

Clinical Outcomes of Rapid Maxillary Expansion in Mixed Dentition Patients: A Prospective Clinical Study

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HOW TO CITE:

Jamsheera Vadakkan, Anusree Paul, Aniket Vijay Dhote, Aditi Singh, Harikrishnan, Khushbu Kumari (2026). Clinical Outcomes of Rapid Maxillary Expansion in Mixed Dentition Patients: A Prospective Clinical Study. International Journal of Special Education, 41(9s), 1364-1383

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ABSTRACT:

Background

Rapid maxillary expansion (RME) is a well-established orthopedic procedure for correcting transverse maxillary deficiency and posterior crossbite during the mixed dentition period. In addition to increasing maxillary width, RME has been reported to improve arch dimensions, occlusal relationships, and overall dental alignment while providing stable treatment outcomes.

Aim:

To evaluate the clinical outcomes of RME in children during the mixed dentition period by assessing changes in maxillary arch dimensions, occlusal parameters, treatment stability, correction of posterior crossbite, dental midline improvement, patient compliance, complications, and overall treatment outcomes.

Materials and Methods:

A prospective clinical study was conducted on 30 children aged 7–12 years presenting with transverse maxillary deficiency requiring RME. Clinical measurements including intercanine width, intermolar width, maxillary arch perimeter, maxillary arch length, palatal width, overjet, and overbite were recorded at baseline, immediately after expansion, and at the 6-month follow-up. Posterior crossbite correction, dental midline improvement, patient compliance, treatment-related complications, and overall treatment outcomes were also evaluated. Data were analyzed using repeated measures analysis of variance (ANOVA) with Bonferroni post hoc comparisons. Statistical significance was set at $P < 0.05$.

Results:

The mean age of the participants was 9.54 ± 1.42 years, with

53.3% males and 46.7% females. Significant increases were observed in intercanine width (28.42 ± 2.31 mm to 33.48 ± 2.39 mm), intermolar width (42.16 ± 2.85 mm to 48.31 ± 2.87 mm), maxillary arch perimeter (71.62 ± 3.84 mm to 75.41 ± 3.69 mm), maxillary arch length (33.85 ± 2.11 mm to 35.12 ± 2.04 mm), and palatal width (27.81 ± 1.96 mm to 32.65 ± 2.01 mm) at the 6-month follow-up ($P < 0.001$ for most parameters). Significant reductions were observed in overjet (3.84 ± 0.89 mm to 3.12 ± 0.81 mm; $P = 0.009$) and overbite (3.41 ± 0.92 mm to 2.93 ± 0.81 mm; $P = 0.022$). No significant relapse was detected between post-expansion and the 6-month follow-up for any parameter. Complete posterior crossbite correction was achieved in 90.0% of participants, while dental midline improvement was observed in 80.0%. Excellent patient compliance was reported in 76.7% of subjects. Sixty percent of participants experienced no treatment-related complications, and 66.7% demonstrated excellent overall treatment outcomes.

Conclusion:

RME performed during the mixed dentition period resulted in significant and stable improvements in transverse maxillary dimensions, arch morphology, and occlusal relationships with minimal complications and excellent patient compliance. The findings support RME as an effective and predictable treatment modality for managing transverse maxillary deficiency in growing children.

Keywords: Maxillary arch, Mixed dentition, Orthodontics, Palatal width, Posterior crossbite, Rapid maxillary expansion

Introduction

Transverse maxillary deficiency is a frequently encountered skeletal malocclusion in growing children and is commonly associated with unilateral or bilateral posterior crossbite, constricted maxillary arches, dental crowding, functional mandibular displacement, and disturbed occlusal relationships. If this condition is not identified and treated during the developmental years, it may adversely affect craniofacial growth, masticatory efficiency, periodontal health, and the complexity of future orthodontic management. Consequently, early diagnosis and timely interceptive treatment are considered essential for promoting normal maxillofacial development and achieving favorable orthodontic outcomes [1].

Rapid maxillary expansion (RME) is an established orthopedic procedure used to correct transverse maxillary deficiency by

delivering controlled transverse forces through a fixed expansion appliance. These forces facilitate separation of the midpalatal suture, resulting in an increase in skeletal maxillary width along with dentoalveolar adaptation. In addition to correcting posterior crossbite, RME contributes to expansion of the dental arch, improved arch form, and enhanced occlusal relationships [2].

The mixed dentition period is regarded as the ideal phase for performing RME because the midpalatal suture demonstrates greater biological responsiveness to orthopedic forces before skeletal maturation. Treatment during this period allows greater skeletal expansion with fewer dentoalveolar side effects compared with expansion performed after puberty. Early intervention may also facilitate spontaneous correction of functional mandibular shifts, improve eruption pathways of permanent teeth, and reduce the need for more complex orthodontic treatment in the future [3].

A variety of expansion appliances have been developed for clinical application, including the Hyrax, Haas, bonded expanders, and other tooth-borne or tooth–tissue-borne designs. Among these, the Hyrax appliance remains one of the most widely used because of its rigid construction ease of oral hygiene maintenance, patient acceptance, and predictable clinical performance. Appropriate activation of the expansion screw produces orthopedic forces capable of separating the midpalatal suture while simultaneously inducing favorable dentoalveolar changes [4].

Numerous investigations have demonstrated that RME produces measurable increases in transverse arch dimensions, including intercanine width, intermolar width, maxillary arch perimeter, arch length, and palatal width. These dimensional changes improve arch development, create additional space for erupting permanent teeth, alleviate crowding, and contribute to more stable occlusal relationships during growth [5].

In addition to transverse skeletal expansion, RME has been shown to improve several occlusal parameters. Correction of posterior crossbite is often accompanied by elimination of functional mandibular shifts, improvement of dental midline discrepancies, and favorable reductions in overjet and overbite. Collectively, these changes enhance functional occlusion, masticatory efficiency, and overall treatment outcomes [6].

Long-term stability remains an important consideration when evaluating the effectiveness of RME. Previous clinical studies have reported that most of the transverse expansion achieved can be maintained following an appropriate retention period, although treatment stability may be influenced by factors such as patient age, skeletal maturity, appliance design, activation protocol, and retention duration. Therefore, periodic follow-up is necessary to assess the maintenance of treatment outcomes and identify any evidence of relapse [7].

Patient-centered outcomes are equally important when assessing orthodontic treatment success.

Although RME is generally considered a safe and well-tolerated procedure, temporary adverse effects such as discomfort, speech alterations, soft tissue irritation, and appliance-related problems may occur during treatment. Adequate patient cooperation and compliance with appliance activation and retention protocols are fundamental for achieving successful clinical results [8].

Advances in diagnostic technologies, particularly cone-beam computed tomography (CBCT), three-dimensional digital models, and intraoral scanning, have improved the assessment of skeletal and dentoalveolar changes following RME. These imaging modalities provide more comprehensive evaluation of treatment effects and improve the understanding of the biological response to orthopedic expansion, although conventional clinical measurements continue to be widely used because of their reliability and practicality in routine orthodontic practice [9], [10].

