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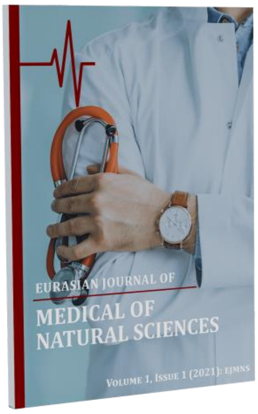

SHORT- AND LONG-TERM OUTCOMES OF USING A MAXILLARY EXPANDER WITH TONGUE CRIB IN GROWING PATIENTS WITH OPEN BITE AND SKELETAL CLASS II MALOCCLUSIONS: A RETROSPECTIVE STUDY

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ABSTRACT

This study aimed to assess the short- and long-term effects of rapid maxillary expansion (RME) in growing patients with Class II malocclusion and anterior open bite. A retrospective cohort study was conducted with 16 growing patients treated with a rapid maxillary expander (RME) combined with a crib (treatment group, TG) and 16 untreated patients with similar malocclusion (control group, CG). Cephalometric analyses were performed at three time points: before treatment (T0), at the end of the latency phase (T1), and prior to fixed appliance therapy (T2), to evaluate skeletal and dental changes in vertical, transverse, and sagittal dimensions. Statistical analysis was conducted with a significance level of α = 0.05.

At the end of active expansion (T1), all patients in the TG achieved corrected overbite, with statistically significant differences compared to the CG (p > 0.05). A significant reduction in jaw divergence was observed in the TG compared to the CG (p < 0.05). By T2, treated patients maintained proper overbite correction. Statistical analysis demonstrated significant reductions in maxillary, mandibular, and intermaxillary divergence in the TG compared to the CG (p < 0.05). This treatment protocol was effective for growing open-bite patients, resulting in a long-term reduction in facial divergence. The fixed crib contributed to normalizing myofunctional activity.

1. Introduction

Anterior open bite (AOB) is characterized by the absence of contact between the upper and lower anterior teeth, reflecting a vertical discrepancy in the alignment of dental arches or skeletal structures. Among children and adolescents, the prevalence of AOB is approximately 16.52%, increasing to 25–38% among patients seeking orthodontic treatment and up to 41.15% in those with non-nutritive sucking habits. Beyond its prevalence, AOB is recognized as one of the most challenging malocclusions to treat due to its impact on aesthetics, speech, and psychological well-being.

The etiology of AOB is multifactorial, involving both genetic and environmental factors. Environmental contributors include non-nutritive sucking habits, abnormal tongue posture, dietary practices, mouth breathing (often linked to enlarged adenoids or tonsils), and conditions affecting orofacial growth. Genetically, hyperdivergent skeletal growth patterns can exacerbate AOB, altering maxillary and mandibular relationships.

In addition to vertical discrepancies, AOB often coincides with transverse issues such as a narrow palatal vault, unilateral or bilateral crossbite, excessive buccal corridors, and lingual inclination of lower teeth. These conditions necessitate early treatment during the primary or mixed dentition stages to facilitate normal anterior dentoalveolar development.

Various therapeutic approaches have been proposed for early AOB correction, including functional appliances (e.g., open-bite Balters' Bionator), fixed devices (e.g., quad-helix or grid), and removable appliances (e.g., spring-loaded bite blocks or elastodontics). These treatments aim to limit vertical skeletal growth while addressing underlying contributing factors. Palatal cribs are commonly employed to prevent harmful habits such as thumb-sucking and tongue-thrusting.

In cases involving transverse maxillary deficiency, skeletal expansion is often recommended to correct maxillary constriction and enhance orofacial harmony. Additionally, behavioral management, speech therapy, and myofunctional treatments are critical components of comprehensive care. A rapid maxillary expander with a crib (RME/c) provides orthopedic effects on maxillary development while managing oral habits, effectively addressing AOB and improving aesthetics. However, challenges such as temporary speech impairment during the adjustment period highlight the need for professional oversight and interdisciplinary collaboration, particularly with speech therapists.

Although early intervention in growing AOB patients has shown variable long-term success, understanding the factors influencing outcomes is crucial. This study aimed to monitor both treated and untreated AOB patients over time, evaluate the effects of growth, and assess the impact of the RME/c protocol.

