



Review Article

Modulating craniofacial growth: The role of maxillary expansion appliances

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Abstract

Background: Modulating craniofacial growth is fundamental in orthodontics, especially during childhood and adolescence, where skeletal structures remain adaptable. Transverse maxillary discrepancies, such as maxillary constriction, are common and can lead to functional and aesthetic complications if untreated.

Objectives: To review biomechanical principles, clinical indications, biological responses, and efficacy of various maxillary expansion techniques including rapid maxillary expansion (RME), slow maxillary expansion (SME), functional appliances, Quad Helix, NiTi expanders, and the Alt-RAMEC protocol.

Materials and Methods: This review followed key elements of the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) framework to ensure transparency and rigor. A comprehensive literature review was conducted focusing on the clinical application and outcomes of different maxillary expansion modalities.

Results: RME effectively produces rapid skeletal expansion in growing patients, improving arch width and nasal airway dimensions. SME offers controlled expansion with reduced side effects, suitable for mild cases and compromised periodontal support. Functional appliances like the Frankel Functional Regulator facilitate transverse growth by modulating soft tissue forces. The Quad Helix appliance allows multidirectional force application and versatility. NiTi expanders utilize shape memory alloys to deliver light continuous forces ideal for non-compliant patients. The Alt-RAMEC protocol enhances circummaxillary suture disarticulation, improving maxillary protraction outcomes in Class III and cleft cases.

Conclusion: Maxillary expansion appliances are integral to orthodontic growth modulation. Treatment success depends on timely intervention, appliance selection, and patient compliance. Emerging technologies promise to refine these techniques further.

Keywords: Craniofacial growth, Maxillary expansion, Rapid maxillary expansion, Slow maxillary expansion, Functional appliances, Quad Helix, NiTi expanders, Alt-RAMEC, Orthodontics, Growth modulation

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1. Introduction

Orthodontic interventions extend beyond simple dental corrections, aiming to influence underlying skeletal structures for long-term functional and aesthetic improvement. Transverse discrepancies, particularly maxillary constriction, represent one of the most common developmental abnormalities seen in pediatric and adolescent patients. This condition can manifest clinically as posterior crossbites, midline discrepancies, dental crowding, compromised nasal airflow, and even speech difficulties, all of which contribute to reduced oral function and patient dissatisfaction.

Maxillary expansion serves as a targeted solution to these issues, mechanically widening the mid-palatal suture while encouraging new bone formation and remodeling. The relative contribution of skeletal versus dentoalveolar changes in expansion outcomes depends heavily on variables such as patient age, growth status, and appliance design. Early interventions tend to yield more pronounced skeletal changes, whereas delayed treatment in skeletally mature patients often requires adjunctive surgical procedures, such as surgically assisted rapid palatal expansion (SARPE). Consequently,

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appropriate timing, appliance choice, and individualized treatment planning are critical to achieving optimal results and minimizing the risk of relapse.¹

Craniofacial growth modulation, as a broader concept, incorporates multiple orthopedic and orthodontic strategies aimed at directing growth of the maxilla, mandible, and associated soft tissues. These approaches may include maxillary expansion, functional jaw orthopedics (e.g., Herbst, Twin Block appliances), and protraction devices such as facemasks, all of which influence the craniofacial architecture to varying degrees. The integration of maxillary expansion within this larger framework provides orthodontists with an opportunity to achieve skeletal harmony, improve airway function, and optimize facial aesthetics during critical growth periods. Understanding the biological basis of these interventions and their interplay with natural growth trajectories allows for a more holistic and individualized approach to patient care.²

2. Methodology

This scoping review was conducted in accordance with the key elements outlined in the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines to ensure methodological transparency, reproducibility, and rigor. The approach was chosen due to the heterogeneity of study designs available in the literature on maxillary expansion and craniofacial growth modulation, allowing for an inclusive synthesis of evidence across different methodologies and populations.