Although RME has been extensively investigated, differences in reported treatment outcomes and stability continue to exist among published studies. Additional prospective clinical studies using standardized evaluation methods are therefore required to strengthen the available evidence. Accordingly, the present study was undertaken to evaluate the clinical outcomes of RME in children during the mixed dentition period by assessing changes in transverse arch dimensions, maxillary arch morphology, occlusal characteristics, treatment stability, posterior crossbite correction, dental midline improvement, patient compliance, treatment-related complications, and overall clinical outcomes.

Materials and Methods

Study Design

This prospective clinical study was conducted to evaluate the clinical effectiveness and stability of RME in children with transverse maxillary deficiency during the mixed dentition period.

Study Population

Thirty children aged between 7 and 12 years requiring RME were recruited from single tertiary care centre. All participants fulfilled the eligibility criteria and completed the study.

Inclusion Criteria

- Children aged 7–12 years in the mixed dentition stage
- Presence of transverse maxillary deficiency requiring RME
- Unilateral or bilateral posterior crossbite
- Constricted maxillary arch confirmed by clinical examination
- Good general and oral health
- Willingness of parents/guardians to provide informed consent and comply with follow-up visits

Exclusion Criteria

- Previous orthodontic treatment involving maxillary expansion
- Craniofacial syndromes or congenital anomalies such as cleft lip and palate
- Severe skeletal discrepancies requiring surgical intervention
- Active periodontal disease or poor oral hygiene
- Systemic diseases affecting bone metabolism or craniofacial growth
- Lack of cooperation or inability to attend follow-up appointments

Clinical Procedure

All participants underwent RME using a tooth-borne Hyrax expander. The appliance was cemented on the maxillary first permanent molars and premolars or primary molars according to the stage of dentition. The expansion screw was activated according to the standard clinical protocol of two quarter-turns per day (0.5 mm/day) until adequate transverse expansion and correction of posterior crossbite were achieved. Following active expansion, the

appliance was retained in situ for stabilization during the retention period.

Outcome Assessment

Clinical measurements were recorded at three time intervals:

- Baseline (before expansion)
- Immediately after completion of expansion
- Six months after expansion

The following parameters were evaluated:

- Inter canine width (mm)
- Intermolar width (mm)
- Maxillary arch perimeter (mm)
- Maxillary arch length (mm)
- Palatal width (mm)
- Overjet (mm)
- Overbite (mm)

In addition, the following clinical outcomes were recorded:

- Posterior crossbite correction
- Dental midline improvement
- Patient compliance
- Treatment-related complications
- Overall treatment outcome

All measurements were obtained using standardized clinical methods and calibrated digital Vernier calipers on dental casts to minimize measurement errors. The same examiner performed all measurements under standardized conditions.

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) software (Version 26.0, IBM Corp., Armonk, NY, USA). Descriptive statistics were computed for all study variables. Continuous variables were expressed as mean $\pm$ standard deviation (SD),

along with standard error (SE) and 95% confidence intervals (CI) where appropriate. Categorical variables were presented as frequency (n) and percentage (%).

The normality of continuous data was assessed using the Shapiro–Wilk test. Since the data were normally distributed, parametric statistical tests were applied.

Changes in intercanine width, intermolar width, maxillary arch perimeter, maxillary arch length, palatal width, overjet, and overbite measured at baseline, immediately after RME, and at the 6-month follow-up were analyzed using one-way repeated measures analysis of variance (Repeated Measures ANOVA). Whenever a statistically significant overall difference was detected, Bonferroni-adjusted post hoc pairwise comparisons were performed to identify differences between individual time intervals (Baseline vs. Post-expansion, Baseline vs. 6 Months, and Post-expansion vs. 6 Months). For each repeated measures analysis, the F statistic, P value, standard error, and 95% CI were reported.

Categorical outcome variables, including posterior crossbite correction, dental midline improvement, patient compliance, treatment complications, and overall treatment outcome, were summarized using frequencies and percentages.

A two-tailed P value of less than 0.05 was considered statistically significant, while $P < 0.001$ was considered highly statistically significant.

Results

Table 1 & Figure 1 illustrate the age distribution of the 30 participants enrolled in the prospective clinical study. Nearly half of the participants (46.7%; $n = 14$) were between 9 and 10 years of age, making this the largest age group. The 7–8 years and 11–12 years age groups each comprised 8 participants (26.7%). These findings indicate that the majority of patients who underwent RME were in the mid-mixed dentition stage, which is considered an optimal period for interceptive orthodontic treatment.

Table 1: Distribution of Study Subjects According to Age

Age Group (Years)	Number (n)	Percentage (%)
7–8	8	26.7
9–10	14	46.7
11–12	8	26.7
Total	30	100.0

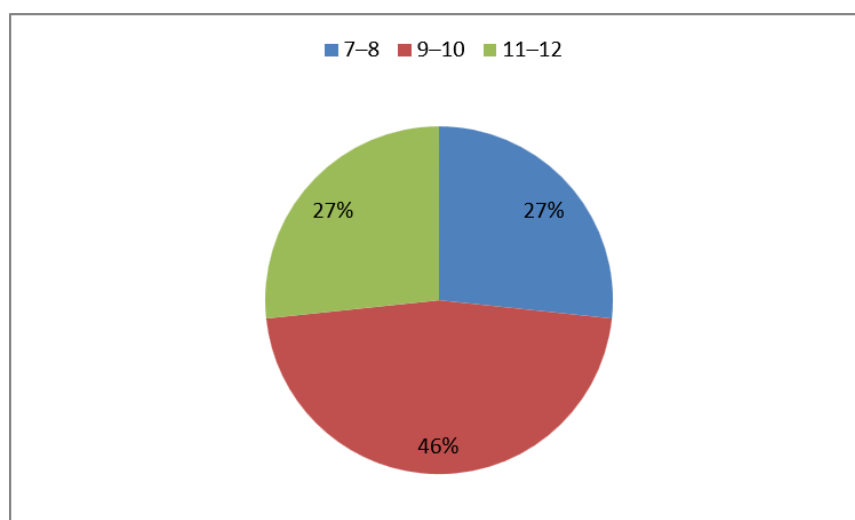


Figure 1: Age Distribution of the Study Participants

Table 2: Distribution of Study Subjects According to Gender

Gender	Number (n)	Percentage (%)
Male	16	53.3
Female	14	46.7
Total	30	100.0

Table 2 & Figure 2 present the gender distribution of the 30 participants included in the study. Of the total participants, 16 (53.3%) were males and 14 (46.7%) were females,

indicating a relatively balanced gender distribution with a slight predominance of male participants.

