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# MINISCREW ASSISTED RAPID PALATAL EXPANSION (MARPE)-A REVIEW

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## INTRODUCTION:

Maxillary transverse deficiency (MTD) is a common concern in orthodontic treatment, affecting about 9.4% of the general population and nearly 30% of adult orthodontic patients, particularly those with a posterior crossbite[1]. While conventional rapid palatal expansion (RPE) has proven effective in correcting transverse skeletal jaw disharmony in prepubertal patients[2], its efficacy in adults is limited, often resulting in minimal skeletal changes and greater dental side effects that may compromise periodontal support.

Surgical assisted RPE (SARPE) has been the preferred method to address MTD in adults, overcoming challenges posed by interdigitated maxillary sutures . However, surgical procedures entail associated morbidity, risks, and expenses, which may deter some adult patients[3,4].

The midpalatal suture, zygomatic apophyses, and pterygomaxillary sutures present significant resistance to maxillary expansion, with histological studies indicating increased interdigitation and closure during puberty [2,6]. In post-pubertal patients, a rigid element capable of directly transferring expansion force to the basal bone may facilitate disjunction[5,7]. Yet, adult patients nearing the end of their growth phase or with limited growth left may be reluctant to undergo surgical interventions, leading to the development of non-surgical alternatives like miniscrew-assisted rapid palatal expansion (MARPE).

MARPE devices have emerged as promising non-surgical solutions for correcting MTD in adult patients, offering advantages over conventional RPE techniques, including reduced risk of dentoalveolar compensations and simpler, less impactful procedures compared to SARPE [8]. However, there is limited information available regarding the skeletal and dental effects of mini-implant-assisted RPE (MARPE) in adult patients.

Various methods have been proposed to assess maxillary suture maturation, with some studies suggesting orthopedic maxillary expansion may be advisable before reaching certain maturation stages. Jang et al. Identified correlations between maxillary suture maturation and both the cervical vertebral maturation (CVM) method and the hand-wrist method (suture maturation index [SMI]) [9]. Their findings suggest that orthopedic maxillary expansion may be advisable before stage 6 in the SMI and stage 3 in the CVM method.

Maxillary expanders can be categorized into MARPE or hybrid types, utilizing both tooth and skeletal anchorage, and bone-borne types, relying solely on skeletal anchorage. The MARPE or hybrid type typically utilizes both tooth and skeletal anchorage, while the bone-borne type relies solely on skeletal anchorage. Despite numerous studies investigating each type of skeletal anchorage RPE and comparing MARPE or hybrid type with bone-borne type, the effectiveness of these treatments remains

a topic of debate. The preference in clinical orthodontics tends to lean towards the MARPE or hybrid type, possibly due to its familiarity with conventional RPE designs[10].
Timing plays a crucial role in determining the outcomes of maxillary expansion therapy, with younger patients typically exhibiting more prominent skeletal effects during prepubertal stages and greater dentoalveolar effects during pubertal or postpubertal stages .

## HISTORY

Angel's initial palatal expansion appliance, devised in 1860, faced reluctance from rhinologists and was not integrated into orthodontic practice. However, European Orthodontists and proponents of maxillary orthopedics revived this approach based on the research of Derischsweiler (1953) and Korkhaus (1960). Haas' experimental demonstration of microscopic processes involved in the method on pigs in 1961 piqued the interest of American orthodontics. Subsequent application in patients with atrophic maxilla yielded positive outcomes, establishing its safety and efficacy, particularly in addressing severe cases like class II malocclusion with posterior crossbite. Various appliance designs have since been introduced with the common objective of treating malocclusions attributed to atrophic maxilla. Achieving the necessary expansion typically takes one to two weeks if the patient undergoes a 2/4 turn daily, encompassing overcorrection and addressing potential relapse, often attributed to imbalances or lack of tensegrity among midfacial components[11].
The orthopedic expansion appliance, whether equipped with a screw secured to a resin support adapted to the palatal mucosa or not, applies force to supporting teeth, leading to reduced blood flow in the buccal periodontium and the formation of extensive hyaline areas. These conditions inhibit the recovery of bone modeling units necessary for tooth movement within the bone, causing bone resorption at a slower rate, which maintains the position of supporting teeth until the suture yields to the resulting stress. After achieving expansion evidenced by diastema opening between maxillary central incisors, the appliance remains inactive for three months before retention is installed and maintained for six months. In cases where orthodontic methods fail to achieve maxillary expansion, surgical intervention for rapid palate expansion may be considered. Unwanted side effects include soreness at incisor or nasal suture sites, as well as ulceration or necrosis of the palatal mucosa. Swelling at the midpalatal suture, particularly immediately after growth, may occur. Failure of the suture to withstand the stresses exerted by the appliance supported by teeth and mucosa may result in ischemia and necrosis of the palatal mucosa. Additionally, mucosal lesions due to diminished blood flow preceding expansion render the treatment impractical. Supporting teeth may also experience buccal surface root resorption as a consequence[12].
The outcomes of palatal expansion procedures vary from failure to achieving a horizontal gain of up to 4mm, with factors such as patient skeletal maturity, variability in transverse measures over time, and issues with retention contributing to potential failures and relapse. To enhance the efficacy of palatal expansion, efforts are directed towards refining or innovating the appliances used. Lee et al. (2010) successfully treated a 20-year-old patient with significant transverse discrepancy and mandibular prognathism using a miniscrew-assisted rapid palatal expander (MARPE), resulting in stable results with minimal tooth and periodontal injury. This technique is deemed effective for transverse correction and may potentially reduce the need for surgical interventions in patients with craniofacial discrepancies by leveraging the capabilities of sutures. Building upon Lee's work, Park and Hwang, Moon, and Mac Ginnis et al. Developed the maxillary skeletal expander (MSE), featuring four miniscrews inserted parallel to both the midpalatal suture and the expansion screw body.
Recently, Suzuki et al. Introduced a modified rapid maxillary expansion appliance anchored with miniscrews (MARPE), utilizing a distinct design (Peclab, Belo Horizonte, Brazil), which has been successfully employed in patients with atrophic maxilla, including both pediatric and adult populations.
Lee et al. Developed an appliance where miniscrews are attached to the turn-key via extensions welded to the expansion screw and bonded with light-curing resin. Maintaining a distance between