The primary goal of this study was to evaluate the long-term effects of a rapid maxillary expander with a crib on growing patients with anterior open bite. The null hypothesis was that no differences would exist between treated and untreated groups. The specific objective was to analyze skeletal and dental changes in vertical, transverse, and sagittal dimensions in growing patients with AOB and maxillary constriction undergoing RME/c treatment.

2. Materials and Methods

2.1. Study Design

This study was conducted as a retrospective cohort study, adhering to the ethical principles outlined in the Declaration of Helsinki. The research protocol was approved by the regional ethical review board of the Tashkent Medical Academy, Uzbekistan (approval number: n.143/2022).

2.2. Study Sample

The study analyzed lateral cephalograms (LC) from patients aged 7 to 12 years with anterior open-bite malocclusion who had received orthodontic treatment. The control group

(CG) consisted of untreated patients with anterior open bite, and their data were retrieved from the archives of the Uzbek Association of Orthodontists Foundation Craniofacial Growth Legacy Collection (http://www.aaoflegacycollection.org). Informed consent was obtained from all participants' parents, permitting the use of intraoral photographs and radiographic data for research purposes.

Inclusion Criteria:

1. Presence of a negative overbite.
2. Transverse maxillary deficiency with unilateral or bilateral crossbite.
3. Fully erupted first permanent molars.
4. Complete eruption of the permanent central incisors (Figure 1).
5. No history of permanent teeth extraction before or during treatment.
6. Prepubertal skeletal maturity stage determined using the cervical vertebral maturation method (CS1 or CS2).
7. Comprehensive radiographic records with adequate follow-ups.

Exclusion Criteria:

- Patients with facial malformations or syndromic conditions.
- Patients with a history of jaw trauma.

This stringent inclusion and exclusion process ensured the selection of a homogeneous sample for evaluating the effects of orthodontic intervention on anterior open-bite malocclusion.

Figure 1. Frontal intraoral view showing a patient with a negative overbite, transverse maxillary deficiency, and fully erupted upper incisors.

2.3. Data Collection Method

Baseline data collection included anamnestic and demographic information, radiographic imaging, and intraoral photographs. The treatment group (TG) followed a protocol involving rapid maxillary expansion with a crib (RME/c) (Figure 2). A two-banded rapid palatal expander (RPE) was bonded to the first permanent molars, with the expansion screw activated twice daily over a three-week period. Following the active expansion phase, the device remained in place for eight months to stabilize the achieved expansion (latency phase).

Lateral cephalograms were taken at three time points for both groups: prior to treatment (T0), at the end of the latency phase (T1, approximately 12 months after T0 for the control group), and before the initiation of fixed orthodontic therapy (T2, approximately five years after T0 for the control group). Cephalometric analyses were performed using Delta Dent software by two experienced investigators. The angular and linear cephalometric parameters analyzed are listed in Table 1.

Table 1. List of angular and linear cephalometric assessments.

Cephalometric Measurement (Unit of Measurement)	Calculation Method	Abbreviation
Sagittal analysis		
Position of the maxilla (°)	Angle: sella–nasion–point A	SNA
Position of the mandible (°)	Angle: sella–nasion–point B	SNB
Intermaxillary relationship (°)	Angle: point A–nasion–point B	ANB
Vertical analysis		
Vertical intermaxillary relationship (°)	Angle between palatal plane and mandibular plane	AnsPns.GoGn
Divergence of the maxilla (°)	Angle between sella–nasion plane and palatal plane	SN.AnsPns
Divergence of the mandible (°)	Angle between sella–nasion plane and mandibular plane	SN.GoGn
Gonial angle (°)	Angle: condylion–gonion–gnathion	CoGoMe
Dentobasal analysis		
Inclination of the lower incisors (°)	Angle between lower incisor axis and mandibular plane	L1.GoGn
Inclination of the upper incisors (°)	Angle between upper incisor axis and palatal plane	U1.AnsPns
Anteroposterior position of the lower incisor (mm)	Distance between pogonion and the projection of the lower incisor axis perpendicular to the Frankfurt plane	L1-Pg
Anteroposterior position of the upper incisor (mm)	Distance between anterior nasal spine and the projection of the upper incisor axis perpendicular to the Frankfurt plane	U1
Molar relationship (mm)	Relationship between upper and lower first molar	U6^L6
Overbite (mm)	Vertical distance between the margins of upper and lower incisors	OVB
Overjet (mm)	Horizontal distance between the margins of upper and lower incisors	OVJ

(°) = degrees; (mm) = millimeters; palatal plane = plane passing through the anterior nasal spine (Ans) and the posterior nasal spine (Pns); mandibular plane = plane passing through the gonion (Go) and gnathion (Gn) points; lower incisor axis = plane passing through the apical point of the inferior incisor (Ap1l) and the incisal point of the inferior incisor (In1l); upper incisor axis = plane passing through the apical point of the upper incisor (Ap1u) and the incisal point of the upper incisor (In1u) and palatal plane.

