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Review

# Diagnosis And Treatment Of Maxillary Transverse Deficiency: A Traditional Review

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**Abstract**

Maxillary transverse deficiency is a common orthodontic condition characterized by a narrow maxillary arch and can lead to various dental and skeletal discrepancies. This traditional review aims to provide comprehensive insights into the diagnosis and treatment of maxillary transverse deficiency in orthodontics.The diagnostic process includes clinical evaluation, analysis of dental models, and radiographic assessments, which are necessary to accurately evaluate the severity of maxillary deficiency and identify associated abnormalities. Various indices and measurements are used to measure maxillary transverse dimensions and assist in treatment planning.Treatment options for maxillary transverse deficiency include orthopedic and orthodontic approaches. The orthopedic approach aims to achieve expansion gradually by separating the maxillary midpalatal suture. This technique can be applied with intraoral appliances in growing patients and with surgical support in later stages.Orthodontic mechanics for comprehensive treatment outcomes after maxillary expansion are important for stabilizing the achieved expansion and optimizing occlusion.In conclusion, the diagnosis and treatment of maxillary transverse deficiency require a multidisciplinary approach involving accurate diagnosis, appropriate treatment planning, and effective orthodontic interventions. Understanding the intricacies of this condition and current treatment methods is essential for successful management and long-term stability of orthodontic outcomes.

# Maksiller Transversal Yetersizlik Tanı ve Tedavisi: Geleneksel derleme

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**Anahtar Kelimeler**
Maksiller transversal yetersizlik
Hızlı maksiller genişletme
Cerrahi destekli hızlı maksiller genişletme
Minivida destekli hızlı maksiller genişletme

**Öz**

Maksiller transversal yetersizlik, dar bir maksiller ark ile karakterize edilen ve çeşitli dental ile iskeletsel düzensizliklere yol açabilen yaygın bir ortodontik durumdur. Bu derleme, ortodontide maksiller transversal yetersizliğin tanı ve tedavisine ilişkin kapsamlı bir bakış sunmayı amaçlamaktadır.

Tanı süreci; klinik değerlendirme, dental model analizleri ve radyografik incelemeleri içermekte olup, maksiller yetersizliğin şiddetinin doğru şekilde belirlenmesi ve eşlik eden anomalilerin saptanması açısından gereklidir. Maksiller transversal boyutların değerlendirilmesi ve tedavi planlamasına rehberlik edilmesi amacıyla çeşitli indeksler ve ölçüm yöntemleri kullanılmaktadır.

Maksiller transversal yetersizliğin tedavi seçenekleri ortopedik ve ortodontik yaklaşımları kapsamaktadır. Ortopedik yaklaşım, maksiller midpalatal sütürün ayrılması yoluyla kademeli genişleme elde etmeyi hedefler. Bu yöntem, büyüme dönemindeki hastalarda ağız içi apareylerle, daha ileri yaşlarda ise cerrahi destekle uygulanabilmektedir.

Maksiller genişletme sonrasında elde edilen kazanımların stabilizasyonu ve oklüzyonun optimize edilmesi açısından ortodontik mekanikler, kapsamlı tedavi sonuçları için kritik öneme sahiptir.

Sonuç olarak, maksiller transversal yetersizliğin tanı ve tedavisi; doğru tanı, uygun tedavi planlaması ve etkili ortodontik müdahaleleri içeren multidisipliner bir yaklaşım gerektirir. Bu durumun karmaşıklığının ve güncel tedavi yöntemlerinin iyi anlaşılması, başarılı yönetim ve uzun dönem stabilite açısından büyük önem taşımaktadır.



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## Introduction

Maxillary transverse deficiency has been recognized in orthodontics for over a century. The earliest clinical attempt to correct this condition was reported by Emerson C. Angell in 1860 using a screw-assisted expansion appliance for posterior crossbite, although this approach was not widely accepted at the time. Widespread clinical acceptance emerged in the mid-20th century with the introduction of the Haas appliance, which emphasized the orthopedic effects of midpalatal suture separation (1). Since then, maxillary expansion has become a fundamental treatment approach for transverse discrepancies, supported by advances in craniofacial growth and biomechanics.

Today, treatment strategies are largely determined by skeletal maturity and the nature of the discrepancy. Slow or rapid maxillary expansion is commonly used in growing patients, whereas surgically assisted approaches are indicated in skeletally mature individuals due to increased sutural resistance (2). This evolution reflects a shift toward achieving more predictable skeletal outcomes.

Given its multifactorial etiology, advances in three-dimensional imaging and digital diagnostics now enable more accurate assessment and individualized treatment planning for maxillary transverse deficiency.

### Maxillary Transverse Deficiency

#### *Definition*

Maxillary transverse deficiency (maxillary constriction) is defined as an insufficient transverse width of the maxilla (3). McNamara described a practical clinical approach based on the transpalatal distance between the closest points of the maxillary first molars; values around 35–39 mm are generally considered adequate in average-sized dentitions, whereas narrower widths may be associated with crowding and indicate the need for expansion (4). Importantly, clinical decision-making should not rely solely on a single measurement and should also consider facial type, soft-tissue profile, and functional environment (4).

Clinically, transverse deficiency may be classified as relative or absolute (true). Relative transverse deficiency can be masked by the sagittal jaw relationship and may resolve after correction of anteroposterior discrepancy (e.g., Class III correction). In contrast, absolute transverse deficiency persists after sagittal correction and is more frequently associated with conditions such as Class II malocclusion or open-bite patterns (5).

#### *Prevalence across different populations*

Epidemiological studies have reported variable prevalence rates of posterior crossbite across populations and age groups. In American samples, prevalence has been reported around 7.7% in primary dentition and approximately 12% in mixed dentition (6, 7), while a Danish adolescent cohort showed rates of 14% in females and 9.4% in males (8). Studies from Turkey have also demonstrated variability, with reported prevalence values ranging from 2.7% to approximately 15% depending on the sample, dentition stage, and regional characteristics (9 - 12). Overall, these findings indicate that posterior crossbite and transverse discrepancies are relatively common and may differ substantially across populations and study designs.

#### *Etiology*

Maxillary transverse deficiency has a multifactorial etiology involving functional, dentoalveolar, and syndromic or developmental influences. Functional imbalance and temporomandibular-related factors have been associated with posterior crossbite and transverse discrepancies (13, 14). Altered oral function, including parafunctional habits and low tongue posture with reduced perioral tone, may further contribute to an unfavorable equilibrium between intraoral and extraoral soft-tissue forces, promoting transverse constriction (3).

Airway-related factors are also implicated. Upper airway obstruction may encourage mouth breathing and a low tongue posture, and craniofacial patterns associated with snoring have been linked to a lower hyoid position; therefore, assessment of airway function and hyoid position may be relevant in etiologic evaluation (15). In early life, non-nutritive sucking behaviors have been associated with reduced intercanine and intermolar dimensions, and mouth-breathing children may show decreased intercanine width (16). Similarly, shorter breastfeeding duration has been linked with increased non-nutritive sucking habits and reduced maxillary transverse width, with a higher risk of posterior crossbite reported in such groups (17). Finally, congenital and syndromic conditions (syndromes with craniosynostosis:Crouzon Syndrome, Carpenter Syndrome, Apert Syndrome, Pfeiffer Syndrome, Seatre-Chotzen Syndrome; genetic disorders: Marfan Syndrome, etc.; and cleft lip/palate) may predispose patients to transverse maxillary deficiency (3).

#### *Diagnosis*

Accurate diagnosis of maxillary transverse deficiency requires an integrated assessment combining clinical examination, radiographic evaluation, and model analysis. Clinical findings often provide the initial indication of transverse discrepancy and should be interpreted together with functional and skeletal factors.

Posterior crossbite is the most common clinical sign and may be unilateral or bilateral, frequently associated with malocclusion (4). Determining its etiology is essential, as posterior crossbite may be dental, skeletal, or functional in origin. Dental crossbite results from tooth malposition, skeletal crossbite reflects a true transverse discrepancy between the jaws, and functional crossbite arises from premature contacts that induce a lateral mandibular shift (18). Compensatory buccal tipping of maxillary posterior teeth and lingual tipping of mandibular posterior teeth may mask the underlying deficiency, often exaggerating the curve of Wilson. Additional features may include dark buccal corridors and a narrow, high-arched palate (3).

Radiographic evaluation complements clinical assessment. Posteroanterior radiographs have traditionally been used to assess transverse dimensions and symmetry; however, limitations related to head positioning and landmark identification reduce their reliability (19). As a result, three-dimensional imaging has gained prominence. Cone Beam Computed Tomography (CBCT) enables accurate evaluation of skeletal width and sutural morphology without superimposition and with lower radiation exposure than conventional CT (20, 21).

Model analysis further supports diagnosis by evaluating the relationship between dental arches and their apical bases. The Howes analysis compares apical base width with interpremolar and intermolar distances; an apical base narrower than the dental arch suggests a higher risk of relapse following expansion (22). The adoption of digital intraoral scanning and software-based analysis has enhanced diagnostic efficiency and reliability compared with conventional plaster models (23).

***Treatment***

Treatment of maxillary transverse deficiency aims to restore transverse skeletal and dentoalveolar harmony while minimizing unwanted side effects and ensuring long-term stability. The choice of treatment approach is primarily influenced by the patient's age, skeletal maturity, severity of the transverse discrepancy, and the relative contribution of skeletal versus dental components.

In growing patients, expansion procedures are generally directed toward modifying skeletal structures by taking advantage of the adaptability of the midpalatal and circummaxillary sutures. In contrast, treatment in skeletally mature individuals often requires alternative strategies due to increased sutural resistance, ranging from dentoalveolar expansion to surgically assisted approaches. Accordingly, maxillary expansion techniques are commonly classified based on their biomechanical mechanism and rate of activation as orthodontic, orthopedic, or surgically assisted procedures.

Each treatment modality differs in its indications, expected skeletal and dental effects, and potential advantages and limitations. Therefore, a clear understanding of these characteristics is essential for selecting the most appropriate expansion method and achieving predictable clinical outcomes.

***Treatment Methods***

Maxillary transverse deficiency can be managed using different expansion approaches depending on the underlying mechanism and the tissues primarily affected. Based on the mode of force application and biological response, expansion methods are generally classified as orthodontic, passive, and orthopedic.

**a. Orthodontic Expansion**

Orthodontic expansion is achieved through dentoalveolar tooth movement using fixed appliances, removable expansion plates, or aligner-based systems. This approach primarily results in buccal tipping of posterior teeth, with crowns moving laterally while roots tend to incline lingually. Because the resistance of the surrounding soft tissues remains unchanged, relapse may occur if retention is inadequate. Orthodontic expansion is therefore more suitable for mild transverse discrepancies with a predominantly dental component.

**b. Passive Expansion**

Passive expansion aims to address transverse deficiency by modifying muscular imbalance rather than applying direct expansion forces to the dentition or skeletal structures. Myofunctional therapy targets dysfunctions such as mouth breathing, tongue thrust, and abnormal swallowing patterns that disturb the equilibrium of intraoral forces. Prefabricated functional appliances and devices incorporating cheek pads may help reduce buccinator pressure on the maxilla and support transverse development, particularly in growing patients (25, 26).

**c. Orthopedic Expansion**

Orthopedic expansion focuses on modifying the skeletal structures of the maxilla by transmitting forces to the midpalatal and circummaxillary sutures. This approach induces separation of the sutures, followed by new bone formation during the retention period, typically within 3–6 months. Orthopedic expansion affects not only the maxilla but also adjacent craniofacial structures and is considered the primary method for managing true skeletal transverse deficiencies in growing individuals (24, 25)

***Maxillary Expansion Methods***

Orthopedic maxillary expansion is based on the application of transverse forces to the midpalatal suture in order to separate the maxillary halves and increase skeletal width. The biological response of this suture is age-dependent; with advancing age, the midpalatal suture undergoes progressive maturation and eventual fusion, which directly influences the effectiveness of expansion procedures.

