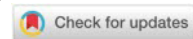


CEPHALOMETRIC ASSESSMENT OF TRANSVERSE CHANGES IN FRONTO-ORBITAL AND ZYGOMATIC WIDTH BEFORE AND AFTER RAPID MAXILLARY EXPANSION IN PATIENTS WITH UNILATERAL POSTERIOR CROSSBITE

Anzhelina Krasteva^{1*} , Miroslava Yordanova¹ 

¹Department of Orthodontics, Faculty of Dental Medicine, Medical University-Plovdiv, Bulgaria,
e-mail: dr.a.krasteva@gmail.com, mirajord@gmail.com



Abstract: Rapid maxillary expansion (RME) is commonly used for the correction of transverse maxillary deficiency associated with posterior crossbite. Although its primary effect is directed toward the maxilla and the midpalatal suture, expansion forces may also induce measurable changes in the circummaxillary and zygomatic regions. The aim of the present study was to evaluate transverse changes in the zygomatic and frontozygomatic regions following RME in patients with unilateral posterior crossbite using posteroanterior cephalometric measurements. A three-year prospective clinical study included 47 patients with clinically diagnosed unilateral posterior crossbite and incomplete craniofacial growth, all treated with a tooth-borne Hyrax rapid maxillary expander. The sample consisted of 18 males (38.3%) and 29 females (61.7%), with a mean age of 16.59 ± 1.89 years. Digital posteroanterior cephalograms were obtained at the diagnostic stage and immediately before removal of the RME appliance. Zygomatic width was assessed as the linear distance between the bilateral Za landmarks (Za–Za), while the transverse dimension of the frontozygomatic region was evaluated as the distance between the bilateral Zmf landmarks (Zmf–Zmf). Pre- and post-treatment values were compared using a paired-samples t-test, and the relationship between the changes in the two parameters was assessed by Pearson correlation analysis. Mean Za–Za increased from 112.91 ± 12.52 mm before RME to 114.42 ± 12.43 mm after treatment, corresponding to a mean increase of 1.51 mm ($p < 0.001$). Mean Zmf–Zmf increased from 85.71 ± 10.73 mm to 86.62 ± 10.98 mm, with a mean change of 0.91 mm ($p < 0.001$). A significant positive correlation was found between the changes in Za–Za and Zmf–Zmf ($r = 0.582$, $p < 0.001$). The findings indicate that tooth-borne RME with a Hyrax appliance in patients with unilateral posterior crossbite is associated with statistically significant transverse changes not only in zygomatic width but also in the frontozygomatic region. These results suggest that the effects of conventional RME may extend beyond the immediate maxillary structures and may involve measurable, although limited, adaptation of more lateral and cranially located components of the midfacial complex.

Keywords: rapid maxillary expansion, unilateral posterior crossbite, posteroanterior cephalometry, zygomatic width, frontozygomatic region.

Field: Medical Sciences and Health

1. INTRODUCTION

Transverse maxillary deficiency is a common morphological basis of posterior crossbite and may be associated with a unilateral clinical presentation. In cases of skeletal maxillary constriction, rapid maxillary expansion (RME) aims to increase the transverse dimensions of the maxilla through an orthopedic effect on the midpalatal suture (Kumar, Gurunathan, Muruganandham, & Sharma, 2011).

Various appliances are used for RME, among which the Hyrax is one of the most widely used tooth-borne expanders. Upon activation, orthopedic forces are transmitted through the anchor teeth and alveolar structures to the maxillary complex; when a sufficient skeletal response is achieved, separation of the midpalatal suture and an increase in the basal width of the maxilla may occur (Kumar, Gurunathan, Muruganandham, & Sharma, 2011; Proffit et al., 2019). However, the skeletal and dentoalveolar components of expansion vary according to age, skeletal maturity, and type of anchorage. Data in older adolescents indicate that conventional tooth-borne RME may also produce measurable skeletal changes (Gokturk&Yavan, 2024). The classical concept of RME assumes that the application of high forces over a short period results not only in dental expansion but also in an orthopedic response of the maxilla and its associated structures (Leonardi et al., 2011; Ok, Kayalar & Sadry, 2023). CBCT studies show that the increase in transverse dimensions is greatest at the level of the dental arch and decreases toward the basal bone. The biological effect of RME is not limited to immediate separation of the midpalatal suture and may be accompanied by adaptation of other structures within the circummaxillary complex

