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Mini-Screw Assisted Maxillary Expansion (MARPE): Benefits and Limitations – A Systematic Review

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Abstract

Introduction: Mini-Screw Assisted Rapid Palatal Expansion (MARPE) has emerged as an innovative approach for treating maxillary transverse deficiencies. By utilizing skeletal anchorage, MARPE distinguishes itself from traditional tooth-supported methods by minimizing adverse effects on dental structures while maximizing skeletal expansion. ***Materials and Methods***: A systematic search was conducted across electronic databases including PubMed, Cochrane Library, and ScienceDirect up to November 2023. The search employed MeSH keywords and Boolean operators. Only articles published from January 1, 2013, in English or French were included. The methodological quality and risk of bias of the selected articles were assessed using the Joanna Briggs Institute (JBI) critical appraisal tools. ***Results***: A total of 28 relevant publications were included, consisting of 5 randomized controlled trials, 8 non-randomized controlled trials, and 15 uncontrolled trials. ***Conclusion***: MARPE represents a significant advancement in the treatment of maxillary transverse deficiencies, providing an effective alternative to traditional expansion methods. Despite its advantages, complications such as alveolar bone resorption and changes in root length require careful clinical evaluation.

Keywords: MARPE, Maxillary Transverse Deficiency, Skeletal Anchorage, Orthodontics, Palatal Expansion.

INTRODUCTION

Miniscrew-Assisted Rapid Palatal Expansion (MARPE) has emerged as an innovative technique for treating maxillary transverse deficiencies. By utilizing skeletal anchorage, MARPE differentiates itself from traditional tooth-supported methods by minimizing adverse effects on dental structures while maximizing skeletal expansion. This technique is particularly relevant for late adolescents and adults, in whom conventional expansion methods are often less effective.

However, despite its many advantages, MARPE presents several challenges and potential side effects that require a thorough understanding to optimize clinical outcomes. These challenges include achieving symmetrical expansion, managing periodontal side effects, and assessing the factors influencing treatment success.

This systematic review analyzes recent studies and available data to provide a comprehensive and critical evaluation of the techniques and outcomes associated with MARPE. It highlights the anatomical, technical, and biomechanical factors that influence the success of the procedure, as well as the clinical implications for managing patients with maxillary transverse deficiencies.

MATERIALS AND METHODS

Objectives of the Literature Review

1. Evaluate the skeletal and dentoalveolar changes resulting from Miniscrew-Assisted Rapid Palatal Expansion (MARPE).
2. Investigate the three-dimensional effects of MARPE on the upper airway.
3. Identify the factors influencing the success of Miniscrew-Assisted Rapid Palatal Expansion (MARPE).

Identification of the research elements

The research elements were developed according to the PICOS [1] schema: population, intervention, comparator, outcome, and study design. In

the current systematic review, the constituents were defined as follows:

- **Population**: Subjects presenting maxillary transverse deficiency, with no restrictions on age, gender, or ethnicity.
- **Intervention**: Rapid maxillary expansion using a mixed anchorage (dental and skeletal).
- **Comparison**: The control group consisted of subjects who received traditional rapid maxillary expansion with dental anchorage only.
- **Outcomes**:
    - **Primary Outcome**: Skeletal and dentoalveolar modifications associated with Miniscrew-Assisted Rapid Palatal Expansion (MARPE) and its effects on the upper airway.
    - **Secondary Outcomes**: Success rate of MARPE, symmetry of the expansion, patterns of mid-palatal suture opening, and periodontal effects resulting from the procedure.
- **Study Design**: Systematic review, randomized controlled trials, non-randomized controlled trials, cohort studies, retrospective and prospective studies.

Search Strategies:

The literature search was conducted in electronic databases including PubMed, Cochrane Library, and ScienceDirect, up to November 2023. The search terms were identified based on an analysis of relevant articles. The search process included the following keywords: "mini-screw," "mini-implant," "dental implants" [MeSH Terms], "Bone screws" [MeSH Terms], and "orthodontic anchorage procedures" [MeSH Terms].

The search restrictions included publication date, with articles published from January 1, 2013. Language restrictions were applied, including only English and French written articles, and full text and reference availability.

Using Boolean operators AND/OR, the following Boolean formulas were applied:

- **Boolean formula #1**: ("mini-screw" OR "mini-implant" OR "dental implants" OR "bone screws" OR "orthodontic anchorage procedures")
- **Boolean formula #2**: ("rapid palatal expansion" OR "maxillary expansion" OR "skeletal expansion")
- **Boolean formula #3**: #1 AND #2

Articles Selection Process

Eligibility Criteria

The inclusion and exclusion criteria for admittance are presented in Table 1.