2.1. Search strategy

A comprehensive and systematic literature search was performed across multiple databases, including PubMed, Scopus, Web of Science, and Google Scholar, ensuring broad coverage of both indexed and grey literature. The search encompassed studies published between January 1990 and April 2025 to capture historical developments as well as the most recent advances in maxillary expansion techniques and craniofacial growth modulation strategies. Search terms were developed using Medical Subject Headings (MeSH) and free-text keywords to maximize sensitivity. Keywords included: “craniofacial growth modulation,” “maxillary expansion,” “rapid maxillary expansion,” “slow maxillary expansion,” “functional appliances,” “Alt-RAMEC,” “orthopaedic appliances,” and “facemask therapy.” Boolean operators (AND/OR) were used to combine terms, and citation tracking of relevant articles was performed to identify additional studies not retrieved through database searches.

2.2. Inclusion criteria

To ensure the clinical relevance of findings, only peer-reviewed studies that addressed craniofacial growth modulation or maxillary expansion in children, adolescents, or young adults were included. Eligible designs encompassed randomized controlled trials (RCTs), non-randomized clinical trials, prospective and retrospective cohort studies, case

series, and systematic reviews. Studies were considered if they reported on at least one of the following outcomes: skeletal or dentoalveolar changes, changes in nasal airway dimensions, soft tissue adaptations, treatment stability, or complications associated with maxillary expansion appliances.

2.3. Exclusion criteria

Exclusion criteria were applied to maintain focus on clinically applicable evidence. Animal studies were excluded due to limited translational applicability. Conference abstracts and unpublished theses were omitted as they often lack sufficient methodological detail and peer review. Non-English language articles were excluded to ensure accurate data extraction and interpretation. Studies with insufficient clinical relevance, such as those focusing solely on laboratory measurements or biomechanical simulations without patient data, were also excluded.

2.4. Data extraction

Data were independently extracted by two reviewers using a standardized data extraction form to minimize bias and ensure consistency. Extracted information included study design, sample size, participant demographics (age, sex, growth stage), type of appliance used (e.g., RME, SME, Alt-RAMEC, functional appliances), treatment duration, activation protocols, primary and secondary clinical outcomes (skeletal and dental changes, soft tissue effects), and any reported complications or adverse events. Disagreements between reviewers were resolved by consensus or by consultation with a third reviewer.

2.5. Bias appraisal

The quality and reliability of included studies were critically appraised using validated tools. Randomized controlled trials were assessed using the Cochrane Risk-of-Bias tool (RoB 2), while non-randomized studies were evaluated using the Newcastle-Ottawa Scale (NOS). Systematic reviews were assessed for methodological quality using the AMSTAR 2 (A Measurement Tool to Assess Systematic Reviews) checklist. The level of evidence for each included study was categorized according to the Oxford Centre for Evidence-Based Medicine guidelines to contextualize the strength of findings.

3. Discussion

Craniofacial growth modulation encompasses a spectrum of orthopedic and orthodontic interventions aimed at influencing skeletal development to achieve balanced facial proportions and functional harmony.³ While maxillary expansion remains a cornerstone of transverse correction, it is only one element of a broader strategy for modifying craniofacial growth. Mandibular orthopedic interventions, in particular, play a crucial role in improving sagittal and vertical skeletal relationships, especially in growing patients. Functional appliances such as the Herbst and Twin Block have demonstrated substantial efficacy in stimulating mandibular growth, promoting condylar remodeling, and

enhancing Class II skeletal correction during active growth phases.^{4,5} These appliances function by posturing the mandible forward, thereby inducing adaptive remodeling of the temporomandibular joint and adjacent skeletal structures. Such remodeling is not purely dentoalveolar but includes changes in condylar growth direction and glenoid fossa positioning, contributing to improved skeletal balance. Although less frequently utilized in contemporary practice, chin cup therapy continues to offer value in the early management of mandibular prognathism by applying orthopedic forces to restrain excessive mandibular growth, particularly when implemented during early developmental stages.⁶ Integrating these appliances into treatment planning facilitates a more comprehensive understanding of how orthopedic interventions can alter facial harmony, occlusal function, and growth trajectories.