*Corresponding author: dr.a.krasteva@gmail.com



(Ahmida et al., 2023; Leonardi et al., 2011). Ghoneima et al. reported a significant increase in the widths of the intermaxillary, internasal, maxillonasal, frontomaxillary, and frontonasal sutures after RME, whereas changes in the frontozygomatic, zygomaticomaxillary, zygomaticotemporal, and pterygomaxillary sutures did not reach statistical significance (Ghoneima et al., 2011).

Of particular interest in this context is the zygomatic complex, which forms an important part of the lateral support of the midface. The three-dimensional study by Ok et al. showed that RME is followed by changes in the position of the zygomatic bone, including lateral displacement and external rotation, with the center of rotational change located near the superior part of the frontozygomatic region (Ok, Kayalar & Sadry, 2023). This suggests that the response of the zygomatic complex cannot be described solely by a change in the width of an individual suture, but should be considered a spatial skeletal adaptation. The literature regarding the magnitude and nature of changes in the frontozygomatic region after maxillary expansion is not entirely consistent. Differences among studies may be related to patient age and skeletal maturity, expander design and anchorage, as well as the methods and timing of imaging assessment (Ghoneima et al., 2011; Gokturk&Yavan, 2024; Sayar& Kılınc, 2019). Direct CBCT measurement of the width of the zygomaticofrontal suture is not equivalent to determining the transverse distance between bilaterally located frontozygomatic landmarks. The former characterizes a local sutural change, whereas the latter may reflect the combined effect of lateral displacement and rotation of the zygomatic complex (Ok, Kayalar & Sadry, 2023). Ahmida et al. reported immediate changes in some cranial and circummaxillary sutures after conventional RPE and MARPE; however, the response was not uniform across all investigated structures, and many of the differences outside the midpalatal suture were not maintained at long-term follow-up (Ahmida et al., 2023). In contrast, three-dimensional data on the zygomatic bone indicate that spatial changes of the complex may be measurable even when direct sutural expansion is limited (Ok, Kayalar & Sadry, 2023). Similar rotational and transverse changes of the midface have also been described with skeletal-borne expansion, although these findings are not directly equivalent to the effects of conventional tooth-borne RME (Alan, Kaya& Sancak, 2025).

Therefore, assessment of the interzygomatic and frontozygomatic transverse dimensions may provide additional information on the extent of the orthopedic effect beyond the immediate maxillary region. The aim of the present study was to assess, by means of posteroanterior cephalometry, changes in zygomatic and frontozygomatic width after rapid maxillary expansion using the Za-Za and Zmf-Zmf parameters.

2. MATERIALS AND METHODS

A three-year prospective clinical study was conducted using the results of posteroanterior (PA) cephalometric measurements in 47 patients with clinically confirmed unilateral posterior crossbite and incomplete growth (late adolescence). All patients were treated with a Hyrax appliance for maxillary expansion. The study sample comprised 18 males (38.3%) and 29 females (61.7%). The mean age was 16.59 ± 1.89 years, with a median age of 17 years.

Patients with craniofacial syndromes, cleft lip and/or palate, previous orthopedic or orthodontic expansion, previous orthognathic surgery, significant facial trauma, or radiographs with inadequate head positioning or insufficient landmark visibility were excluded.

The Hyrax rapid maxillary expander used in our study consisted of a 9–13 mm Leone expansion screw (Leone, Florence, Italy), with individually bent arms extending along the lingual surfaces of the posterior teeth and four bands on the anchor teeth (first premolars and first molars), with factory-soldered buccal tubes and free palatal surfaces. The bands were soldered to the rigid stainless-steel arms of the expansion screw. (Fig. 1)

Fig. 1: Hyrax appliance



Source: Created by the authors

During the initial 3–4 days, an intensive activation protocol was applied: $\frac{1}{4}$ turn = 0.25 mm every 6 hours, resulting in approximately 1 mm of expansion per day. After the appearance of clinical signs of midpalatal suture disjunction, activation was reduced to $\frac{1}{4}$ turn every 12 hours. The duration of active expansion was determined individually according to the required transverse correction and the achievement of adequate occlusal compensation (Stoilova- Todorova, 2018).

