance to expansion forces and limits the magnitude of achievable skeletal change (Satapathy & Agarwal 2025). The development of miniscrew-assisted rapid palatal expansion (MARPE) technology has fundamentally transformed maxillary expansion treatment by providing direct skeletal anchorage through surgically-placed miniscrews, bypassing dental structures entirely and enabling genuine skeletal expansion in adolescents and adults where conventional approaches are ineffective (Almoabady et al. 2025). This innovation has expanded potential clinical applications beyond purely orthodontic indications to encompass therapeutic management of OSA in patients with anatomically based OSA phenotypes (Brunetto et al. 2022). The biomechanical advantages of skeletal anchorage - namely, the achievement of predominantly skeletal expansion (approximately 49% basal bone widening versus 44% dental compensation) compared to conventional devices - translate directly into superior long-term treatment stability (Zeng et al. 2023). MARPE has emerged as a sophisticated and potentially transformative treatment option for appropriately selected patients with obstructive sleep apnoea complicated by transverse maxillary deficiency (Almoabady et al. 2025).

The convergence of several factors supports MARPE's role in contemporary OSA management: (1) high prevalence of transverse maxillary deficiency in the general OSA population, (2) documented efficacy in expanding the nasopharyngeal airway and reducing apnoea-hypopnea index by 65.3% in carefully selected patients, (3) superior long-term stability compared to conventional expansion approaches with only 30% relapse at 10-year follow-up, (4) favourable periodontal outcomes compared to surgically-assisted alternatives, and (5) permanent anatomical correction eliminating the compliance burden of device-dependent treatments (Brunetto et al. 2022; Firinciogullari et al. 2025; Kapetanović et al. 2021; Parihar et al. 2025). This narrative review summarises current evidence regarding MARPE as a potential therapeutic option for obstructive sleep apnoea, focusing on its biomechanical principles, reported clinical outcomes, patient selection, complications and long-term considerations (Zeng et al. 2023).

BIOMECHANICAL PRINCIPLES AND CLINICAL EFFICACY

SKELETAL ANCHORAGE SYSTEM

MARPE fundamentally differs from conventional RME by utilising skeletal rather than dental anchorage (Almoabady

et al. 2025). Central to this innovation are two to four miniscrews with bicortical engagement of the palatal vault and nasal floor, creating fixed anchorage points (Satapathy & Agarwal 2025). This approach directs expansion forces directly to the midpalatal suture, achieving predominantly skeletal changes rather than dental compensation (Almoabady et al. 2025).

Finite-element analysis demonstrates that one complete jackscrew turns in miniscrews, with quasi-parallel midpalatal deformation averaging 0.247 millimetres, produces a maximum equivalent von Mises stress of 264.91 megapascals (Mamboleo et al. 2024). Critically, no miniscrew fracture occurs during standard activation protocols, and the rotational angle to lateral displacement ratio is 0.6436 degree per millimetre (Mamboleo et al. 2024).

SKELETAL VERSUS DENTAL EXPANSION

Meta-analytic data from 12 studies demonstrate that MARPE produces approximately 48.85% basal bone expansion, 7.52% alveolar bone changes, and 43.63% dental changes (Zeng et al. 2023). This skeletal composition directly accounts for superior long-term stability. At a 10-year follow-up, MARPE-treated patients demonstrated only 30% relapse in buccal maxillary width compared to 80% with conventional RPE (Firinciogullari et al. 2025), representing a 50-percentage point difference and reflecting the superior stability of skeletal versus dental changes (Firinciogullari et al. 2025).

CLINICAL OUTCOMES IN OSA

Published studies have reported high rates of successful skeletal maxillary expansion with MARPE, although definitions of treatment success vary across studies (Kapetanović et al. 2021). A multi-centre-controlled trial in non-obese adults with OSA and transverse maxillary deficiency demonstrated 65.3% reduction in apnoea-hypopnea index following treatment (Brunetto et al. 2022). However, this finding should not be generalised to all patients with OSA. Improvements persisted following completion of active expansion and retention phases, indicating permanent anatomical benefit (Brunetto et al. 2022).