Table 1: Inclusion and exclusion criteria of our study

	Inclusion Criteria	Exclusion Criteria
Study Type:	Randomized or non-randomized controlled trial. Clinical prospective or retrospective studies.	Systematic reviews, non-original articles, narrative reviews, letters to the editor, case reports.
Participants:	Human subjects with maxillary transverse deficiency	History of maxillofacial surgery, cleft lip and palate, craniofacial anomalies or syndromes. Prior orthodontic treatment. Animal studies.
Intervention	Miniscrew-Assisted Rapid Palatal Expansion (MARPE).	
Comparator:	The control group consisting of subjects who received traditional rapid maxillary expansion with dental anchorage or surgically assisted rapid palatal expansion.	
Outcomes	Primary outcomes: Nasal width (mm or %), sutural and maxillary widths (mm or %), intermolar, interpremolar, and intercanine widths (mm or %), the inclination of dental axes (mm, degree, or %), the inclination of the alveolar bone (mm, degree, or %). Secondary outcomes: Transverse expansion symmetry (mm or %), root lengths of premolars and molars (mm or %), height and width of the vestibular alveolar bone (mm or %).	Other outcomes
Other Criteria:	Publication date starting from 2013. Articles written in English or French. Full-text access.	Publication date before 2013. Articles in languages other than English or French

Study Selection

Zotero software was used to load all search results, remove duplicates, and manage citations and bibliographies. The study selection process was carried out in two steps, independently:

1. Initial screening of titles and abstracts of all studies based on pre-determined inclusion criteria.
2. Full-text assessment of the selected articles.

Any discrepancies between the reviewers were resolved through discussion, with a third researcher consulted if necessary.

Data Extraction

The relevant data presented in the articles featured in this study were extracted according to a customized data collection form. Then results were confronted, discussed and revised by the working group. Data collection and synthesis were presented in Table 6.

Assessment of the Risk of Bias in Included Studies

Using the —JBI's critical appraisal tools [2], the research group independently assessed the risk of bias in included studies after article selection. After answering the questions listed in the JBI critical appraisal tool checklists, the percentage of detailed information is calculated which allows us to rank the risk of bias:

>70% the study is considered to have a low risk of bias.

50%-70% the study has a moderate risk of bias.

<50% the study has a high risk of bias.

The critical evaluation procedure and evaluation scores are listed in table 2,3 and 4.

Level of Evidence and Quality Assessment

According to the Oxford center of evidence-based medicine [3], levels of evidence were assigned to the included articles.

RESULTS

Study Selection

The search resulted in a total of 317 articles. After removing duplicates, 296 items were retained. A pre-selection was carried out by examining the titles and abstracts, which led to the exclusion of 260 articles. The remaining 57 papers were reviewed by full text, resulting in the exclusion of 29 papers, leaving 28 valid papers that passed the full-text screening. The global selection process is illustrated in the PRISMA flow diagram (Figure 1).

