

ORIGINAL ARTICLE

Correlation between cervical vertebrae maturation stage and midpalatal suture maturation stage in population aged 8-19: an observational analytic study

Shelly Novliana¹
Harryanto Wijaya^{2*}
Sariyani Pancasari Audry Arifin³
Yeoh Chiew Kit^{4,5}

¹Undergraduate Program, Faculty of Dentistry, Trisakti University, Jakarta, Indonesia

²Department of Orthodontics Faculty of Dentistry, Trisakti University, Jakarta, Indonesia

³Department of Dental Radiology, Faculty of Dentistry, Trisakti University, Jakarta, Indonesia

⁴Orthodontist CK Dental Surgery and Blanc Dental Clinic, Malaysia

⁵Lecturer and clinical supervisor Universiti Kebangsaan Malaysia

* Correspondence:
harryanto.w@trisakti.ac.id

Received: 15 Februari 2025

Revised: 20 June 2025

Accepted: 17 July 2025

Published: 31 July 2025

DOI: [10.24198/pjd.vol37no2.61582](https://doi.org/10.24198/pjd.vol37no2.61582)

p-ISSN [1979-0201](#)

e-ISSN [2549-6212](#)

Citation:

Novliana, S; Wijaya, H; Arifin, SPA; Kit, YC. Correlation between cervical vertebrae maturation stage and midpalatal suture maturation stage: an observational analytic study. *Padj J Dent*, July. 2025; 37(2): 197-204.

ABSTRACT

Introduction: One of the treatments for malocclusion, especially class II and class III cases often associated with maxillary constriction, is Rapid Maxillary Expansion (RME). Successful RME treatment requires evaluation of the Midpalatal Suture Maturation Stage using Cone-Beam Computed Tomography (CBCT). However, CBCT entails increased cost and radiation exposure. Meanwhile, the Cervical Vertebrae Maturation Stage serves as a biological indicator of skeletal growth. This study aims to analyze the correlation between Cervical Vertebrae Maturation Stage and Midpalatal Suture Maturation Stage. **Methods:** This study used an observational analytic research design with a consecutive sampling method. Secondary data of cephalogram and CBCT images of 47 subjects aged 8–19 years were analyzed. CVMS was assessed using the Baccetti method, while MPSMS was evaluated using the Angelieri method. The Spearman rank correlation test was applied to assess the correlation between the two variables. This research was conducted at the Department of Orthodontics, Faculty of Dentistry, Trisakti University from September to December 2024. **Results:** A distribution of MPSMS stages (A to E) corresponding to increasing CVMS stages (CS1 to CS5). Spearman correlation analysis revealed a strong and highly significant positive correlation between CVMS and MPSMS, with a correlation coefficient of $r=0.640$ and $p=0.001$, consistent across the entire sample and within gender subgroups. **Conclusion:** There is a strong correlation between CVMS and MPSMS in the population aged 8–19 years.

KEYWORDS

Cervical vertebrae, midpalatal suture, maturation stage, palatal expansion technique

INTRODUCTION

Orthodontics is a branch of dentistry that deals with facial and jaw growth, tooth development and occlusion, and the diagnosis and treatment planning of malocclusion. Malocclusion is a deviation from normal occlusion and defined as an abnormal relationship between the teeth.¹ Malocclusion not only affects orofacial functions such as chewing, speaking, and swallowing, but can also cause psychosocial effects due to its impact on facial aesthetics. This highlights the importance of establishing an accurate diagnosis of malocclusion for effective orthodontic treatment planning.^{2,3}

Maxillary transverse deficiency is a complex dentofacial deformity that may be associated with several conditions, including class II and class III malocclusions, which are frequently related to maxillary constriction, altered tooth inclination, posterior crossbite, occlusion disharmony, altered tongue posture and

mouth breathing.^{4,5} These conditions can be corrected using Rapid Maxillary Expansion (RME), an orthodontic appliance used for maxillary transverse deficiency by opening the sutures midpalatal.⁶