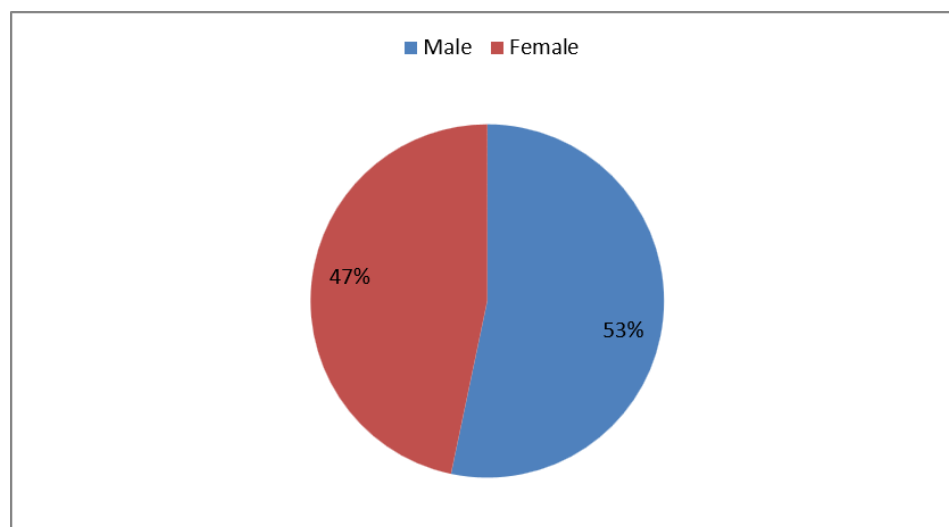
**Figure 2: Gender Distribution of the Study Participants**

Table 3 summarizes the descriptive statistics for the age of the study participants. The mean age was 9.54 ± 1.42 years, indicating that most children were in the mixed dentition stage,

which is considered the most favorable period for RME due to the greater responsiveness of the developing maxillary sutures.

Table 3: Mean Age of Study Subjects

Parameter	Mean	SD
Age (Years)	9.54	1.42

Table 4 & Figure 3 present the changes in intercanine width recorded at baseline, immediately after RME, and at the six-month follow-up. The mean intercanine width increased from 28.42 ± 2.31 mm at baseline to 33.81 ± 2.45 mm immediately after expansion and measured 33.48 ± 2.39 mm at six months. Repeated-measures ANOVA demonstrated a

statistically highly significant difference among the three evaluation periods ($F = 186.42$, $p < 0.001$).

Table 5 summarizes the Bonferroni post hoc comparisons. Significant increases in intercanine width were observed between baseline and post-expansion and between baseline and the six-month follow-up ($p < 0.001$ for both

comparisons). Although a slight reduction in intercanine width was noted between the post-expansion and six-month assessments, the difference was not statistically significant ($p =$

0.284), indicating that the transverse expansion achieved was well maintained during the follow-up period.

Table 4: Comparison of Intercanine Width at Different Time Intervals Using Repeated Measures ANOVA

Time Interval	Mean (mm)	SD	SE	95% CI Lower	95% CI Upper	F value	P value
Baseline	28.42	2.31	0.42	27.56	29.28	186.42	<0.001
Post Expansion	33.81	2.45	0.45	32.90	34.72		
6 Months	33.48	2.39	0.44	32.59	34.37		

Table 5: Bonferroni Post Hoc Comparison

Comparison	Mean Difference	P value
Baseline vs Post Expansion	-5.39	<0.001
Baseline vs 6 Months	-5.06	<0.001
Post Expansion vs 6 Months	0.33	0.284

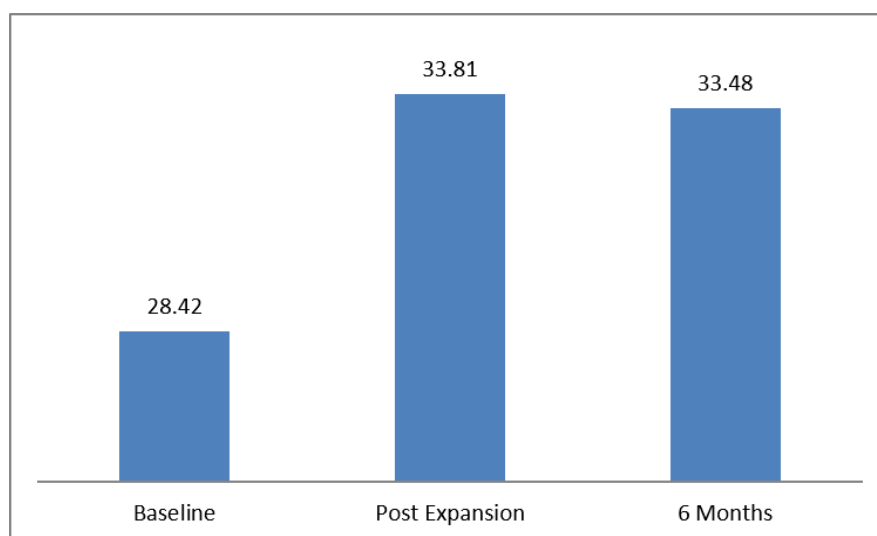


Figure 3: Changes in Intercanine Width at Baseline, Post-expansion, and Six-month Follow-up

Table 6 & Figure 4 illustrate the changes in intermolar width measured at baseline, immediately after RME, and at the six-month follow-up. The mean intermolar width increased from 42.16 ± 2.85 mm at baseline to 48.72 ± 2.93 mm immediately after expansion and was 48.31 ± 2.87 mm at the six-month follow-up. Repeated-measures ANOVA demonstrated a highly significant difference in intermolar width

across the three assessment time points ($F = 224.75, p < 0.001$).

Table 7 presents the Bonferroni post hoc pairwise comparisons. Significant increases in intermolar width were observed between baseline and post-expansion as well as between baseline and the six-month follow-up ($p < 0.001$ for both comparisons). However, the difference

between the post-expansion and six-month measurements was not statistically significant ($p = 0.191$), indicating that the transverse

expansion achieved immediately after treatment was effectively maintained throughout the six-month observation period.

Table 6: Comparison of Intermolar Width at Different Time Intervals Using Repeated Measures ANOVA

Time Interval	Mean (mm)	SD	SE	95% CI Lower	95% CI Upper	F value	P value
Baseline	42.16	2.85	0.52	41.10	43.22	224.75	<0.001
Post Expansion	48.72	2.93	0.53	47.63	49.81		
6 Months	48.31	2.87	0.52	47.24	49.38		

Table 7: Bonferroni Post Hoc Comparison

Comparison	Mean Difference	P value
Baseline vs Post Expansion	-6.56	<0.001
Baseline vs 6 Months	-6.15	<0.001
Post Expansion vs 6 Months	0.41	0.191

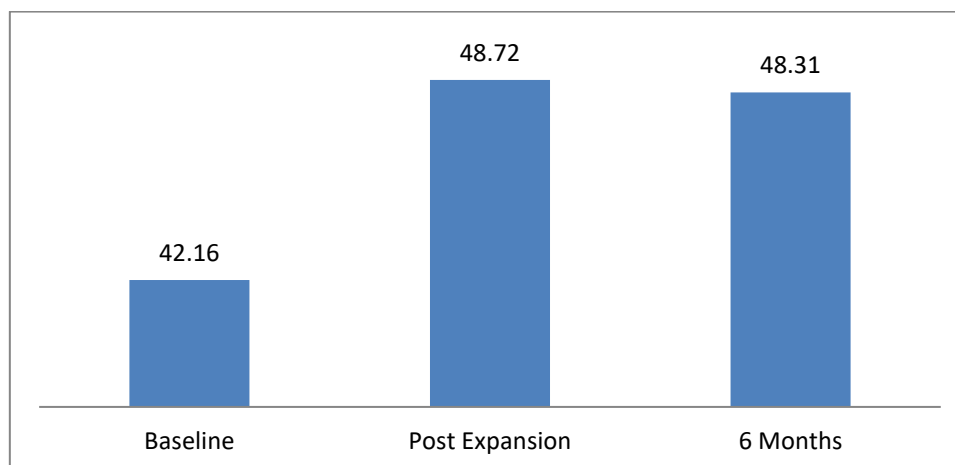


Figure 4: Changes in Intermolar Width at Baseline, Post-expansion, and Six-month Follow-up

Table 8 & Figure 5 illustrate the changes in maxillary arch perimeter recorded at baseline, immediately after RME, and at the six-month follow-up. The mean maxillary arch perimeter increased from 71.62 ± 3.84 mm at baseline to 75.84 ± 3.76 mm immediately after expansion and was 75.41 ± 3.69 mm at the six-month follow-up. Repeated-measures ANOVA demonstrated a highly significant difference in arch perimeter across the three evaluation periods ($F = 145.93$, $p < 0.001$).