A critical appraisal of the available literature reveals varying levels of evidence supporting these treatment modalities. Systematic reviews and meta-analyses consistently affirm the effectiveness of rapid maxillary expansion (RME) in producing significant skeletal expansion of the maxilla, improving arch perimeter, and increasing nasal airway dimensions in growing patients.^{7,8,9} When performed before the closure of the mid-palatal suture, RME has been associated with more stable long-term outcomes, underscoring the importance of early diagnosis and intervention. Conversely, slow maxillary expansion (SME) and Nickel-Titanium (NiTi)-based devices, while demonstrating favorable dentoalveolar outcomes, provide comparatively limited skeletal changes. However, their use remains justified in patients with mild transverse discrepancies, compromised periodontal conditions, or where patient comfort and compliance are prioritized.¹⁰

Recent evidence highlights the clinical value of the Alternating Rapid Maxillary Expansion and Constriction (Alt-RAMEC) protocol, particularly when combined with protraction facemask therapy. Studies indicate that this combined approach enhances maxillary protraction outcomes by effectively disarticulating circummaxillary sutures, allowing for greater orthopedic movement of the maxilla. This has been especially beneficial in patients with Class III malocclusion and those with cleft lip and palate, reducing the need for more invasive surgical interventions.^{11,12} For instance, Sitaropoulou et al. reported significant advancement of the maxilla and improved disarticulation of circummaxillary sutures in growing Class III patients treated with the Alt-RAMEC protocol combined with facemask therapy over a 9-week period, confirming its enhanced orthopedic effects relative to conventional RME. Similarly, Montaruli et al. documented the treatment of young adults with bilateral or unilateral posterior crossbites using a Nickel-Titanium Palatal Expander (NPE-2), highlighting its ability to achieve effective transverse expansion with minimal discomfort and reduced need for active patient participation.

Functional orthopedic appliances have also been supported by meta-analyses showing clinically meaningful mandibular advancement and improvements in sagittal

skeletal relationships in Class II malocclusion cases.⁵ While their effects on long-term mandibular growth may be partially reversible after appliance removal, the orthopedic and neuromuscular adaptations achieved during therapy contribute significantly to overall treatment success. These findings collectively underscore the importance of individualized appliance selection, precise timing of intervention, and careful monitoring to optimize outcomes and minimize the risk of relapse.

Despite these promising outcomes, many studies are limited by small sample sizes, heterogeneous methodologies, and short follow-up periods. This underscores the need for high-quality randomized controlled trials and long-term observational studies to better establish the efficacy and stability of these interventions.

1. **Functional Regulator (FR) (Figure 1):** The Functional Regulator appliance, devised by Rolf Frankel, is designed to passively stimulate maxillary expansion by eliminating abnormal perioral muscular forces. The vestibular shields embedded in the appliance displace the cheeks and lips away from the dental arches, thereby allowing natural transverse development of the maxilla without direct dental forces.^{10,4} This mechanism is especially beneficial in patients with soft tissue dysfunctions that contribute to narrow arches. Clinical studies have validated its efficacy in expanding dental arches and improving facial aesthetics, particularly in Class II malocclusion cases with deficient maxillary development. Its long-term stability has been well-documented through serial model analysis and clinical observations.⁶

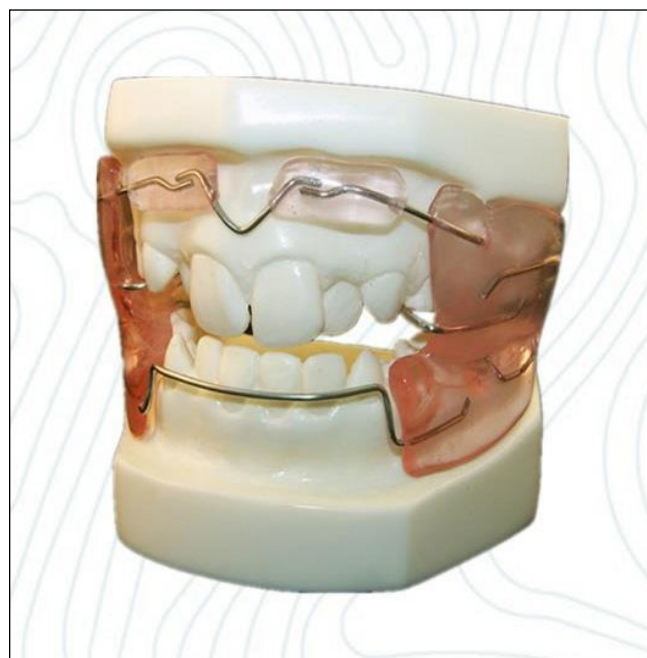


Figure 1: Frankel Functional Regulator appliance – Demonstrates vestibular shield design for passive expansion by modulating perioral muscular forces, particularly beneficial in Class II cases with soft tissue dysfunction.