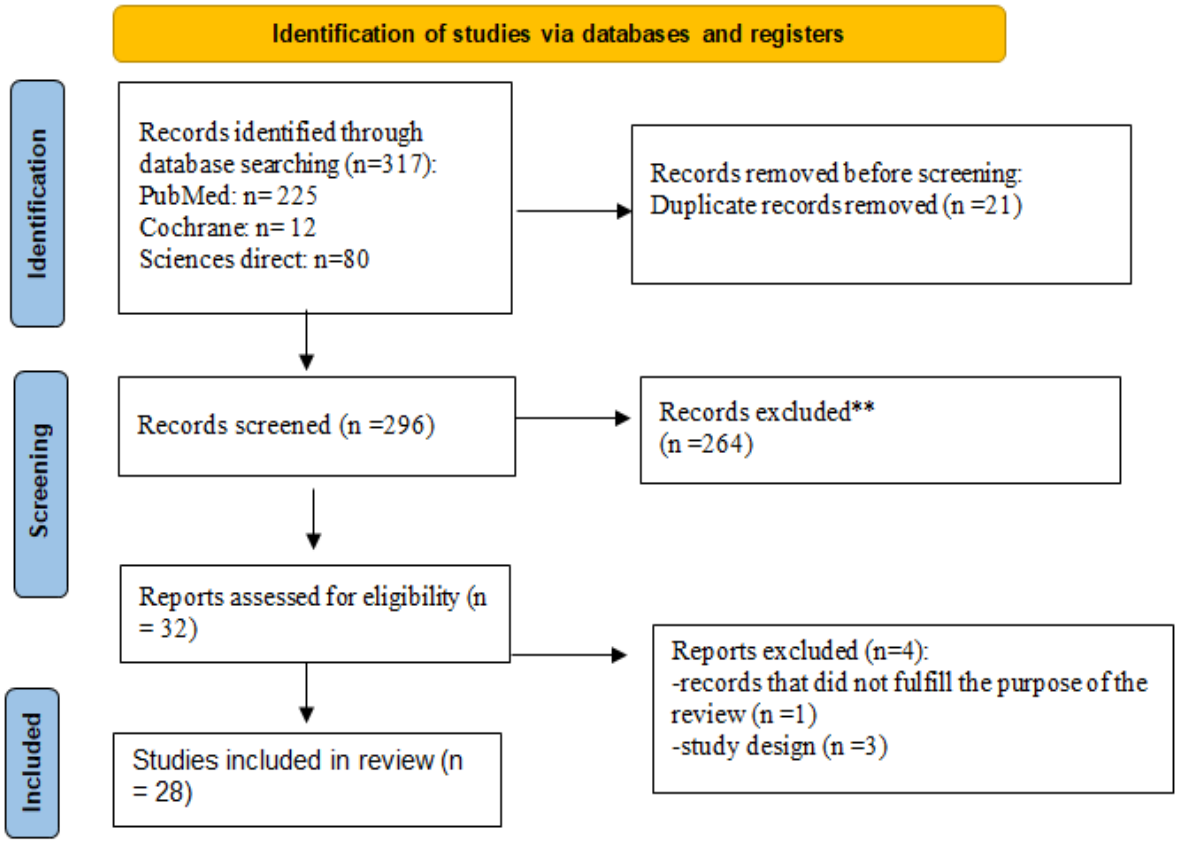

Fig-1: PRISMA 2020 flow diagram [4]

Study Characteristics

A total of 28 relevant publications were identified as eligible based on the pre-determined inclusion criteria for this review:

- 5 randomized controlled trials
- 8 non-randomized controlled trials
- 15 uncontrolled trials

Risk of bias in included studies:

Table 2: Bias Risk and Methodological Quality Assessment for Randomized Clinical Trials

Colonne1	1	2	3	4	5	6	7	8	9	10	11	12	13	Pourcentage	Bias Risk
Jia [5]	O	O	O	N	N	I	O	O	O	O	O	O	I	69,23%	Moderate
Lagravère 2013 [6]	O	O	O	N	N	O	I	O	O	O	O	O	O	76,92%	Low
Lagravère 2020 [7]	O	O	O	N	N	O	O	O	O	O	O	O	O	84,61%	Low
Davami [8]	O	I	O	N	N	I	I	O	O	O	O	O	N	53,84%	Moderate
Celenk-Koca	O	O	O	N	N	O	O	O	O	O	O	O	O	84,61%	Low

Table 3: Bias Risk and Methodological Quality Assessment for Non-Randomized Clinical Trials

Colonne1	1	2	3	4	5	6	7	8	9	Pourcentage	Bias Risk
Brunetto	O	I	N	O	O	O	N	O	O	66,66%	Moderate
Cantarella [9]	O	O	O	N	O	O	O	O	O	88,88%	Low
Jeon [10]	O	I	O	N	O	O	N	O	O	66,66%	Moderate
Kapetanović [11]	O	O	O	N	O	O	O	O	O	88,88%	Low
Lim [12]	O	I	O	N	O	O	O	O	O	77,77%	Low
Lin [13]	O	N	O	O	O	O	O	O	I	77,77%	Low
Mehta 2021 [14]	O	O	O	O	O	O	O	O	O	100%	Low
Mehta 2022 [15]	O	O	O	O	O	O	O	O	O	100%	Low
Oliveira	O	N	I	O	O	O	O	O	O	77,77%	Low
Paredes [16]	O	O	O	N	O	O	NA	I	O	66,66%	Moderate
Park [17]	O	O	O	N	O	O	O	N	N	66,66%	Moderate
Shetty [18]	O	N	O	N	I	O	O	O	I	55,55%	Moderate
Mendoza [19]	O	N	O	N	O	O	O	O	O	77,77%	Low
Storto [20]	O	NA	O	N	O	O	O	O	O	77,77%	Low
Winsauer [21]	O	NA	O	N	O	O	O	O	O	88,88%	Low
YI 2022 [22]	O	N	O	N	I	O	O	O	O	66,66%	Low
YI 2020 [23]	O	O	O	N	O	O	O	O	O	88,88%	Low
Yilmaz [24]	O	N	O	O	O	I	O	I	O	66,66%	Moderate
Zong [25]	O	O	O	N	O	O	O	O	I	77,77%	Low

Table 4: Bias Risk and Methodological Quality Assessment for Cohort Studies

Colonne1	1	2	3	4	5	6	7	8	9	10	11	Pourcentage	Bias Risk
Chane-Fane [26]	N	O	O	O	O	I	O	O	O	O	N	72,72%	low
Annarumma [27]	O	O	O	NA	NA	O	O	O	N	O	O	72,72%	low
Moslah [28]	O	O	O	O	O	O	O	N	O	N	O	81,81%	Low

Certainty Assessment:

Among the 28 articles, according to the criteria of the Oxford Centre for Evidence-Based Medicine, 11 were classified at level A, 16 were deemed to be at level B, and only one was classified at level C.