Angelieri et al. evaluated CBCT images of 140 patients aged 5.6 to 58.4 years and proposed a classification of midpalatal suture maturation into five stages (A–E) based on morphological characteristics (21). Early stages (A and B) are typically observed in younger individuals and are characterized by a straight or scalloped suture with high density, whereas intermediate stages (C) may be present in adolescents and some adults. Advanced stages (D and E) demonstrate partial or complete fusion of the suture and are more commonly observed in skeletally mature patients. Importantly, the presence of different maturation stages across age groups highlights that chronological age alone is insufficient for predicting sutural responsiveness, and individual assessment of suture morphology is essential for treatment planning.

Based on the biological response of the midpalatal suture and the rate of force application, maxillary expansion procedures are commonly classified as slow, semi-rapid, or rapid expansion, each differing in their skeletal and dentoalveolar effects as well as clinical indications.

### *A. Slow Maxillary Expansion*

Slow maxillary expansion (SME) is characterized by the application of relatively low and continuous forces that allow gradual dentoalveolar adaptation rather than abrupt sutural disruption (27). Clinically, SME is commonly performed at an expansion rate of approximately 1 mm per week, generating forces of around 900 g (2 pounds) in children during the mixed dentition period, which is thought to better match the physiological rate of bone formation at the sutural level (28). Hicks suggested that SME may preserve maxillary tissue integrity and reduce relapse potential; however, the sutural response to these forces diminishes with increasing age (29).

Radiographically, midpalatal suture separation and midline diastema formation are not consistently observed with SME. Nevertheless, both skeletal and dental changes may occur (28). The proportion of skeletal contribution to total expansion has been reported to vary widely. Implant-based studies have estimated skeletal expansion to account for approximately 16–30% of total expansion (29), whereas studies using banded or bonded appliances have reported more balanced skeletal and dental effects (30). Comparisons of different expansion rates have further demonstrated that treatment outcomes depend on appliance design and activation protocol (9).

One of the primary rationales for SME is the attempt to minimize potential adverse effects associated with rapid maxillary expansion, such as microtrauma of the temporomandibular joint, microfractures of the midpalatal suture, and external root resorption (31). However, comparative CBCT-based studies evaluating slow and rapid expansion using the same appliance have reported no statistically significant differences in transverse expansion immediately after treatment (32). Similarly, investigations using the Haas appliance have shown buccal tipping of molar teeth in both slow and rapid expansion protocols, with more pronounced tipping tendencies observed in rapid expansion, while skeletal expansion was predominantly associated with rapid protocols (33).

#### ***Slow Maxillary Expansion Appliances***

#### ***Coffin Appliance***

The Coffin spring, developed by Walter Coffin in 1877, is an orthodontic appliance designed to increase arch width in young patients by inducing separation of the midpalatal suture (34). It consists of a 1.25-mm thick wire bent into an omega shape, with the open end facing anteriorly and positioned in the midpalatal region (Figure 1). The distal arms extend posteriorly to the permanent first molars and are embedded in the palatal acrylic. The appliance is supported by clasps on the teeth and activated manually by expanding the omega loop to achieve transverse maxillary widening (2).

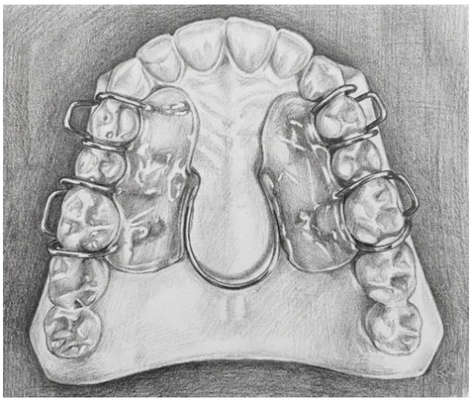

Figure 1. Coffin Appliance

#### ***W-Arch / Porter Appliance***

Developed by Ricketts et al. for patients with cleft lip and palate, the W-Arch is a fixed appliance fabricated from 0.036-inch (0.9 mm) stainless steel wire and attached to molar bands. It is positioned 1–1.5 mm away from the palatal mucosa to minimize soft tissue irritation (Figure 2). Activation is achieved by opening the W-shaped bends, allowing selective anterior or posterior expansion as needed (35). Expansion of 3–4 mm beyond the existing arch width generates adequate orthopedic force. Clinically, the appliance is activated by approximately 2 mm per month until crossbite correction and sufficient transverse expansion are obtained (2). In a study involving 10 patients in the primary and mixed dentition, Harberson and Myers reported midpalatal suture opening in 8 patients following maxillary expansion with the W-Arch (36).

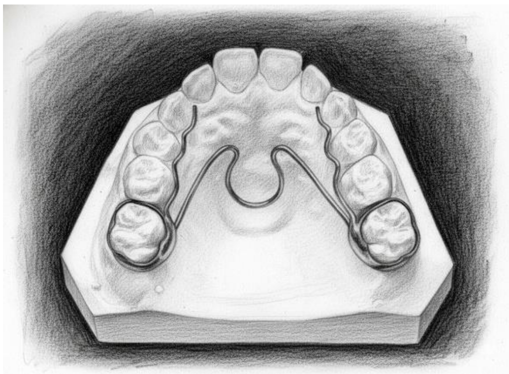

Figure 2. W Arch/Porter Appliance

### *Quad-Helix Appliance*

The Quad-Helix appliance, introduced by Ricketts in 1975 together with the W-Arch, is primarily used in patients with cleft lip and palate. Each helical loop increases wire length by approximately 25 mm, allowing lighter and more sustained force delivery (Figure 3). The appliance produces forces of 0.5–1.5 pounds (225–675 g), and fan-shaped activation may result in distal rotation of the maxillary molars (37).

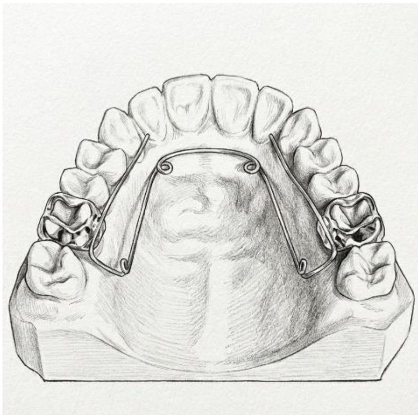

Figure 3. Quadhelix

Martinelli et al. compared Coffin, W-Arch, and Quad-Helix appliances in 90 patients using two wire dimensions (0.032 and 0.036 inches). They reported that Coffin appliance activation with 0.032-inch wire should not exceed 5 mm, while W-Arch with 0.032-inch wire could be activated up to 12 mm for dental crossbite correction. Orthopedic effects with W-Arch required 0.036-inch wire activated between 8–12 mm. A Quad-Helix with 0.036-inch wire activated up to 12 mm was sufficient for dental crossbite correction. Appliances ranked by force and elastic modulus from highest to lowest: Coffin, W-Arch, and Quad-Helix, with Coffin's resilience significantly higher. As wire radius increased, so did elastic modulus; activation also increased force, resilience, and elastic modulus, impacting treatment expectations (38).

In a study of 312 patients, Huynh et al. found no significant differences in transverse stability among Haas, Hyrax, and Quad-Helix appliances, although Haas showed the lowest relapse rate; intermolar width remained stable across all groups (39).

### *Nickel-Titanium (Ni-Ti) Palatal Expansion Appliance*

In 1993, Arndt introduced a semi-rigid, pre-programmed nickel–titanium (Ni-Ti) palatal expander that produces slow expansion with light, continuous forces. Owing to its shape-memory and superelastic properties, Ni-Ti delivers force over a wider activation range than stainless steel. When cooled below its transformation temperature (94°F/34.4°C), the alloy becomes formable and returns toward its programmed shape intraorally, enabling sustained gentle loading of the suture and teeth. The appliance is available in eight sizes and generates approximately 180–300 g of force (Figure 4).

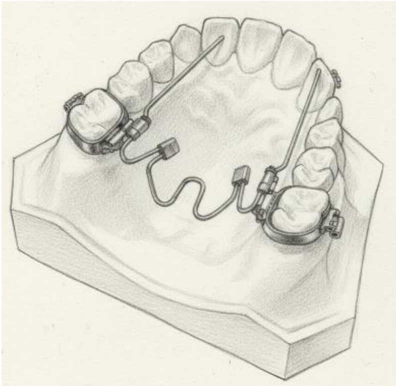

Figure 4. Nickel-Titanium (Ni-Ti) Palatal Expansion Appliance

Paul et al. reported significant maxillary expansion with this appliance and an orthodontic-to-orthopedic effect ratio of 6:1 (40). In a comparison of Ni-Ti expander and quad-helix in 28 crossbite patients, Donohue et al. found similar overall effectiveness over time, although the quad-helix allowed easier force control (41). Revankar et al. likewise observed significant monthly expansion with both appliances; quad-helix produced more uniform expansion, while the Ni-Ti expander showed less initial premolar expansion, and changes were predominantly dentoalveolar with no significant intergroup differences on PA cephalometrics (42).

***Removable Appliances***

In removable expansion appliances, an expansion screw is positioned perpendicular to the midpalatal suture at the level of the premolars or deciduous molars and embedded within an acrylic palatal plate. The plate is divided anteroposteriorly into two halves, which separate by 0.25 mm per activation, generating transverse forces on the teeth and alveolar bone from the palatal aspect. Retention is provided by clasps engaging the approximal and vestibular tooth surfaces. The incorporation of a bite plane may enhance retention, prevent functional crossbite, eliminate intercuspation, and facilitate expansion (43).

A comparative study evaluating quad-helix, removable screw expansion appliances, and untreated controls demonstrated significant increases in intercanine and intermolar widths in both treatment groups compared with controls, with no significant difference between the two appliances. However, removable screw appliances were associated with longer treatment duration, more appointments, and greater appliance use, while greater relapse was observed in the quad-helix group (44).

Another study assessing the short-term effects of interceptive treatment with removable expansion plates reported significant transverse dental expansion and additional sagittal improvement in molar relationships, supporting the effectiveness of this appliance in early orthodontic intervention (45).

***B. Semi-Rapid Maxillary Expansion***

Semi-rapid maxillary expansion (SRME) refers to an expansion protocol performed with activation rates between slow and rapid expansion, and is commonly described as a more frequent activation regimen during mixed dentition than conventional slow expansion (46).

In 1977, John Mew introduced the Bioblock, a removable screw-type appliance extending along the palatal surfaces of the maxillary incisors, enabling approximately 1 mm of weekly expansion (Figure 5). He described this approach as more physiological and, in a series of 25 children treated with SRME, reported favorable long-term stability after prolonged retention (47). He recommended wearing the appliance during meals, turning the screw 1/8 turn daily, and verifying that expansion approaches ~1 mm/week, as lower rates may fail to achieve suture separation (48).