Indications for RME include severe maxillary constriction, unilateral or bilateral posterior crossbite involving multiple teeth, anteroposterior discrepancies, class II malocclusions with excessive maxillary growth, borderline skeletal Class III malocclusions, pseudo-Class III malocclusions, and cleft lip and palate with maxillary collapse.^{7,8} The ideal age for RME is up to 16 years in females and 18 years in males. However, individuals beyond those ages have been reported to exhibit no signs of midpalatal suture fusion. This suggests that the developmental stage of midpalatal suture fusion can vary significantly and may not correspond directly to chronological age.⁹

Midpalatal Suture Maturation Stage is a classification method that determines the stage of midpalatal suture maturation. Initial assessments of the midpalatal suture were performed using occlusal radiographs. However, occlusal radiography is not considered reliable for evaluating midpalatal suture morphology, as the vomer and external nasal structures often superimpose the midpalatal area, potentially leading to misinterpretation of the radiographs regarding the fusion of the midpalatal suture.^{10,11}

With technological advances, Cone-Beam Computed Tomography (CBCT) has enabled three-dimensional evaluation of maxillofacial structures. Angelieri et al.,¹⁸ introduced a CBCT method to evaluate the MPSMS more accurately. CBCT is a technology that utilizes X-rays to produce high-resolution, three-dimensional images of the internal anatomical structures, particularly the skull and jaw bones. The advantages of CBCT include high image resolution and greater diagnostic accuracy in assessing the bone structure.

However, CBCT also has limitations: it is costly, offers limited soft tissue visualization and involves relatively high radiation exposure.¹² Orthodontic indications for CBCT include impacted teeth, angulation, morphology, and root resorption, supernumerary teeth, maxillary transverse dimension, jaw expansion, cleft lip and palate, TMJ morphology and pathology causing malocclusion, jaw pathology, respiratory tract morphology, vertical malocclusion, obstructive sleep apnea, and orthodontic implant placement.¹³

Lateral cephalogram is a radiographic technique commonly used in orthodontics that utilizes X-rays to produce two-dimensional images. Lateral cephalometric analysis is essential for assessing the facial skeleton, establishing a diagnosis, evaluating the shape of the face, planning orthodontic treatment, and monitoring the development of the skull and facial bone structure. The advantages of a cephalogram are that it provides a fairly detailed picture of the facial bone structure, including the relative position of the teeth, jaws, and skull bone. It is also cost-effective, and has relatively low radiation exposure.

The Cervical Vertebrae Maturation Stage is a well-established biological indicator used to assess the peak of puberty and predict further development of bone growth.¹⁴ Cervical Vertebrae Maturation Stage is particularly useful in determining the optimal time for intervention, especially in cases that require growth modification such as functional appliances, jaw expansion, headgear, skeletal anchorage devices, and orthognathic surgery planning.¹⁵ Baccetti et al.,¹⁶ introduced five new and simpler cervical vertebrae stages, namely Cervical Vertebrae Maturation Stage I through Cervical Vertebrae Maturation Stage V.

There is considerable variability in the developmental stage of midpalatal suture fusion which is often unrelated to chronological age, therefore we can use Cervical Vertebrae Maturation Stage to predict Midpalatal Suture Maturation Stage seen on a cephalogram which is a routine radiograph in the field of orthodontics. If Cervical Vertebrae Maturation Stage can reliably estimate MPSMS, this will benefit clinical applications.¹⁷ The novelty is to find a method for predicting Midpalatal Suture Maturation Stage without using CBCT and provide a more affordable, lower-radiation alternative for patient populations in settings such as

Jakarta in children 8-19 years old. Based on the background above, this study aims to analyze the correlation between Cervical Vertebrae Maturation Stage (CVMS) and Midpalatal Suture Maturation Stage (MPSMS).