Table 5: Level of scientific evidence

Article	Level of evidence	Grade of recommendation
Brunetto	1c	A
Cantarella [9]	2c	B
Celenk-coka [29]	1b	A
Chane-Fane [26]	4	C
Davami [30]	1c	A
Annarumma [27]	1c	A
Jeon [10]	3b	B
Jia [31]	1b	B
Kapetanovic [11]	2b	B
Lagravère 2013 [32]	1b	A
Lagravère 2020 [7]	1b	A
Lim [12]	3b	B
Lin [13]	1c	A
Mehta 2021 [14]	1c	A
Mehta 2022 [15]	1c	A

Article	Level of evidence	Grade of recommendation
Moslah [28]	1c	A
Oliveira [33]	3b	B
Paredes [16]	3b	B
Park [17]	3b	B
Shetty [18]	3b	B
Shin [34]	3b	B
Mendoza [19]	3b	B
Storto [20]	2b	B
Winsauer [21]	2c	B
YI 2020 [23]	3b	B
Yilmaz [24]	2b	B
Zong [25]	3b	B
YI 2022 [22]	3c	B

Table 6: Epidemiological and clinical data

Study	Participants	Intervention	Primary Outcome	Secondary Outcome	conclusion
Jia [5]	62 participants (3 groups: MARPE: 21, T-RPE: 20, Control: 21, Ages: 12.86–14.24 years)	MARPE and T-RPE expanders activated twice daily (0.25 mm per turn) with 6 months retention. CBCT at T1 (baseline), T2 (post-expansion), T3 (6 months), T4 (12 months).	Significant transverse expansion for crowns, root apices, and alveoli at T1-T4. Negligible vertical and anteroposterior changes.	Symmetrical molar expansion observed.	Both MARPE and T-RPE yielded similar results. MARPE may be considered an alternative to T-RPE.
Lagravère 2013 [6]	42 participants (3 groups: MARPE: 14, Sealed-Groove: 14, Banded: 14, Ages: 8.1–15.7 years)	MARPE with bone support vs. conventional expanders. Semi-rapid activation (0.5 mm/day). Evaluations: cephalometry, radiographs, dental impressions.	Significant increases in nasal and intermolar widths in all groups. MARPE showed greater skeletal expansion and lingual molar inclination.	MARPE had minimal vertical effects and better control in vertical growers.	MARPE is preferable for patients with vertical growth or reduced anchor teeth.
Lagravère 2020 [7]	16 participants MARPE: 9, Hyrax: 7, Ages: 12.2–16.7 years)	0.5 mm/day activation; 4-month retention. CBCT and impressions for MARPE group only.	MARPE preserved vestibular cortical bone with less buccal tipping. Expansion primarily skeletal.	Significant differences in Wilson curve and interdental distances; Hyrax showed greater dental expansion.	MARPE provides controlled skeletal expansion and is suitable for preserving alveolar bone.
Davami [8]	28 participants (MARPE: 15, Hyrax: 13, Females only, Ages: 17.4–18.1 years)	Expanders activated by 0.25 mm/day for >7 mm; CBCT scans pre-expansion (T1) and 3 months post-expansion (T2).	MARPE achieved greater palatal suture expansion than Hyrax.	Hyrax showed more buccal tipping and alveolar bending; MARPE had less vertical bone loss.	MARPE is effective for late adolescent maxillary expansion with minimal side effects.
Celenk-Koca [29]	20 participants (Females only, Age: 12 ± 0.6 years)	MARPE vs. Hyrax evaluated by CBCT before and after expansion.	Both groups showed significant skeletal and nasal width increases; Hyrax had greater dental expansion.	Hyrax demonstrated more dental tipping than MARPE.	Both devices achieved skeletal expansion, but Hyrax caused more significant dental tipping.
Brunetto	14 participants (9 men, 5 women, Ages: 16–26, Mean: 20.1 ± 2.4)	MARPE activated 1 turn/day (0.2 mm per turn). CBCT scans pre- and post-expansion, paired t-test analysis.	Expansion: Crown: 5.5 mm, CEJ: 3.2 mm, Basal bone: 2.0 mm. Vestibular tipping of premolars and molars: 1.1°–2.9°.	Success rate for mid-palatal suture separation: 84.2%. Decrease in alveolar bone thickness: 0.6–1.1 mm.	MARPE achieved pyramidal expansion with skeletal and dentoalveolar effects, with moderate bone loss.