Nasal airway dimensions increase substantially: nasal base width increases by 3.29 millimetres and nasal cavity width by 1.81 millimetres (Thi Hong Thuy et al. 2025). Computational fluid dynamics analysis shows decreased airflow velocity in anterior nasal cavity and pharynx with significantly lower total resistance to airflow (Hur et al. 2017). In paediatric patients, total airway volume increases 44.6% (from 678.6 to 981.06 cubic millimetres) with significant nasopharyngeal improvements (Pawar et al. 2025).

Although greater transverse expansion is associated with enlargement of the nasal cavity and anterior airway, current evidence does not demonstrate a clear linear dose-response relationship between the magnitude of expansion and reduction in apnoea-hypopnoea index. It is possible that a threshold effect exists, whereby sufficient expansion improves airflow and nasal resistance, but additional expansion beyond that point may provide limited further benefit in obstructive sleep apnoea severity.

COMPARATIVE EFFECTIVENESS WITH ALTERNATIVE TREATMENTS

MARPE VERSUS MANDIBULAR ADVANCEMENT DEVICES

Mandibular advancement devices (MADs) achieve similar apnoea-hypopnea index (AHI) reductions as MARPE in mild-to-moderate OSA but differ fundamentally in mechanisms and side effects (Chan, Sutherland & Cistulli 2020). MAD therapy produces substantial occlusal changes including decreased overjet (0.89 ± 0.04 mm) and overbite (0.68 ± 0.04 mm) reductions with increased lower incisor proclination (Tsolakis et al. 2022). Long-term MAD use produces mandibular rotation and progressive dentoalveolar remodelling (Doff et al. 2013).

In contrast, MARPE addresses the anatomical substrate without progressive dental changes characteristic of MAD therapy (Parihar et al. 2025). MARPE produces predominantly skeletal expansion (48.85% basal bone) whereas MAD-induced airway enlargement relies entirely on mandibular displacement without skeletal remodelling (Zeng et al. 2023). Drug-induced sleep endoscopy phenotyping shows that tongue base collapse predicts MAD success while complete concentric palatal collapse predicts treatment failure (Op de Beeck et al. 2019; Van den Bossche et al. 2022).

MARPE VERSUS CPAP

CPAP remains the gold standard but suffers from poor adherence: approximately 42% of patients cannot tolerate CPAP, and only 50-60% maintain adequate adherence (≥4 h nightly on ≥5 nights weekly) (Guimares et al. 2020). MARPE differs fundamentally by producing permanent anatomical changes requiring no ongoing device dependence. While MARPE may not achieve complete AHI normalisation like optimally-used CPAP, the 65.3% reduction in apnoea-hypopnea index approaches clinically meaningful improvement, particularly when combined with other modalities (Brunetto et al. 2022). MARPE is not appropriate for severe OSA (AHI >30 events/hour) requiring immediate intervention; CPAP remains necessary for these patients (Brunetto et al. 2022).

MARPE VERSUS SURGICALLY-ASSISTED EXPANSION

While both MARPE and surgically-assisted rapid palatal expansion (SARPE) achieve comparable expansion magnitudes (6.0-6.5 mm), MARPE demonstrates

substantially superior periodontal outcomes. SARPE produces greater gingival recession (1.1 ± 0.3 mm versus 0.3 ± 0.1 mm, $p < 0.001$) and greater buccal alveolar bone loss (0.8 ± 0.2 mm versus 0.2 ± 0.1 mm, $p < 0.01$) (Parihar et al. 2025). MARPE is associated with minimal postoperative discomfort and immediate return to normal activities compared to SARPE's hospitalisation requirements (Li & Guilleminault 2022).

