

MORPHOLOGICAL AND FUNCTIONAL CHANGES IN THE UPPER RESPIRATORY TRACT FOLLOWING RAPID PALATAL EXPANSION IN ADOLESCENTS

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Rapid palatal expansion may affect not only maxillary dimensions but also upper airway patency in adolescents; however, the role of tooth-supported and miniscrew-assisted appliances remains to be clarified. This study aimed to assess morphological and functional changes in the upper respiratory tract associated with rapid palatal expansion and to compare these changes between the use of Hyrax and MARPE systems. We conducted a prospective pilot study involving 24 adolescents aged 12–16 years with transverse maxillary insufficiency. Fourteen participants received Hyrax appliances, while ten received MARPE devices. Time points: T0 — before treatment, T1 — 6 months after completion of activation. The measured indicators were the volume of the nasal cavity, nasopharynx, and oropharynx, the minimum area of the retropalatal level, and the total nasal resistance at 150 Pa. We also calculated the NOSE score. After treatment, the volume of the nasal cavity increased by 14.6% ($p < 0.001$), nasopharyngeal volume by 8.9% ($p = 0.003$), the minimum area of the retropalatal level by 12.1% ($p = 0.012$), total nasal resistance decreased by 24.7% ($p < 0.001$), and NOSE score by 35.4 points ($p < 0.001$). The change in oropharyngeal volume was insignificant ($p = 0.091$). We established no differences between Hyrax and MARPE groups ($p > 0.05$). Rapid palatal expansion improved nasal cavity and nasopharynx parameters. Further comparisons of techniques require a priori sample size calculations.

Keywords: rapid palatal expansion, MARPE, upper airway, CBCT, rhinomanometry, NOSE, adolescents, nasal cavity, nasopharynx

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МОРФОФУНКЦИОНАЛЬНЫЕ ИЗМЕНЕНИЯ ВЕРХНИХ ДЫХАТЕЛЬНЫХ ПУТЕЙ ПОСЛЕ БЫСТРОГО НЕБНОГО РАСШИРЕНИЯ У ПОДРОСТКОВ

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Быстрое небное расширение может влиять не только на размеры верхней челюсти, но и на проходимость верхних дыхательных путей у подростков, однако вклад зубо-опорных и мини-винт-ассистированных аппаратов требует уточнения. Цель работы — оценить морфофункциональные изменения верхних дыхательных путей после быстрого небного расширения и сопоставить динамику при использовании Hyrax и MARPE. Проведено проспективное пилотное исследование 24 подростков 12–16 лет с трансверсальной недостаточностью верхней челюсти: в 14 наблюдениях применяли Hyrax, в 10 — MARPE. Контрольные точки: T0 — до лечения, T1 — через 6 месяцев после завершения активации. Оценивали объем полости носа, носоглотки и ротоглотки, минимальную площадь ретропалатального уровня, суммарное носовое сопротивление при 150 Па и балл NOSE. После лечения объем полости носа увеличился на 14,6% ($p < 0,001$), объем носоглотки — на 8,9% ($p = 0,003$), минимальная площадь ретропалатального уровня — на 12,1% ($p = 0,012$), суммарное носовое сопротивление снизилось на 24,7% ($p < 0,001$), балл NOSE — на 35,4 пункта ($p < 0,001$). Изменение объема ротоглотки не достигло статистической значимости ($p = 0,091$). Межгрупповых различий между Hyrax и MARPE не выявлено ($p > 0,05$). Быстрое небное расширение улучшило показатели полости носа и носоглотки; сравнение методик требует исследований с априорным расчетом выборки.

Ключевые слова: быстрое небное расширение, MARPE, верхние дыхательные пути, КЛКТ, риноманометрия, NOSE, подростки, носовая полость, носоглотка

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Rapid palatal expansion (RPE) is prescribed to patients with maxillary constriction. It is not only an orthodontic treatment but also a technique that functionally corrects impaired nasal breathing. There are Russian clinical studies that describe RPE, the associated age-related aspects, and skeletal support variants [1–4]. Expansion of the median palatal suture increases the width of the nasal cavity floor, which can reduce airflow resistance — an effect that is especially significant in mouth-breathing adolescents, individuals with nasal congestion, and those with combined ENT pathologies [5–7].

Evaluation of the effect of RPE on the upper respiratory tract requires a combination of morphological and functional methods. Active anterior rhinomanometry at a reference pressure of 150 Pa objectively measures total nasal resistance, while the NOSE scale assesses the subjective severity of nasal obstruction and the clinical significance of changes [8, 9]. Patency may vary with phases of the nasal cycle, seasonal changes in the mucous membrane, and tongue position, even when bone architecture remains unchanged; therefore, standardized interpretation of results is necessary [10].

On cone-beam computed tomography (CBCT) images, clinically significant data include not only the total volumes of the nasal cavity and pharynx, but also the minimum cross-sectional area, especially at the retropalatal level, as this parameter is more closely related to airflow aerodynamics [11–16]. At the same time, changes in the oropharynx after RPE remain less predictable, and the potential advantages of skeletal support in adolescents require careful interpretation and independent statistical verification [17–19].