Study	Participants	Intervention	Primary Outcome	Secondary Outcome	conclusion
Cantarella [9]	24 participants (8 men, 16 women, Ages: 18.25–26.75, Mean: 21.55 ± 3.14)	MARPE activated 1 turn/day (0.2 mm per turn). CBCT scans at T0, T1 (immediate post-expansion), and T2 (1 year later).	Immediate effects (T0–T1): 39.1% skeletal, 7.1% alveolar, 53.8% dental expansion. Long-term (T0–T2): 43.2% skeletal, 15.0% alveolar, 41.8% dental.	Significant vestibular inclination of alveolar bone and minimal reduction in buccal bone thickness.	MARPE achieved long-term expansion with reduced buccal bone loss and moderate dental tipping.
Jeon [10]	15 participants (6 men, 9 women, Ages: 13.9–26.2, Mean: 17.2 ± 4.2)	MARPE activated at 0.25 mm per turn. Expansion continued until inter-incisal diastema appeared, then reduced to 1 turn/day.	Expansion at ANS (4.8 mm) and PNS (4.3 mm). No significant difference in suture opening between genders.	Asymmetric suture expansion: One half of ANS displaced more than the other by 1.1 ± 1.0 mm.	MARPE effectively expanded suture but with some asymmetry; age had negligible influence on suture opening.
Kapetanović [11]	40 participants (25 women, 15 men, Ages: ~13.8)	MARPE vs. Hyrax, activated 2 turns/day. Retention for 6 months without fixed retainers.	Skeletal expansion: 68% MARPE, 26% Hyrax at PM1.	MARPE induced lingual crown tipping, while Hyrax caused vestibular tipping.	MARPE supported buccal alveolar bone better and achieved greater skeletal effects.
Lim [12]	22 participants (11 men, 11 women, Age: 14.97 ± 6.6)	Expansion protocol adjusted by age and skeletal maturity. Stopped after 2–3 mm over-expansion. CBCT at T1 and T2.	Total expansion at first molar: 5.41 ± 2.18 mm (59.23% skeletal). Dental tipping: 2.56 ± 2.64°.	Parallel mid-palatal suture opening.	MARPE achieved effective skeletal expansion with minimal dental tipping.
Lin [13]	31 participants (Mean Age: 22.52 ± 5.11)	MARPE treatment analyzed with occlusal radiographs. Correlations studied by age, sex, and suture maturity.	Negative correlations between suture opening and age, palate length, and suture maturity ($r = -0.746$, $p < 0.01$).		Mid-palatal suture opening decreases with age and suture ossification.
Mehta 2021 [14]	20 participants (13 women, 7 men, Mean Age: 17.1)	Respiratory tests at T0 (pre-expansion), T1 (post-expansion), and T2 (5 months later). CBCT scans of nasal cavity and maxilla.	Significant increases in inspiratory and expiratory pressures after expansion. Nasal cavity and interdental distances increased.	Maximal airflow improvements noted in obstructed airways.	MARPE improved nasal breathing and expanded the maxilla effectively.
Mehta 2022 [15]	29 participants (Ages: 11–17, MARPE: 15, Hyrax: 14)	MARPE: 1 turn/day, Hyrax: 2 turns/day. 4–6 months retention. CBCT scans pre- and 2+ years post-expansion.	Posterior skeletal expansion: 1.91 mm (MARPE), 1.96 mm (Hyrax). No significant differences in crown tipping or alveolar displacement.	Skeletal expansion greater posteriorly than anteriorly.	Both devices produced similar results; MARPE was slightly more effective in skeletal expansion.
Oliveira	13 participants (3 men, 10 women, Ages: 15–29, Mean: 19.61 ± 5.25)	MARPE activated 2 turns/day (0.25 mm per turn) for 14 days. CBCT pre- and 3 months post-expansion.	Skeletal, alveolar, and dental expansion: 73%, 26%, and 1% of total, respectively. Nasopharyngeal volume increased by 8.48%.	Parallel suture opening pattern with reduced transverse expansion posteriorly.	MARPE is effective for skeletal expansion and airway improvement in adults with maxillary transverse deficiencies.
Paredes [16]	50 participants (B-RME: 17, T-RME: 17, Control: 16, Ages: ~13.3–14.1)	Expansion with 0.5 mm/day until 20% overcorrection achieved. CBCT pre- and 6 months post-expansion.	Skeletal expansion: ~1.3 mm (both B-RME and T-RME, $p < 0.01$). Significant vestibular tipping in T-RME.	Symmetrical expansion in B-RME; vertical molar extrusion only in T-RME.	B-RME achieved skeletal expansion with minimal dental effects compared to T-RME.
Park [17]	39 participants (13 men, 26 women, Ages: 13.3–27.3, Mean: 18.2 ± 4.2)	MARPE with angular and linear analyses for zygomaticomaxillary complex. CBCT pre- and post-expansion.	Skeletal expansion angles: 2.82° (right), 2.93° (left). Dental tipping negligible.	Skeletal expansion ~96%; minimal alveolar bending (~0.3%).	MARPE produced almost exclusively skeletal expansion, suitable for both young and adult patients.