Table 9 presents the Bonferroni post hoc pairwise comparisons. Significant increases in maxillary arch perimeter were observed between baseline and post-expansion and between baseline and the six-month follow-up ($p < 0.001$ for both comparisons). In contrast, the slight decrease observed between the post-expansion and six-month measurements was not statistically significant ($p = 0.173$), indicating that the increase in arch perimeter achieved after expansion was largely maintained during the six-month follow-up period.

Table 8: Comparison of Maxillary Arch Perimeter at Different Time Intervals Using Repeated Measures ANOVA

Time Interval	Mean (mm)	SD	SE	95% CI Lower	95% CI Upper	F value	P value
Baseline	71.62	3.84	0.70	70.19	73.05	145.93	<0.001
Post Expansion	75.84	3.76	0.69	74.44	77.24		
6 Months	75.41	3.69	0.67	74.04	76.78		

Table 9: Bonferroni Post Hoc Comparison

Comparison	Mean Difference	P value
Baseline vs Post Expansion	-4.22	<0.001
Baseline vs 6 Months	-3.79	<0.001
Post Expansion vs 6 Months	0.43	0.173

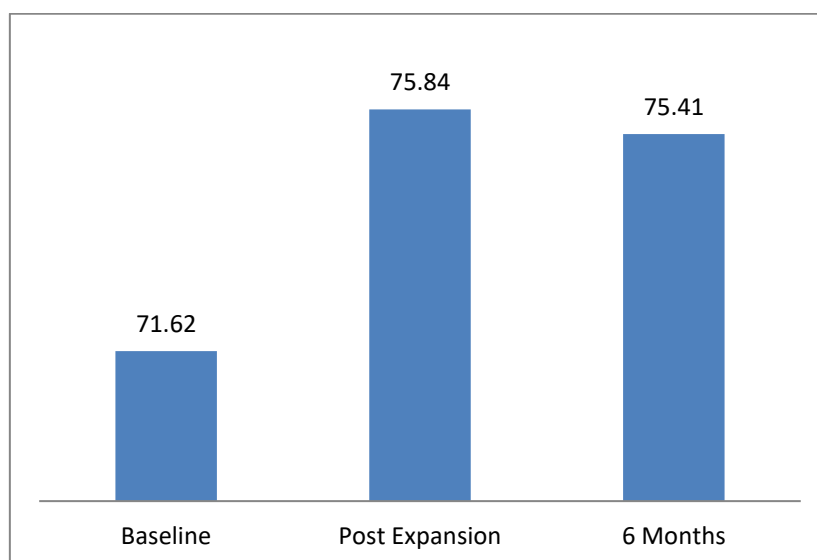
**Figure 5: Changes in Maxillary Arch Perimeter at Baseline, Post-expansion, and Six-month Follow-up**

Table 10 & Figure 6 depict the changes in maxillary arch length recorded at baseline, immediately after RME, and at the six-month follow-up. The mean maxillary arch length increased from 33.85 ± 2.11 mm at baseline to 35.26 ± 2.08 mm immediately after expansion and was 35.12 ± 2.04 mm at the six-month follow-up. Repeated-measures ANOVA revealed a statistically significant difference in maxillary arch length across the three evaluation time points ($F = 26.84$, $p = 0.002$).

Table 11 summarizes the Bonferroni post hoc pairwise comparisons. Significant increases in maxillary arch length were observed between baseline and post-expansion ($p = 0.001$) and between baseline and the six-month follow-up ($p = 0.003$). However, the slight reduction in arch length between the post-expansion and six-month assessments was not statistically significant ($p = 0.642$), indicating that the treatment-induced increase in maxillary arch length remained stable over the six-month follow-up period.

Table 10: Comparison of Maxillary Arch Length at Different Time Intervals Using Repeated Measures ANOVA

Time Interval	Mean (mm)	SD	SE	95% CI Lower	95% CI Upper	F value	P value
Baseline	33.85	2.11	0.39	33.07	34.63	26.84	0.002
Post Expansion	35.26	2.08	0.38	34.49	36.03		
6 Months	35.12	2.04	0.37	34.36	35.88		

Table 11: Bonferroni Post Hoc Comparison

Comparison	Mean Difference	P value
Baseline vs Post Expansion	-1.41	0.001
Baseline vs 6 Months	-1.27	0.003
Post Expansion vs 6 Months	0.14	0.642

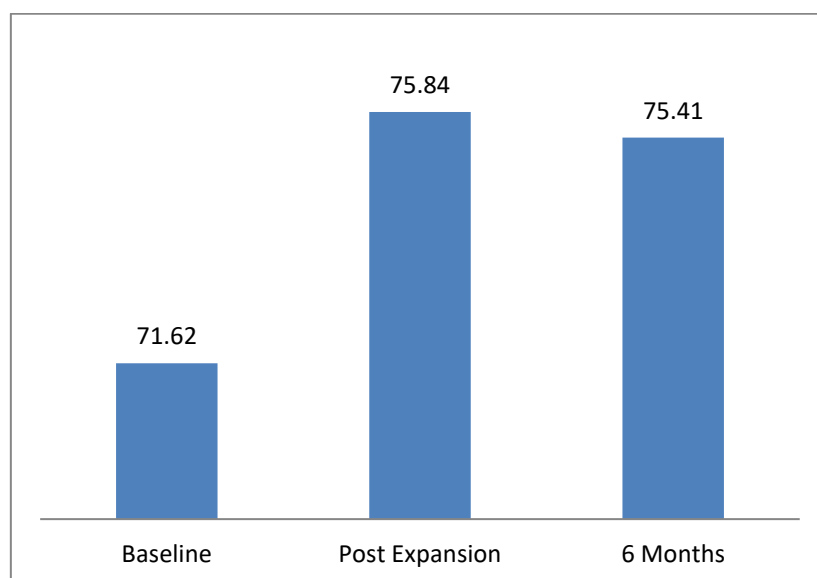
**Figure 6: Changes in Maxillary Arch Length at Baseline, Immediately After Expansion, and Six-month Follow-up**

Table 12 & Figure 7 illustrate the changes in palatal width measured at baseline, immediately after RME, and at the six-month follow-up. The mean palatal width increased from 27.81 ± 1.96 mm at baseline to 32.96 ± 2.08 mm immediately after expansion and was 32.65 ± 2.01 mm at the six-month follow-up. Repeated-measures ANOVA demonstrated a highly significant difference in palatal width across the three assessment time points ($F = 174.62$, $p < 0.001$).