This study aimed to assess morphological and functional changes in the upper respiratory tract associated with rapid palatal expansion and to compare the dynamics of these changes depending on the expander appliance used.

METHODS

This prospective pilot clinical trial was conducted between 2024 and 2025 at the orthodontics clinic of the Department of Dentistry No. 2. The study included 24 adolescents aged 12–16 years (mean age 13.9 ± 1.3 years), 14 girls and 10 boys. All patients presented with maxillary constriction (≥ 4 mm), unilateral or bilateral crossbite, and varying degrees of impaired nasal breathing. We did not perform an a priori sample size calculation, as this study was designed as a pilot trial aimed at an initial assessment of morphological and functional dynamics and a comparison of two expander options.

Inclusion criteria: clinical and CBCT evidence of a narrow maxilla; no history of orthodontic treatment; willingness to undergo a follow-up examination 6 months after completion of appliance activation. Exclusion criteria: congenital craniofacial abnormalities; acute inflammatory diseases of the ENT organs at the time of inclusion; severe hypertrophy of the adenoid

tissue requiring primary surgical treatment; decompensated allergic rhinitis; refusal to undergo the follow-up examination.

Fourteen participants received a Hyrax expander, and ten participants had a MARPE appliance installed. The appliances were activated twice daily by 0.25 mm until clinical hypercorrection was achieved; total expansion was 6–8 mm. After completion of activation, the appliances were left in the oral cavity for 6 months as retainers.

Time points of the study: T0 — before treatment, T1 — 6 months after completion of activation. Comparison of the data collected at T0 and T1 was the main analytical part of the work. All instrumental examinations were performed on the same standard equipment of the clinic, and followed a unified protocol. At both time points, all patients underwent CBCT, active anterior rhinomanometry at a reference pressure of 150 Pa, and completed the NOSE survey. CBCN allowed measuring the volume of the nasal cavity, nasopharynx, and oropharynx, as well as the minimum area of the retropalatal level. This examination was performed with the patient's head in a natural position, while maintaining habitual occlusion and calm nasal breathing. Repeated CBCT was part of a clinically justified orthodontic monitoring routine, with adherence to dose optimization principles for adolescents [20].

Statistical processing and post hoc power estimation were performed in the Python 3.11 environment using the SciPy and statsmodels libraries. The normality of the distribution of quantitative variables and their changes ($\Delta = T1 - T0$) was assessed using the Shapiro–Wilk test. With normally distributed data, results were presented as mean $\pm$ standard deviation ($M \pm SD$). Paired comparisons between T0 and T1 were performed using the paired Student's *t*-test, while differences in changes between the Hyrax and MARPE groups were assessed using the independent samples Student's *t*-test. In cases of non-normal distribution, we applied the Wilcoxon signed-rank test and the Mann–Whitney *U* test, respectively. For the intergroup analysis, we compared the values of relative changes; the level of statistical significance was assumed at $p < 0.05$. Since the study was of a pilot trial, no a priori calculation of the sample size was performed. Post hoc power assessment showed that with a total sample of $n = 24$, paired analysis ensured 80% power to detect at least a medium-large effect ($d \geq 0.60$), whereas with $n = 14$ and $n = 10$, an intergroup comparison provided the same power only to detect a very large effect ($d \geq 1.21$).

RESULTS

Table 1 presents the quantitative data of the sample; table 2 gives the results of the pilot intergroup comparison of relative changes.

After RPE, the volume of the nasal cavity and nasopharynx has increased significantly. The strongest positive changes

Table 1. Dynamics of upper respiratory tract parameters after RPE

Indicator	Before treatment	After treatment	Change	<i>p</i>
Nasal cavity volume, cm ³	14.6 $\pm$ 2.8	16.7 $\pm$ 3.1	+14.6%	< 0.001
Nasopharyngeal volume, cm ³	8.9 $\pm$ 1.9	9.7 $\pm$ 2.0	+8.9%	0.003
Oropharyngeal volume, cm ³	12.4 $\pm$ 2.6	12.8 $\pm$ 2.7	+3.2%	0.091
Minimum area of the retropalatal level, mm ²	126 $\pm$ 28	141 $\pm$ 31	+12.1%	0.012
Total nasal resistance, Pa/cm ³ /s	0.41 $\pm$ 0.08	0.31 $\pm$ 0.07	–24.7%	< 0.001
NOSE, points	61.4 $\pm$ 12.7	26.0 $\pm$ 10.8	–35.4 points	< 0.001

Note: the table shows relative changes from baseline for morphometric and functional indicators; for the NOSE survey, it shows absolute changes in points. Additionally, the total NOSE score decreased by 57.8% from baseline.