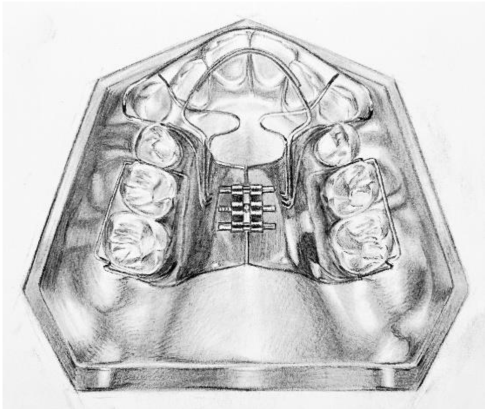

Figure 5. Bioblock

Sandıkçıoğlu et al. compared slow, semi-rapid, and rapid maxillary expansion in terms of expansion characteristics, complications, and relapse. They used a quad-helix for slow expansion, a removable screw plate for SRME, and a banded Hyrax for rapid expansion. Mean expansion duration was 56 days (slow), 5.5 months (SRME), and 19.2 days (rapid). Quad-helix produced comparable dental and skeletal expansion, while rapid expansion yielded significant skeletal and dental changes across planes. In the SRME group, changes were most pronounced transversely, followed by vertical changes, with no sagittal effects. Transverse improvement was the dominant effect in all three methods, and no relapse was observed after retention (9).

Işeri et al. assessed long-term SRME outcomes and reported significant immediate increases in nasal width, basal maxillary width, intercanine distance, and upper and lower intermolar widths. These changes remained stable after retention and were still evident 3.5 years after the start of treatment. They suggested that SRME may involve less periosteal resistance, facilitating tissue adaptation (46).

Ramoğlu et al. compared SRME (¼ turn/day) with rapid expansion (½ turn/day) during the first week until the desired expansion was achieved. The only significant difference was greater inferior displacement of the posterior nasal spine in the rapid expansion group; otherwise, transverse, vertical, and sagittal dentofacial effects were similar. They proposed that SRME may leave less residual stress in surrounding tissues and therefore may be associated with reduced relapse risk (49).

Using micro-CT, Malkoç et al. evaluated root resorption of the maxillary first premolars with three different expanders (Hyrax, acrylic cap splint, and full-coverage acrylic bonded) under two activation rhythms (rapid vs SRME). Root resorption volume was lower with the full-coverage acrylic bonded appliance, but no significant difference was found between rapid expansion and SRME, indicating that activation rhythm did not affect root resorption (50).

### *C. Rapid Maxillary Expansion*

Initially described by Emerson Angell and later reintroduced by Haas (1961), rapid maxillary expansion (RME) is intended to maximize orthopedic and minimize orthodontic effects. By applying heavy, frequent forces to the posterior teeth, tooth movement is limited and the load is transferred to the circummaxillary sutures. These forces exceed sutural resistance, resulting in suture opening with relatively limited tooth displacement. Nevertheless, RME may induce buccal tipping of anchorage teeth, periodontal ligament compression, and bending of the alveolar bone, ultimately contributing to opening of the midpalatal and other maxillary sutures.

A single screw activation can generate approximately 3–10 pounds (2–5 kg) of force (51). Zimring and Isaacson reported that cumulative forces may reach 23.3 pounds by day 15, reflecting resistance of the maxillofacial structures, which increases with age. They recommended, in younger patients, two quarter-turns/day until sutural opening (≈4–5 days), followed by one quarter-turn/day thereafter. For older patients, they suggested two quarter-turns/day for the first 2 days, then one quarter-turn/day until sutural opening (≈5–7 days), and continuing with one quarter-turn/day afterward (52). Other protocols have also been reported, including two quarter-turns/day until adequate expansion (53) or three quarter-turns/day until sutural opening followed by two quarter-turns/day (54, 55). Overall, a commonly recommended regimen is two quarter-turns/day (morning and evening) until the desired expansion is achieved.

Baldini et al. compared one vs two quarter-turns/day using a banded expander and found that two activations/day produced greater expansion, particularly in intercanine width, after retention (55) (56) . Because activation rate may influence adverse effects, micro-CT evidence comparing RME vs slow maxillary expansion (SME) reported that, after 6 months of retention, RME did not show superiority over SME regarding skeletal expansion or the amount of root resorption (57).

***Appliances Used in Rapid Maxillary Expansion***

***1. Tooth-Tissue-Borne Appliances***

***Haas Appliance***

Designed by Haas (1961), this appliance consists of an acrylic palatal base incorporating a central expansion screw, with wires extending from the acrylic and soldered to bands on the first premolars and first permanent molars (Figure 6). Owing to its combined support from the acrylic palatal plate and banded teeth, it is classified as a tooth- and tissue-borne expander. The acrylic support is thought to distribute forces to both skeletal and dentoalveolar structures of the maxilla, promoting more parallel expansion and a greater orthopedic than orthodontic effect (58). However, the acrylic plate may compromise oral hygiene and cause soft tissue irritation (59).

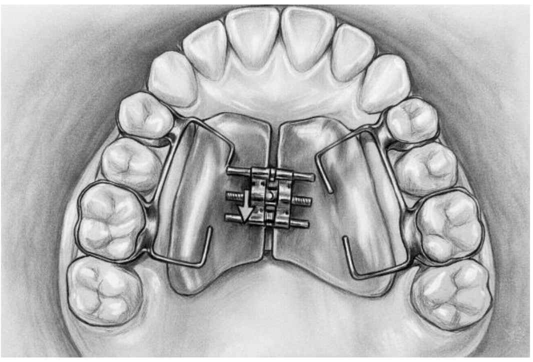

Figure 6. Haas Appliance

Handelmann et al. compared adult and pediatric patients treated with the Haas appliance to untreated controls using pre-treatment, post-treatment, and retention models. They reported that the amount of expansion achieved was similar and statistically significant in both adults and children (60).

***Derishweiler Appliance***

The Derishweiler appliance consists of bands on the upper first premolar and permanent molars, to which wire attachments are soldered on the palatal surfaces. (Figure 7) Embedded in the acrylic plate with a central expansion screw, these wire attachments are connected to the support teeth via the acrylic base. Unlike the Haas appliance where the acrylic base makes contact with the supporting teeth, the Derishweiler appliance ensures that the acrylic base follows the contours of the support teeth (34).

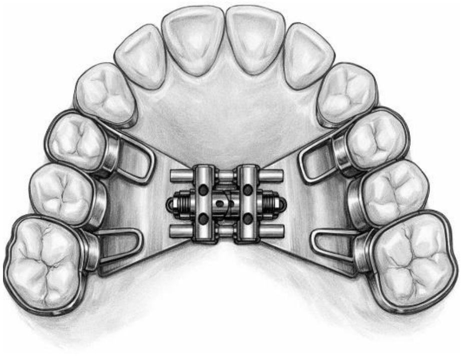

Figure 7. Derishweiler Appliance

***Rigid Acrylic Bonded Maxillary Expansion Appliance***

The rigid acrylic bonded maxillary expansion appliance is created by placing a screw between the premolars in the midpalatal plane within rigid acrylic that fully surrounds the buccal, occlusal, and palatal surfaces of the posterior teeth and only the palatal surfaces of the anterior teeth, as well as the palatal aspect of the maxilla. This appliance is designed by Memikoğlu and İşeri as a tooth-tissue-supported appliance (61).(Figure 8)

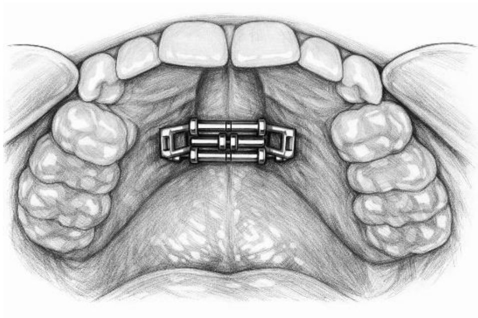

Figure 8. Rigid Acrylic Bonded Maxillary Expansion Appliance

Kimberly and colleagues compared CBCT images taken before and immediately after expansion in 24 patients (14 males, 10 females) with an average age of 9.9 years who used the rigid acrylic bonded maxillary expansion appliance. The study measured basal bone width of the maxilla, inclinations of the right and left molars, distances between the right and left first and second deciduous molars and premolars, distances between the right and left deciduous canines, and width of the midpalatal suture at the level of the second deciduous molars. The research found statistically significant changes in all measured values (62).

***Cap Splint Appliance***

Introduced by Timms in 1981, this appliance consists of a chrome cobalt cast plate covering the occlusal and incisal edges of all teeth except the upper central incisors, along with a screw. However, over time, modifications have been made, and the cast plate has been replaced with an acrylic plate (63). (Figure 9)

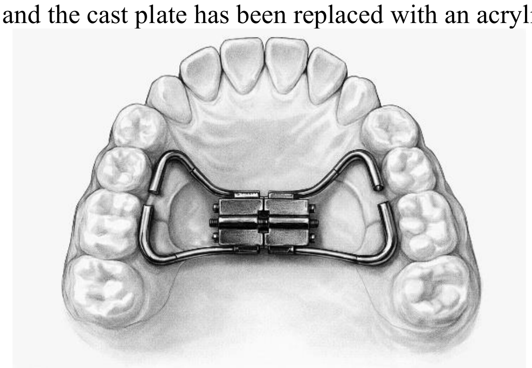

Figure 9. Cap Splint Appliance

***2. Tooth-Borne Appliances***

***Hyrax Appliance***

Introduced by Biedermann in 1968 as the "Hygienic rapid expander," this tooth-supported appliance consists of wires soldered only to the premolar and molar bands, without acrylic support, and a screw. (Figure 10) It has been noted to be more hygienic compared to the Haas appliance (64). The Hyrax appliance, made of stainless steel, is observed to be the most preferred rapid maxillary expander among clinicians. Additional wire bending can be added to the palatal and buccal surfaces of the supporting teeth to increase tooth support (65).

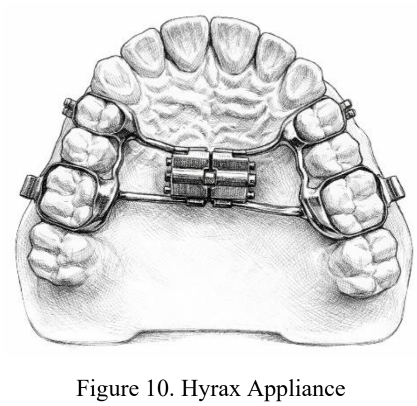

Figure 10. Hyrax Appliance

Weissheimer et al. compared the immediate effects of Haas and Hyrax appliances in patients undergoing RME using CBCT images. The study concluded that the group treated with the Hyrax appliance experienced greater skeletal expansion in both the anterior and posterior regions, while the group treated with the Haas appliance showed more buccal tipping in the premolar and molar teeth (66).

Fernandes and colleagues evaluated tooth displacement dependent on the position of the expanding screw and stress distribution on the periodontal ligament using the finite element method in the hyrax appliance. In the supporting teeth, crowns showed a tendency for buccal displacement and roots showed lingual displacement, which was correlated with compression zones in the vestibular-cervical region and tensile forces in the linguoapical region. When the expanding screw was placed in a more occlusal and anterior position, it led to increased mechanical stress transmission, resulting in greater tooth displacement.(67)

***Isaacson Appliance***

The Isaacson appliance (Minne Expander) is a fixed, tooth-borne expansion device without acrylic support. Similar to the Hyrax appliance, the first premolars and first permanent molars are banded and encircled by metal on both the buccal and palatal surfaces. Expansion is achieved via a central Minne screw containing an internal spring; tightening the screw compresses the spring and delivers expansion forces to the banded teeth (65) (Figure 11).