miniscrews and the midpalatal suture increases the risk of damaging underlying structures, including canals and nerves in both anterior and posterior regions, as well as on the sides, which presents a more serious concern due to the need to select four individual sites. Alves et al. delineated the areas of risk associated with securing miniscrews on the human palate. In MSE and MARPE appliances, miniscrews serve as support for the expansion screw and are positioned more evenly parallel to the suture to target thicker bone areas, enhancing primary stability and efficient force transmission to the nasomaxillary complex[13].
Placing miniscrews away from the body of the expansion screw allows for more versatile application in orthodontic and orthopedic treatments, albeit with increased associated risks, including the potential for contextualization within treatment modalities utilizing elastics and wires as well as functioning as anchorage units. However, when miniscrews are internalized as in the design by Suzuki et al., such applications are not feasible. The miniscrew-assisted rapid palatal expander (MARPE) is characterized by a reduction in excessive loads on the buccal periodontal ligament of anchored teeth, mitigating the risk of root resorption. MARPE presents minimal clinical risks and decreases accidental tooth movement by shifting palatal expansion support from dental to osseous structures. Recent studies endorse MARPE for treating growing patients with maxillary deficiencies, particularly advocating its use for maxillary protraction, as MARPE miniscrews augment skeletal effects while minimizing dental impacts through anchorage in the maxillary basal bone[14].

**MIDPALATAL SUTURE CHRONOLOGY AS PER AGE GROUP**
Persson and Thilander (1977) conducted microscopic studies on the ossification phases of the human midpalatal suture in 24 individuals aged 15 to 35 years old, revealing that ossification initiates in the posterior region with mineralized bridges forming from posterior to anterior, varying based on chronological age and facial development stage [15].

Mann et al. (1991) [16] further identified the ossification sequence in human skulls
1. Starting with the incisive suture
2. Followed by the posterior segment of the midpalatal suture
3. The transverse palatine suture
4. Finally, the middle segment of the midpalatal suture.

Ossification of the midpalatal suture, particularly its posterior segment, has been recognized as a limiting factor for rapid palatal expansion.
However, imaging diagnosis of midpalatal suture closure or ossification remains challenging, especially in occlusal radiographs or tomographic slices, due to the microscopic nature of the formed bridges, which may not be visible in imaging examinations.
Despite recent advances, studies by Ennes, Ennes et al.,[17] and Ennes and Consolaro[18] in 2002 and 2004 remain relevant.

1.They highlighted the difficulty in precisely and safely analyzing midpalatal suture ossification onset and its structural implications using modern diagnostic tools.
2.They suggested that ossification occurs in adulthood to elderly stages of life, but the fragility of ossification bridges may not solely account for unsuccessful expansion procedures. They recommended reevaluation of technique factors and consideration of ossification in other facial sutures. Encouraging the development of new means and appliances for palatal expansion is crucial for improving outcomes and advancing the technique for patient benefit.

## PREOPERATIVE ASSESSMENT

Accurate diagnosis of transverse discrepancies is essential in orthodontic practice to ensure appropriate treatment outcomes. Clinical evaluation combined with model assessments forms the cornerstone of diagnosis. This review discusses established methods such as Mcnamara's technique[19] and the Andrews Wala ridge method for evaluating intermolar and basal arch width. Additionally, advanced imaging techniques like CBCT offer precise insights into skeletal and dental components of transverse discrepancies. Yonsei’s index[20] and CWRU transverse analysis are introduced as valuable tools for quantifying and analyzing these deviations.

### Clinical evaluation methods:

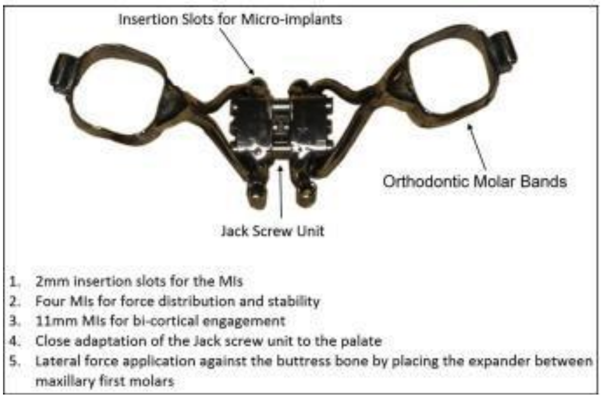
Mcnamara's method involves measuring transpalatal width clinically
Transpalatal width includes measurement of the distance between the gingival margin of the lingual groove of 1st molar counterparts on both sides of the arches. comparing it with age-based norms to determine the need for expansion.
Andrews Wala ridge method assesses mandibular arch form to infer maxillary transverse deficiency.
The distance between the mesiolingual cusp tips of right and left maxillary first molars should be equal to the distance between the mandibular right and left central fossa.
These clinical techniques serve as initial diagnostic tools for identifying transverse issues.

**Model assessment:** utilizing models for assessing transverse discrepancies offers quantitative insights. Mcnamara's technique and the Andrews Wala Ridge method provide specific measurements aiding in treatment planning. These model assessments complement clinical evaluations, especially when discrepancies are not obvious.