METHODS

This study was an observational analytic study with a consecutive sampling design. Researchers collected 47 cephalograms and CBCT scans, which were used as samples to analyze the stages of cervical vertebrae maturation and midpalatal suture maturation. Sequential observations were then performed to assess the relationship between CVMS and MPSMS. A total of 15 samples were randomly selected and re-evaluated after one month to conduct an agreement test and minimize interpretation bias. The inclusion criteria were patients who had never undergone orthodontic treatment and had simultaneously obtained cephalogram and CBCT data. Exclusion criteria included patients with pathological conditions and patients with trauma to the neck and palate.

The tools used in this study included a Dell Precision T7810 computer (Windows 7 Ultimate, Intel(R) Xeon(R) CPU ES-2623 v3, 2013, China) for sample selection, a MacBook Air M1 laptop (version 14.5, 2021, USA) to open and capture sample images, an iPad Pro (version 18.1.1, 2021, USA) for tracing, an Apple Pencil (2nd generation, 2018, USA) for manual tracing of CVMS and MPSMS, the Goodnotes Application (version 5.0, 2022, UK) for annotation. SPSS data analysis software (version 29.0, 2022, USA) was used for statistical analysis, i-Dixel 2.2 software for imaging processing, a Veraviewepocs 2D lateral cephalogram machine (90kV, 6.8mA, 4.8sec, DAP 10.8mGycm2, 2000s, Japan), and a Morita 3D CBCT machine (Accuitomo 170, axial view, FOV 100x100, slice thickness 2mm, 2011, Japan) to acquire CBCT images. The materials used were radiographic outputs from cephalograms and CBCTs.

Determination of the cervical vertebrae maturation stages I-V (CVMS I-V) was based on the Baccetti method. CVMS stage I is characterized by flat inferior borders on all three cervical vertebrae, with the possible exception of a concavity at the inferior border of C2; the bodies of C3 and C4 are trapezoidal, where the superior borders of the vertebral bodies taper from posterior to anterior. CVMS stage II shows concavities at the inferior borders of C2 and C3; the bodies of C3 and C4 may be either trapezoidal or horizontally rectangular. In CVMS stage III has concavities at the inferior borders of C2, C3, and C4; with the bodies of C3 and C4 appearing horizontally rectangular. CVMS stage IV also presents concavities at the inferior borders of C2, C3, and C4; but at this stage, at least one of the bodies of C3 or C4 is rectangular, while the other remains horizontally rectangular. CVMS stage V include concavities at the inferior borders of C2, C3, and C4; with at least one of the bodies of C3 or C4 appearing vertically rectangular and the other is square (Figure. 1).¹⁶ Two investigators were involved in evaluating the data: S.N., an undergraduate student in the faculty of dentistry, and S.P.A.A., a dental radiology specialist.

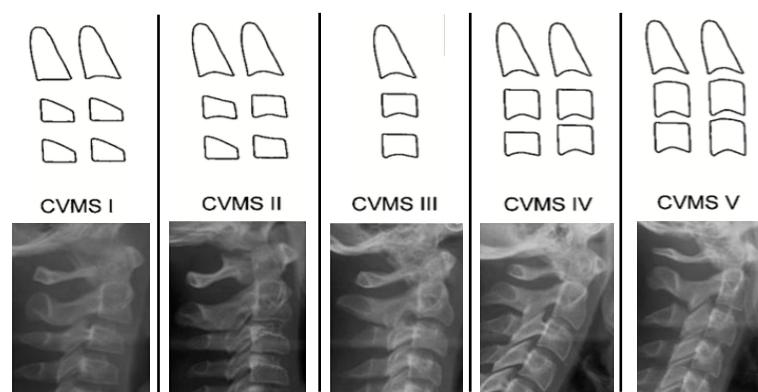


Figure 1. Cervical vertebrae maturation stage according to the Baccetti method^{16,17}

Determination of the midpalatal suture maturation stages (Stages A-E) followed the Angelieri method. Stage A, the midpalatal suture appears as a straight line with high density (unfused suture). Stage B, the midpalatal suture appears as a curved line with high density (unfused suture). Stage C, the midpalatal suture appears as two curved lines parallel to each other (beginning of suture fusion). Stage D, the midpalatal suture appears as two curved lines on the front of the palate that disappear toward the back (partial suture fusion). Stage E, complete absence of the midpalatal suture (complete suture fusion) (Figure 2).^{6,18}