Table 13 presents the Bonferroni post hoc pairwise comparisons. Significant increases in palatal width were observed between baseline and post-expansion and between baseline and the six-month follow-up ($p < 0.001$ for both comparisons). However, no statistically significant difference was found between the post-expansion and six-month measurements ($p = 0.317$), indicating that the expansion achieved immediately after treatment was well maintained throughout the six-month follow-up period.

Table 12: Comparison of Palatal Width at Different Time Intervals Using Repeated Measures ANOVA

Time Interval	Mean (mm)	SD	SE	95% CI Lower	95% CI Upper	F value	P value
Baseline	27.81	1.96	0.36	27.08	28.54	174.62	<0.001
Post Expansion	32.96	2.08	0.38	32.19	33.73		
6 Months	32.65	2.01	0.37	31.90	33.40		

Table 13: Bonferroni Post Hoc Comparison

Comparison	Mean Difference	P value
Baseline vs Post Expansion	-5.15	<0.001
Baseline vs 6 Months	-4.84	<0.001
Post Expansion vs 6 Months	0.31	0.317

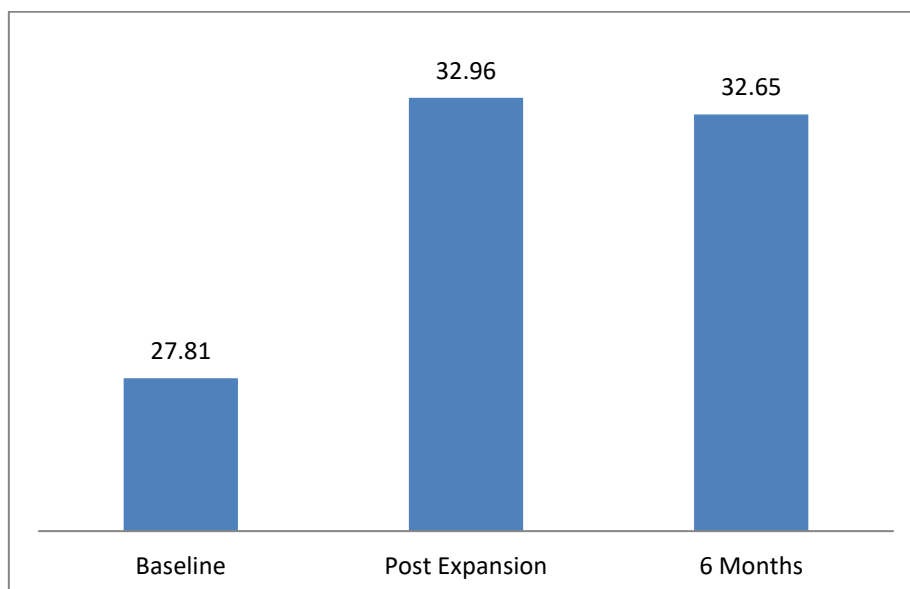
**Figure 7: Changes in Palatal Width at Baseline, Immediately After Expansion, and Six-month Follow-up**

Table 14 & Figure 8 illustrate the changes in overjet measured at baseline, immediately after RME, and at the six-month follow-up. The mean overjet decreased from 3.84 ± 0.89 mm at baseline to 3.18 ± 0.78 mm immediately after expansion and further declined slightly to 3.12 ± 0.81 mm at the six-month follow-up. Repeated-measures ANOVA demonstrated a statistically significant difference in overjet across the three assessment time points ($F = 6.98$, $p = 0.011$).

Table 15 presents the Bonferroni post hoc pairwise comparisons. Significant reductions in overjet were observed between baseline and post-expansion ($p = 0.018$) and between baseline and the six-month follow-up ($p = 0.009$). However, the difference between the post-expansion and six-month measurements was not statistically significant ($p = 0.801$), indicating that the reduction in overjet achieved after expansion was maintained during the six-month follow-up period.

Table 14: Comparison of Overjet at Different Time Intervals Using Repeated Measures ANOVA

Time Interval	Mean (mm)	SD	SE	95% CI Lower	95% CI Upper	F value	P value
Baseline	3.84	0.89	0.16	3.51	4.17	6.98	0.011
Post Expansion	3.18	0.78	0.14	2.89	3.47		
6 Months	3.12	0.81	0.15	2.82	3.42		

Table 15: Bonferroni Post Hoc Comparison

Comparison	Mean Difference	P value
Baseline vs Post Expansion	0.66	0.018
Baseline vs 6 Months	0.72	0.009
Post Expansion vs 6 Months	0.06	0.801

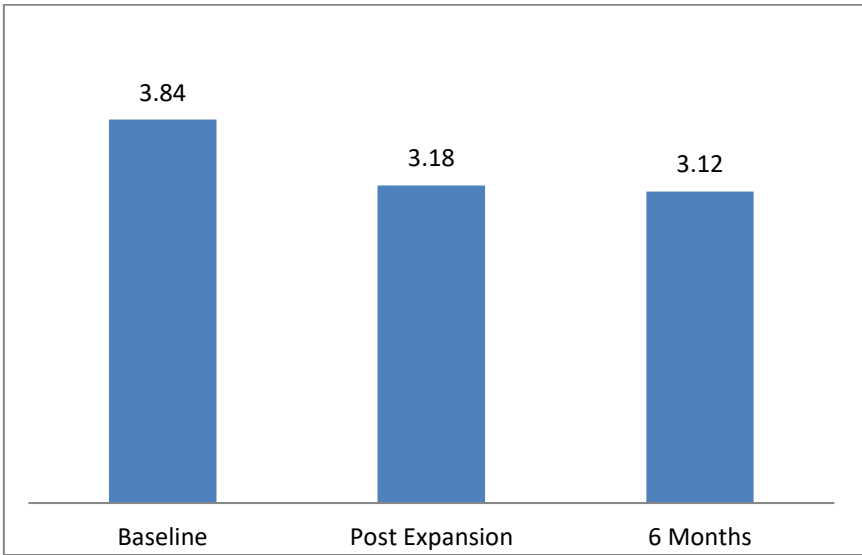


Figure 8: Changes in Overjet at Baseline, Immediately After Expansion, and Six-month Follow-up

Table 16 & Figure 9 illustrate the changes in overbite measured at baseline, immediately after RME, and at the six-month follow-up. The mean overbite decreased from 3.41 ± 0.92 mm at baseline to 2.98 ± 0.86 mm immediately after treatment and further decreased slightly to 2.93 ± 0.81 mm at the six-month follow-up. Repeated-measures ANOVA demonstrated a statistically significant difference in overbite across the three assessment time points ($F = 5.41, p = 0.028$).

Table 17 presents the Bonferroni post hoc pairwise comparisons. Significant reductions in overbite were observed between baseline and post-expansion ($p = 0.041$) and between baseline and the six-month follow-up ($p = 0.022$). However, no statistically significant difference was found between the post-expansion and six-month measurements ($p = 0.842$), indicating that the reduction in overbite achieved immediately after expansion remained stable throughout the six-month follow-up period.