**Advanced imaging techniques:** CBCT plays a pivotal role in diagnosing transverse problems by providing detailed 3D images. Yonsei’s index quantifies differences in transverse width, in Yonsei transverse index the average difference between the maxillary and the mandibular transverse width at the estimated center of resistance level was -0.39mm+/- 1.87mm ,while CWRU transverse analysis evaluates buccolingual inclinations to identify deviations from norms. These indices facilitate precise diagnosis and treatment planning.

## MARPE APPLIANCE DESIGN

Dr. Won Moon's original design of the miniscrew-assisted rapid palatal expansion (MARPE) appliance, proposed in [22], involved placement at the center of the palate and banding to the molars. This initial design aimed to address maxillary transverse deficiencies by targeting the midpalatal suture. However, Dr. Keejoon Lee later modified the design by incorporating the banding of the first premolars along with the first molars. This modification was based on the topography of the palate and aimed to improve anchorage and adaptation,
thereby facilitating effective separation of the midpalatal suture. (22)




The evolution of MARPE appliances from the conventional HYRAX rapid palatal expander was further advanced by Carlson et al[21]., who introduced modifications to enhance its efficacy. These modifications included the incorporation of miniscrews into the design, resulting in the development of maxillary skeletal expanders or miniscrew-assisted rapid palatal expanders. Carlson et al. Claimed that their modified design achieved more parallel expansion of the maxillary bone with negligible dental tipping, leading to improved treatment outcomes.

**Key changes suggested by Carlson et al. Included**:
1.Bi-cortical anchorage of the miniscrew implants to ensure stability and support during expansion.
2.Posterior placement of the implants for optimal force distribution and effectiveness in addressing maxillary transverse deficiencies.
3.Reduction in the rigidity of the connecting wires to allow for controlled and gradual expansion, minimizing the risk of complications.
Based on Lee's studies, Mac Ginnis et al.[21] developed the maxillary skeletal expander (MSE), featuring four miniscrews strategically placed parallel to the midpalatal suture. The device comprised two anterior screws with diameters ranging from 1.5 to 1.8mm and lengths of 11 to 13mm, which could be adjusted based on the anatomical thickness of the patient's palate. Additionally, two posterior screws with a length of 9mm were incorporated into the design.[30]
Subsequent modifications to the screw design in the MSE resulted in the adoption of Hex head miniscrews, such as the medusa by FavAnchor™SAS, India. These screws are smoother and less bulky, facilitating secure and precise insertion while offering increased patient comfort. Hex head miniscrews are available in two sizes:
short (2x10mm) and long (2x12mm), providing flexibility to accommodate varying anatomical requirements[23].
To enable controlled activation of the MSE, Biomaterials Korea inc. Introduced two activation pin types:[24]
1.MSE pin type, featuring a cycle of four activation turns of 90° each, resulting in 0.2mm separation per turn.
2.Spanner type activation key, offering six activation turns per cycle of 60° each, resulting in 0.33mm separation.
These activation mechanisms allow for precise adjustment of the MSE, facilitating gradual expansion of the maxilla while minimizing patient discomfort.
Furthermore, various design types of the MSE have been classified based on the position of miniscrews and stress distribution. These classifications aid in selecting the most appropriate MSE design for individual patient cases, optimizing treatment outcomes while ensuring patient comfort and safety

The following summarizes the design types based on miniscrew placement and stress distribution:

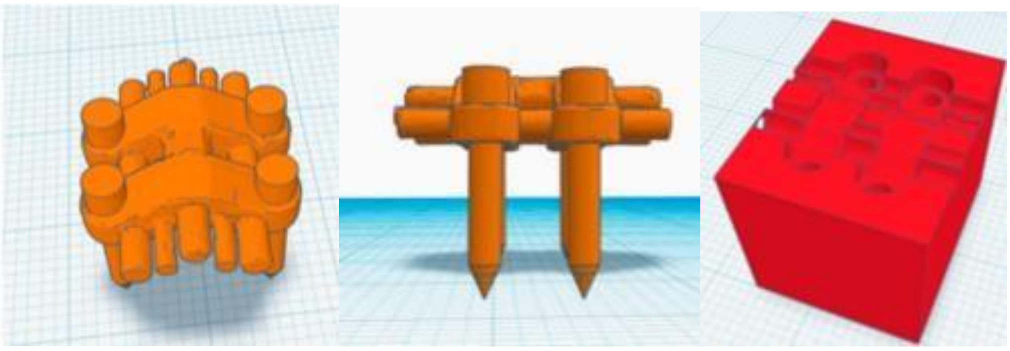
**Type 1:**
*Miniscrew placement:* lateral to the midpalatal suture.
*Stress distribution:* concentrated around the miniscrews and midpalatal suture (MPS).

**Type 2:**
*Miniscrew placement:* at the palatal slope.
*Stress distribution:* low stresses distributed evenly around the implants.

**Type 3:**
*Miniscrew placement:* similar to type 1, with additional conventional hyrax arms.
*Stress distribution:* predominantly on the MPS and around micro-implants, as well as anchor teeth roots.

**MANUFACTURING PROCESS**

**Digital workflow for MARPE placement:** The digital workflow begins with CBCT imaging for threedimensional bone assessment. CAD-CAM technology enables the fabrication of customized MARPE appliances based on intraoral or dental model scans. Virtual planning involves superimposing CBCT-derived stereo-lithographic files to identify optimal appliance positioning in sagittal, coronal, and axial views. Miniscrew insertion is guided by surgical guides or direct virtual planning using CBCT landmarks, ensuring precise directional positioning and parallelism. Qualitative and quantitative bone assessment from CBCT
DICOM files guarantees primary stability and reliable anchorage.(25,26)
Enhanced precision with CBCT DICOM files: a key advancement in the workflow is the incorporation of CBCT DICOM files for qualitative bone discernment, addressing limitations in Cantarella et al.'s digital workflow. This allows for a more comprehensive evaluation of bone availability, critical for optimizing appliance placement and clinical outcomes.(27)