Study	Participants	Intervention	Primary Outcome	Secondary Outcome	conclusion
Shetty [18]	24 participants (Ages ≤16: 11; Ages >16: 13)	MARPE with Dolphin CBCT superimposition for pre- and post-expansion measurements.	Skeletal expansion: 2.82 mm (young group), 2.14 mm (older group). Posterior expansion greater in younger group.	Buccal bone resorption: 0.14–0.40 mm, not significant.	MARPE was effective with minimal dental effects; younger patients showed slightly greater expansion.
Mendoza [19]	60 participants (MARPE: 20, Hyrax: 21, Control: 19, Ages: ~13.3–13.9)	CBCT at pre-treatment, post-expansion, and post-treatment stages.	Airway volume increased significantly post-expansion (MARPE and Hyrax). Nasopharyngeal volume increased long-term only in MARPE.	Similar airway effects for MARPE and Hyrax post-treatment.	MARPE provided long-term nasal cavity expansion benefits compared to Hyrax.
Storto [20]	28 participants (10 men, 18 women, Ages: 15–37)	MARPE with CBCT pre- and post-expansion. Correlations between success, age, and other factors analyzed.	Success rates: 83.3% (ages 15–19), 81.8% (ages 20–29), 20% (ages 30–37). Negative correlation between age and success.	Failures correlated with advanced suture maturity (stage D/E).	MARPE success is age-dependent, with reduced success in patients >30 years.
Winsauer [21]	60 participants (MARPE: 30, Control: 30, Ages: ~12.3–18.1)	MARPE and Hyrax activated at 0.5 mm/day; CBCT pre- and post-expansion.	Skeletal/dental expansion ratio: MARPE: 61.4%/38.6%, Hyrax: 32.2%/67.8%.	MARPE reduced dental tipping and alveolar bone loss compared to Hyrax.	MARPE showed better skeletal outcomes with less dental and alveolar impact, making it a superior alternative to Hyrax.
YI 2022 [22]	33 participants (10 men, 23 women, Ages: 18–58, Mean: 29.1 ± 10.2)	MARPE with CBCT post-expansion. Predictive variables for failure analyzed.	Success rate: 84.4%; failure correlated with older age (p = 0.019).	Anterior V-pattern suture opening in 22/25 successful cases.	MARPE success decreases with age but remains effective in most adults.
YI 2020 [23]	24 participants (MSE: 14, Control: 10)	MARPE with sleep apnea tests and QSQ questionnaire pre- and 6 months post-expansion.	Daytime sleepiness and quality of life improved; apnea-hypopnea index reduced by 65.3%.	35.7% of participants had apnea-hypopnea index <5 post-treatment	MARPE provided significant respiratory and quality-of-life benefits.
Yilmaz [24]	215 participants (95 men, 120 women, Ages: 6–60, Mean: 20 ± 7.3)	Retrospective CBCT analysis for MARPE outcomes.	Success rate: 61.05% in men, 94.17% in women. Significant age-related failures in men (p < 0.001).		MARPE is more successful in younger patients and women; older men face reduced success.
Zong [25]	60 participants (MARPE: 20, Hyrax: 21, Control: 19)	Retrospective CBCT analysis from randomized trial (2–3 years post-expansion).	Nasal and maxillary transverse widths increased significantly with MARPE and Hyrax.	Long-term: Posterior nasal cavity width increased only with MARPE.	MARPE and Hyrax positively impacted nasal dimensions; MARPE showed more durable effects.
Chane-Fane [26]	10 participants (Ages: 18–30)	MARPE with facial soft tissue and airway volume analysis using Romexis software.	Airway volume increased from 19.20 to 22.25, but not significant. Soft tissue parameters (H angle) showed significant changes.		MARPE caused minor airway and soft tissue changes; effective for transverse maxillary deficiencies.
Annarumma [27]	15 participants (Mean Age: 17 ± 4)	MARPE activated 0.26 mm/day until full expansion. CBCT and impressions pre- and post-expansion.	Nasal and maxillary skeletal widths increased (2.1–2.5 mm).	Alveolar bone thickness reduced by ~0.3 mm across all teeth.	MARPE provided primarily skeletal expansion with minor alveolar effects.