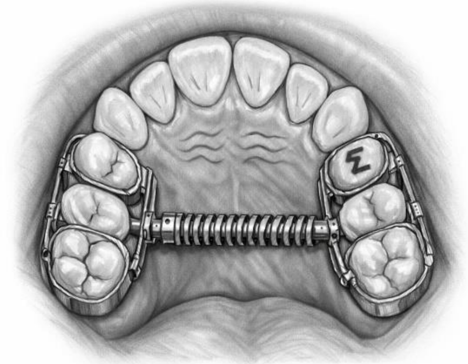

Figure 11. Isaacson Appliance

In a biomechanical study using anatomical models duplicated from human skulls, the forces generated by Haas, Hyrax, Minne, Quad Helix, and removable expansion appliances were compared. Fixed appliances produced concentrated stresses in the anterior region of the midpalatal suture, which then propagated posteriorly into the palatal bone and superiorly toward the lacrimal, nasal, zygomatic, and pterygoid regions. Although the Quad Helix produced palatal separation, it exhibited the lowest orthopedic effect, while removable appliances failed to generate sufficient force for suture opening before removal (68).

Another study comparing rapid and slow maxillary expansion with bonded appliances evaluated vertical and sagittal changes using lateral cephalograms. The RME group used a Hyrax screw, whereas the SME group used a Minne expander. Both groups demonstrated anterior maxillary displacement and increases in interincisal angle and overjet; however, significant downward and backward mandibular rotation was observed only in the RME group. Overall, no significant differences were found between the two groups in net skeletal changes (69).

***Bonded Fan Type Expansion Appliance***

Schellino and colleagues developed a fan-type rapid maxillary expansion screw called Ragno to achieve selective and asymmetric expansion. Unlike other expansion screws placed perpendicular to the midpalatal suture and as close to the palatal mucosa as possible at the sagittal level of the second premolars and first molars, with these teeth's transversal midpoints, this screw is positioned at the sagittal level of the distal aspect of the first molars. The arms connecting the screw to the acrylic splint typically follow the premolar teeth inside the acrylic in other appliances, but in this appliance, they follow the canine and first premolar teeth. (Figure 12)

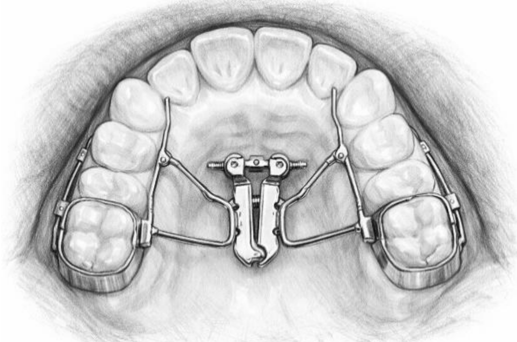

Figure 12. Bonded Fan Type Expansion Appliance

In their study, Gopalakrishnan and colleagues evaluated the changes following maxillary expansion in patients using Hyrax and Ragno screws by examining lateral and posteroanterior cephalometric films taken before expansion and after retention. The research concluded that expansion with Hyrax resulted in a more parallel opening at the midpalatal suture, significant increases in intermolar and intercanine widths were observed with both appliances, but the intermolar distance increased more with the Hyrax appliance. Regarding intercanine distance, no significant difference was found between the two groups (70).

***Expander with Differantial Opening (EDO) Appliance***

The Expander with Differential Opening (EDO) appliance (Great Lakes Orthodontics, NY, USA) is indicated for patients with complex alveolar cleft deformities and for non-cleft patients presenting atypical arch forms. Its fan-shaped design allows greater anterior (intercanine) expansion while limiting excessive intermolar widening. The appliance incorporates two transversely positioned expansion screws (Figure 13); the anterior screw can be selectively activated when increased canine expansion is required, whereas both screws may be activated simultaneously to achieve parallel expansion. Pivoting corner screws enable differential expansion with minimal risk of binding during activation (71).

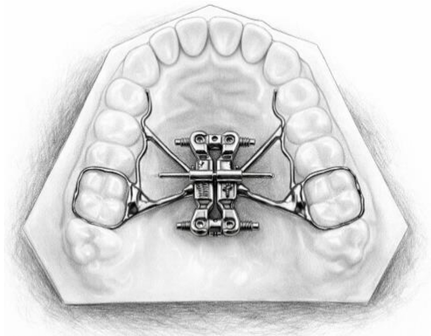

Figure 13. Expander with Differantial Opening (EDO) Appliance

Garib et al. reported that EDO permitted controlled correction of intermolar width relative to intercanine width in cleft lip and palate patients, preventing excessive posterior expansion and potential periodontal side effects. They further noted that in adult cleft patients requiring SARME, neither Hyrax nor fan-type expanders achieved an ideal arch form, whereas EDO allowed precise control of anterior and posterior expansion. The appliance was also suggested for non-cleft patients with severe maxillary constriction and disproportionate anterior–posterior arch widths (72).

In a comparative study during mixed dentition, Alves et al. found that EDO produced greater orthopedic and dental changes in the anterior maxilla than the Hyrax expander, while both appliances showed similar effects in the posterior region, arch perimeter, arch length, palatal depth, and posterior tooth inclination (73). Massaro et al. observed distinct arch width and form changes between EDO and fan-type expanders, with greater anterior expansion for fan-type appliances and greater posterior expansion for EDO, as well as slightly increased spontaneous mandibular expansion at the molar level with EDO (74).

***Bonded Hyrax Expansion Appliance***

The appliance developed by Mc Namara and Brudon is designed to minimize the vertical effects of maxillary expansion during expansion. This appliance, which consists of a Hyrax appliance with an acrylic splint, is also called the Mc Namara type expansion appliance. (Figure 14)

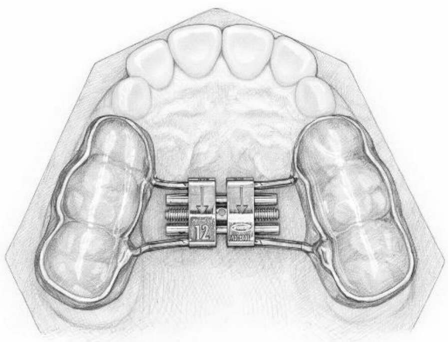

Figure 14. Bonded Hyrax Expansion Appliance

Pinto and colleagues evaluated the effects of the bonded Hyrax appliance in 26 patients with an average age of 8.5 years using lateral cephalometric radiographs taken before expansion and after retention. They concluded that the appliance had no significant effect on vertical growth pattern (75).

Kanomi and colleagues compared the effects of McNamara type bonded and Hyrax banded expansion appliances in 89 patients aged 6-15 years using CBCT images taken before treatment and immediately after removal of the retention appliance. The research results showed that both appliances caused a significant amount of expansion, but the Hyrax banded expansion appliance was reported to be more effective in the age group of 9-11 years (76).

***Memory screws***

These screws, designed by Wichelhaus and Sander, contain a coil made of a nickel-titanium alloy. The aim was to reduce the disadvantages of high force during expansion by applying continuous and less force. (Figure 15)

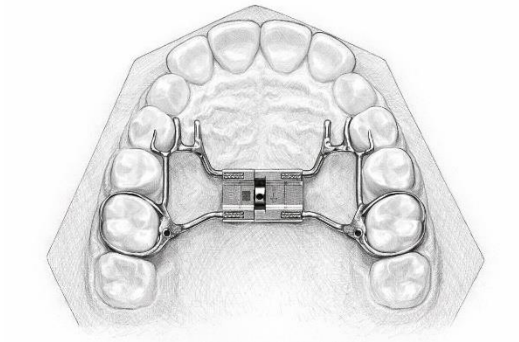

Figure 15. Memory screws

Wichelhaus and colleagues compared arch widths before and after expansion in 10 patients using the Ni-Ti expansion screw, which they turned ¼ turn six times a day for two weeks in their research. In laboratory research, they recommended turning the Ni-Ti rapid maxillary expansion screw twice a day, morning and evening, by ¼ (quarter) turn. In their research, they mentioned that the screw applied a continuous force of 1,224-1,428 g with six activations per day, which was sufficient for sutural opening. Based on their clinical observations, they also indicated that six turns of activation per day could be performed as two activations of three-quarters of a turn each day (77).

Halıcıoğlu et al. investigated and compared the cephalometric effects of a conventional Hyrax expansion screw and a memory screw on the skeletal, dentoalveolar structures, and soft tissues of the face. They concluded that the memory expansion screw takes advantage of rapid and slow maxillary expansion protocols. The suture is opened, and the maxilla is expanded with relatively lighter forces over a shorter time. Also, rapid maxillary expansion using the memory screw resulted in similar sagittal and vertical changes to those produced by the Hyrax screw.(78)

***Mini-Screw Assisted Rapid Palatal Expansion (MARPE)***

Miniscrew-assisted rapid palatal expansion appliances were first proposed by Lee et al. to deliver expansion forces more directly to the maxillary basal bone, addressing concerns that conventional tooth-borne and tooth–tissue-borne RME appliances may transmit insufficient orthopedic force.

MARPE designs differ mainly in miniscrew number and dimensions, most commonly using 2 or 4 miniscrews. In 4-screw designs, stainless steel helical hooks are positioned anteriorly and posteriorly to the Hyrax-type expansion screw to connect the appliance to four palatal miniscrews placed under infiltrative anesthesia. In 2-screw designs, two helical hooks are located either anterior or posterior to the expansion screw for miniscrew placement (Figure 16). The expansion screw is typically activated once daily starting the day after placement.

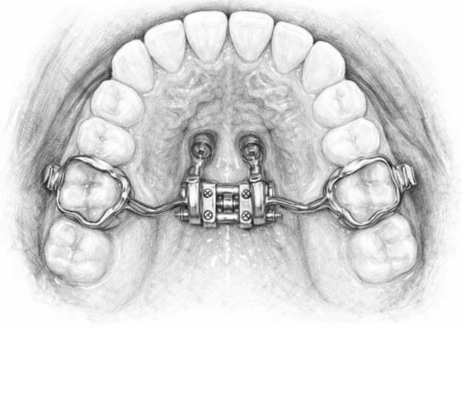

Figure 16. Miniscrew assisted rapid palatal expander (MARPE)

Ning et al. compared tissue-borne versus tooth-borne MARPE in young adults and found similar expansion efficiency; however, tooth-borne MARPE produced greater dentoalveolar side effects, including buccal tipping, root resorption, and alveolar bone loss (79). In a 3D study, Ahmida et al. reported that both MARPE and conventional RPE significantly increased several cranial and circummaxillary suture widths immediately after expansion, but long-term changes were largely comparable except for the midpalatal suture, which remained significantly wider at incisor, canine, and molar levels in the MARPE group (80).

Case reports further support its orthopedic potential: Lee et al. documented ~8.3 mm intermolar expansion over 6 weeks using a 4-miniscrew MARPE (1.8 × 7 mm) with minimal molar inclination changes after retention, alongside increases in basal maxillary width (2.4 mm) and nasal width (2.5 mm) (81). Carlson et al. reported 4–6 mm expansion in the zygomatic and nasal bones, circummaxillary suture changes, and minimal molar buccal tipping using a 4-microimplant MARPE (1.5 × 11 mm) with twice-daily activation during the first two weeks (82).

Miniscrew dimensions may influence outcomes: Choi et al. suggested that longer miniscrews can enhance basal and canine-region alveolar expansion and improve miniscrew stability, although increased length does not guarantee midpalatal suture separation (83).

***Surgical Assisted Rapid Maxillary Expansion (SARME)***

In adults, orthopedic maxillary expansion may be associated with undesirable effects, including posterior tooth tipping and extrusion, periodontal ligament compression, buccal root resorption, alveolar bending and buccal cortical fenestration, palatal tissue necrosis, failure of midpalatal suture opening, pain, and reduced post-expansion stability. Therefore, surgical approaches are often recommended to manage transverse maxillary discrepancies in skeletally mature patients (28) (Figure 17).