Digital posteroanterior cephalograms were obtained and analyzed for all patients at the diagnostic stage and immediately before removal of the RME appliance. PA cephalograms are an appropriate choice because they are sufficient for measuring the selected parameters and limit radiation exposure in accordance with the ALARA principle (Krasteva, 2019). Each patient and the patient's parents were informed about the purpose of the study and signed informed consent for the radiographic examination. The patients' legal guardians also provided consent for the use of RME as part of the orthodontic treatment and for the use of the resulting data for scientific purposes without disclosure of patient identity. Digital frontal cephalograms were obtained according to the established method of Ricketts R.M. (Ricketts, 1981). All cephalograms were traced twice by two operators in accordance with the described protocol for PA cephalometric analysis. After a period of 7 days, the measurements were repeated, and the arithmetic mean values of the investigated parameters were used to control for potential measurement errors. The initial and final PA cephalograms were traced using CorelDRAW Graphics Suite 2026 for digital tracing and graphic processing of the frontal cephalograms (Corel Corporation, 2026). The following landmarks were identified:

Zmf – zygomaticofrontal suture – its most medial aspect (left/right).

ZA – zygomatic arch – the point located at the most lateral aspect of the center of the zygomatic arch (left/right).

To assess changes in the fronto-orbital region and zygomatic width before and after RME, the following parameters were used:

Distance is in millimeters between the left and right Zmf landmarks (Zmf–Zmf).

Zygomatic width (Za–Za) – the left and right Za landmarks were connected and the linear distance was measured in millimeters (Ricketts, 1981). (Fig. 2)

Fig. 2: Measurement of zygomaticofrontal (Zmf-Zmf) and bizygomatic (ZA-ZA) width



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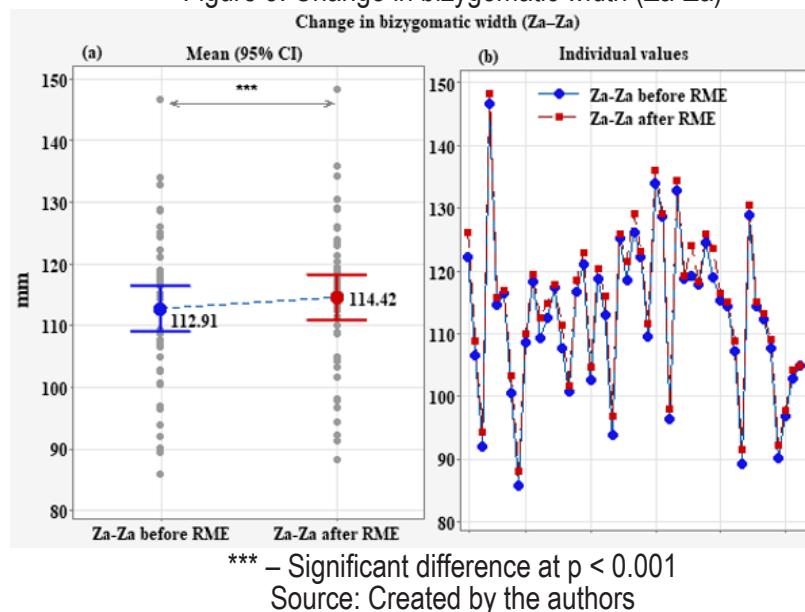
Data analysis was performed using IBM SPSS Statistics for Windows, version 28.0 (Armonk, NY: IBM Corp.).

3. RESULTS

Zygomatic width (Za–Za) and the zygomaticofrontal distance (Zmf–Zmf) showed normal distributions before and after RME. Changes in the values were analyzed using a paired-samples t-test. A significant increase was found for both measurements. Before RME, the mean zygomatic width (Za–Za) was 112.91 ± 12.52 mm and increased to 114.42 ± 12.43 mm after RME. The mean change was 1.51 mm and was statistically significant ($p < 0.001$). The mean distance between the left and right zygomaticofrontal landmarks (Zmf–Zmf) increased from 85.71 ± 10.73 mm to 86.62 ± 10.98 mm after RME, representing a significant change of 0.91 mm ($p < 0.001$).