2. **Rapid Maxillary Expansion (RME):** RME is the cornerstone technique for skeletal maxillary expansion in growing patients. By exerting heavy intermittent forces of 0.5 mm per day, the mid-palatal suture is rapidly separated, triggering bone deposition and widening of the maxillary base.^{7,8} This method is effective in correcting unilateral and bilateral posterior crossbites, relieving anterior crowding, and expanding the nasal cavity to improve airflow. A key clinical sign of successful RME is the appearance of a midline diastema, which subsequently closes as the transseptal gingival fibers contract.⁹ RME appliances such as the HYRAX expander (**Figure 2**) can be banded or bonded, with each design offering specific advantages related to anchorage, hygiene, and control of vertical dimension.^{7,13} Indications include:

1. Skeletal posterior crossbites
2. Narrow maxilla with nasal constriction
3. Severe maxillary crowding
4. Pre-surgical expansion in cleft palate patients

Contraindications include advanced skeletal maturity, vertical maxillary excess, and periodontal compromise. RME remains highly successful in patients below the age of 16 due to the pliability of the mid-palatal suture.

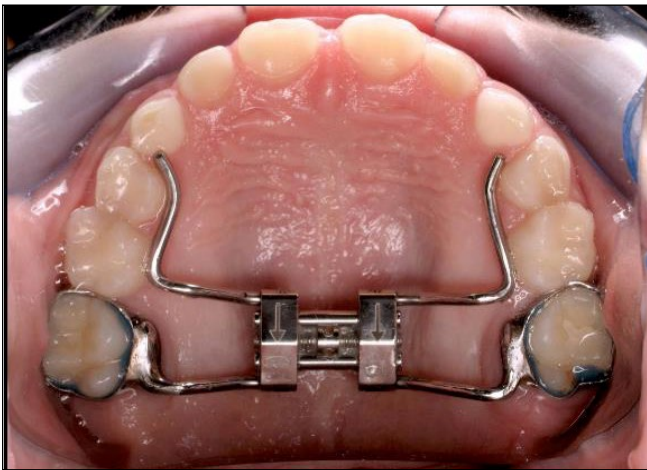


Figure 2: Rapid Maxillary Expander (HYRAX) – A fixed, screw-activated appliance producing heavy intermittent forces for rapid skeletal expansion, commonly used in growing patients to correct crossbites and increase nasal airway volume.

3. **Slow Maxillary Expansion (SME) (Figure 3)** SME provides gradual orthopedic and dental expansion using low-intensity forces over a prolonged period. Typically, an upper removable appliance (URA) with an expansion screw is activated weekly to achieve a total expansion rate of 0.5 mm per week.⁸ SME is suited for mild transverse discrepancies, patients with compromised periodontal support, and when minimal skeletal change is required. Although less dramatic than RME, SME offers better control over tipping and bodily movement of teeth, with reduced risk of tissue damage or root resorption.¹¹

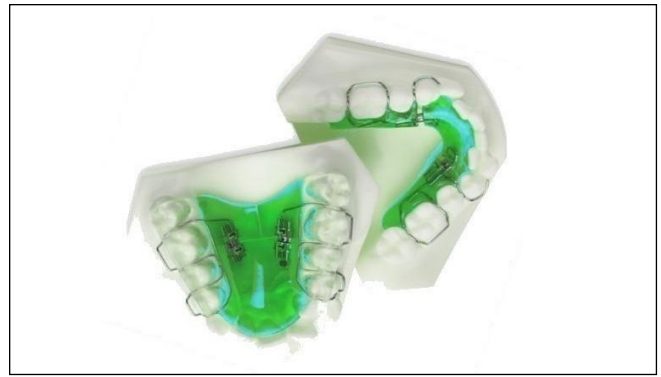


Figure 3: Slow expansion appliance (Schwarz plate) – A removable acrylic plate with a midline screw for gradual dentoalveolar and mild skeletal expansion, suitable for mild transverse discrepancies and patients with periodontal compromise.