Clinical implications and future directions: CAD-CAMdesigned MARPE offers increased accuracy and better adaptation to palatal anatomy, promising improved clinical outcomes. Embracing advanced technology in orthodontics necessitates a learning curve, but the potential benefits justify its integration into clinical practice.
Future research should focus on refining digital workflows and assessing the cost-effectiveness of digital orthodontic appliances.(28)

**FACTORS RELATED TO THE SUCCESS OF MARPE**
**INSERTION FACTOR CONSIDERATIONS**
**APPLIANCE POSITION**

Placement of miniscrews for maxillary skeletal expanders (MSE) is crucial for optimizing primary stability and treatment outcomes. Three key positions have been identified based on anatomical considerations[1]

Anterior placement:
Placing miniscrews distal to the third rugae along the anterior palate is recommended. This location benefits from thick palatal bone, enhancing primary stability and facilitating effective force propagation to the nasomaxillary complex. The robust bone support in this area contributes to secure anchorage during expansion.

Middle placement:
Miniscrews placed on the flat palatal surface in the region of the second premolars offer a close contact area with the jackscrew, promoting efficient force transmission. However, the bone in this area is thinner, increasing the risk of bicortical penetration. Careful attention is required during insertion to minimize this risk while ensuring adequate stability for expansion.

Posterior placement:
Posterior placement of miniscrews immediately anterior to the soft palate, at the region of the first permanent molars, is recommended. This positioning capitalizes on the resistance offered by the pterygoid plates, resulting in an increased orthopedic effect. The robust skeletal support in this region enhances the effectiveness of expansion and contributes to stable treatment outcomes.

**APPLIANCE INSERTION**

The placement of temporary anchorage devices (TADS), particularly in hard palatal bone, can be challenging due to the lack of torque and directional control with conventional drivers. However, advancements in orthodontic technology have led to the development of specialized tools to address this issue[29].

One such tool is the uniquely designed palatal driver known as the "l'il one" by FavAnchor™SAS, india. This innovative device offers several advantages for precise TAD placement:

Angulation control: the design of the l'il one driver allows for precise angulation control during TAD placement. Orthodontists can accurately position TADS at the desired angle, optimizing anchorage and enhancing treatment outcomes.

Ease of use: the ergonomic design of the l'il one driver facilitates ease of use for clinicians, reducing fatigue and improving efficiency during TAD placement procedures. Its compact size and maneuverability make it particularly well-suited for use in the limited space of the oral cavity.

**CLINICAL PROCEDURE**

Separator placement and banding:
The first step involves separator placement on maxillary permanent first molars to facilitate subsequent band placement. Following separator removal, bands are placed on the first molars after prophylaxis, ensuring proper fit and stability.

Impression and appliance soldering:
Alginate impressions are made, and models are poured with regular plaster. The selected MARPE appliance is then soldered to the bands, ensuring curvature conformity with a 2mm separation from the palate. Optional reverse traction screws may be soldered on the buccal aspect of the molar bands for enhanced stability.

Expander activation and post-placement care:
After appliance cementation under topical anesthesia, self-drilling miniscrews are placed under local infiltrative anesthesia. Immediate expander activation is performed using a digital key, accompanied by hygiene and activation instructions. Antibiotic coverage may be optional, depending on the patient's general health.

Follow-up and monitoring:
Regular follow-up appointments are scheduled to check miniscrew stability and monitor the distance of the expander from the mucosa. Treatment can proceed cautiously if miniscrew mobility is detected, with proper miniscrew placement on each side.

Removal procedure:
MARPE removal is conducted by counterclockwise rotation of the jackscrew with a digital key. Hydrogen peroxide is applied to the miniscrew removal site to promote asepsis, and oral prophylaxis is performed to prevent plaque accumulation.

**CLINICAL TIPS FOR INSERTION**
Impression material selection:
Silicon-based impression material is favored for its ability to capture intricate details accurately. Its use ensures high-quality impressions essential for precise digital modeling and fabrication of orthodontic appliances.

Miniscrew placement protocol:
Strategic placement of miniscrews before curing luting cement is paramount for stability and effectiveness. Adopting a diagonal sequence of miniscrew insertion into the appliance optimizes anchorage and enhances treatment outcomes.

Evaluation of root status:
Before band placement, evaluating the root status of supporting teeth on orthopantomography (OPG) is recommended. This step ensures sufficient root support and minimizes the risk of complications during appliance placement.

**APPLIANCE ACTIVATION**
Customized activation protocol:
The activation protocol for MARPE varies based on treatment objectives and patient biotype. It is essential to adhere to activation schedule guidelines, ensuring a consistent average of 0.2mm of separation per turn. This tailored approach facilitates precise and controlled expansion, minimizing treatment duration and complications. [30]

Termination of activation:
Activation should be terminated upon achieving edge-to-edge contact between the lingual cusps of maxillary first molars and the buccal cusps of the mandibular first molar. This milestone indicates optimal expansion and stability, signaling the completion of the activation phase.

| Age Group | Initial Expansion Rate | Expansion After Diastema Formation (MPS) |
|---|---|---|
| Beginning of Adolescence (13-16 years) | 3-4 turns/week | 3 turns/week (on MI head hinders MI gripping) |
| End of Adolescence (16-19 years) | 1 turn/day | 1 turn/day |
| Young Adults (19-25 years) | 2 turns/day | 1 turn/day |
| Adults (Older than 25 years) | 2 or more turns/day | 1 turn/day |

Activation limits
The activation limits for miniscrew-assisted rapid palatal expansion (MARPE) are crucial to prevent expander deformation and maintain treatment efficacy. Depending on the size of the maxillary skeletal expander (MSE), a maximum number of activations is recommended to ensure expander rigidity. These limits should be carefully observed throughout the treatment process to optimize outcomes and minimize complications.