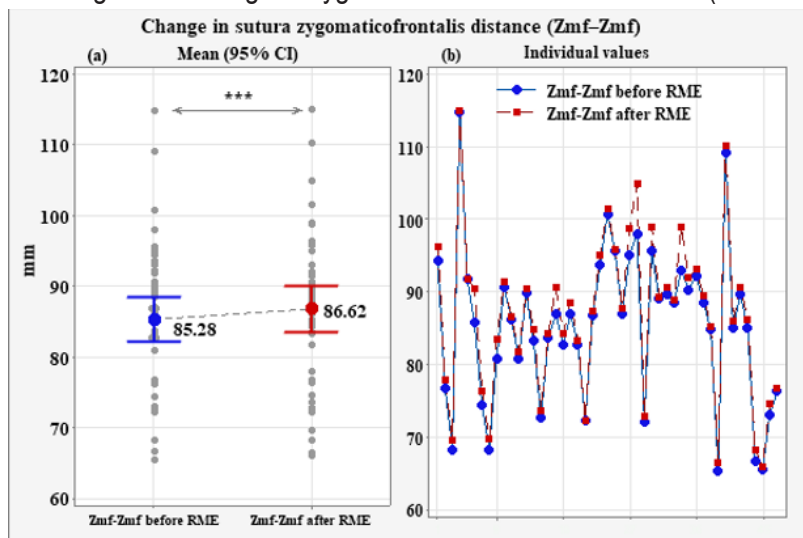
Figure 3(a) illustrates the mean values of zygomatic width (Za–Za) before and after RME. The changes in individual values show an increase in zygomatic width in all patients, with a minimum increase of 0.29 mm and a maximum increase of 2.84 mm (Figure 3b).

Figure 3: Change in bizygomatic width (Za–Za)



The mean values of the distance between the left and right zygomaticofrontal landmarks (Zmf–Zmf) before and after RME are presented in Figure 4(a). Changes in the individual values are shown in Figure 4(b). An increase was observed in all patients, with a minimum change of 0.03 mm and a maximum change of 1.80 mm.

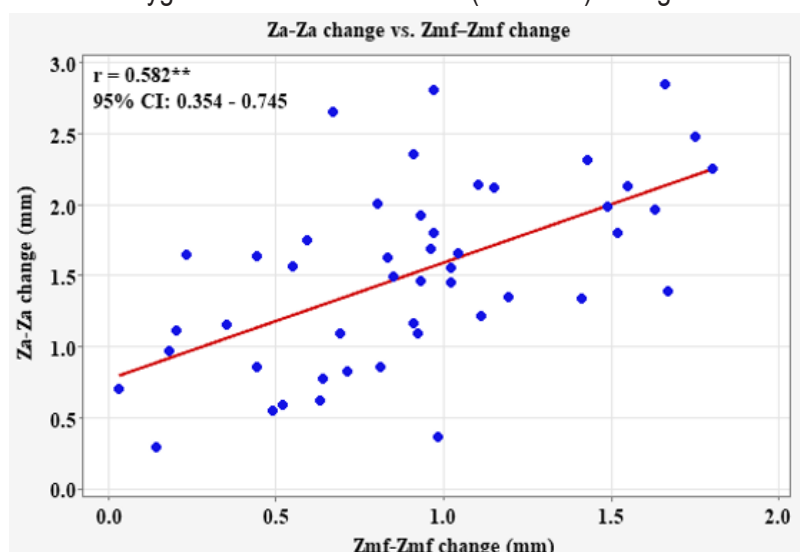
Figure 4: Change in zygomaticofrontal suture distance (Zmf-Zmf)



*** - Significant difference at $p < 0.001$
Source: Created by the authors

The relationship between the changes in the investigated transverse parameters after RME was assessed by correlation analysis using Pearson's test because the data were normally distributed. A strong positive correlation was found between the change in zygomatic width (Za-Za) and the change in the distance between the left and right zygomaticofrontal landmarks (Zmf-Zmf) ($r = 0.582$, $p < 0.001$) (Fig. 5).