Study	Participants	Intervention	Primary Outcome	Secondary Outcome	conclusion
Moslah [28]	25 participants (Ages: 15–29, Mean: 19.84 ± 3.96)	MARPE with CBCT for suture density and maturation analysis. Spearman correlation for expansion predictors.	Expansion correlated negatively with age and suture maturity.	Palatal suture density ratios also negatively correlated with expansion.	Age, suture maturity, and density significantly affect MARPE outcomes.
Shin [34]	34 participants (8 men, 26 women, Ages: 17.1–56, Mean: 27 ± 9.4)	MARPE with 3D custom design and palatal mini-screws. CBCT pre- and post-expansion.	Skeletal contribution: 60.4% at molars, 92.2% at premolars.	Significant nasal cavity expansion; minor alveolar thickness loss (0.31 mm).	MARPE achieved high skeletal expansion rates with minimal dental and alveolar side effects.

DISCUSSION

Skeletal Expansion with MARPE

The studies included in this review consistently demonstrate that Mini-Screw Assisted Rapid Palatal Expansion (MARPE) results in a higher proportion of skeletal expansion compared to traditional palatal expanders. Numerous studies [5, 35] report that MARPE yields approximately 60% skeletal expansion, which is a significant advantage over the Hyrax and other traditional expanders, which generally produce a smaller proportion of skeletal changes. This higher skeletal contribution results in more stable and predictable maxillary expansion, as it is driven by actual bone growth at the suture level, reducing the likelihood of relapse compared to dental-based expansion methods.

Additionally, Mendoza *et al*., [36] demonstrated that MARPE is effective in obtaining skeletal expansion in mature patients, even those with partially fused palatal sutures. This underscores the potential of MARPE to address maxillary transverse deficiencies in skeletally mature patients, who traditionally present more challenges with conventional methods.

Dento-Alveolar Effects of MARPE

The dento-alveolar effects of MARPE were also a focal point in several studies. Compared to traditional expanders like Hyrax, MARPE tends to cause minimal dental tipping and alveolar bone flexion. For example, Lim *et al*., [35] showed that Hyrax devices, which apply force directly to the teeth, result in more significant buccal tipping of molars and greater dental inclination. This highlights the advantage of MARPE in limiting the excessive dental movement that often accompanies conventional expansion techniques. By applying the expansion forces to the skeleton, MARPE minimizes the unwanted effects on the teeth and alveolar bone.

This is corroborated by studies like Mendoza *et al*., [36], which observed that only a small portion of the expansion (around 40%) is due to dental and alveolar changes, with the majority attributed to skeletal expansion. This can lead to better long-term stability of the treatment, as the dental structures are less affected by excessive movements.

Effects on Vertical Dimensions

Another critical aspect of palatal expansion, particularly when using traditional RPE, is the potential for vertical changes, such as open bite or extrusion of the posterior teeth. MARPE, however, has shown minimal vertical effects due to its skeletal anchorage. Studies such as Yilmaz *et al*., [37] and Lagravère [6] suggest that traditional RPE methods can result in a downward and forward movement of the maxilla, contributing to vertical opening of the bite. In contrast, MARPE is more effective at maintaining vertical dimensions, making it a preferable option for patients who are hyperdivergent or at risk of developing bite opening.

Mid-Palatal Suture Opening Patterns

The mid-palatal suture opening patterns achieved by MARPE have been a subject of debate. Studies comparing Hyrax and MARPE devices have found differing suture opening patterns. Hyrax typically causes a V-shaped opening, where the anterior part of the suture opens more than the posterior portion, leading to a triangular expansion. Conversely, MARPE, with its skeletal anchorage, tends to produce a more parallel opening, which can be more favorable in certain cases, especially for posterior maxillary expansion.

The design of MARPE, including the placement of mini-implants, plays a crucial role in determining whether the suture opens in a V or a parallel pattern. A more posterior mini-screw placement appears to favor a parallel opening, which can be beneficial in terms of achieving a more symmetrical expansion. However, as seen in some studies, even MARPE may still exhibit some asymmetry in suture opening depending on factors such as implant placement, bone density, and application of force.

Airway Effects of MARPE

A notable advantage of MARPE is its positive impact on the nasal and pharyngeal airways. Studies such as Mehta *et al*., [38] and Shetty *et al*., [39] show that MARPE significantly increases airway volume, especially in the nasal cavity. This improvement is attributed to the skeletal expansion achieved by MARPE, which helps to widen the palatal suture, potentially improving nasal breathing. Moreover, MARPE's effect on the airway appears to be more long-lasting compared to other expansion techniques like Hyrax.