**CORRELATION OF AGE AND SKELETAL EFFECTS**

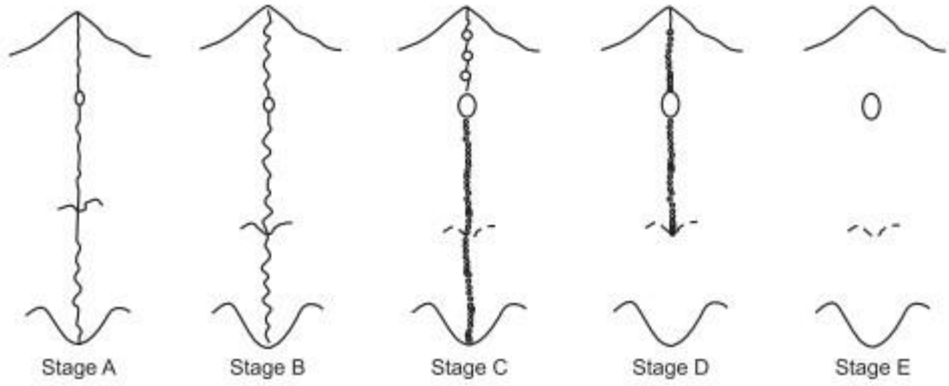
In a retrospective analysis conducted by Cantarella et al. [30], comprising 15 patients, age was found to have no significant influence on the success of suture separation achieved through miniscrew-assisted rapid palatal expansion (MARPE)
Age negatively correlated with maxillary transverse skeletal increases post-MARPE, with older patients demonstrating lesser improvements.[31]
Age showed negligible correlation with midpalatal and pterygopalatine suture opening following treatment with maxillary skeletal expander (MSE) in late adolescents.[32]

**PALATE LENGTH AND DEPTH**

Palatal length and depth may influence midpalatal suture expansion during miniscrew-assisted rapid palatal expansion (MARPE) in young adults, potentially delaying expansion in the anterior side in cases of longer palate length. [33]

**MIDPALATAL SUTURE MATURATION (MPSM) STAGE**

The study assessed predictors of midpalatal suture expansion during miniscrew-assisted rapid palatal expansion
(MARPE) in young adults, utilizing midpalatal suture maturation (MPSM) stages and midpalatal suture density (MPSD) ratio. MPSM stages, categorized from A to E based on midpalatal suture morphology, and MPSD ratio were evaluated as potential indicators of conventional rapid palatal expansion (RPE) response.[6]




The maturation stages of the midpalatal suture (MPSM) are classified as follows:
Stage A: characterized by a straight high-density line of the midpalatal suture with minimal interdigitation.
Stage B: exhibits a scalloped high-density line of the suture.
Stage C: shows two parallel, scalloped, high-density lines in both the maxillary and palatine bones.
Stage D: marked by the fusion of the midpalatal suture in the palatine bone.
Stage E: signifies the absence of the midpalatal suture, even in the maxillary portion.
Tukey test results indicated significant differences in midpalatal suture opening ratio among subjects with MPSM stage C compared to others, with stages A and B absent in the study population. These

findings underscore the utility of MPSM stages[34] and MPSD ratio[35] as predictors of MARPE outcomes in young adults.

## MIDPALATAL SUTURE DENSITY (MPSD) RATIO

In this preliminary study, the midpalatal suture density (MPSD) ratio, evaluated based on grey scales in the midpalatal suture, palatine process of the maxilla, and soft palate, did not show significant correlation with the midpalatal suture opening ratio in young adults undergoing miniscrew-assisted rapid palatal expansion (MARPE). This differed from previous findings by Grünheid et al., likely due to differences in patient age and methodology. Specifically, in adults, the grey scales of the midpalatal suture and palatal process were not significantly different, unlike in growing patients. Additionally, variations in the location of the measurement rectangle on the palatal process may have influenced the grey scale readings. These findings suggest the need for further research to elucidate predictors of midpalatal suture expansion in adult populations undergoing MARPE.

## MIDPALATAL SUTURE OPENING EFFICIENCY

A retrospective study assessing miniscrew-assisted rapid palatal expansion (MARPE) revealed an opening efficiency of 71% in the anterior and 63% in the posterior midpalatal suture. These findings underscore the effectiveness of MARPE in achieving midpalatal suture separation, particularly in the anterior region[36].

## SELLA-NASION (SN)- MANDIBULAR PLANE (MP) ANGLE

In a preliminary study investigating predictors of midpalatal suture expansion through miniscrew-assisted rapid palatal expansion (MARPE) in young adults, the vertical skeletal pattern was observed to influence palate depth. Higher sella-nasion (SN)-mandibular plane (MP) angles correlated with increased palate depth or decreased dental arch width[37,38]. Additionally, dental arch widths were notably narrower in class II and III malocclusion groups compared to class I[39].

## ZYGOMATIC ARCHES AND FRONTOMAXILLARY SUTURE[36,40]

Cantarella et al. Observed that during miniscrew-assisted rapid palatal expansion (MARPE), the splitting of the pterygopalatine suture was crucial for effective maxillary expansion. They suggested that incomplete disengagement of the pyramidal process from the pterygoid plate could limit expansion. Additionally, they proposed that differences in the geometry of zygomatic arches and separation of the frontomaxillary suture may contribute to asymmetric expansion.

## LENGTH OF THE MINISCREW

In a randomized clinical trial comparing the skeletal and dentoalveolar effects of miniscrew-assisted rapid palatal expansion (MARPE) based on miniscrew length, two groups were evaluated: group S with anterior miniscrews of 8 mm length and posterior 6 mm, and group l with anterior miniscrews of 13 mm length and posterior 11 mm. The study found that MARPE with longer miniscrews (group l) resulted in increased expansion of the maxillary basal bone and canine alveolar bone compared to group S. Additionally, longer miniscrews contributed to enhanced miniscrew stability. However, despite these benefits, the use of longer miniscrews did not guarantee successful midpalatal suture separation[41].