Figure 5: Significant correlation between bizygomatic width change (Za-Za) and sutura zygomaticofrontalis distance (Zmf-Zmf) change



*** - Significant correlation at $p < 0.001$
Source: Created by the authors

4. DISCUSSION

In the present study, the transverse parameters Za–Za and Zmf–Zmf allow assessment of the possible involvement of the zygomatic and frontozygomatic complexes in the response to expansion. The results show that RME is followed by measurable changes not only in the maxillary region but also lateral to it, supporting the concept of RME as an intervention with a potential orthopedic effect on the circummaxillary complex (Ahmida et al., 2023; Ok, Kayalar & Sadry, 2023).

Following expansion, the Za–Za width increased by 1.51 mm. The increase in this parameter may be regarded as an indirect indicator of transverse adaptation of the zygomatic complex. This interpretation is consistent with the three-dimensional observations of Ok et al., who found changes in both maxillary width and the frontozygomatic and zygomaticomaxillary regions after RME in growing patients. According to their findings, the interzygomatic distance increased by approximately 2.00 mm (Ok, Kayalar & Sadry, 2023). In addition to linear changes, the authors described lateral displacement and external rotation of the zygomatic bone. Although the 3D measurements used in that study are not directly comparable with the PA cephalometric Za–Za parameter, the similar magnitude of the observed changes supports the presence of a moderate skeletal response beyond the immediate region of the midpalatal suture.

Patient age is an important factor in the interpretation of these results. With advancing skeletal maturation, resistance of the circummaxillary sutures increases, and a more limited orthopedic component may be expected compared with the early mixed dentition. Nevertheless, the data of Gokturk and Yavan show that conventional tooth-borne RME can produce measurable skeletal changes even in older adolescents (Gokturk & Yavan, 2024). The mean age in their conventional RME group was 16.74 years, which is close to the mean age of 16.59 years in the present study. Their findings demonstrate that a skeletal effect is possible even in late adolescence. This concept is also supported by a 2026 CBCT study including patients aged 10–17 years and comparing tooth-borne Hyrax, hybrid, and bone-borne expansion (Yazdan Ozen & Ceylan, 2026). Significant skeletal and dental maxillary expansion was observed with all three appliance types, although the bone-borne approach produced a greater skeletal component. In the context of the present study, these findings indicate that a conventional Hyrax appliance may produce a skeletal response even during adolescence, although the expected magnitude of this effect is smaller than with bone-borne designs.

A statistically significant increase was also found for the Zmf–Zmf parameter, with a mean post-expansion change of 0.91 mm. In interpreting this result, it is important to emphasize that Zmf–Zmf represents a linear transverse distance between the left and right Zmf cephalometric landmarks and does not directly measure the width of the zygomaticofrontal suture. Therefore, the observed change should not be regarded as direct evidence of disjunction of the zygomaticofrontal suture. It more likely reflects spatial adaptation of the zygomatic complex involving a combination of lateral displacement and rotational changes. This distinction is also essential when comparing the present findings with the CBCT literature. Ahmida et al. directly assessed changes in several cranial and circummaxillary sutures after conventional RPE and MARPE (Ahmida et al., 2023). The authors reported immediate changes in some of the investigated sutures but did not identify a uniform directional response across all analyzed structures, and at long-term follow-up most changes outside the midpalatal suture were not maintained. Therefore, the increase in Zmf–Zmf in the present study should be interpreted more conservatively—as an indicator of a change in the position of the frontozygomatic region rather than as evidence of direct opening of the suture itself (Ahmida et al., 2023).

In summary, the observed changes in Za–Za and Zmf–Zmf suggest that the effect of RME in the investigated patients is not entirely limited to the maxilla. The transverse response of the zygomatic and frontozygomatic complexes was moderate in magnitude and most likely reflects the combined effects of lateral displacement and rotational adaptation of the adjacent structures.

5. CONCLUSION

Rapid maxillary expansion with a Hyrax appliance in patients with unilateral posterior crossbite results in a statistically significant increase in zygomatic width (Za–Za) and in the transverse distance between the frontozygomatic landmarks (Zmf–Zmf). The findings show that the effect of RME is not limited to the maxilla but also involves more lateral and cranially located structures of the midface. These results support the concept that, even in late adolescence, conventional rapid maxillary expansion may be associated with limited but measurable circummaxillary skeletal changes.