Furthermore, MARPE has shown promise in treating conditions such as obstructive sleep apnea (OSA), with Brunetto *et al*., demonstrating that MARPE can improve airway patency, reduce snoring, and decrease the Apnea-Hypopnea Index (AHI) in patients with maxillary transverse deficiency. These findings underscore the multifaceted benefits of MARPE, addressing maxillary expansion and improving respiratory function and sleep quality.

Symmetry of Expansion and Challenges

Despite the advantages of MARPE, achieving perfectly symmetrical expansion remains a challenge. Various studies have highlighted the potential for asymmetry due to factors such as mini-screw placement, bone density variations, and uneven force distribution. Although MARPE offers an advantage over Hyrax in terms of skeletal anchorage, which can reduce asymmetry, some degree of asymmetry can still occur. Careful planning and customized mini-screw placement are essential to minimizing these risks and achieving more symmetrical results.

Side Effects of MARPE

Like any medical procedure, MARPE is not without its risks. Alveolar bone resorption is a potential side effect of the treatment, particularly in the vestibular alveolar bone. Studies such as Park *et al*., [40] have shown that while vestibular alveolar bone loss is minimal in most cases, it remains an important consideration when planning MARPE treatment. Additionally, studies on root length changes have shown minimal impact on root lengths, but there is still some potential for root resorption, especially in cases where the forces applied are too high.

Factors Influencing MARPE Success

While MARPE is effective across a wide age range, its success is influenced by several key factors, as evidenced by the studies reviewed:

Age: Age is one of the most significant factors influencing the effectiveness of MARPE. Younger patients, particularly those under 20 years old, show a better response to the treatment, with a higher proportion of skeletal expansion. This is because younger patients have more pliable sutures that allow for more effective skeletal remodeling. In contrast, older patients exhibit more resistant sutures that make skeletal expansion more difficult, often resulting in a greater reliance on dental expansion.

Studies by Yi *et al*., [41] and Oliveira *et al*., [42] found that the maturation of the mid-palatal suture plays a crucial role in the success of MARPE, with the rigidity of the suture in older individuals significantly impacting the outcome.

Mid-Palatal Suture Maturation and Suture Density: The maturation and density of the mid-palatal suture are critical predictors of the success of MARPE. Yi *et al*., observed a negative correlation between the maturation of the mid-palatal suture (MPSM) and the amount of skeletal expansion achieved. Denser sutures in older patients are associated with less expansion, while younger patients with less dense sutures show greater success. Additionally, high MPSD (Mid-Palatal Suture Density Ratio) is associated with reduced expansion, particularly in the posterior part of the suture.

Length and Depth of the Palate: The palatal length and depth are emerging as significant factors in the success of MARPE. Shin *et al*., [34] identified palatal length as a predictor of expansion success, with longer palates showing delayed expansion in the anterior region. The depth of the palate, though less consistently significant, is suggested by some studies to influence the efficiency of suture opening and overall expansion.

Design of the Expander and Anchorage: The design of the MARPE device and the type of anchorage used are also critical factors. Bicortical anchorage, where mini-implants are placed in both cortical bones, has been shown to provide greater stability and more efficient expansion. Studies like Yi *et al*., [41] demonstrated that bicortical anchorage improved MARPE success, while others like Oliveira *et al*., [42] found no significant difference between bicortical and monocortical anchorage. The rigidity of the expander itself also influences outcomes, with rigid expanders being particularly beneficial for older patients who have more resistant sutures.

Application of Force and Protocol: The force applied during MARPE treatment, as well as the protocol used, also impact the outcomes. Two-step treatment protocols that involve gradual force application have been found to improve the success of the treatment by allowing for more controlled expansion and reducing the risk of unwanted side effects, such as dental tipping or alveolar bone resorption.

CONCLUSION

Mini-Screw Assisted Rapid Palatal Expansion (MARPE) represents a significant breakthrough in the treatment of maxillary transverse deficiencies, offering a highly effective alternative to traditional methods. Studies show that MARPE provides a higher proportion of skeletal expansion, with minimal dental movement, leading to more stable and predictable results. However, complications such as alveolar bone resorption and potential impacts on root length remain concerns.

The success of MARPE is influenced by several key factors, including age, palatal suture maturation, and bone density. Younger patients generally experience more favorable outcomes, though MARPE has proven effective even in adults.

To optimize the success of MARPE, a personalized approach is essential. This includes assessing individual patient characteristics, such as age and skeletal maturity, and customizing the device design and expansion protocol. By considering these factors, practitioners can maximize the treatment's effectiveness, minimize side effects, and provide better long-term results.

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