## CORTICOPUNCTURE

Corticopuncture, also known as corticotomy-assisted expansion (CAE), is a method utilized in the treatment of maxillary transverse deficiency. This technique involves bilateral decortication of the alveolar, buccal, and palatine bones in conjunction with the use of dental expanders. Research by Hassan et al. Suggests that Corticotomy during expansion can reduce resistance, expedite tooth movement, and mitigate side effects associated with conventional expansion methods[42].

Suzuki et al[43] reported success in achieving midpalatal suture separation after corticopuncture in an adult patient where previous MARPE attempts had failed to produce separation. However, it was noted that resistance to expansion reoccurred after a certain degree of opening, suggesting that the midpalatal suture alone may not be the sole source of resistance.

## MID PALATINE SUTURE REPAIR

Midpalatal suture repair following rapid palatal expansion (RPE) has been extensively studied in growing patients, with evidence suggesting a sequential process of inflammation, osteoblastic activity, and eventual complete suture repair over several months of retention. Studies by Melsen and Ekstrom evaluated histological and radiographic changes in children aged 8 to 13 years, reporting intense osteoblastic activity followed by the formation of bone islands along the suture, ultimately leading to complete repair after 1 year of retention. Tomographic evaluations in children aged 5 to 10 years showed ossification of the suture within 8 to 9 months of retention, while bone scintigraphy studies observed increased bone activity in the initial months postexpansion, followed by a return to baseline levels[44]

In contrast, studies on surgically assisted rapid palatal expansion (SARPE) in adults have shown incomplete sutural repair after several months of retention. However, miniscrew-assisted rapid palatal expansion (MARPE) has emerged as an effective treatment for adult patients, with decreased bone density observed post-retention compared to pre-expansion levels. Despite most adult patients demonstrating incomplete suture repair 16 months after MARPE, a significant proportion (80.95%) exhibited adequate bone repair covering more than half of the hard palate extension.

## POST EXPANSION ASSESSMENT

### SUCCESS RATE

The study estimated the mean success rate to be 92.5%, with a range between 80.7% and 100%[45].

Oliveira et al. Found a negative correlation between age and MARPE success rate, with rates of 83.3%, 81.8%, and 20% for individuals aged 15–19 years, 20–29 years, and 30–37 years, respectively[46].

Choi et al. Reported a success rate of 86.96% in their study.

Lim et al. Observed a success rate of 86.8% among 38 patients with MTD treated with MARPE , with five patients showing no midpalatal suture opening.

Park et al. Noted a success rate of 84.2% among 19 patients with MTD.

In other studies, midpalatal suture opening with MARPE was successful in all patients.

## SKELETAL AND DENTAL EFFECTS

In conventional bone-borne RPE appliances, the center of rotation of the maxilla is higher than the miniscrew placement position, resulting in torque generation and dental tipping due to alveolar bone bending[21].

Customized MARPE appliances with appropriate microimplant positioning can apply forces closer to the maxilla's center of resistance, reducing dental tipping and facilitating more parallel midpalatal sutural opening.

MARPE achieves parallel expansion by separating the pterygoid plates, contrasting with SARPE, which results in a "V" expansion[48].

Children and adolescents may experience less bony resistance to expansion due to less mature pterygomaxillary and zygomaticomaxillary sutures.

In adults, greater bony resistance can lead to orthopedic force on anchor teeth, causing dental tipping and alveolar bone bending.

Zygomatic bone displacement during expansion is primarily lateral, with potential for asymmetric expansion due to differences in bone densities and morphology.

Cantarella et al[31,47]. Suggest a more posterior and lateral fulcrum of rotation in MARPE, leading to lateral and anterior movement of the maxilla, aiding in pterygopalatine suture disarticulation.
Minimal displacement is observed above the frontozygomatic suture, with potential for asymmetric expansion.
Skeletal and dentoalveolar changes with MARPE: Park et al. Highlighted that MARPE induces both skeletal and dentoalveolar changes, with a significant skeletal expansion ratio (37%) and minor buccal tipping of maxillary molars [Park et al., 49].
Extended skeletal effects: the review emphasizes extended skeletal effects of MARPE, including midpalatal suture separation and widening of the maxillary bone up to zygomatic arch levels, as reported by Park et al.
And other retrospective studies [Park et al., 49; Cantarella et al., 50].
Maxillary transverse deficiency correction: MARPE demonstrates effectiveness in correcting maxillary transverse deficiency in young adults, evidenced by significant lateral movement of the maxilla and decreased alveolar crest height[52].
Skeletal and dental changes in skeletally mature patients: in skeletally matured patients, MARPE achieves significant midpalatal suture separation and dental tipping, with 41% of total maxillary expansion attributed to skeletal expansion [53].
Comparison with SARPE and RPE: MARPE shows favourable skeletal transverse maxillary expansion compared to SARPE and RPE, with mean skeletal width increase of 2.33 mm and immediate post-expansion rate of 35.6% [54].
Soft tissue effects: short-term soft tissue effects of MARPE include positional changes in nasal soft tissues, with widened and forward-moving nasal structures post-treatment [55].
Alveolar changes: studies report stable tooth inclination post-MARPE, with no significant difference between right and left maxillary molars[56]. Additionally, MARPE leads to a decrease in buccal alveolar height, though not clinically significant [49]

**AIRWAY**

Airway volume enhancement with MARPE: studies have demonstrated a significant increase in nasal airway volume (12.0%) post-MARPE, indicating improved breathing function[57].
Effectiveness in nasal cavity widening: MARPE is more efficient than conventional RPE in widening the bony maxilla, leading to better airway expansion. However, caution is advised in evaluating its effectiveness on breathing function, considering the influence on surrounding soft tissues[58].
Long-term airway effects: MARPE results in a significant long-term increase in nasopharyngeal volume, indicating sustained improvement in airway function. However, the amount of expansion does not directly correlate with the increase in pharyngeal airway volume[59].
Impact on nasal function and resistance: MARPE has been associated with short-term improvement in muscle strength, decreased nasal and airway resistance, and increased nasal breathing. This suggests positive effects on nasal function and respiratory dynamics[60].
Respiratory airway effects: orthopedic expansion with MARPE leads to alterations in breathing patterns[61], with post-treatment patients showing increased nasal breathing and inspiratory peak flow. The increase in airway volume surpasses that achieved with conventional rme, contributing to improved respiratory function and muscle strength[62].