4. **Quad Helix Appliance (Figure 4):** The Quad Helix Appliance, derived from Coffin's W-spring, uses four helices to provide flexibility and multidirectional expansion forces. It is cemented to molar bands and can be adjusted periodically without removal.^{4,5} The device corrects crossbites, develops arch perimeter for crowding resolution, and controls molar rotation. Its effectiveness stems from a combination of dental tipping and skeletal expansion, with the latter more pronounced in younger patients due to open sutures. In cleft palate cases and severe constrictions, the Quad Helix demonstrates superior adaptability and force distribution compared to traditional RME devices.⁶

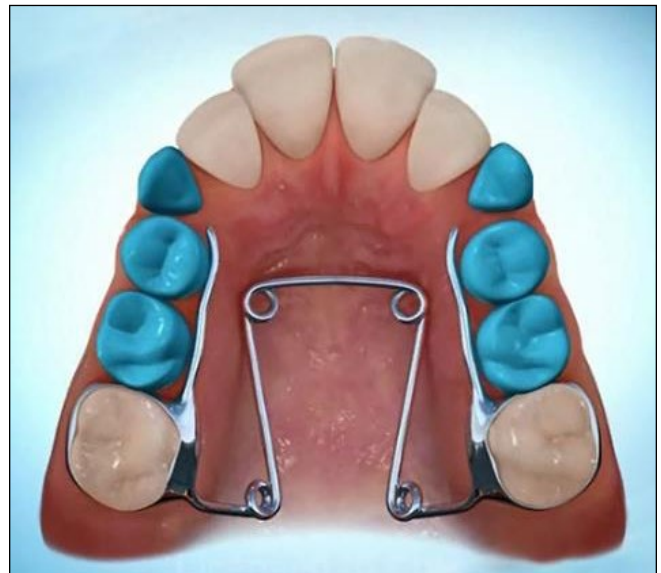


Figure 4: Quad Helix Appliance – A fixed device with four helices providing multidirectional expansion and rotation correction, commonly used for crossbite correction and arch development in cleft and non-cleft patients.

5. **NiTi Expanders NiTi (Nickel-Titanium) (Figure 5)** expanders exploit the alloy's shape memory and superelastic properties to deliver continuous light

forces conducive to slow and steady transverse development.¹⁴ These appliances are especially useful for non-compliant patients and can be easily activated by body heat without manual screw adjustments.^{2–11} NiTi expanders are ideal for initial maxillary expansion, mild crowding resolution, and arch coordination in cleft lip and palate patients. Their clinical use is associated with minimal discomfort and a low risk of periodontal side effects.¹⁵

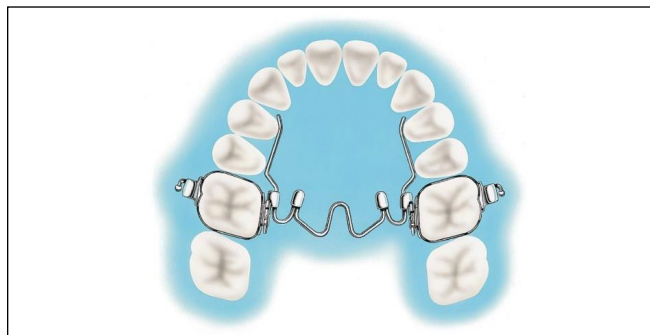


Figure 5: NiTi Palatal Expander – A shape-memory alloy device delivering light, continuous forces, ideal for non-compliant patients and those requiring slow, steady expansion with minimal discomfort.

6. **Alt-RAMEC Protocol** The Alternating Rapid Maxillary Expansion and Constriction (Alt-RAMEC) (**Figure 6**) protocol involves cycles of expansion and contraction to disarticulate the circummaxillary sutures more effectively than RME alone.¹⁶ Over 7–9 weeks, the protocol facilitates enhanced maxillary protraction using orthopedic facemask therapy. Studies demonstrate that Alt-RAMEC achieves greater skeletal advancement of the maxilla, especially in Class III malocclusion and cleft lip/palate cases. This method reduces the need for surgical intervention and produces stable long-term outcomes, although it requires high patient compliance and careful monitoring.¹⁷