Table 2. Intergroup comparison of relative changes after RPE (pilot trial)

Indicator	Hyrax (<i>n</i> = 14)	MARPE (<i>n</i> = 10)	Numerical trend	<i>p</i>
Nasal cavity volume, %	+0.13	+0.168	higher with MARPE	> 0.05
Minimum area of the retropalatal level, %	+0.098	+0.154	higher with MARPE	> 0.05
Суммарное носовое сопротивление, %	–22.5%	–27.6%	decrease is greater with MARPE	> 0.05

Note: relative changes from baseline are shown for indicators with the greatest differences in effect (by subgroups); some intergroup comparisons were not statistically significant.

were registered in the anterior nasal cavity and along the nasal fundus. The increase of the oropharyngeal volume was small (+3.2%) and did not reach statistical significance ($p = 0.091$).

As for the total nasal resistance, active anterior rhinomanometry showed that it decreased from 0.41 ± 0.08 to 0.31 ± 0.07 Pa/cm³/s ($p < 0.001$). Clinically, this was reflected in a reduction in the severity of nasal obstruction: the mean NOSE score decreased from 61.4 ± 12.7 to 26.0 ± 10.8 , a decrease of 35.4 points (57.8% from baseline). Out of 24 patients, 19 reported improved nasal breathing already in the first weeks of the retention period.

The pilot intergroup comparison of relative changes in the indicators (presented in Table 2) did not reveal significant differences between Hyrax and MARPE groups ($p > 0.05$). However, the morphometric changes were numerically greater in MARPE group: 15.4% vs. 9.8% in Hyrax group for the minimum area of the retropalatal level, and 16.8% vs. 13.0% for the nasal cavity volume increase. The differences in the reduction of total nasal resistance between the subgroups were less pronounced (–27.6% and –22.5%). Given the limited number of subgroups and the insufficient power of this pilot study, these results should be interpreted as suggesting a hypothesis rather than proving the advantage of one appliance over another. No serious complications were reported; the participants mentioned transient discomfort, incisive diastema, and pressure around the support elements.

DISCUSSION

The results of our study show that the main effect of RPE in adolescents is realized at the level of the nasal cavity and nasopharynx. This is consistent with the literature about the expansion of the middle zone of the face and nasal septum alteration in children, as well as with CBCT images that indicate a direct relationship between the opening of the median palatine suture and an increase in the volume of the upper respiratory tract [2, 11, 13–15].

The observed reduction in total nasal resistance is consistent with classical studies by Hershey, Hartgerink, and De Felipe, who found that RPE improves nasal patency in both short- and long-term follow-up periods [5–7]. As for the obtained data on the minimum area of the retropalatal level and the general increase of the nasopharyngeal volume, these are supported by the results of three-dimensional CT scans, systematic reviews, and meta-analyses [12, 14–19].

We observed certain variability in oropharyngeal change dynamics. This likely results not only from bone transformations but also from tongue position, vertical growth pattern, soft palate condition, and concurrent ENT pathology. Therefore, the expansion of all parts of the upper respiratory tract may not be uniform in adolescents with severe hypertrophy of the

nasopharyngeal tonsil, residual deviation of the septum, or an unfavorable myofunctional pattern.

Pilot intergroup comparison revealed more pronounced morphometric dynamics in MARPE group, but the differences in the compared indicators were insignificant ($p > 0.05$). This direction of change is consistent with some reports covering cases of mini-screw-assisted expansion [17–19]. However, in this study, the small sample and inequality of subgroups, as well as limited power, do not allow interpreting these observations as a proven advantage of MARPE; clinical improvement in nasal breathing was observed in both Hyrax and MARPE groups.

Study limitations

Limitations of this pilot study include the small sample size, absence of a priori power calculation and randomization, short follow-up, and possible seasonal effects on nasal mucosa function. The post hoc power assessment showed that the overall sample was sufficient mainly to detect large intragroup effects and insufficient to reliably detect moderate intergroup differences. The subgroup analysis comparing Hyrax and MARPE appliances was a pilot trial and therefore did not permit conclusions about whether one approach is statistically superior to the other. In addition, the trade names of the appliances, the software used for CBCT segmentation, dosimetric parameters, and a formal assessment of inter- and intraoperative reproducibility were not detailed in this work, which limits the study's reproducibility. In the future, larger prospective studies with standardized CBCT segmentation, a single protocol of rhinofunctional examination, and long-term retention monitoring are advisable.

CONCLUSIONS

Rapid palatal expansion in adolescents is accompanied by a statistically significant increase in nasal cavity and nasopharyngeal volume, an increase in the minimum retropalatal area, a decrease in total nasal resistance, and a reduction in nasal obstruction severity on the NOSE scale. The change in oropharyngeal volume in the sample was small and did not reach statistical significance ($p = 0.091$), which indicates the heterogeneity of the response of different parts of the upper respiratory tract to RPE. In the pilot intergroup comparison of Hyrax versus MARPE, there were no statistically significant differences in the main morphometric and functional indicators. The larger morphometric changes seen in the MARPE group should be confirmed in studies with adequate statistical power. The post hoc power assessment showed that this study was suitable mainly for detecting large effects; for evidence-based method comparisons, larger prospective studies with a priori sample-size calculations are needed.

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