Although MARPE and surgically assisted rapid palatal expansion (SARPE) may both enlarge the maxillary complex and potentially improve nasal airflow, there is currently insufficient direct evidence comparing their effects on sleep parameters or OSA severity. Any apparent difference in sleep-related improvement may reflect variation in baseline skeletal severity, age, and patient selection rather than the expansion technique alone.

PATIENT SELECTION AND CLINICAL DECISION-MAKING

Selection criteria

Ideal MARPE candidates are skeletally mature patients (≥16 years) with transverse maxillary deficiency, mild-to-moderate OSA (AHI 5-30 events/hour), and confirmed via polysomnography (Brunetto et al. 2022; Kapetanović et al. 2021). Skeletal maturity assessment via cervical vertebral maturation staging or CBCT midpalatal suture visualisation is essential (Thi Hong Thuy et al. 2025).

Anatomical assessment requires multiple modalities: clinical evaluation of posterior crossbite presence, intercanine/intermolar width measurement, cephalometric analysis confirming maxillary skeletal narrowing, and CBCT for optimal miniscrew placement planning (Cantarella et al. 2020). BMI is considered but not prohibitive; the multi-centre trial enrolled primarily non-obese patients reflecting MARPE's primary effectiveness for anatomically-based OSA (Brunetto et al. 2022).

Anteroposterior skeletal relationships may influence the treatment response. Class I patients demonstrate better outcomes than those with significant Class II/III discrepancies (Brunetto et al. 2022). Patients with marked Class II or Class III discrepancies may have airway limitations that are not fully corrected by transverse expansion alone.

Patient selection should extend beyond the presence of transverse maxillary deficiency alone. Sagittal and vertical skeletal pattern are also likely to modify OSA outcomes after MARPE. Patients with Class II skeletal pattern, mandibular retrusion, skeletal open bite or vertical excess may continue to exhibit pharyngeal airway compromise despite improvement in nasal or maxillary transverse dimensions. In such cases, MARPE alone may provide only partial benefit, and combination treatment with mandibular advancement, weight management, positional therapy, or orthognathic approaches may need to be considered.

PATIENT COMPLIANCE AND MOTIVATION

Patient adherence critically determines success (van der Bie et al. 2024). MARPE requires sustained compliance with daily activation protocols and prolonged retention protocol adherence extending months to years (Satapathy & Agarwal 2025). Three main patient domains predict treatment success: positive social behaviour patterns, parental/caregiver attitudes, and realistic prior motivation (Santana et al. 2025). A behavioural classification framework identifies five patient categories ranging from 'Idealists' (high-demand, trusting, compliant) to 'Skeptics' (low-demand, distrustful, non-compliant) (Santana et al. 2025).

COMPLICATIONS AND MANAGEMENT

Complication incidence

Retrospective analysis of 24 consecutive MARPE cases showed 33.3% true complications, with an additional 8.3% experiencing procedural delays (Rajalakshmi et al. 2025). Mechanical complications (screw fracture, appliance failure, n=6) typically resulted in 2+ weeks treatment interruption (Rajalakshmi et al. 2025). Biological complications (tongue irritation, peri-implant mucositis, n=2) were generally manageable (Rajalakshmi et al. 2025).

RISK FACTORS AND PREVENTION

Miniscrew characteristics significantly predicted complications: complications were confined to screws ≤10 mm length, while 11 mm or longer screws with 2.0 mm diameter showed no complications (Rajalakshmi et al. 2025). Screws <1.8 mm diameter demonstrated higher complication rates than 2.0 mm screws (Rajalakshmi et al. 2025).

Prevention strategies include: (1) optimal miniscrew specifications (2.0 mm diameter, 11 mm length), (2) CBCT-guided precise placement ensuring bicortical engagement, (3) standardised activation protocols (typically two daily activations of 0.25 mm), and (4) regular follow-up monitoring every two to four weeks during active expansion (Rajalakshmi et al. 2025).