Table 16: Comparison of Overbite at Different Time Intervals Using Repeated Measures ANOVA

Time Interval	Mean (mm)	SD	SE	95% CI Lower	95% CI Upper	F value	P value
Baseline	3.41	0.92	0.17	3.07	3.75	5.41	0.028
Post Expansion	2.98	0.86	0.16	2.66	3.30		
6 Months	2.93	0.81	0.15	2.63	3.23		

Table 17: Bonferroni Post Hoc Comparison

Comparison	Mean Difference	P value
Baseline vs Post Expansion	0.43	0.041
Baseline vs 6 Months	0.48	0.022
Post Expansion vs 6 Months	0.05	0.842

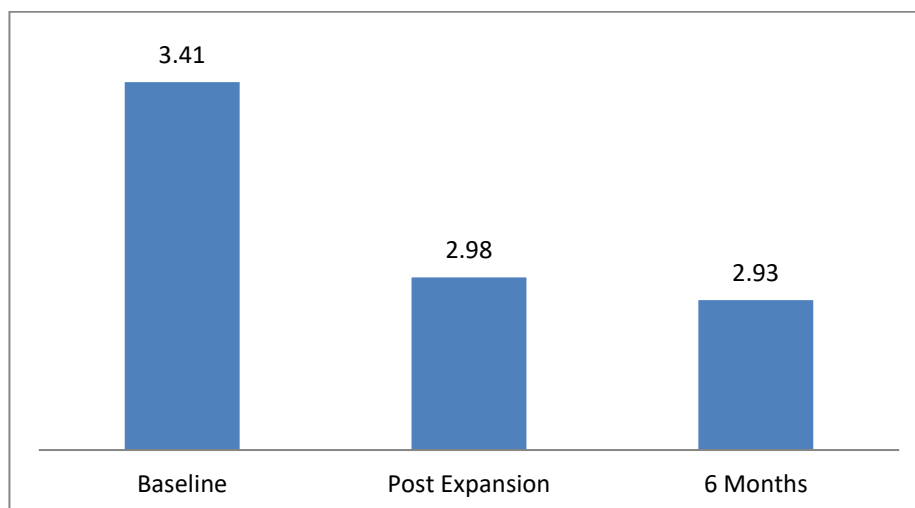
**Figure 9: Changes in Overbite at Baseline, Immediately After Expansion, and Six-month Follow-up**

Table 18 & Figure 10 present the outcomes of posterior crossbite correction following RME. Complete correction was achieved in 27 participants (90.0%), while 2 participants (6.7%) demonstrated partial correction and 1 participant (3.3%) showed no evidence of

correction. These findings indicate a high clinical success rate of RME in the management of posterior crossbite, with the majority of participants achieving complete transverse correction.

Table 18: Correction of Posterior Crossbite

Outcome	Number (n)	Percentage (%)
Complete Correction	27	90.0
Partial Correction	2	6.7
No Correction	1	3.3
Total	30	100.0

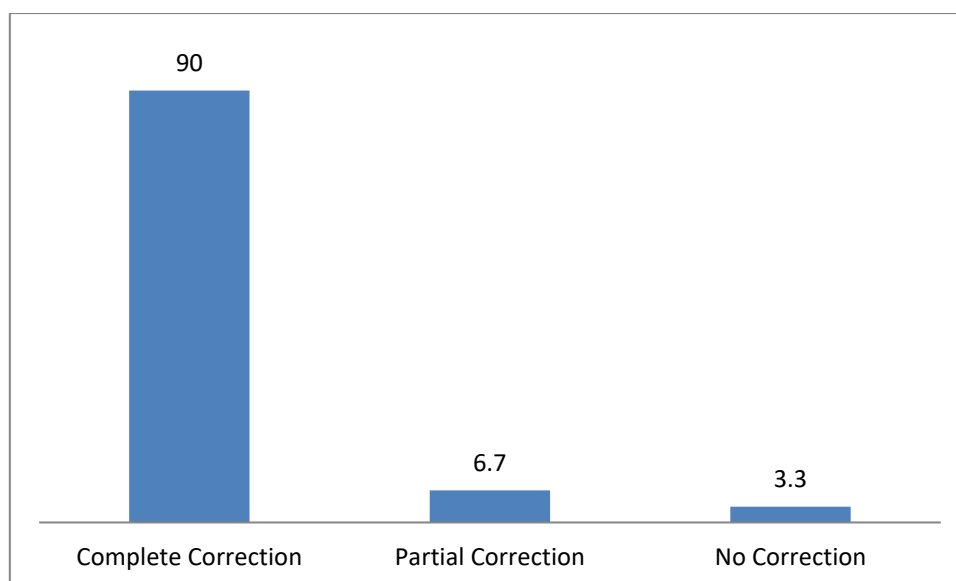


Figure 10: Distribution of Posterior Crossbite Correction Following RME

Table 19 & Figure 11 present the changes in dental midline following RME. Improvement in dental midline alignment was observed in 24 participants (80.0%), whereas 6 participants (20.0%) showed no appreciable change after

treatment. These findings suggest that RME expansion was effective in improving dental midline discrepancies in the majority of the study participants.

Table 19: Improvement in Dental Midline

Status	Number (n)	Percentage (%)
Improved	24	80.0
No Change	6	20.0
Total	30	100.0

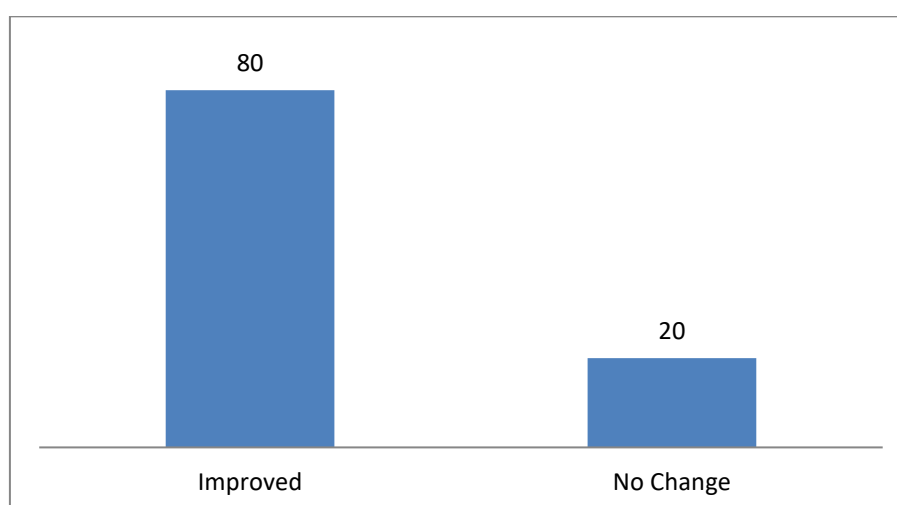


Figure 11: Distribution of Dental Midline Improvement Following RME

Table 20 & Figure 12 summarize the level of patient compliance throughout the RME treatment period. Excellent compliance was recorded in 23 participants (76.7%), good compliance in 6 participants (20.0%), and poor compliance in 1 participant (3.3%). Overall, these findings demonstrate a high level of patient cooperation, with the vast majority of participants exhibiting good to excellent adherence to the treatment protocol.