**STRESS DISTRIBUTION**

Displacement patterns: FEM studies have revealed significant lateral displacement (up to 5.313 mm) at the region of the upper central incisors during maxillary expansion, along with marked lateral displacement of the inferior parts of the pterygoid plates. Interestingly, minimal displacement of the pterygoid plates near the cranial base was observed. Additionally, forward displacement (up to 1.077 mm) was noted at the anteroinferior border of the nasal septum. Furthermore, vertical displacement, particularly downward, was observed in midline structures, including the anterior nasal spine (ANS) and point A[63].

Stress distribution in MARPE: FEM studies comparing different maxillary expansion methods, including miniscrew-assisted rapid palatal expansion (MARPE), have shown distinct stress distribution patterns. MARPE demonstrated less propagation of stress to the buttresses within the maxillary complex compared to conventional expansion methods. The highest stress concentrations were observed in the implant-supported region, gradually decreasing along the connecting arms. Higher stress levels were noted in specific regions such as the canine and molar regions of the maxilla, lateral wall of the inferior nasal cavity, zygomatic, and nasal bones. Notably, the greatest stress concentration was observed at the pterygoid plates of the sphenoid bone near the cranial base[64].

Comparative analysis: comparative studies have highlighted the advantages of MARPE over conventional expansion methods and bone-borne RPE in terms of stress distribution and force delivery. MARPE with miniscrews placed in the palatal slope exhibited the lowest stress concentrations without buccal tipping of dentition. Additionally, variations in miniscrew length, position, and expander screw position were investigated, with stress distribution being wider when four miniscrews supported MARPE compared to only two. Notably, there was no significant difference in stress distribution between monocortical and bicortical miniscrews, contradicting previous findings[65].

## DURATION OF EXPANSION

Duration of maxillary expansion protocols: a range of approaches

In various maxillary expansion protocols, the mean duration of expansion ranged notably, from 20 to 126 days, reflecting the diverse approaches employed to achieve the necessary amount of expansion[55].

Rapid expansion protocols:

Notably, rapid expansion protocols, designed for swift correction of maxillary transverse discrepancies, exhibited a narrower time frame. The duration of rapid expansion protocols ranged between 20 and 35 days

## ARCH PERIMETER

Intermolar width: Choi et al[66]., Park et al., Jia et al[67]., Ngan et al[69]., and Vılmaz et al[68]. Conducted investigations on intermolar width changes before and after MARPE. Through a fixed-effects model analysis, it was determined that MARPE resulted in a statistically significant increase in intermolar width, with an average increment of 6.48 mm.

Alveolar width: Choi et al., Park et al., and Jia et al[67]. Examined changes in alveolar width pre and postMARPE treatment. Utilizing a fixed-effects model, it was revealed that MARPE led to a statistically significant increase in alveolar width, with an average augmentation of 3.23 mm.

Expansion pattern: Cantarella et al[70]. Investigated the expansion pattern of the midpalatal suture during MARPE treatment. Their findings indicated a parallel expansion of the midpalatal suture, with the transverse width at the anterior nasal spine (ANS) being 4.75 mm and at the posterior nasal spine (PNS) being 4.33 mm. This parallel expansion was further supported by Vılmaz et al., who reported similar increases in intermolar and intercanine width, indicating anteroposterior parallel expansion. Additionally, Lin et al. Confirmed a parallel expansion pattern in the MARPE group.

## NASOMAXILLARY COMPLEX

Stress distribution: forces applied to the maxillary teeth typically distribute stresses along the trajectories of the three maxillary buttresses. However, MARPE demonstrates a unique stress distribution pattern, with tension and compression directed to the palate. This results in less rotation and tipping of the maxillary complex compared to conventional hyrax expanders[71].

Rotation and tipping: conventional hyrax expanders often induce rotation of the maxilla around the teeth, contrasting with MARPE, which minimizes rotation by targeting the midpalatal suture. MARPE effectively causes lateral bending of the maxilla while preventing undesired rotation of the complex.
Clinical implications: these findings suggest that MARPE may offer particular benefits for hyperdivergent patients or those with closed midpalatal sutures. In such cases, where palatal expansion is necessary and buccal tipping of teeth or the maxillary complex could exacerbate existing issues, MARPE presents a favorable alternative.

## MIDFACIAL CHANGES

Resistance and circummaxillary sutures: the resistance to midpalatal suture opening during RPE is not solely attributed to the suture itself but also involves surrounding structures, including the sphenoid and zygomatic bones. Various cranial sutures, such as the internasal, nasomaxillary, and zygomaticotemporal, are affected by expansion forces.
Anatomic sites of resistance: different studies have identified various anatomical sites as primary areas of resistance to RPE, including the frontozygomatic, zygomaticomaxillary, and zygomaticotemporal sutures. High stress levels are observed in regions such as the zygomatic process of the maxilla and the frontozygomatic suture[72].
Rotational fulcrum: the exact location of the rotational fulcrum of the maxillary bone during RPE is still debated. Some studies propose the frontomaxillary suture, while others suggest the superior orbital fissure as potential sites.
Role of miniscrews: miniscrew-assisted RPE appliances, such as the maxillary skeletal expander (MSE), utilize miniscrews to enhance orthopedic effects and prevent buccal tipping of lateral teeth. These appliances aim to achieve greater orthopedic changes compared to conventional expanders.
Advancements in imaging: the introduction of cone-beam computed tomography (CBCT) has revolutionized the analysis of midfacial changes during maxillary expansion. CBCT technology allows for multiplanar, 3D reconstructions, providing valuable insights into the craniofacial complex in living subjects.