Vertical skeletal relationships were evaluated by measuring mandibular divergence (SN^GoGn), maxillary divergence (SN^ANS-PNS), and the maxillo-mandibular relationship (ANS-PNS^GoGn). Sagittal skeletal relationships were determined using the angles SNA, SNB, and ANB. Additionally, overjet and overbite values were recorded to assess dental relationships.

Figure 2. Occlusal view of a bonded rapid palatal expander equipped with a fixed palatal crib.

2.4. Study Variables

The primary predictor variable was the therapeutic approach, distinguishing the treatment group (TG) from the control group (CG).

The primary outcome variable focused on vertical skeletal and dental relationships, specifically SN^GoGn, ANS-PNS^GoGn, and overbite (OVB). Sagittal intermaxillary relationships and dentoskeletal features were defined as secondary outcome variables.

Additional study variables included patient demographics (age and gender), myofunctional issues, and changes observed across the three time intervals: T0–T1, T1–T2, and T0–T2.

2.5. Statistical Analysis

Sample size calculation was conducted with the following parameters: 80% power, a significance level of 0.05, a standard deviation of 1, and a mean difference of 1 mm. Based on this calculation, each group consisted of 16 subjects.

A dedicated Excel database (Microsoft, Redmond, WA, USA) was created for data management. Intra- and inter-rater agreement coefficients were calculated for the cephalometric measurements. Intra-rater reliability assessed the consistency of measurements taken by the same investigator after one month, while inter-rater reliability evaluated agreement between two investigators performing the same analysis.

Descriptive statistics were calculated for all cephalometric measurements at T0, T1, and T2 in both groups. For continuous quantitative variables, the mean and standard deviation were recorded for symmetric distributions, and the median with interquartile range was used for asymmetric distributions. Absolute and relative frequencies were reported for categorical data.

To compare outcomes across time points, bivariate analysis was performed using the paired Student's t-test for normally distributed data and the Wilcoxon test for non-normal distributions. Multivariate regression analysis was used to evaluate outcome variables in relation to recorded measurements, with the percentage of the R-squared coefficient reported for each model. The level of significance was set at $\alpha = 0.05$. All statistical analyses were conducted using STATA software (STATA 11, StataCorp, College Station, TX, USA).

3. Results

3.1. Study Sample

The study included 32 patients evenly distributed between the treatment group (TG) and the control group (CG). All participants exhibited dentoskeletal Class II malocclusion with a hyperdivergent growth pattern. The TG comprised 14 females (87.5%) and 2 males, with a mean age of 7.5 ± 0.5 years at T0. The CG consisted of 11 females (68.7%) and 5 males, with a mean age of 7.3 ± 0.7 years at T0.

A bilateral crossbite was present in most patients across both groups (62.5%). At T0, all participants were classified as being in the prepubertal skeletal maturity stage. In the TG, 37.5% of patients were categorized as CS1, and 62.5% as CS2. Conversely, in the CG, 62.5% were classified as CS1, and 37.5% as CS2.

3.2. Comparative Analysis

The inter-rater agreement coefficient was $\kappa = 0.91$, while the intra-rater agreement coefficient was $\kappa = 0.93$, indicating high reliability in cephalometric measurements. At T0, no significant differences were observed in cephalometric variables between the two groups. All patients had Class II malocclusion with increased vertical skeletal dimensions, anterior open bite, and transverse skeletal crossbite. By the end of the latency phase, maxillary contraction was corrected in all patients.

Bivariate statistical analysis results are summarized in Table 2. At T1, a significant reduction in jaw divergence was observed in the TG compared to the CG, based on vertical skeletal relationships ($p < 0.05$). Although the intermaxillary angle was lower in the TG than in the CG, the difference was not statistically significant ($p > 0.05$). All patients demonstrated an increased overbite, with a statistically significant difference between the TG and CG ($p < 0.05$). Positive overbite values were recorded exclusively in the TG.