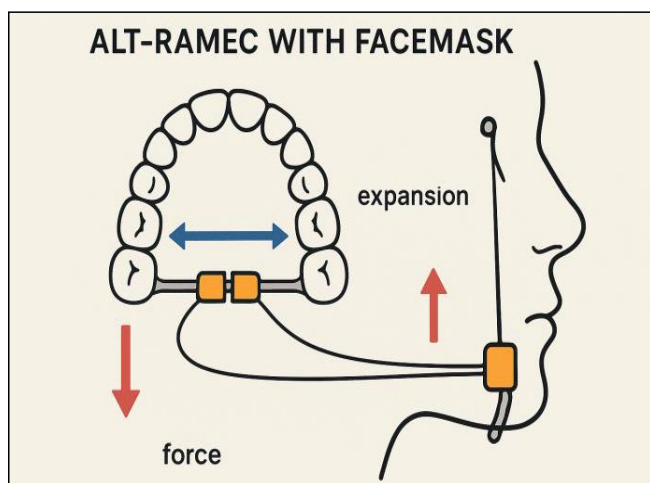


Figure 6: Alt-RAMEC with Facemask – Demonstrates alternating expansion–constriction protocol combined with orthopedic facemask therapy for enhanced maxillary protraction in Class III and cleft patients.

4. Future Directions

The landscape of maxillary expansion therapy is rapidly evolving, with several emerging technologies and treatment paradigms poised to enhance both precision and clinical outcomes. One of the most promising developments is the advent of 3D-printed expansion appliances, which allow for fully customized appliance design based on patient-specific anatomical data. This customization improves fit, enhances patient comfort, and optimizes force distribution across the palate, potentially reducing unwanted dental tipping and soft tissue irritation.¹² Miniscrew-assisted rapid palatal expansion (MARPE) represents another significant advancement, particularly in skeletally mature patients where conventional expansion methods are less effective. By engaging skeletal anchorage through temporary anchorage devices (TADs), MARPE minimizes dentoalveolar side effects while achieving greater skeletal expansion, thereby extending the age range for nonsurgical palatal expansion.¹⁶

Cone-beam computed tomography (CBCT) has also become increasingly integral in treatment planning and assessment. CBCT imaging provides three-dimensional visualization of sutural morphology, airway volume, and dental root positioning, enabling more accurate diagnosis, individualized treatment planning, and monitoring of post-expansion changes.¹⁷ Additionally, integrating artificial intelligence (AI)-driven analytics with CBCT data may soon allow for predictive modeling of treatment outcomes based on baseline skeletal and soft tissue parameters.

Looking further ahead, the development of personalized expansion protocols incorporating genetic, epigenetic, and phenotypic predictors holds potential to revolutionize growth modulation therapies. Identifying genetic markers associated with sutural maturation rates or responsiveness to expansion could enable orthodontists to tailor appliance selection, activation protocols, and treatment timing to individual biological profiles, thus maximizing efficacy and stability while minimizing the need for surgical intervention.¹⁸ Furthermore, ongoing investigations into the long-term effects of maxillary expansion on airway health, temporomandibular joint function, and facial aesthetics are expected to provide valuable insights into the broader functional and psychosocial impacts of these interventions.

Collectively, these advancements underscore a paradigm shift toward precision orthodontics, where biologically informed, technology-driven, and patient-centered approaches will define the future of craniofacial growth modulation.

5. Conclusion

Maxillary expansion appliances play a pivotal role in modulating craniofacial growth, particularly during the developmental window when sutural adaptability is maximal. RME provides rapid skeletal changes, while SME offers controlled dentoalveolar expansion. Functional appliances like the Frankel Regulator influence soft tissue balance, and devices such as Quad Helix and NiTi expanders offer

specific mechanical advantages in diverse clinical scenarios. The Alt-RAMEC protocol exemplifies advanced orthopedic manipulation that enhances maxillary protraction. The success of these techniques hinges on accurate diagnosis, patient selection, compliance, and timing relative to growth potential. Future developments may include digitally designed custom expanders, skeletal anchorage-assisted expansion, and real-time imaging to optimize outcomes.

6. Source of Funding

None.

7. Conflict of Interest

None.