Interdental papilla height
Effects of MARPE on papilla height: during MARPE treatment, the separation of the midpalatal suture leads to gradual widening of the diastema between the maxillary central incisors. This temporary separation affects the alveolar bone crest and the approximal contact point between the incisors, potentially influencing papilla height. [73]
Findings: post-MARPE treatment, 18% of patients experienced mild papilla recession between the maxillary central incisors. Factors associated with papilla recession included overlap of central incisors before treatment, small central diastema post-expansion, increased distance between bone crest and approximal contact point, and a smaller width-to-length ratio of central incisors.
Predictors of papilla recession: overlapping and smaller width-to-length ratio of maxillary central incisors were identified as predictors for interdental papilla recession post-MARPE treatment.

## SHORT AND LONG TERM IMPACT

Short-term impact on nasal soft tissues
Utilized stereophotogrammetry to assess 3D changes in facial features post-MARPE in adults[74]
Found significant positional changes in soft tissue landmarks around the nasal region, including widening and forward-downward movement of the nose.
Observed a significant increase in post-treatment nasal volume relative to initial volume.
Highlighted the importance of thoroughly explaining anticipated changes to patients before initiating MARPE treatment.

Long-term effects on airway
Both MARPE and RPE significantly increased various airway parameters in the short term, including nasal cavity volume, oropharyngeal volume, and total airway volume.
In the long term, MARPE led to a significant increase in nasopharyngeal volume and palatal width compared to RPE and control groups.
MARPE and RPE groups exhibited greater external maxillary width in the long term compared to controls, with no significant differences in airway parameters other than nasopharyngeal volume.
Age and growth of the patient were identified as potential overriding factors influencing long-term airway changes[59].
Lack of correlation between expansion parameters (e.g., external maxillary width, palatal width) and airway volume suggested a complex interplay of factors affecting airway dimensions.

Effect and stability of MARPE
Long-term stability studies by Lim et al. And Lagravère et al. Reported significant changes in intermolar and alveolar width immediately post-MARPE and after 1 year.
The fixed-effects model applied for synthesis revealed statistically significant decreases in intermolar width by 1.56 mm and alveolar width by 0.55 mm after 1 year.
Highlights the need for understanding long-term stability implications of MARPE.

Long-term stability reports:
Difficulties in finding long-term stability reports[75].
Studies with 1-year post-expansion follow-up demonstrated stable skeletal and dental changes, with minimal changes (<0.5 mm) in skeletal and dental expansion.[76]
Return to pre-treatment bone thickness patterns observed during follow-up, indicating good stability without significant periodontal side effects.
Emphasizes the importance of establishing well-defined retention protocols post-MARPE.
Stability of dental, alveolar, and skeletal changes:
Significant increases in dentoalveolar and skeletal measurements observed 1 year after MARPE.
However, buccal alveolar bone thickness and height at the first premolar decreased after 1 year, highlighting the importance of careful monitoring for potential alveolar dehiscence, particularly in patients with thin buccal alveolar bone[77].

Advantages of MARPE:
Reduced treatment duration: MARPE offers a shorter treatment period (one to four weeks) compared to conventional expansion methods (2-6 months), leading to faster orthodontic outcomes.
Simultaneous fixed orthodontic therapy: MARPE allows for simultaneous fixed orthodontic therapy and expansion, eliminating the need for separate treatment phases.
Maximal skeletal displacement with minimal dental tipping: MARPE achieves maximal skeletal displacement with minimal dental tipping effects, resulting in more stable outcomes post-treatment.
Independence of anchor teeth units: MARPE is independent of anchor teeth units, providing flexibility in treatment planning and implementation.

Limitations of MARPE:
Potential for microimplant deformation: forces applied during MARPE may lead to microimplant deformation, especially when the procedure is attempted on a narrow, high-arched palate.
Variability in craniofacial architecture: unpredictable variability in maxillary-palatal suture (MPS) calcification and craniofacial architecture may contribute to treatment failure in some cases.

Stress distribution and discomfort: MARPE can cause stress distribution around anchor teeth and the zygomaticomaxillary process, potentially leading to discomfort such as dizziness and tension in facial regions.
Challenges with missing anchor units: incorporating missing or compromised anchor units in classic MARPE designs poses challenges and may affect treatment outcomes.
Surgical considerations: in cases with heavy sutural interdigitation or dense bone, surgically assisted expansion may be necessary.

Indications for MARPE:
Maxillary deficiency and crossbite correction: MARPE is indicated for class iii malocclusions, bilateral or severe unilateral expansions, and cases of extreme arch narrowing with crossbites.
Asymmetries and skeletal discrepancies: MARPE corrects asymmetries of condylar position, skeletal discrepancies, and mandibular functional shifts.
Respiratory and medical considerations: MARPE can address nasal obstruction, mouth breathing, and medical conditions like nocturnal enuresis, serving as a preliminary step to septoplasty.

Contraindications of MARPE:
Soft tissue pathologies and gingival enlargement: patients with soft tissue pathologies or severe gingival enlargement are contraindicated for MARPE.
Malocclusions and skeletal asymmetries: MARPE is contraindicated in cases of cover bite, normal buccal occlusion, single teeth crossbite, anterior open bite, steep mandibular planes, convex profiles, and skeletal asymmetries.

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