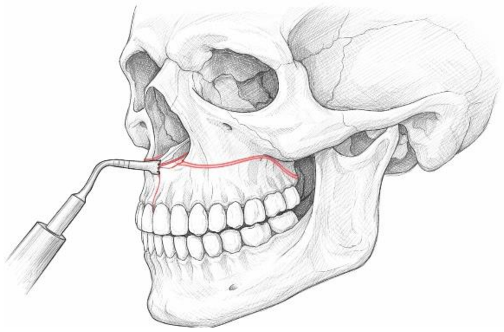

Figure 17. Surgical Assisted Rapid Maxillary Expansion (SARME)

In their systematic review, Menon et al. summarized surgical techniques used for adult transverse expansion. Bell and Epker compared several osteotomy designs in unilateral and bilateral crossbite cases, including variants of lateral maxillary osteotomies (performed at different vertical levels and extents), midline osteotomies to facilitate anterior separation/mobilization, combined palatal–lateral–pterygomaxillary osteotomies in cases with palatal exostosis or suture ossification, and segmental/parasagittal approaches for posterior or unilateral corrections. They reported clinically meaningful expansion in all patients except one with a palatal torus and highlighted surgery as a viable option for adult maxillary expansion (84). Haas suggested that subtotal Le Fort I combined with median palatal suture osteotomy yields more stable long-term results (85). Timms and Vero proposed a more conservative approach focused primarily on midpalatal synostosis (86), while Glassman et al. reported adult expansion using lateral osteotomy alone as a conservative alternative (87).

Surgical management of transverse maxillary deficiency is generally discussed in two categories: (1) Le Fort I osteotomy with repositioning, typically indicated when maxillary repositioning is required (e.g., relative maxillary deficiency, often in Class III patterns), and (2) SARME, considered when overcoming mature sutural and soft-tissue resistance is necessary, particularly after skeletal maturation or when orthopedic expansion is unsuccessful (88) (89). SARME may be considered when transverse deficiency exceeds 5 mm in adults and is generally indicated when the discrepancy exceeds 7 mm (90).

In SARME, the expander is typically placed preoperatively. While tooth-borne devices were used initially, concerns about dentoalveolar side effects have increased interest in bone-supported or hybrid designs (91). Kunz et al. compared a bone-supported transpalatal distractor and a Hyrax-type expander in 28 patients undergoing subtotal Le Fort I osteotomy with partial pterygoid separation; at ~3.5 months, the distractor produced greater anterior expansion, whereas the Hyrax achieved greater overall expansion. Buccal tipping occurred in both, more pronounced with Hyrax; the distractor tended to create a V-shaped pattern, while Hyrax produced more parallel expansion. In contrast, Garreau et al. reported that both Hyrax and bone-supported distractors achieved planned expansion, with no significant difference between them at 6 months when assessed by molar palatal tubercle distance (92).

To reduce dentoalveolar effects, Ludwig et al. introduced a hybrid transpalatal distractor by supporting a Hyrax-type design with two miniscrews placed 8 mm posterior to the incisive papilla, banding only the first molars and using palatal arms resembling a quadhelix configuration. Kayalar et al. compared this hybrid appliance with Hyrax in 20 SARME patients (Le Fort I + midline osteotomy + pterygomaxillary separation). CBCT evaluation showed significantly less anterior expansion with the hybrid device, greater molar buccal tipping during active expansion (which improved during retention), and a greater reduction in buccal alveolar bone thickness in the Hyrax group (93).

***The Effects of Maxillary Expansion on the Maxilla and Surrounding Tissues***

***Maxillary Skeletal Effects***

Inoue et al. reported that, when viewed occlusally, the midpalatal suture expands in a triangular pattern, narrowing posteriorly rather than opening in parallel, which they attributed to resistance from the zygomatic and pterygoid bones. In the frontal view, the suture separates in a pyramidal configuration, with the base directed toward the oral cavity (94).

Using his own expansion appliance, Haas investigated the tissue effects of rapid maxillary expansion in 10 patients and reported several characteristic findings. The earliest and most prominent change was the formation of a midline diastema between the maxillary central incisors, which later closed due to transseptal fiber activity, leaving separation first at the crown and subsequently at the root level. Lateral cephalometric analysis showed anterior displacement of point A in all patients and inferior displacement in some, accompanied by downward and backward mandibular rotation. Continued expansion resulted in lateral bending of the alveolar bone, opening of the midpalatal suture, and inferior displacement of the palatal shelves, leading to flattening and lowering of the palatal vault. Buccal tipping of the maxillary posterior teeth was observed, along with secondary buccal tipping of mandibular teeth, which Haas attributed to altered occlusal relationships and changes in buccolingual muscular balance. Posteroanterior radiographs further demonstrated an increase in nasal cavity width following expansion (95).

Using CBCT, Ghoneima et al. evaluated cranial and circummaxillary sutural changes in 20 patients after rapid maxillary expansion. With the exception of the frontozygomatic, zygomaticomaxillary, zygomaticotemporal, and pterygomaxillary sutures, all assessed sutures demonstrated increased width. The greatest expansion occurred at the intermaxillary and internasal sutures, followed by the bilateral nasomaxillary, frontonasal, and frontomaxillary sutures (53).

Özbek et al. assessed hyoid bone position changes in patients with and without maxillary transverse deficiency using lateral cephalograms and found a significant reduction in the angle between the hyoid bone and the mandibular plane after expansion. Additionally, the distance between the tongue dorsum and palatal vault decreased, and these changes remained stable during follow-up (96).

***Histological Effects of Maxillary Expansion***

Caprioglo and colleagues histologically examined the changes occurring after rapid maxillary expansion in control and experimental groups on the 7th and 30th days.

On the 7th day of expansion, it was observed that needle-shaped trabecular bone near the bone margins began to mature in a fishbone pattern within the soft tissue. This bone, not in contact with existing bone, was surrounded by osteoid matrix. Additionally, blood clots and red blood cells due to mechanical trauma were present. At this stage, 14% new bone and 86% soft tissue were detected in the midpalatal suture.

By the 30th day, newly formed bone trabeculae showed perpendicular orientation to the long axis of the suture and were aligned parallel to each other, gradually approaching each other. Osteoblasts producing osteoid matrix were arranged at the bone margins. Lymphocytes, small or large blood vessels, and bone marrow spaces were present in the trabecular bone. At this stage, 43% new bone and 57% soft tissue were detected in the midpalatal suture.

Under polarized light, in the untreated control group, collagen fibrils showed a parallel arrangement to the midpalatal suture. In the experimental group, on the 7th day, only the central fibrils were parallelly arranged, and a needle-like structure of connective tissue was observed, while on the 30th day, collagen fibrils began to align parallelly (97).

***Nasal Airway***

Anatomically, widening of the nasal cavity after expansion leads to an increase in width, decreasing resistance to breathing and facilitating airflow development (27).

Wertz observed a significant widening in the inferior part of the nasal cavity in 60 patients with bilateral crossbite treated with rapid maxillary expansion, noting that the shape of the nasal septum did not change with expansion (98).

In a study conducted by Izuka et al., they examined changes in airway capacity after rapid maxillary expansion in 25 mouth-breathing patients with maxillary transverse deficiency by obtaining CBCT images before and after the treatment. The data showed a significant widening in both anterior and posterior nasal floors, as well as a significant increase in nasopharynx and nasal cavity volume; however, the increase in oropharynx volume was not statistically significant (99).

In a systematic review by Buck et al., where they evaluated data from 3 controlled clinical studies and 14 cohort studies, they found that total airway capacity significantly increased immediately after expansion based on the existing literature (100).

***Hearing Loss***

***Effects of Expansion on Otitis Tube Function***

One of the changes associated with expansion is an increase in the tension of the tensor veli palatini muscle. This leads to the opening of the Eustachian tube, improved respiration with expansion, and enhanced function of the Eustachian tube. The functions of the Eustachian tube include equalizing middle ear and atmospheric pressure, draining secretions produced in the middle ear to the nasopharynx for ear cleanliness, and protecting the middle ear from bacteria originating in the oral-nasal-pharyngeal region or from secretions in the nasopharynx. Partial restoration of Eustachian tube function after expansion results in decreased hearing loss due to middle ear infections. Furthermore, if the Eustachian tube becomes obstructed and middle ear pressure cannot be balanced, the concavity of the tympanic membrane increases, leading to progressive deafness (101).

In the literature, clinical studies on conductive hearing loss and maxillary expansion clearly indicate positive and stable effects of maxillary expansion on conductive hearing loss (101, 102). Also Peyvandi et al. investigated the relationship between maxillary transverse deficiency and conductive hearing loss. According to the study, patients with maxillary transverse deficiency had 3.5 times more conductive hearing loss compared to those without the deficiency (103).

In a systematic review encompassing 8 different studies, Bueno et al. concluded that while there is some hearing loss regained during the retention period after rapid maxillary expansion, overall, hearing improves (104).

***Nocturnal Enuresis***

Enuresis is defined as inappropriate, nonvoluntary discharge of urine past the age of usual control, which is considered to be a developmental age of 5 to 7 years. Enuresis can be classified in two main ways to better understand its causes and determine the most appropriate treatment for each patient. These classifications are primary versus secondary, and monosymptomatic versus polysymptomatic. Primary nocturnal enuresis occurs when a child has never experienced a period of nighttime dryness lasting longer than 6 months. The majority of cases are composed of primary nocturnal enuresis. On the other hand, secondary nocturnal enuresis happens when involuntary urine discharge recurs after at least a 6-month period of nighttime dryness. When a patient has monosymptomatic enuresis, the only symptom present is involuntary loss of urine during sleep. In contrast, polysymptomatic enuresis indicates that the patient experiences at least one additional lower urinary tract symptom such as urgency, frequency, dysuria, or dribbling (105). According to several case reports and studies, treatment of upper airway obstruction seems to influence nocturnal enuresis (NE). It is believed that the positive effects of maxillary expansion on the airway may have potential benefits for NE. The cause of NE appears linked to changes in the antidiuretic hormone (ADH) secretion, especially in individuals with sleep problems and breathing issues. Rapid maxillary expansion (RME) widens the upper airway, possibly increasing oxygen levels during sleep. This can lower the frequency of breathing interruptions, stimulate ADH production in the brain, and potentially decrease or stop NE episodes.(106)

Some researchers investigated whether rapid maxillary expansion (RME) is a beneficial treatment method for NE and whether the treatment effect is due to placebo. Similarly, it was observed that RME has a therapeutic effect in some children with NE, and researchers suggested that this effect could be associated with the positive influence of RME on sleep architecture (107, 108).

## CONCLUSION

Maxillary transverse deficiency is a prevalent and clinically significant condition that requires careful diagnostic evaluation and individualized treatment planning. This review highlights that successful management of transverse discrepancies depends not only on the selection of an expansion appliance, but primarily on accurate differentiation between dental and skeletal components, assessment of skeletal maturity, and understanding of the biological response of the midpalatal and circummaxillary sutures.

Contemporary diagnostic approaches combining clinical examination, digital model analysis, and three-dimensional imaging allow a more precise evaluation of transverse deficiencies and facilitate appropriate treatment selection. In particular, assessment of midpalatal suture maturation has emerged as a valuable tool for guiding the choice between orthopedic, dentoalveolar, miniscrew-assisted, or surgically supported expansion protocols, especially in adolescent and adult patients.

The reviewed evidence demonstrates that slow, semi-rapid, and rapid maxillary expansion protocols differ in their biomechanical characteristics, skeletal and dental effects, and potential side effects. No single expansion method can be considered universally superior; rather, each approach has specific indications, advantages, and limitations. Similarly, appliance design influences force distribution, treatment efficiency, and dentoalveolar response, underscoring the importance of method selection based on individual patient characteristics rather than appliance preference alone.