Table 2. Bivariate comparative analysis between the treatment group and the control group at different time points.

	T0		p-Value	T1		p-Value	T1-T0		p-Value	T2		p-Value	T2-T1		p-Value	T2-T0		-Value
	TG	CG		TG	CG		TG	CG		TG	CG		TG	CG		TG	CG	
Sagittal analysis																		
SNA	82.6 ± 3.4	83.9 ± 5.8	NS	82.6 ± 2.9	84.5 ± 6.1	NS	0.09 ± 1.80	0.57 ± 2.30	NS	83.1 ± 3.2	84.3 ± 5.3	NS	0.49 ± 1.17	−0.17 ± 3.18	NS	0.58 ± 2.88	0.40 ± 3.83	S
SNB	78.2 ± 2.1	78.8 ± 5.3	NS	79.1 ± 2.3	80.4 ± 5.3	NS	0.99 ± 1.55	1.62 ± 1.96	NS	79.6 ± 2.3	80.7 ± 5.5	NS	0.47 ± 1.35	0.27 ± 2.85	NS	1.46 ± 1.91	1.89 ± 3.84	S
ANB	4.6 ± 2.9	5.01 ± 2.3	NS	3.72 ± 1.7	4.16 ± 1.6	NS	−0.88 ± 1.45	−0.84 ± 1.75	NS	4.03 ± 1.9	3.9 ± 1.5	NS	0.31 ± 0.77	−0.26 ± 1.80	NS	−0.56 ± 1.25	−1.11 ± 1.98	S
Vertical analysis																		
AnsPns.GoGn	28.3 ± 3.2	27.2 ± 4.9	NS	26.7 ± 3.3	28.9 ± 4.6	NS	−1.62 ± 0.52	1.71 ± 1.80	*	25.2 ± 3.1	30.2 ± 4.5	*	−1.46 ± 0.43	1.29 ± 0.76	*	−3.08 ± 0.63	2.99 ± 2.22	
SN.AnsPns	6.6 ± 2.1	7.3 ± 3.2	NS	6.1 ± 0.8	8.2 ± 2.9	*	−0.51 ± 1.84	0.83 ± 0.74	*	5.5 ± 1.7	9.2 ± 2.8	*	−0.62 ± 1.46	1.05 ± 1.14	*	−1.14 ± 2.82	1.88 ± 1.45	

	T0		p-Value	T1		p-Value	T1-T0		p-Value	T2		p-Value	T2-T1		p-Value	T2-T0		-Value
	TG	CG		TG	CG		TG	CG		TG	CG		TG	CG		TG	CG	
SN.GoGn	34.6 ± 4.9	34.8 ± 6.2	NS	32.6 ± 5.1	35.3 ± 5.9	*	−1.93 ± 1.39	0.52 ± 0.98	*	29.9 ± 4.5	36.1 ± 5.6	*	−2.69 ± 2.99	0.79 ± 1.31	*	−4.63 ± 3.49	0.88 ± 1.93	
CoGoMe	128.1 ± 4.7	126.7 ± 6.9	NS	126.6 ± 3.5	126.4 ± 5.8	NS	−1.45 ± 1.50	−0.37 ± 3.61	NS	124.4 ± 2.6	127.4 ± 5.6	NS	−2.20 ± 2.15	1.07 ± 1.72	*	−3.65 ± 3.01	0.71 ± 4.82	S
Dentobasal analysis																		
L1.GoGn	100.2 ± 7.7	97.3 ± 7.7	NS	99.5 ± 5.9	97.7 ± 5.8	NS	−0.69 ± 3.09	0.44 ± 5.22	NS	97.8 ± 5.8	97.2 ± 4.9	NS	−1.63 ± 5.85	−0.49 ± 4.93	NS	−2.33 ± 8.88	−0.06 ± 7.06	S
U1.AnsPns	115.3 ± 7.0	117.4 ± 7.7	NS	114.4 ± 6.6	117.4 ± 6.4	NS	−0.89 ± 7.24	0.06 ± 6.75	NS	109.9 ± 7.0	116.4 ± 5.9	*	−4.50 ± 5.92	−1.03 ± 5.67	NS	−5.39 ± 11.24	−0.98 ± 6.61	S
L1	2.8 ± 3.5	5.4 ± 2.8	NS	3 ± 2.3	5.6 ± 2.8	*	0.17 ± 1.49	0.24 ± 0.89	NS	2.9 ± 1.8	5.7 ± 2.6	*	−0.14 ± 0.73	0.11 ± 0.77	NS	0.03 ± 2.03	0.34 ± 1.34	S
U1	0.4	−2.6	NS	1 ±	−2.2	*	0.61	0.44 ±	NS	1.6	−1.1	*	0.54	1.15	NS	1.15	1.59	S