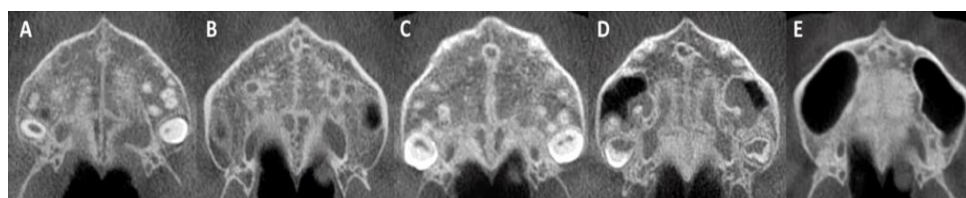


Figure 2. Midpalatal suture maturation stage according to the Angelieri method^{6,18}

Weighted Kappa was used to assess inter-rater agreement between S.N. and S.P.A.A. in the interpretation of CVMS and MPSMS. Agreement was evaluated at a single time point. If disagreement occurred between the two raters and was $\leq 20\%$, the result was accepted. If disagreement exceeded 20%, re-examination was conducted. Spearman's rank correlation test was used to analyze the correlation between CVMS and MPSMS. The level of significance determined for this study was $p < 0.05$ and a correlation coefficient greater than 0.8 was considered strong.

RESULTS

The Weighted Kappa test was used to assess the inter-rater agreement in observing skeletal maturation using CVMS and midpalatal suture maturation using MPSMS. The results showed a Weighted Kappa value of 0.894. The distribution of CVMS and MPSMS observed in the samples is presented in Table 1. The sample consisted of 47 individuals aged 8-19 years. Among CVMS classifications, the most frequent was the fourth cervical stage, while for MPSMS, stage C was the most commonly observed.

Table 1. Distribution of samples based on CVMS and MPSMS

Age	n	CVMS (n)					MPSMS (n)				
		CS1	CS2	CS3	CS4	CS5	A	B	C	D	E
8-10	11	4	1	-	5	1	2	3	5	1	-
11-13	12	5	1	3	1	2	4	6	2	-	-
14-16	13	2	2	5	4	-	1	5	4	3	-
17-19	11	-	-	1	7	3	-	-	4	5	2
Total	47	11	4	9	17	6	7	14	15	9	2

The distribution of MPSMS stages across CVMS classifications demonstrates a gradual pattern of midpalatal suture maturation and fusion (from stage A to E) as cervical vertebrae maturation progresses (from CS1 to CS5), as shown in Table 2. Again, the fourth cervical stage was the most frequent CVMS stage, and MPSMS stage C was the most frequent among all categories.

Sample distribution according to the results of skeletal maturation assessment using CVMS and the results of midpalatal suture maturation assessment using MPSMS stages by gender is shown in Table 3. The majority of male and female participants were classified under the fourth cervical stage of CVMS. Similarly, stage C of MPSMS was the most common across both male and female.

Table 2. Distribution of MPSMS according to CVMS (n/%)

CVMS	MPSMS					Total
	A	B	C	D	E	
CS1	4/36.4	6/54.5	1/9.1	-	-	11
CS2	-	3/75	1/25	-	-	4
CS3	2/22.2	3/33.3	3/33.3	1/11.1	-	9
CS4	1/5.9	1/5.9	8/47	6/35.3	1/5.9	17
CS5	-	1/16.7	2/33.3	2/33.3	1/16.7	6
Total	7	14	15	9	2	47

Table 3. Distribution of CVMS and MPSMS samples by gender

Maturation stage	Gender				Total	%
	Male		Female			
	n	%	n	%		
CVMS						
CS1	7	26.9	4	19.1	11	23.4
CS2	2	7.7	2	9.5	4	8.5
CS3	4	15.4	7	33.3	11	23.4
CS4	9	34.6	8	38.1	17	36.2
CS5	4	15.4	0	0	4	8.5
Total	26	100	21	100	47	100
MPSMS						
A	4	15.4	3	14.3	7	14.9
B	6	23.1	8	38.1	14	29.8
C	8	30.8	7	33.3	15	31.9
D	7	26.9	2	9.5	9	19.1
E	1	3.8	1	4.8	2	4.3
Total	26	100	21	100	47	100

Scatter plots were used to visualize the correlation between CVMS and MPSMS. The correlation between CVMS and MPSMS based on all samples was linear (Figure. 3.A), while the correlation for males was also linear (Figure. 3.B) and for females was monotonic (Figure. 3.C).