Beyond transverse correction, maxillary expansion may induce clinically relevant changes in surrounding skeletal structures, nasal airway dimensions, and functional parameters. However, these effects are variable and should be interpreted cautiously, particularly when extrapolating benefits beyond orthodontic indications.

In summary, effective management of maxillary transverse deficiency requires a structured diagnostic process and a tailored treatment strategy that balances skeletal and dentoalveolar objectives while minimizing adverse effects. This review emphasizes that evidence-based, patient-specific decision making remains the cornerstone of achieving stable and predictable outcomes in maxillary expansion therapy.

### List of abbreviations

SME: Slow Maxillary Expansion; SRME:Semi-Rapid Maxillary Expansion; RME: Rapid Maxillary Expansion; CBCT: Cone Beam Computed Tomography; Micro-CT: micro-computed tomography; EDO: The Expander with Differantial Opening; MARPE: Mini-Screw Assisted Rapid Palatal Expansion; SARME: Surgical Assisted Rapid Maxillary Expansion; NE: Nocturnal Enuresis.

## Declarations

### Ethics Committee Permission Statement

Ethics committee approval was not required for this study, as no human or animal subjects were involved. The ethical principles of scientific research and publication were followed throughout the study.

### Conflict of Interest Statement

The author declares no conflict of interest.

### Funding

This research received no external funding.

### Authors Contribution Statement

**Hilal Tarkan:** The author contributed to conceptualisation, methodology, data analysis, writing, review, and editing of the manuscript.

The author approved the final version of the manuscript.

## References

1. D. J. Timms, “The dawn of rapid maxillary expansion.,” Angle Orthod, vol. 69, no. 3, pp. 247–250, Jun. 1999. https://doi.org/10.1043/0003-3219(1999)069%3C0247:TDORME%3E2.3.CO;2
2. A. Agarwal and R. Mathur, “Maxillary Expansion.,” Int J Clin Pediatr Dent, vol. 3, no. 3, pp. 139–146, Dec. 2010. https://doi.org/10.5005/jp-journals-10005-1069
3. R. Nowak, A. Strzalkowska, and E. Zawiślak, “Treatment Options and Limitations in Transverse Maxillary Deficiency,” Dental and Medical Problems, vol. 52, pp. 389–400, Dec. 2015. https://doi.org/10.17219/dmp/48525
4. J. A. McNamara, “Maxillary transverse deficiency.,” Am J Orthod Dentofacial Orthop, vol. 117, no. 5, pp. 567–570, May 2000. https://doi.org/10.1016/s0889-5406(00)70202-2
5. J. D. Jacobs, W. H. Bell, C. E. Williams, and J. W. 3rd Kennedy, “Control of the transverse dimension with surgery and orthodontics.,” Am J Orthod, vol. 77, no. 3, pp. 284–306, Mar. 1980. https://doi.org/10.1016/0002-9416(80)90083-4
6. G. Kutin and R. R. Hawes, “Posterior cross-bites in the deciduous and mixed dentitions.,” Am J Orthod, vol. 56, no. 5, pp. 491–504, Nov. 1969. https://doi.org/10.1016/0002-9416(69)90210-3
7. M. L. Hanson, L. W. Barnard, and J. L. Case, “Tongue-thrust in preschool children.,” Am J Orthod, vol. 56, no. 1, pp. 60–69, Jul. 1969. https://doi.org/10.1016/0002-9416(69)90259-0
8. S. Helm, “Malocclusion in Danish children with adolescent dentition: an epidemiologic study.,” Am J Orthod, vol. 54, no. 5, pp. 352–366, May 1968. https://doi.org/10.1016/0002-9416(68)90304-7
9. M. Sandikçioğlu and S. Hazar, “Skeletal and dental changes after maxillary expansion in the mixed dentition.,” Am J Orthod Dentofacial Orthop, vol. 111, no. 3, pp. 321–327, Mar. 1997. https://doi.org/10.1016/s0889-5406(97)70191-4

10. F. A. Başçiftçi, A. Demir, Z. Sarı, and T. Uysal, "Prevalence Of Orthodontıc Malocclusıons On School Chıldren In Konya: An Epıdemıologıc Study," Turk J Orthod, vol. 15, no. 2, pp. 92–98, 2002. https://doi.org/10.13076/1300-3550-15-2-92
11. R. B. Nur Yilmaz, D. İlhan, E. Fisekcioglu, I. Oktay, and T. Arun, "Prevalence of Orthodontic Malocclusion and Evaluation Criteria in 7 Geographic Regions of Turkey," Turkish Journal of Orthodontics, vol. 26, pp. 154–161, Dec. 2013. https://doi.org/10.13076/TJO-D-13-00008
12. K. Gungor, L. Taner, and E. Kaygisiz, "Prevalence of Posterior Crossbite for Orthodontic Treatment Timing.," J Clin Pediatr Dent, vol. 40, no. 5, pp. 422–424, 2016. https://doi.org/10.17796/1053-4628-40.5.422
13. B. Thilander and K. Bjerklin, "Posterior crossbite and temporomandibular disorders (TMDs): need for orthodontic treatment?," Eur J Orthod, vol. 34, no. 6, pp. 667–673, Dec. 2012. https://doi.org/10.1093/ejo/cjr095
14. B. Thilander, G. Rubio, L. Pena, and C. de Mayorga, "Prevalence of temporomandibular dysfunction and its association with malocclusion in children and adolescents: an epidemiologic study related to specified stages of dental development.," Angle Orthod, vol. 72, no. 2, pp. 146–154, Apr. 2002. https://doi.org/10.1043/0003-3219(2002)072%3C0146:POTDAI%3E2.0.CO;2
15. S. Nelson, B. Cakirer, and Y.-Y. Lai, "Longitudinal changes in craniofacial factors among snoring and nonsnoring Bolton-Brush study participants.," Am J Orthod Dentofacial Orthop, vol. 123, no. 3, pp. 338–344, Mar. 2003. https://doi.org/10.1067/mod.2003.85
16. T. Aznar, A. F. Galán, I. Marín, and A. Domínguez, "Dental arch diameters and relationships to oral habits.," Angle Orthod, vol. 76, no. 3, pp. 441–445, May 2006. https://doi.org/10.1043/0003-3219(2006)076(0441:DADART)2.0.CO;2
17. S. S. Agarwal, K. Nehra, M. Sharma, B. Jayan, A. Poonia, and H. Bhattal, "Association between breastfeeding duration, non-nutritive sucking habits and dental arch dimensions in deciduous dentition: a cross-sectional study.," Prog Orthod, vol. 15, no. 1, p. 59, Oct. 2014. https://doi.org/10.1186/s40510-014-0059-4
18. T. Żyła, B. Kawala, and M. Dubowik, "The etiology and treatment of posterior crossbite in children," in Wellness and health, W. Kurlej and G. Nowak-Starz, Eds. NeuroCentrum, 2015, pp. 373–381. (Online). Available: https://api.semanticscholar.org/CorpusID:36283561
19. R. M. Ricketts, "Perspectives in the clinical application of cephalometrics. The first fifty years.," Angle Orthod, vol. 51, no. 2, pp. 115–150, Apr. 1981. https://doi.org/10.1043/0003-3219(1981)051%3C0115:PITCAO%3E2.0.CO;2. H.-S. Hwang, C. H. Hwang, K.-H. Lee, and B.-C. Kang, "Maxillofacial 3-dimensional image analysis for the diagnosis of facial asymmetry.," Am J Orthod Dentofacial Orthop, vol. 130, no. 6, pp. 779–785, Dec. 2006, doi: 10.1016/j.ajodo.2005.02.021
20. F. Angelieri, L. H. S. Cevidanes, L. Franchi, J. R. Gonçalves, E. Benavides, and J. A. J. McNamara, "Midpalatal suture maturation: classification method for individual assessment before rapid maxillary expansion.," Am J Orthod Dentofacial Orthop, vol. 144, no. 5, pp. 759–769, Nov. 2013. https://doi.org/10.1016/j.ajodo.2013.04.022
21. M. Ülgen, "8. Bölüm: Diş Kavsi, Çene Genişletilmesi," in Ortodontik Tedavi Prensipleri, 7th ed., Ankara: Ankara Üniversitesi Diş Hekimliği Fakültesi Yayınları Ankara Basımevi, 2005, pp. 107–111.
22. H. Yılmaz, F. Ç. Özlü, C. Karadeniz, and E. İ. Karadeniz, "Efficiency and Accuracy of Three-Dimensional Models Versus Dental Casts: A Clinical Study.," Turk J Orthod, vol. 32, no. 4, pp. 214–218, Dec. 2019. https://doi.org/10.5152/TurkJOrthod.2019.19034
23. A. J. Haas, "Palatal expansion: just the beginning of dentofacial orthopedics.," Am J Orthod, vol. 57, no. 3, pp. 219–255, Mar. 1970. https://doi.org/10.1016/0002-9416(70)90241-1
24. L. W. Graber, R. L. Vanarsdall, K. W. L. Vig, and G. J. Huang, Orthodontics: Current Principles and Techniques, 6th ed. Mosby, 2016.
25. V. Ciftci and A. Uzel, "Dento-skeletal effects of myofunctional appliance on patients with class II div 1 in mixed dentition stage: A cephalometric study," Pediatric Dental Journal, vol. 31, no. 3, pp. 235–241, Dec. 2021. https://doi.org/10.1016/j.pdj.2021.08.005
26. S. E. Bishara and R. N. Staley, "Maxillary expansion: clinical implications.," Am J Orthod Dentofacial Orthop, vol. 91, no. 1, pp. 3–14, Jan. 1987. https://doi.org/10.1016/0889-5406(87)90202-2
27. W. R. Proffit, H. W. Fields, B. I. Larson, and D. M. Sarver, Contemporary Orthodontics, 6th ed. Elsevier, 2018.
28. E. P. Hicks, "Slow maxillary expansion. A clinical study of the skeletal versus dental response to low-magnitude force.," Am J Orthod, vol. 73, no. 2, pp. 121–141, Feb. 1978. https://doi.org/10.1016/0002-9416(78)90183-5
29. K. Mossaz-Joëlson and C. F. Mossaz, "Slow maxillary expansion: a comparison between banded and bonded appliances.," Eur J Orthod, vol. 11, no. 1, pp. 67–76, Feb. 1989, doi: 10.1093/oxfordjournals.ejo.a035967