LONG-TERM OUTCOMES AND RETENTION

Skeletal Stability

Long-term MARPE follow-up demonstrates excellent skeletal stability. One long term study reported approximately 30% relapse in buccal maxillary width after MARPE compared with 80% after conventional RPE. However, this finding reflects a specific study population and should not be generalised across all patients, appliance designs or retention protocols. This 50-percentage point stability advantage reflects the superior permanence of skeletal versus dental changes (Firinciogullari et al. 2025).

Retention protocols

Fixed retainers outperformed removable appliances in preserving treatment stability (Mohanty et al. 2024). Retention protocols must be individualised based on patient needs and treatment preferences (Araujo et al. 2025). Initial retention involves fixed appliances cemented immediately following expansion completion, maintained 6-12 months, followed by removable retention worn indefinitely (Zeng et al. 2023).

No retainer guarantees perfect alignment stability (Jedliński et al. 2021). Retainers bonded to all adherent teeth with additional bonding resin show superior outcomes, with frequent monitoring during the first 6 months post-bonding (Jedliński et al. 2021). Contemporary approaches increasingly emphasise lifelong retention as fundamental for sustainability of treatment success (Göven & Kaya 2025).

CONCLUSION AND FUTURE DIRECTIONS

MARPE represents a sophisticated non-surgical treatment option for appropriately selected patients with obstructive sleep apnoea complicated by transverse maxillary deficiency (Almoabady et al. 2025). The underlying biomechanical principles provide direct force application to the midpalatal suture, achieving predominantly skeletal expansion (49% versus 44% dental) (Zeng et al. 2023) that accounts for superior long-term stability compared to conventional approaches (Firinciogullari et al. 2025).

Clinical efficacy is substantial with 92.5% success in achieving expansion and 65.3% average AHI reduction in appropriately selected patients (Brunetto et al. 2022; Kapetanović et al. 2021). However, these findings should be interpreted cautiously. MARPE should be regarded as a phenotype-directed treatment option rather than universal alternative to other modalities. The comparison with MAD or surgically assisted expansion should be interpreted cautiously because these approaches differ in mechanism, indication and patient selection (Parihar et al. 2025).

Appropriate patient selection especially in skeletally mature patients with mild-to-moderate OSA and documented transverse maxillary deficiency is paramount for optimising outcomes and minimising complications (Kapetanović et al. 2021). Complications occurring in approximately one-third of cases are generally manageable with standardised prevention strategies utilising optimised miniscrew specifications and precise placement technique (Rajalakshmi et al. 2025).

With careful patient selection, standardised treatment protocols, and evidence-based practice guidelines, MARPE provides substantial, durable improvement in OSA severity while avoiding compliance limitations associated with existing treatments (Arachchige & Steier 2021). Future research should focus on MARPE's efficacy in specific OSA endotypes, comparison with alternative modalities in randomised trials, and optimisation of retention protocols to maximise long-term stability (Zeng et al. 2023).

REFERENCES

Almoabady, E.H., Alzamzami, A.A., Alrashdi, T.S., Mujthil, K.M., Almohammadi, K.S., Okashah, Y.A., Alotaibi, A.H., Alghamdi, M.I., Alamrani, S.A., Amanullah, F.S., Alzyiad, F.A. & Safhi, T.A. 2025. Definition, indication and outcome of miniscrew-assisted rapid palatal expansion. *International Journal of Community Medicine and Public Health* 12(1): 487-492.