	T0		*p*-Value	T1		*p*-Value	T1-T0		*p*-Value	T2		*p*-Value	T2-T1		*p*-Value	T2-T0		-Value
	TG	CG		TG	CG		TG	CG		TG	CG		TG	CG		TG	CG	
	± 2.3	± 2.1		1.0	± 2.0		± 1.58	1.28		± 1.1	± 2.4		± 1.00	± 1.88		± 2.40	± 2.22	
U6^L6	0.7 ± 0.2	0.8 ± 0.2	NS	0.7 ± 0.2	0.9 ± 0.1	*	0.02 ± 0.10	0.08 ± 0.19	NS	0.8 ± 0.2	1 ± 0.1	*	0.07 ± 0.10	0.16 ± 0.13	*	0.10 ± 0.13	0.23 ± 0.20	
OVB	−2.9 ± 1.1	−4.4 ± 1.9	NS	1.5 ± 0.6	−3.3 ± 1.3	*	4.49 ± 0.92	1.04 ± 1.13	*	1.8 ± 0.6	−2.1 ± 1.3	*	0.32 ± 0.20	0.32 ± 0.20	*	4.81 ± 0.96	2.30 ± 1.65	
OVJ	2.7 ± 1.3	2.6 ± 2.8	NS	2.6 ± 1.0	3 ± 2.3	NS	−0.06 ± 0.43	0.43 (1.02)	NS	2.6 ± 0.7	3.7 ± 2.1	NS	0.00 ± 0.62	0.65 ± 0.58	*	-0.06 ± 0.98	1.08 ± 1.48	-

NS = not significant *p*-value; * = significant *p*-value; SNA = angle: sella—nasion—point A; SNB = angle: sella—nasion—point B; ANB = angle: point A—nasion—point B; AnsPns.GoGn = angle between palatal plane and mandibular plane; SN.AnsPns = angle between sella—nasion plane and palatal plane; SN.GoGn = angle between sella—nasion plane and mandibular plane; CoGoMe = angle: condylion—gonion—gnathion; L1.GoGn = angle between lower incisor axis and mandibular plane; U1.AnsPns = angle between upper incisor axis; L1 = distance between pogonion and the projection of the lower incisor axis perpendicular to the Frankfurt plane; U1 = distance between anterior nasal spine and the projection of the upper incisor axis perpendicular to the Frankfurt plane; U6^L6 = relationship between upper and lower first molar; OVJ = overjet; OVB = overbite.

At T2, statistical analysis revealed a significant reduction in maxillary and mandibular divergence in the treatment group (TG) compared to the control group (CG) ($p < 0.05$). The intermaxillary divergence angle was also significantly smaller in the TG than in the CG ($p < 0.05$). All treated patients maintained open bite correction, with higher overbite (OVB) values compared to the CG ($p = 0.00000007$). None of the patients showed relapse in terms of bad habits.

Multivariate regression analysis indicated a significant correlation between vertical mandibular changes (SN^GoGn angle) and patient age, showing that the SN^GoGn angle decreases with age. Additionally, a statistically significant relationship was observed between the SN^GoGn angle and OVB values: at long-term follow-up, SN^GoGn angle values decreased as post-treatment OVB values increased. This model explained 64% of the variability ($p < 0.0001$).

Discussion

This retrospective study aimed to evaluate skeletal and dental changes in vertical and sagittal relationships by comparing growing patients with anterior open bite (AOB) treated with rapid maxillary expansion and crib (RME/c) therapy to untreated age-matched controls. Open-bite malocclusion often involves skeletal and dentoalveolar alterations in both the maxilla and mandible. Hyperdivergency, associated with a vertical growth pattern of the jaw, is a genetic risk factor for AOB. Mandibular post-rotation can result from imbalanced vertical growth between the molar region and the condylar area. Additionally, open bites are frequently linked to reduced maxillary transverse development, posterior crossbite, and atypical swallowing patterns. Orthodontic therapy should focus on addressing skeletal, dentoalveolar, and functional abnormalities, with maxillary expansion and habit correction being critical components of early treatment.