30. L. A. Cotton, “Slow maxillary expansion: skeletal versus dental response to low magnitude force in Macaca mulatta.,” Am J Orthod, vol. 73, no. 1, pp. 1–23, Jan. 1978. https://doi.org/10.1016/0002-9416(78)90098-2
31. R. Martina et al., “Transverse changes determined by rapid and slow maxillary expansion--a low-dose CT-based randomized controlled trial.,” Orthod Craniofac Res, vol. 15, no. 3, pp. 159–168, Aug. 2012. https://doi.org/10.1111/j.1601-6343.2012.01543.x
32. J. da S. Pereira, H. B. Jacob, A. Locks, M. Brunetto, and G. L. U. Ribeiro, “Evaluation of the rapid and slow maxillary expansion using cone-beam computed tomography: a randomized clinical trial.,” Dental Press J Orthod, vol. 22, no. 2, pp. 61–68, Apr. 2017. https://doi.org/10.1590/2177-6709.22.2.061-068.oar
33. P. B. Subhashchandra, “Chapter-16 History of Expansion Appliances,” in History of Orthodontics, 1/e., Jaypee Medical Ltd, 2013, pp. 154–160. (Online). Available: 10.5005/jp/books/12065
34. S. W. Frank and G. A. Engel, “The effects of maxillary quad-helix appliance expansion on cephalometric measurements in growing orthodontic patients.,” Am J Orthod, vol. 81, no. 5, pp. 378–389, May 1982. https://doi.org/10.1016/0002-9416(82)90075-6
35. V. A. Harberson and D. R. Myers, “Midpalatal suture opening during functional posterior cross-bite correction.,” Am J Orthod, vol. 74, no. 3, pp. 310–313, Sep. 1978. https://doi.org/10.1016/0002-9416(78)90207-5
36. R. W. Bench, “The quad helix appliance.,” Semin Orthod, vol. 4, no. 4, pp. 231–237, Dec. 1998. https://doi.org/10.1016/s1073-8746(98)80028-5
37. F. L. Martinelli, P. S. Couto, and A. C. O. Ruellas, “Three palatal arches used to correct posterior dental crossbites.,” Angle Orthod, vol. 76, no. 6, pp. 1047–1051, Nov. 2006. https://doi.org/10.2319/111105-397
38. T. Huynh, D. B. Kennedy, D. R. Joondeph, and A.-M. Bollen, “Treatment response and stability of slow maxillary expansion using Haas, hyrax, and quad-helix appliances: a retrospective study.,” Am J Orthod Dentofacial Orthop, vol. 136, no. 3, pp. 331–339, Sep. 2009. https://doi.org/10.1016/j.ajodo.2007.08.026
39. P. Rahul, T. Kapoor, V. Malhotra, U. Nayak, and S. Bhatt, “Efficacy of Nickel-Titanium Palatal Expanders,” Journal of Indian Orthodontic Society, vol. 45, pp. 243–250, Dec. 2011. https://doi.org/10.1177/0974909820110506S
40. V. E. Donohue, L. A. G. Marshman, and L. J. Winchester, “A clinical comparison of the quadhelix appliance and the nickel titanium (tandem loop) palatal expander: a preliminary, prospective investigation.,” Eur J Orthod, vol. 26, no. 4, pp. 411–420, Aug. 2004. https://doi.org/10.1093/ejo/26.4.411
41. A. V. Revankar, S. S. Bhat, and J. E. Rozario, “A comparison of the quadhelix and the nickel-titanium palatal expander in the treatment of narrow maxillary arches: A prospective clinical study.,” J Orthod Sci, vol. 12, p. 8, 2023. https://doi.org/10.4103/jos.jos_29_22
42. R. E. Binder, “Correction of posterior crossbites: diagnosis and treatment.,” Pediatr Dent, vol. 26, no. 3, pp. 266–272, Jun. 2004.
43. F. Godoy, J. Godoy-Bezerra, and A. Rosenblatt, “Treatment of posterior crossbite comparing 2 appliances: a community-based trial.,” Am J Orthod Dentofacial Orthop, vol. 139, no. 1, pp. e45-52, Jan. 2011. https://doi.org/10.1016/j.ajodo.2010.06.017
44. A.-S. Van de Velde, L. De Boodt, M. Cadenas de Llano-Pérula, A. Laenen, and G. Willems, “Short term effects of interceptive expansion treatment: a prospective study.,” Eur J Orthod, vol. 43, no. 3, pp. 324–331, Jun. 2021. https://doi.org/10.1093/ejo/cjab006
45. H. Işeri and S. Ozsoy, “Semirapid maxillary expansion--a study of long-term transverse effects in older adolescents and adults.,” Angle Orthod, vol. 74, no. 1, pp. 71–78, Feb. 2004, doi: 10.1043/0003-3219(2004)074<0071:SMESOL>2.0.CO;2
46. J. Mew, “Relapse following maxillary expansion. A study of twenty-five consecutive cases.,” Am J Orthod, vol. 83, no. 1, pp. 56–61, Jan. 1983. https://doi.org/10.1016/0002-9416(83)90272-5
47. J. Mew, “In favor of semirapid expansion.,” Am J Orthod Dentofacial Orthop, vol. 112, no. 4, pp. 20A-21A, Oct. 1997. https://doi.org/10.1016/s0889-5406(97)70063-5
48. S. I. Ramoglu and Z. Sari, “Maxillary expansion in the mixed dentition: rapid or semi-rapid?,” Eur J Orthod, vol. 32, no. 1, pp. 11–18, Feb. 2010. https://doi.org/10.1093/ejo/cjp057
49. S. Malkoç, R. Alçin, and A. Uzel, “Does the rhythm and appliance type of rapid maxillary expansion have an effect on root resorption?,” Angle Orthod, vol. 91, no. 3, pp. 293–300, May 2021. https://doi.org/10.2319/052220-465.1
50. R. J. Isaacson, J. L. Wood, and A. H. Ingram, “Forces Produced By Rapid Maxillary Expansion: I. Design of the Force Measuring System,” The Angle Orthodontist, vol. 34, no. 4, pp. 256–260, Oct. 1964. https://doi.org/10.1043/0003-3219(1964)034%3C0256:FPBRME%3E2.0.CO;2
51. J. F. Zimring and R. J. Isaacson, “Forces Produced By Rapid Maxillary Expansion: III. Forces Present During Retention,” The Angle Orthodontist, vol. 35, no. 3, pp. 178–186, Jul. 1965. https://doi.org/10.1043/0003-3219(1965)035%3C0178:FPBRME%3E2.0.CO;2

52. A. Ghoneima, E. Abdel-Fattah, J. Hartsfield, A. El-Bedwehi, A. Kamel, and K. Kula, "Effects of rapid maxillary expansion on the cranial and circummaxillary sutures.," Am J Orthod Dentofacial Orthop, vol. 140, no. 4, pp. 510–519, Oct. 2011. https://doi.org/10.1016/j.ajodo.2010.10.024
53. I. Ceylan, H. Oktay, and M. Demirci, "The effect of rapid maxillary expansion on conductive hearing loss.," Angle Orthod, vol. 66, no. 4, pp. 301–307, 1996. https://doi.org/10.1043/0003-3219(1996)066%3C0301:TEORME%3E2.3.CO;2
54. F. Taşpinar, H. Uçüncü, and S. E. Bishara, "Rapid maxillary expansion and conductive hearing loss.," Angle Orthod, vol. 73, no. 6, pp. 669–673, Dec. 2003. https://doi.org/10.1043/0003-3219(2003)073%3C0669:RMEACH%3E2.0.CO;2
55. A. Baldini, A. Nota, C. Santariello, V. Assi, F. Ballanti, and P. Cozza, "A comparative assessment of changes in dental arches associated with different activation protocols of rapid maxillary expansion.," Eur J Paediatr Dent, vol. 19, no. 1, pp. 35–39, Mar. 2018. https://doi.org/10.23804/ejpd.2018.19.01.06
56. C. Colak, B. Aras, L. L. Cheng, S. Elekdag-Turk, T. Turk, and M. A. Darendeliler, "Effects of rapid and slow maxillary expansion on root resorption: a micro-computed tomography study.," Eur J Orthod, vol. 43, no. 6, pp. 682–689, Dec. 2021. https://doi.org/10.1093/ejo/cjab024
57. A. J. Haas, "Palatal expansion: just the beginning of dentofacial orthopedics.," Am J Orthod, vol. 57, no. 3, pp. 219–255, Mar. 1970. https://doi.org/10.1016/0002-9416(70)90241-1
58. W. Biederman, "Rapid correction of Class 3 malocclusion by midpalatal expansion.," Am J Orthod, vol. 63, no. 1, pp. 47–55, Jan. 1973. https://doi.org/10.1016/0002-9416(73)90109-7
59. C. S. Handelman, L. Wang, E. A. BeGole, and A. J. Haas, "Nonsurgical rapid maxillary expansion in adults: report on 47 cases using the Haas expander.," Angle Orthod, vol. 70, no. 2, pp. 129–144, Apr. 2000. https://doi.org/10.1043/0003-3219(2000)070%3C0129:NRMEIA%3E2.0.CO;2
60. T. U. T. Memikoglu and H. Işeri, "Effects of a bonded rapid maxillary expansion appliance during orthodontic treatment," The Angle Orthodontist, vol. 69, no. 3, pp. 251–256, Jun. 1999. https://doi.org/10.1043/0003-3219(1999)069%3C0251:EOABRM%3E2.3.CO;2
61. K. F. Christie, N. Boucher, and C.-H. Chung, "Effects of bonded rapid palatal expansion on the transverse dimensions of the maxilla: a cone-beam computed tomography study.," Am J Orthod Dentofacial Orthop, vol. 137, no. 4 Suppl, pp. S79-85, Apr. 2010. https://doi.org/10.1016/j.ajodo.2008.11.024
62. D. J. Timms and D. Vero, "The relationship of rapid maxillary expansion to surgery with special reference to midpalatal synostosis.," Br J Oral Surg, vol. 19, no. 3, pp. 180–196, Sep. 1981. https://doi.org/10.1016/0007-117x(81)90003-2
63. W. Biederman, "Rapid correction of Class 3 malocclusion by midpalatal expansion.," Am J Orthod, vol. 63, no. 1, pp. 47–55, Jan. 1973. https://doi.org/10.1016/0002-9416(73)90109-7
64. P. B. Subhashchandra, Ed., "Removable Appliances," Orthodontics: Principles and Practice. Jaypee Brothers Medical Publishers (P) Ltd., pp. 297–318, 2017. (Online). Available: https://doi.org/10.5005/jp/books/12999_31
65. A. Weissheimer, L. M. de Menezes, M. Mezomo, D. M. Dias, E. M. S. de Lima, and S. M. D. Rizzatto, "Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders: a randomized clinical trial.," Am J Orthod Dentofacial Orthop, vol. 140, no. 3, pp. 366–376, Sep. 2011. https://doi.org/10.1016/j.ajodo.2010.07.025
66. L. C. Fernandes, R. W. Farinazzo Vitral, P. Y. Noritomi, G. S. Maximiano, and M. José da Silva Campos, "Influence of the hyrax expander screw position on displacement and stress distribution in teeth: A study with finite elements.," Am J Orthod Dentofacial Orthop, vol. 160, no. 2, pp. 266–275, Aug. 2021. https://doi.org/10.1016/j.ajodo.2020.04.031
67. S. J. Chaconas and A. A. Caputo, "Observation of orthopedic force distribution produced by maxillary orthodontic appliances.," Am J Orthod, vol. 82, no. 6, pp. 492–501, Dec. 1982. https://doi.org/10.1016/0002-9416(82)90318-9
68. S. Akkaya, S. Lorenzon, and T. T. Uçem, "A comparison of sagittal and vertical effects between bonded rapid and slow maxillary expansion procedures.," Eur J Orthod, vol. 21, no. 2, pp. 175–180, Apr. 1999. https://doi.org/10.1093/ejo/21.2.175
69. U. Gopalakrishnan and P. Sridhar, "Assessment of the dental and skeletal effects of fan-type rapid maxillary expansion screw and Hyrax screw on craniofacial structures.," Contemp Clin Dent, vol. 8, no. 1, pp. 64–70, Mar. 2017, https://doi.org/10.4103/0976-237X.205066
70. "Maxillary Expander with Differential Opening (EDO)." Great Lakes Dental Technologies. (Online). Available: https://www.greatlakesdentaltech.com/maxillary-expander-with-differential-opening-edo.html
71. D. G. Garib, L. C. Garcia, V. Pereira, R. C. M. C. Lauris, and S. Yen, "A rapid maxillary expander with differential opening.," J Clin Orthod, vol. 48, no. 7, pp. 430–435, Jul. 2014.
72. A. C. de M. Alves, G. Janson, J. A. Mcnamara, J. R. P. Lauris, and D. G. Garib, "Maxillary expander with differential opening vs Hyrax expander: A randomized clinical trial," American Journal of Orthodontics and Dentofacial Orthopedics, vol. 157, no. 1, pp. 7–18, 2020, doi: https://doi.org/10.1016/j.ajodo.2019.07.010