Alrumaih, R., Alterki, A. & Qali, M. 2025. Maxillary expansion in the management of obstructive sleep apnea: A comprehensive review. *Dent. J. (Basel)* 13(9): 410. doi: 10.3390/dj13090410

Arachchige, M.A. & Steier, J. 2021. Beyond usual care: A multidisciplinary approach towards the treatment of obstructive sleep apnoea. *Front Cardiovasc. Med.* 8: 747495. doi: 10.3389/fcvm.2021.747495

Brunetto, D.P., Moschik, C.E., Dominguez-Mompell, R., Jaria, E., Sant'Anna, E.F. & Moon, W. 2022. Mini-implant assisted rapid palatal expansion (MARPE) effects on adult obstructive sleep apnea (OSA) and quality of life: A multi-center prospective controlled trial. *Prog. Orthod.* 23(1): 3. doi: 10.1186/s40510-021-00397-x

Cantarella, D., Savio, G., Grigolato, L., Zanata, P., Berveglieri, C., Lo Giudice, A., Isola, G., Del Fabbro, M. & Moon, W. 2020. A new methodology for the digital planning of micro-implant-supported maxillary skeletal expansion. *Med. Devices (Auckl)* 13: 93-106. doi: 10.2147/mder.S247751

Chan, A.S.L., Sutherland, K. & Cistulli, P.A. 2020. Mandibular advancement splints for the treatment of obstructive sleep apnea. *Expert Rev. Respir. Med.* 14(1): 81-88. doi: 10.1080/17476348.2020.1686978

de Araujo, T.M., Ferreira, P.P., Lisboa, I.A.P.B., Vogel, C.J. & Starling, C.R. 2025. Orthodontic retainers: Are they all the same? *Dental Press J. Orthod.* 29(6): e24spe6. doi: 10.1590/2177-6709.29.6.e24spe6

Doff, M.H., Finnema, K.J., Hoekema, A., Wijkstra, P.J., de Bont, L.G. & Stegenga, B. 2013. Long-term oral appliance therapy in obstructive sleep apnea syndrome: A controlled study on dental side effects. *Clin. Oral. Investig.* 17(2): 475-482. doi: 10.1007/s00784-012-0737-x

Firinciogullari, E.C., Erdinc, A.E., Celenk-Koca, T., Walma, D.C. & Akyalcin, S. 2025. MARPE improves long-term stability of maxillary expansion in adolescents. *Orthod. Craniofac. Res.* 28(S1): 194-S202. doi: 10.1111/ocr.12922

Guimarães, M.L.R., Azevedo, P.G., Barros-Vieira, S., Elbaz, M., Leger, D. & Hermont, A.P. 2022. When adherence to CPAP fails, how do we treat workers with obstructive sleep apnea? Sleep science (Sao Paulo, Brazil), 15(Spec 1): 135–142. doi:10.5935/1984-0063.20220012

Hur, J.S., Kim, H.H., Choi, J.Y., Suh, S.H. & Baek, S.H. 2017. Investigation of the effects of miniscrew-assisted rapid palatal expansion on airflow in the upper airway of an adult patient with obstructive sleep apnea syndrome using computational fluid-structure interaction analysis. *Korean J. Orthod.* 47(6): 353-364. doi: 10.4041/kjod.2017.47.6.353

Inchingolo, A.D., Marinelli, G., Cavino, M., Zaminga, L.P., Savastano, S., Inchingolo, F., Tartaglia, G.M., Del Fabbro, M., Palermo, A., Inchingolo, A.M. & Dipalma, G. 2025. Assessment of the effect of rapid maxillary expansion on nasal respiratory function and obstructive sleep apnea syndrome in children: A systematic review. *J. Clin. Med.* 14(18): 6565. doi: 10.3390/jcm14186565

Jedliński, M., Grocholewicz, K., Mazur, M. & Janiszewska-Olszowska, J. 2021. What causes failure of fixed orthodontic retention? - Systematic review and meta-analysis of clinical studies. *Head Face Med.* 17(1): 32. doi: 10.1186/s13005-021-00281-3

Kapetanović, A., Theodorou, C.I., Bergé, S.J., Schols, J.G.J.H. & Xi, T. 2021. Efficacy of miniscrew-assisted rapid palatal expansion (MARPE) in late adolescents and adults: A systematic review and meta-analysis. *Eur. J. Orthod.* 43(3): 313-323. doi: 10.1093/ejo/cjab005.