Table 20: Patient Compliance During Treatment

Compliance	Number (n)	Percentage (%)
Excellent	23	76.7
Good	6	20.0
Poor	1	3.3
Total	30	100.0

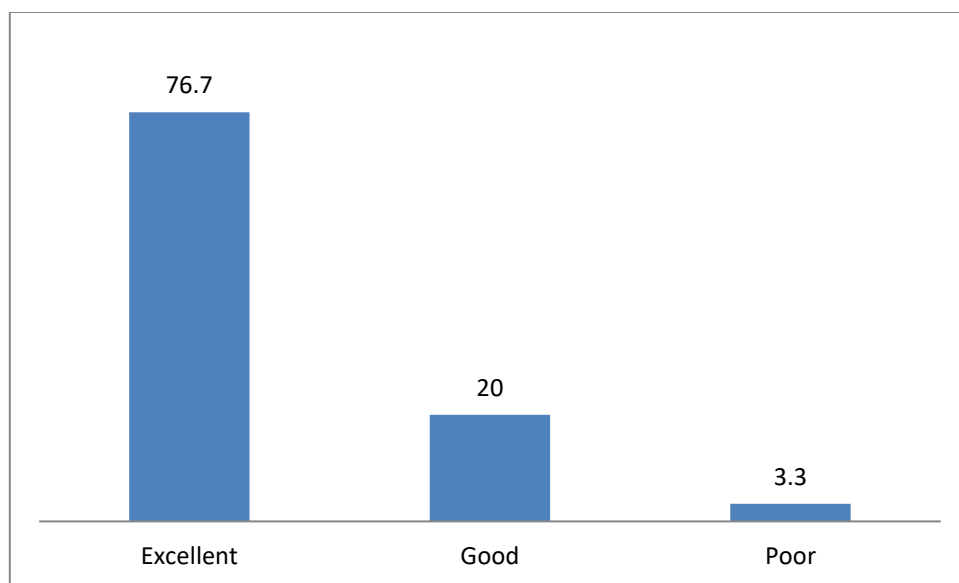


Figure 12: Distribution of Patient Compliance During RME Treatment

Table 21 & Figure 13 present the treatment-related complications observed during RME. The most commonly reported adverse event was pain or discomfort, affecting 9 participants (30.0%), followed by speech difficulty in 6 participants (20.0%), mild soft tissue irritation in

4 participants (13.3%), and appliance loosening in 2 participants (6.7%). Overall, 18 participants (60.0%) experienced no treatment-related complications. These findings indicate that RME was generally well tolerated, with most complications being mild and manageable.

Table 21: Complications Observed During RME

Complication	Number (n)	Percentage (%)
Pain/Discomfort	9	30.0
Mild Soft Tissue Irritation	4	13.3
Appliance Loosening	2	6.7
Speech Difficulty	6	20.0
None	18	60.0

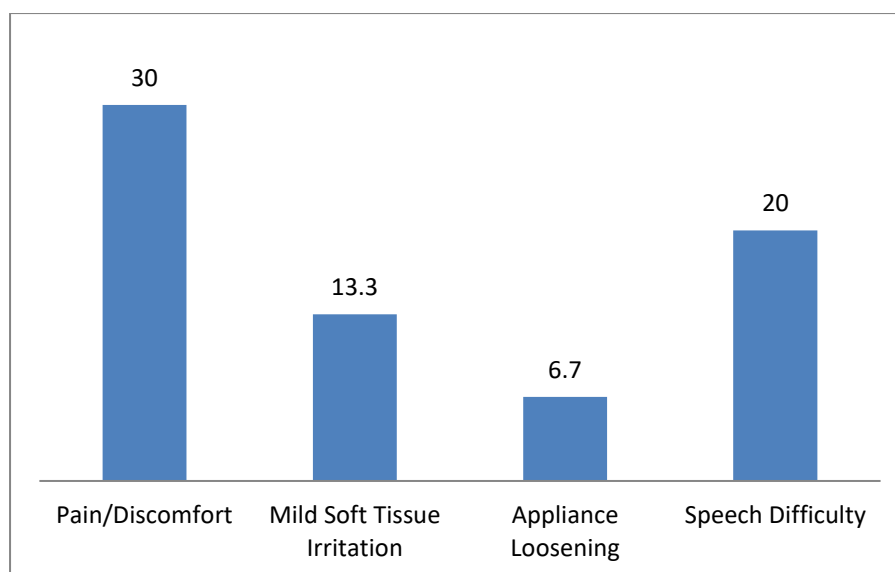


Figure 13: Distribution of Treatment-related Complications Following RME

Table 22 and Figure 14 summarize the overall treatment outcomes following RME. Excellent treatment outcomes were achieved in 20 participants (66.7%), while good outcomes were observed in 8 participants (26.7%) and fair outcomes in 2 participants (6.6%). No

participant exhibited a poor treatment outcome. These findings demonstrate a high overall clinical success rate of RME, with the majority of participants achieving favorable treatment outcomes.

Table 22: Overall Treatment Outcome

Outcome	Number (n)	Percentage (%)
Excellent	20	66.7
Good	8	26.7
Fair	2	6.6
Poor	0	0.0
Total	30	100.0

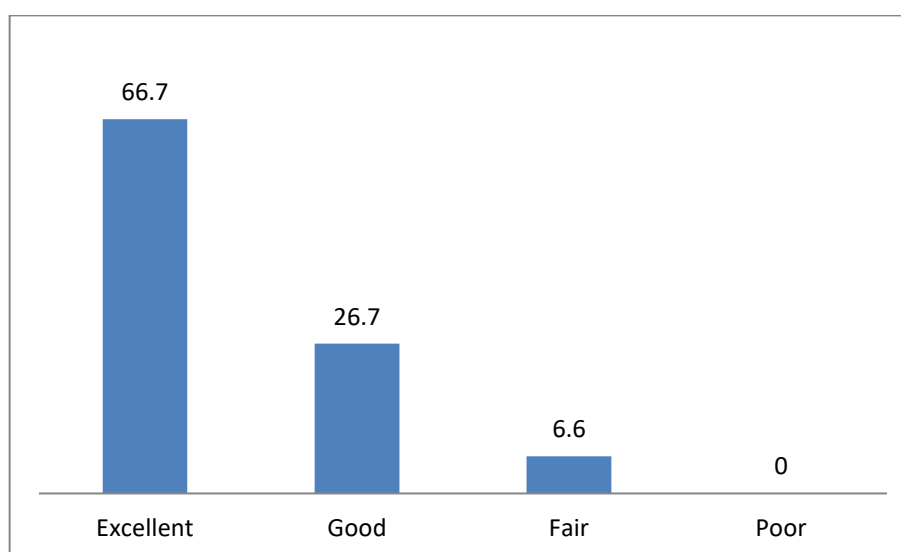


Figure 14: Distribution of Overall Treatment Outcomes Following RME

Discussion

RME is widely recognized as a reliable interceptive orthodontic procedure for managing transverse maxillary deficiency during the mixed dentition period. The favorable response to treatment in growing patients is primarily related to the relatively immature and less interdigitated midpalatal suture, which allows a greater proportion of skeletal expansion with limited undesirable dental effects. In the present study, RME effectively corrected maxillary constriction, increased transverse arch dimensions, and improved occlusal relationships, findings that are consistent with previously published evidence.