REFERENCES

- Ahmida, A., Mehta, S., Amelemah, E., Bashir, R., Vich, M. L., Tadinada, A., Allareddy, V., & Yadav, S. (2023). Short-term and long-term effects of miniscrew-assisted and conventional rapid palatal expansion on the cranial and circummaxillary sutures. *American Journal of Orthodontics and Dentofacial Orthopedics*, 163(4), e115–e126. <https://doi.org/10.1016/j.ajodo.2023.01.007>
- Alan, A., Kaya, Y., & Sancak, K. (2025). Mid-facial skeletal and soft tissue changes after maxillary skeletal expander application: A retrospective CBCT study. *BMC Oral Health*, 25(1), 1168. <https://doi.org/10.1186/s12903-025-06569-z>
- Cobourne, M. T., & DiBiase, A. T. (2025). *Handbook of orthodontics* (3rd ed.). Elsevier.
- Corel Corporation. (2026). CorelDRAW® Graphics Suite 2026. <https://www.coreldraw.com/en/product/coreldraw/>
- Ghoneima, A., Abdel-Fattah, E., Hartsfield, J., El-Bedwehi, A., Kamel, A., & Kula, K. (2011). Effects of rapid maxillary expansion on the cranial and circummaxillary sutures. *Am J Orthod Dentofacial Orthop.*, 140(4), 510–519. doi:10.1016/j.ajodo.2010.10.024
- Gokturk, M., & Yavan, M. A. (2024). Comparison of the short-term effects of tooth–bone-borne and tooth-borne rapid maxillary expansion in older adolescents. *Journal of Orofacial Orthopedics / Fortschritte der Kieferorthopädie*, 85, 43–55. <https://doi.org/10.1007/s00056-022-00401-x>
- Krasteva, S. (2019). Graphical and analytical analysis of transverse deviations during movement of the lower jaw (2nd expanded ed.). MU-Plovdiv.
- Kumar, S. A., Gurunathan, D., Muruganandham, & Sharma, S. (2011). Rapid maxillary expansion: A unique treatment modality in dentistry. *Journal of Clinical and Diagnostic Research*, 5(4), 906–911. <https://doi.org/10.7860/JCDR/2011/1449>
- Leonardi, R., Sicurezza, E., Cutrera, A., & Barbato, E. (2011). Early post-treatment changes of circummaxillary sutures in young patients treated with rapid maxillary expansion. *The Angle Orthodontist*, 81(1), 36–41. doi: 10.2319/050910-250.1
- Ok, U., Kayalar, E., & Sadry, S. (2023). Three-dimensional zygomatic changes after rapid maxillary expansion in growing patients. *Journal of Orofacial Orthopedics / Fortschritte der Kieferorthopädie*, 84(3), 147–156. <https://doi.org/10.1007/s00056-021-00348-5>
- Proffit, W. R., Fields, H. W., Larson, B. E., & Sarver, D. M. (2019). *Contemporary orthodontics* (6th ed.). Elsevier.- 208-240;430
- Ricketts, R. M. (1981). Perspectives in the clinical application of cephalometrics. *Angle Orthod.*, 51(2), 115–150. doi: 10.1043/0003-3219(1981)051<0115:PITCAO>2.0.CO;2.
- Sayar, G., & Kiliç, D. D. (2019). Rapid maxillary expansion outcomes according to midpalatal suture maturation levels. *Prog Orthod.*, 20, 27. doi: 10.1186/s40510-019-0278-9.
- Stoilova-Todorova, M. (2018). Rapid maxillary expansion for correction of maxillary transverse insufficiency [Candidate dissertation]. Plovdiv.
- Yazdan Özen, G., & Ceylan, İ. (2026). Investigation of the effects of tooth-borne, tooth-bone-borne and bone-borne rapid maxillary expansion appliances on the nasomaxillary complex using CBCT. *Turkish Journal of Orthodontics*, 39(1), 17–25. <https://doi.org/10.4274/TurkJOOrthod.2026.2025.25>