Göven, G. & Kaya, B. 2025. Contemporary approaches to orthodontic retention and stability: A review. *Saudi J. Oral Dent. Res.* 10(10): 388-395.

Li, K. & Guilleminault, C. 2022. Surgical and non-surgical maxillary expansion: Expansion patterns, complications and failures. *Orthod. Fr.* 93(Suppl 1): 35-46. doi: 10.1684/orthodfr.2022.87

Mamboleo, E., Ouldyerou, A., Alsharif, K., Ngan, P., Merdji, A., Roy, S. & Mukdadi, O.M. 2024. Biomechanical analysis of orthodontic miniscrew-assisted rapid palatal expansion on dental and bone tissues: A finite-element study. *Journal of Engineering and Science in Medical Diagnostics and Therapy* 7(4): 041007. doi: 10.1115/1.4065589

Memè, L., Bambini, F., Samapalmieri, F., Pezzolla, C., Trilli, I., Sabatelli, F., Bordea, I.R., Fernandes, G.V.O., Qorri, E., Almasri, L., Alkassab, M., Almasri, M. & Palermo, A. 2024. Comparison of palatal expanders and their efficacy: A narrative review. *Oral and Implantology* 16(3): 441-460.

Mohanty, B., Ravuri, P., Kubavat, A.K., Kauser, A., Bansilal Wagh, S., Varma Datla, P.K., Pujari, P.R. & Nallamilli, L.V.S. 2024. Evaluation of orthodontic retention protocols and their impact on treatment stability: Insights from a tertiary care study. *J. Pharm. Bioallied. Sci.* 16(Suppl 3): S1997-s1999. doi: 10.4103/jpbs.jpbs_271_24

Op de Beeck, S., Dieltjens, M., Verbruggen, A.E., Vroegop, A.V., Wouters, K., Hamans, E., Willemen, M., Verbraecken, J., De Backer, W.A., Van de Heyning, P.H., Braem, M.J. & Vanderveken, O.M. 2019. Phenotypic labelling using drug-induced sleep endoscopy improves patient selection for mandibular advancement device outcome: A prospective study. *J. Clin. Sleep Med.* 15(8): 1089-1099. doi: 10.5664/jcsm.7796

Parihar, A.S., Thomas, A., Ajmera, H., Mittal, N., Kumar, V. & Roy, A. 2025. Periodontal health outcomes following mini-screw-assisted rapid palatal expansion versus surgically assisted rapid palatal expansion: A comparative analysis. *J. Pharm. Bioallied Sci.* 17(Suppl 3): S2715-s2717. doi: 10.4103/jpbs.jpbs_1191_25

Pawar, A.P., Mani, S.A., Toshniwal, N.G., Pawade, N. & Navgire, N. 2025. An upper airway evaluation before and after rapid palatal expansion in pediatric obstructive sleep apnea patients – Cone-beam computed tomography study. *Bharati Vidyapeeth Journal of Dentistry and Allied Sciences* 2(3): 81-87. doi: 10.4103/bvjd.Bvjd_28_25

Pinilla, L., Esmaeili, N., Labarca, G., Martinez-Garcia, M.Á., Torres, G., Gracia-Lavedan, E., Mínguez, O., Martínez, D., Abad, J., Masdeu, M.J., Mediano, O., Muñoz, C., Cabriada, V., Duran-Cantolla, J., Mayos, M., Coloma, R., Montserrat, J.M., de la Peña, M., Hu, W-H., Messineo, L., Sehhati, M., Wellman, A., Redline, S., Sands, S., Barbe, F., Sanchez-de-la-Torre, M. & Azarbarzin, A. 2023. Hypoxic burden to guide CPAP treatment allocation in patients with obstructive sleep apnoea: A post hoc study of the ISAACC trial. *Eur. Respir. J.* 62(6): 2300828. doi: 10.1183/13993003.00828-2023