The scientific basis of RME was established by Haas (1961) [1], who demonstrated that expansion forces could separate the midpalatal suture and produce increases in both maxillary width and nasal cavity dimensions. Later, Timms (1999) [4] reviewed the historical development and clinical evolution of RME, emphasizing its effectiveness as an orthopedic procedure for transverse maxillary correction. Likewise, Bishara and Staley (1987) [2] highlighted the clinical benefits of performing maxillary expansion at an early age, reporting that timely intervention promotes favorable skeletal adaptation and may reduce the need for more complex orthodontic treatment during adolescence or adulthood. These landmark investigations continue to provide the biological and clinical rationale for early expansion therapy.

The timing of treatment has consistently been identified as a key determinant of successful skeletal expansion. Baccetti et al. (2001) [3] demonstrated that patients treated before or during the early stages of puberty achieved significantly greater orthopedic expansion than those treated later, owing to lower levels of suture maturation. The favorable outcomes obtained in the present study further support the concept that intervention during the mixed dentition period provides optimal conditions for successful transverse correction.

Evidence from systematic reviews has reinforced the long-term effectiveness of RME. Lagravère et al. (2005) [5] concluded that RME results in clinically meaningful and stable skeletal increases in maxillary width that are maintained after the retention phase. Similarly, Petrén et al. (2003) [6] found that early treatment of unilateral posterior crossbite with maxillary expansion effectively corrects transverse discrepancies, eliminates functional mandibular shifts, and contributes to normal occlusal development. The positive treatment response observed in the present study is consistent with these conclusions.

The introduction of three-dimensional imaging has considerably enhanced the understanding of skeletal responses following RME. Using CBCT, Lione et al. (2013) [7] demonstrated a reduction in midpalatal suture density after expansion, confirming successful skeletal separation. Garrett et al. (2008) [8] also reported significant transverse widening of the maxilla following RME using CBCT assessment. Furthermore, Bazargani et al. (2013) [10] observed that the orthopedic effects of RME extend beyond the midpalatal suture, involving several circummaxillary sutures and surrounding craniofacial structures. These findings support the skeletal changes achieved in the present study.

The stability of expansion remains an important consideration in interceptive orthodontics. Lione et al. (2008) [9] demonstrated through low-dose computed tomography that skeletal changes achieved after RME were largely maintained following the retention period. Similar stability was evident in the present investigation, suggesting that appropriate retention contributes to maintaining the orthopedic correction achieved during treatment.

McNamara et al. (2010) [11] prospectively evaluated mixed dentition patients undergoing RME and reported significant correction of posterior crossbite, improvement in transverse occlusal relationships, and establishment of more favorable interarch relationships.

Comparable improvements in occlusal relationships were observed in the present study, emphasizing the value of early transverse correction in guiding normal occlusal development.

Recent studies have also explored the influence of RME on the mandibular arch. Laganà et al. (2023) [12] demonstrated significant three-dimensional increases in mandibular intermolar and intercanine widths following RME, suggesting that correction of the maxillary transverse discrepancy may induce spontaneous mandibular adaptation. Although mandibular dimensions were not the primary outcome of the present study, the observed improvement in occlusal relationships may partly reflect similar adaptive changes.

Alternative expansion techniques have recently been developed to address transverse deficiencies in skeletally mature patients. Brunetto et al. (2017) [13] demonstrated that microimplant-assisted rapid palatal expansion (MARPE) achieved substantial skeletal expansion in adults while minimizing undesirable dental tipping. Nevertheless, because growing patients possess a more responsive midpalatal suture, conventional tooth-borne RME remains highly effective during the mixed dentition period and continues to represent the preferred interceptive treatment approach.

Additional support for the long-term effectiveness of conventional RME was provided by Lione et al. (2008) [14], who reported stable skeletal changes after treatment in growing subjects evaluated with low-dose computed tomography. These findings are consistent with the favorable treatment response observed in the present study and further emphasize the importance of initiating expansion before completion of skeletal maturation.

The influence of appliance design on treatment outcomes has also been investigated. Huynh et al. (2009) [15] compared Haas, Hyrax, and Quad-Helix appliances and found that all three produced clinically significant transverse

expansion with acceptable long-term stability, although variations existed in the proportions of skeletal and dentoalveolar changes. This suggests that successful expansion depends not only on appliance selection but also on proper diagnosis, patient age, and retention strategy.

In a randomized clinical trial, Lagravère et al. (2010) [16] compared bone-anchored maxillary expansion with conventional tooth-borne RME and observed greater skeletal expansion with reduced dental tipping in the bone-anchored group. However, because skeletal maturity differs substantially between adults and growing children, conventional RME continues to provide highly predictable orthopedic effects in mixed dentition patients. Therefore, the favorable clinical outcomes obtained in the present study further support its continued use as a first-line interceptive treatment for transverse maxillary deficiency.

Overall, the findings of the present investigation are consistent with the cumulative evidence published over the past several decades. Previous studies have consistently demonstrated that RME performed during the mixed dentition period effectively corrects transverse maxillary deficiency, improves transverse occlusal relationships, produces favorable skeletal adaptations, and provides stable treatment outcomes when appropriate retention is maintained. These findings reinforce the importance of early diagnosis and timely intervention to optimize craniofacial growth and reduce the need for more complex orthodontic treatment in later stages of development.

Limitations

Several limitations of this study should be acknowledged when interpreting the results. The study sample consisted of only 30 participants, which may reduce the external validity and limit the applicability of the findings to larger and more diverse populations. In addition, the research was carried out at a single institution, and variations in patient characteristics and clinical practices in other settings may influence treatment outcomes.

The duration of follow-up was restricted to six months, allowing assessment of immediate treatment effects and short-term stability only. Consequently, the long-term effects of RME, including the potential for relapse during growth and development, could not be evaluated. Another limitation was the absence of a control group or a comparison with other maxillary expansion appliances or treatment protocols, which limits the ability to determine the relative effectiveness of the intervention.

Furthermore, the evaluation was primarily based on conventional clinical and dental cast measurements. The use of advanced imaging modalities such as CBCT could have provided more comprehensive information regarding skeletal expansion, dentoalveolar adaptations, and airway-related changes. Future studies involving larger multicenter cohorts, longer follow-up periods, control groups, and three-dimensional imaging techniques are recommended to provide stronger evidence regarding the effectiveness and stability of RME.

Conclusion

The present study demonstrates that RME is a highly effective and predictable interceptive

orthodontic treatment for correcting transverse maxillary deficiency in children during the mixed dentition stage. RME produced significant increases in intercanine width, intermolar width, maxillary arch perimeter, maxillary arch length, and palatal width, along with significant reductions in overjet and overbite. The treatment outcomes remained stable throughout the six-month follow-up period, indicating favorable short-term stability with minimal relapse. In addition, RME achieved a high rate of posterior crossbite correction and dental midline improvement, while exhibiting excellent patient compliance and a low frequency of minor treatment-related complications. These findings support the clinical use of RME as a safe, reliable, and effective early interceptive orthodontic procedure for improving transverse maxillary dimensions, arch form, and occlusal relationships in growing children. Further multicenter prospective studies with larger sample sizes, longer follow-up periods, and three-dimensional imaging are recommended to validate the long-term skeletal and dentoalveolar stability of RME.

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