Patients were assessed at short-term (approximately 12 months post-T0, end of active expansion) and long-term follow-ups (approximately five years post-T0, before fixed orthodontic therapy). Two homogeneous groups were selected based on vertical, transverse, and sagittal skeletal and dental characteristics to ensure reliable outcomes.

Results demonstrated both skeletal and dental improvements following treatment. At T1, all patients in the TG exhibited positive OVB, achieving the primary goal of anterior seal formation, with a mean OVB increase of 4.4 mm post-maxillary expansion. These findings align with previous studies reporting similar OVB improvements in patients treated with a quad-helix appliance and palatal crib. Comparable OVB increases have also been reported in studies employing protocols such as a palatal crib combined with a high-pull chin cup. In this study, significant differences in OVB improvement were noted between TG and CG at both T1 and T2, with no relapse, highlighting the effectiveness of the approach.

Dental changes included lingual tipping of upper and lower incisors at both short- and long-term follow-ups, aiding open bite closure. Such outcomes may result from myofunctional rehabilitation, with cessation of tongue thrusting and non-nutritive sucking habits due to the palatal crib. While molar extrusion and mandibular post-rotation can occur with rapid maxillary expansion, these effects were likely mitigated in this study through habit correction and restored myofunctionality, consistent with previous findings.

Transverse correction also prompted significant skeletal modifications in maxillomandibular relationships. Sagittally, both groups showed limited improvement in maxillary and mandibular position, with ANB° decreasing by less than 1°. This aligns with prior studies assessing long-term outcomes in open-bite patients treated with maxillary expansion and bite-blocks.

In vertical skeletal analysis, maxillary-cranial base relationships showed minimal changes (~1.0°), slightly lower than earlier reports of downward palatal plane rotation.

However, the TG exhibited an average 2.0° reduction in the maxillomandibular angle at both T1 and T2, indicating a unique pattern of reduced maxillomandibular divergence over time. This is consistent with earlier findings. The TG demonstrated mandibular counterclockwise rotation (~2.0°), a key factor in open bite closure, with results slightly exceeding prior findings of reductions in the SN-GoMe angle with removable appliances. Variations in appliance design and usage frequency may explain these differences.

This study employed a fixed two-band maxillary expander with a tongue crib for rapid maxillary expansion, which transmitted substantial forces to the maxilla through anchored teeth. Initially, the periodontal ligament undergoes hyalinization, preventing tooth movement and enabling an orthopedic effect. Performing this treatment before peak pubertal growth may enhance skeletal outcomes, as shown in this study. Discomfort from palatine suture separation, although rare, was noted as a potential risk.

Transverse correction influenced vertical and sagittal maxillomandibular relationships, facilitating long-term OVB improvement. Key skeletal contributors to open bite closure included mandibular anterior rotation, reduced mandibular divergence, and decreased gonial angle. Dentoalveolar modifications, such as reduced upper incisor inclination and lingual tipping of lower incisors, also played significant roles. Tongue cribs have been noted to enhance labial muscle tone, reduce tongue thrusting, and promote normalized myofunctional activity.

Although numerous studies have explored outcomes of different approaches to AOB malocclusion, this research is novel in its short- and long-term evaluation of palatal expander and tongue crib therapy, alongside a control group. However, the retrospective design and reliance on a historical database for CG recruitment may introduce potential biases. While the sample size met the calculated requirement (16 patients per group), larger cohorts could enhance the generalizability of findings. Additionally, molar extrusion post-expansion was not directly evaluated, although improvements in facial divergence suggest vertical growth control.

5.Conclusions

This study provides a detailed analysis of the short- and long-term outcomes of treating anterior open-bite malocclusion using a palatal expander with a lingual crib (RME/c). The null hypothesis was disproven, as significant differences were observed between the treated and untreated groups. Maxillary expansion combined with a tongue crib proved to be an effective therapeutic approach for growing patients with open bite and unfavorable oral habits. The results demonstrated significant and lasting dental and skeletal improvements at both short- and long-term follow-ups. Specifically, the treatment achieved overbite correction, regulated vertical growth, and facilitated successful myofunctional rehabilitation.

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