References

1. Maruswamy K, Nayak UA, Nayak PA, Ramasamy S. Management of Class III malocclusion: A review with report of four cases. *Ann Dent Spec.* 2018;6(4):464–71.
2. Yepes E, Quintero P, Rueda ZV, Pedroza A. Optimal force for maxillary protraction facemask therapy in the early treatment of Class III malocclusion. *Eur J Orthod.* 2014;36(5):586–94. doi: 10.1093/ejo/cjt091.
3. Agarwal A, Mathur R. Maxillary Expansion. *Int J Clin Pediatr Dent.* 2010;3(3):139–46. doi: 10.5005/jp-journals-10005-1069
4. Alammar A. Difference in Pain Perception Between Banded and Bonded Hyrax during Rapid Palatal Expansion. *Int J Dent Sci Res.* 2021;9(2):34–6. doi:10.12691/ijdsr-9-2-3.
5. Parkin NA, McKeown HF, Sandler PJ. Comparison of 2 modifications of the twin-block appliance in matched Class II samples. *Am J Orthod Dentofac Orthop.* 2001;119(6):572–7. doi: 10.1067/mod.2001.113790.
6. Owen AH 3rd. Crozat treatment. *J Clin Orthod.* 1985;19(2):109–27.
7. Proffit WR, Fields HW, Larson B, Sarver DM. Contemporary orthodontics. 6th ed. St. Louis: Mosby; 2018. 752 p.
8. McNamara Jr JA, Lione R, Franchi L, Angelieri F, Cevdanes LHS, Darendeliler MA, et al. The role of rapid maxillary expansion in the promotion of oral and general health. *Prog Orthod.* 2015;16(33):3–7. doi: 10.1186/s40510-015-0105-x.
9. Hata S, Itoh T, Nakagawa M, Kamogashira K, Ichikawa K, Matsumoto M, et al. Biomechanical effects of maxillary protraction on the craniofacial complex. *Am J Orthod Dentofacial Orthop.* 1987;91(4):305–11. doi: 10.1016/0889-5406(87)90171-5.
10. Miralles R, Berger B, Bull R, Manns A, Carvajal R. Influence of the activator on electromyographic activity of mandibular elevator muscles. *Am J Orthod Dentofacial Orthop.* 1998;94(2):97–103. doi: 10.1016/0889-5406(88)90357-5.
11. Montaruli G, Laurenziello M, Russo LL, Chimenti C, Muzio LL, Ciavarella D. Bilateral or Unilateral Cross-Bite Treatment with Nickel Titanium Palatal Expander (NPE-2) in Young Adults. *J Dent Oral Disord Ther.* 2016;4(2):1–6.12n. .
12. Suzuki H, Moon W, Previdente LH, Suzuki SS, Garcez AS, Consolaro A. Miniscrew-assisted rapid palatal expander (MARPE): the quest for pure orthopedic movement. *Dental Press J Orthod.* 2016;21(4):17–23. doi: 10.1590/2177-6709.21.4.017-023.oin.
13. Kapetanović A, Theodorou CI, Bergé SJ, Schols JGJH, Xi T. Efficacy of Miniscrew-Assisted Rapid Palatal Expansion (MARPE) in late adolescents and adults: a systematic review and meta-analysis. *Eur J Orthod.* 2021;43(3):313–23. doi:10.1093/ejo/cjab005.
14. Sitaropoulou V, Yilmaz HN, Yilmaz BE, Kucukkeles N. Three-dimensional evaluation of treatment results of the Alt-RAMEC and facemask protocol in growing patients. *J Orofac Orthop.* 2020;81(6):407–18. doi: 10.1007/s00056-020-00240-8
15. Clark WJ. The twin block technique. A functional orthopedic appliance system. *Am J Orthod Dentofacial Orthop.* 1988;93(1):1–18. doi:10.1016/0889-5406(88)90188-6.
16. Kapila S, Conley RS, Harrell Jr WE. The current status of cone beam computed tomography imaging in orthodontics. *Dentomaxillofac Radiol.* 2011;40(1):24–34. doi: 10.1259/dmfr/12615645
17. Andriani AT, Zahra PK, Auerkari EI. Genetic contributions to craniofacial growth: A review. *J Phys Conf Ser.* 2021;1943(1):1–7. doi:10.1088/1742-6596/1943/1/012095.
18. Vieira AR. Orthodontics and genetics. *Dental Press J Orthod.* 2019;24(2):92–97. doi: 10.1590/2177-6709.24.2.092-097.sar.

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