73. C. Massaro et al., “Dental arch changes comparison between expander with differential opening and fan-type expander: a randomized controlled trial.,” Eur J Orthod, vol. 43, no. 3, pp. 265–273, Jun. 2021, doi: https://doi.org/10.1093/ejo/cjaa050
74. F. Pinto, L. Abi-Ramia, A. Stuani, B. Stuani, and F. Artese, “Vertical growth control during maxillary expansion using a bonded Hyrax appliance,” Dental Press Journal of Orthodontics, vol. 17, pp. 101–107, Feb. 2012. https://doi.org/10.1590/S2176-94512012000100013
75. R. Kanomi, T. Deguchi, E. Kakuno, T. Takano-Yamamoto, and W. E. Roberts, “CBCT of skeletal changes following rapid maxillary expansion to increase arch-length with a development-dependent bonded or banded appliance.,” Angle Orthod, vol. 83, no. 5, pp. 851–857, Sep. 2013. https://doi.org/10.2319/082012-669.1
76. A. Wichelhaus, M. Geserick, and J. Ball, “A new nickel titanium rapid maxillary expansion screw.,” J Clin Orthod, vol. 38, no. 12, pp. 677–80; quiz 671–672, Dec. 2004.
77. K. Halicioğlu and I. Yavuz, “A comparison of the sagittal and vertical dentofacial effects of maxillary expansion produced by a memory screw and a hyrax screw.,” Aust Orthod J, vol. 32, no. 1, pp. 31–40, May 2016.
78. R. Ning, J. Chen, S. Liu, and Y. Lu, “Treatment effects after maxillary expansion using tooth-borne vs tissue-borne miniscrew-assisted rapid palatal expansion appliance.,” Am J Orthod Dentofacial Orthop, vol. 164, no. 4, pp. 545–553, Oct. 2023. https://doi.org/10.1016/j.ajodo.2023.02.022
79. A. Ahmida et al., “Short-term and long-term effects of miniscrew-assisted and conventional rapid palatal expansion on the cranial and circummaxillary sutures.,” Am J Orthod Dentofacial Orthop, vol. 163, no. 4, pp. e115–e126, Apr. 2023. https://doi.org/10.1016/j.ajodo.2023.01.007
80. K.-J. Lee, Y.-C. Park, J.-Y. Park, and W.-S. Hwang, “Miniscrew-assisted nonsurgical palatal expansion before orthognathic surgery for a patient with severe mandibular prognathism.,” Am J Orthod Dentofacial Orthop, vol. 137, no. 6, pp. 830–839, Jun. 2010. https://doi.org/10.1016/j.ajodo.2007.10.065
81. C. Carlson, J. Sung, R. W. McComb, A. W. Machado, and W. Moon, “Microimplant-assisted rapid palatal expansion appliance to orthopedically correct transverse maxillary deficiency in an adult.,” Am J Orthod Dentofacial Orthop, vol. 149, no. 5, pp. 716–728, May 2016. https://doi.org/10.1016/j.ajodo.2015.04.043
82. E.-H. A. Choi et al., “Skeletal and dentoalveolar effects of miniscrew-assisted rapid palatal expansion based on the length of the miniscrew: a randomized clinical trial.,” Angle Orthod, vol. 93, no. 4, pp. 390–397, Jul. 2023. https://doi.org/10.2319/072322-512.1
83. W. H. Bell and B. N. Epker, “Surgical-orthodontic expansion of the maxilla.,” Am J Orthod, vol. 70, no. 5, pp. 517–528, Nov. 1976. https://doi.org/10.1016/0002-9416(76)90276-1
84. A. J. Haas, “Long-term posttreatment evaluation of rapid palatal expansion.,” Angle Orthod, vol. 50, no. 3, pp. 189–217, Jul. 1980. https://doi.org/10.1043/0003-3219(1980)050%3C0189:LPEORP%3E2.0.CO;2
85. D. J. Timms and D. Vero, “The relationship of rapid maxillary expansion to surgery with special reference to midpalatal synostosis.,” Br J Oral Surg, vol. 19, no. 3, pp. 180–196, Sep. 1981. https://doi.org/10.1016/0007-117x(81)90003-2
86. A. S. Glassman, S. J. Nahigian, J. M. Medway, and H. I. Aronowitz, “Conservative surgical orthodontic adult rapid palatal expansion: sixteen cases.,” Am J Orthod, vol. 86, no. 3, pp. 207–213, Sep. 1984. https://doi.org/10.1016/0002-9416(84)90372-5
87. L. Suri and P. Taneja, “Surgically assisted rapid palatal expansion: a literature review.,” Am J Orthod Dentofacial Orthop, vol. 133, no. 2, pp. 290–302, Feb. 2008. https://doi.org/10.1016/j.ajodo.2007.01.021
88. M. J. Koudstaal, L. J. Poort, K. G. H. van der Wal, E. B. Wolvius, B. Prahl-Andersen, and A. J. M. Schulten, “Surgically assisted rapid maxillary expansion (SARME): a review of the literature.,” Int J Oral Maxillofac Surg, vol. 34, no. 7, pp. 709–714, Oct. 2005. https://doi.org/10.1016/j.ijom.2005.04.025
89. K. Silverstein and P. D. Quinn, “Surgically-assisted rapid palatal expansion for management of transverse maxillary deficiency.,” J Oral Maxillofac Surg, vol. 55, no. 7, pp. 725–727, Jul. 1997. https://doi.org/10.1016/s0278-2391(97)90587-5
90. S. Menon, R. Manerikar, and R. Sinha, “Surgical management of transverse maxillary deficiency in adults.,” J Maxillofac Oral Surg, vol. 9, no. 3, pp. 241–246, Sep. 2010. https://doi.org/10.1007/s12663-010-0034-7
91. E. Garreau, J. Bouscaillou, S. Rattier, J. Ferri, and G. Raoul, “Bone-borne distractor versus tooth-borne distractor for orthodontic distraction after surgical maxillary expansion: The patient’s point of view.,” Int Orthod, vol. 14, no. 2, pp. 214–232, Jun. 2016. https://doi.org/10.1016/j.ortho.2016.03.013
92. E. Kayalar, M. Schauseil, S. V. Kuvat, U. Emekli, and S. Fıratlı, “Comparison of tooth-borne and hybrid devices in surgically assisted rapid maxillary expansion: A randomized clinical cone-beam computed tomography study.,” J Craniomaxillofac Surg, vol. 44, no. 3, pp. 285–293, Mar. 2016. https://doi.org/10.1016/j.jcms.2015.12.001
93. N. Inoue, K. Oyama, K. Ishiguro, M. Azuma, and T. Ozaki, “Radiographic observation of rapid expansion of human maxilla.,” Bull Tokyo Med Dent Univ, vol. 17, no. 3, pp. 249–261, Sep. 1970.

94. A. J. Haas, “Rapid Expansion Of The Maxillary Dental Arch And Nasal Cavity By Opening The Midpalatal Suture,” The Angle Orthodontist, vol. 31, no. 2, pp. 73–90, Apr. 1961. https://doi.org/10.1043/0003-3219(1961)031%3C0073:REOTMD%3E2.0.CO;2
95. M. M. Ozbek, U. T. T. Memikoglu, A. T. Altug-Atac, and A. A. Lowe, “Stability of maxillary expansion and tongue posture.,” Angle Orthod, vol. 79, no. 2, pp. 214–220, Mar. 2009. https://doi.org/10.2319/010908-12.1
96. A. Caprioglio et al., “Cellular Midpalatal Suture Changes after Rapid Maxillary Expansion in Growing Subjects: A Case Report.,” Int J Mol Sci, vol. 18, no. 3, Mar. 2017. https://doi.org/10.3390/ijms18030615.
97. R. A. Wertz, “Skeletal and dental changes accompanying rapid midpalatal suture opening.,” Am J Orthod, vol. 58, no. 1, pp. 41–66, Jul. 1970. https://doi.org/10.1016/0002-9416(70)90127-2
98. E. N. Izuka, M. F. N. Feres, and S. S. N. Pignatari, “Immediate impact of rapid maxillary expansion on upper airway dimensions and on the quality of life of mouth breathers.,” Dental Press J Orthod, vol. 20, no. 3, pp. 43–49, Jun. 2015. https://doi.org/10.1590/2176-9451.20.3.043-049.oar
99. L. M. Buck, O. Dalci, M. A. Darendeliler, S. N. Papageorgiou, and A. K. Papadopoulou, “Volumetric upper airway changes after rapid maxillary expansion: a systematic review and meta-analysis.,” Eur J Orthod, vol. 39, no. 5, pp. 463–473, Oct. 2017. https://doi.org/10.1093/ejo/cjw048
100. N. Kılıç and H. Oktay, “Effects of Rapid Maxillary Expansion on Conductive Hearing Loss: Literature Review.,” Ata Diş Hek Fak Derg., vol. 2006, no. Supplement 1, pp. 32–35, 2006
101. F. Taşpinar, H. Uçüncü, and S. E. Bishara, “Rapid maxillary expansion and conductive hearing loss.,” Angle Orthod, vol. 73, no. 6, pp. 669–673, Dec. 2003. https://doi.org/10.1043/0003-3219(2003)073%3C0669:RMEACH%3E2.0.CO;2
102. A. A. Peyvandi, A. Jamilian, and E. Moradi, “Relationship between conductive hearing loss and maxillary constriction.,” J Laryngol Otol, vol. 128, no. 9, pp. 765–767, Sep. 2014. https://doi.org/10.1017/S0022215114001716
103. C. D. Bueno, C. Z. Neves, P. Sleifer, J. R. Prietsch, and E. Gomes, “Effects of rapid maxillary expansion on hearing: a systematic review,” Audiology - Communication Research, vol. 21, 2016. https://doi.org/10.1590/2317-6431-2016-1708
104. T. Nevéus et al., “The Standardization of Terminology of Lower Urinary Tract Function in Children and Adolescents: Report from the Standardisation Committee of the International Children’s Continence Society,” The Journal of Urology, vol. 176, no. 1, pp. 314–324, 2006. https://doi.org/10.1016/S0022-5347(06)00305-3
105. H. L. Zhiyong Yue Mingming Wang, Wei Xu and H. Wang, “Secretion of antidiuretic hormone in children with obstructive sleep apnea-hypopnea syndrome,” Acta Oto-Laryngologica, vol. 129, no. 8, pp. 867–871, 2009. https://doi.org/10.1080/00016480802441762
106. I. J. Ring, T. Nevéus, A. Markström, A. Magnuson, and F. Bazargani, “Rapid Maxillary Expansion in Children with Nocturnal Enuresis: A Randomized Placebo-controlled trial,” The Angle Orthodontist, vol. 90, no. 1, pp. 31–38, Jul. 2019. https://doi.org/10.2319/031819-219.1
107. F. Bazargani, I. Jönson-Ring, and T. Nevéus, “Rapid maxillary expansion in therapy-resistant enuretic children: An orthodontic perspective.,” Angle Orthod, vol. 86, no. 3, pp. 481–486, May 2016. https://doi.org/10.2319/051515-329.1
108. Merry, R. Insha, M. Sanjay, A. Isha, and P. Tanzin, “Slow expansion in orthodontics -A review article,” International Dental Journal of Student’s Research, vol. 2022, p. 17457, Sep. 2022. https://doi.org/10.18231/j.idjsr.2022.019