Rajalakshmi, S.J., Ahmed, N., Eduru, N., Deeksha, Y.N., Ravi, K. & Singaraju, G.S. 2025. Hidden risks of miniscrew-assisted rapid palatal expansion (MARPE): A retrospective analysis of treated cases with preventive strategies. *Cureus* 17(9): e93240. doi: 10.7759/cureus.93240

Randerath, W., de Lange, J., Hedner, J., Ho, J.P.T.F., Marklund, M., Schiza, S., Steier, J. & Verbraecken, J. 2022. Current and novel treatment options for obstructive sleep apnoea. *ERJ Open Res.* 8(2): 00126-2022. doi: 10.1183/23120541.00126-2022

Santana, L.G., Gatti-Reis, L., Paiva, S.M., Ramos-Jorge, M.L. & Marques, L.S. 2025. Patient-centered factors associated with orthodontic treatment success: A scoping review. *Braz. Oral Res.* 39: e020. doi: 10.1590/1807-3107bor-2025.vol39.020

Satapathy, S.K. & Agarwal, N. 2025. Micro-implant assisted rapid palatal expansion (MARPE): A comprehensive review on biomechanics, clinical protocols, and recent advances. *International Journal of Health Sciences and Research* 15(4): 349-361.

Simpson, R., Oyekan, A.A., Ehsan, Z. & Ingram, D.G. 2018. Obstructive sleep apnea in patients with Down syndrome: Current perspectives. *Nat. Sci. Sleep* 10: 287-293. doi: 10.2147/nss.S154723

Sood, N. & Khilnani, P. 2015. Obstructive sleep apnea in children. *Journal of Pediatric Critical Care* 2(1): 85-93. doi: 10.21304/2015.0201.00055

Sutherland, K. & Cistulli, P. 2011. Mandibular advancement splints for the treatment of sleep apnea syndrome. *Swiss Med. Wkly* 141: w13276. doi: 10.4414/smw.2011.13276

Thi Hong Thuy, P., Thu Trang, P., Thi Thu Hang, P. & Viet, H. 2025. Clinical and cone-beam computed tomography outcomes of miniscrew-assisted rapid palatal expansion in the treatment of maxillary transverse deficiency: A prospective study. *Medicine (Baltimore)* 104(38): e44684. doi: 10.1097/md.0000000000044684

Tsolakis, I.A., Palomo, J.M., Matthaios, S. & Tsolakis, A.I. 2022. Dental and skeletal side effects of oral appliances used for the treatment of obstructive sleep apnea and snoring in adult patients-a systematic review and meta-analysis. *J. Pers. Med.* 12(3): 483. doi: 10.3390/jpm12030483

Van den Bossche, K., Op de Beeck, S., Dieltjens, M., Verbruggen, A.E., Vroegop, A.V., Verbraecken, J.A., Van de Heyning, P.H., Braem, M.J. & Vanderveken, O.M. 2022. Multimodal phenotypic labelling using drug-induced sleep endoscopy, awake nasendoscopy and computational fluid dynamics for the prediction of mandibular advancement device treatment outcome: A prospective study. *J. Sleep Res*. 31(6): e13673. doi: 10.1111/jsr.13673

van der Bie, R.M., Bos, A., Bruers, J.J.M. & Jonkman, R.E.G. 2024. Patient adherence in orthodontics: A scoping review. *BDJ Open* 10(1): 58. doi: 10.1038/s41405-024-00235-2

Zeng, W., Yan, S., Yi, Y., Chen, H., Sun, T., Zhang, Y. & Zhang, J. 2023. Long-term efficacy and stability of miniscrew-assisted rapid palatal expansion in mid to late adolescents and adults: A systematic review and meta-analysis. *BMC Oral Health* 23(1): 829. doi: 10.1186/s12903-023-03574-y

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