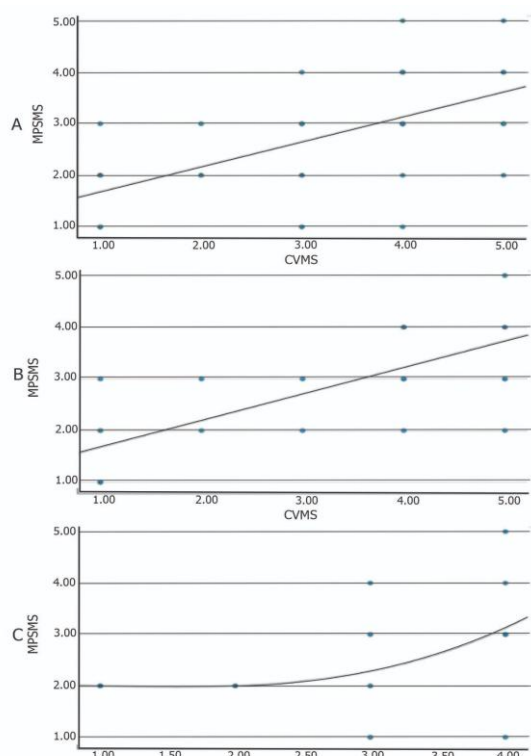


Figure 3. Scatter plot graphs showing the relationship between CVMS and MPSMS. A. All samples; B. Male; C. Female

The Spearman rank correlation test was conducted to determine the correlation between CVMS and MPSMS. The results for male, female, and total samples are shown in Table 4. Overall, a strong and statistically significant correlation was found between CVMS and MPSMS across all groups.

Table 4. Results of the Spearman rank correlation test between CVMS and MPSMS

Variable	Respondent	Value	MPSMS
CVMS	Male	Correlation Coefficient	0.672
		p Value	<0.001
		n	26
	Female	Correlation Coefficient	0.514
		p Value	0.017
		n	21
	Total	Correlation Coefficient	0.640
		p Value	<0.001
		n	47

DISCUSSION

This study was an observational analytic study with a consecutive design that used secondary data in the form of cephalograms and CBCT scans as research samples. Data was collected from 2012 to 2024. The selected age range of 8-19 years represents a period of active growth in children and adolescents in Indonesia, during which significant changes occur in the structure of the facial bones and jaws.¹⁹ In this age range, individuals undergo several important stages in their biological development, including the growth of teeth and facial skeletons, which form the basis for determining effective orthodontic treatment.²⁰ The age range of subjects in this study aligns with that used by Liu et al.,⁶ who included participants aged 8-20 years.

The distribution of samples based on CVMS and MPSMS (Table 1.) is consistent with the findings of Liu et al.,⁶ Luz et al.,⁹ and Jang et al.²⁴ Liu et al.,⁶ applied the same age grouping approach used in this study, in which 8-10 years represents the mixed dentition period, 11-13 years corresponds to the early-to-peak puberty, 14-16 years marks the post-peak puberty, and 17-20 years represents the age range typically used for adult orthodontic treatment planning. These groupings are based on differing treatment strategies for each developmental stage. In contrast, Luz et al.'s did not use age grouping and only included participants aged 11-14 years, whereas Jang et al. followed the same age grouping as Liu et al.'s study, which is also applied in this study. The sample size in this study is smaller, primarily due to ethical limitations regarding radiation exposure, CBCT imaging involves higher radiation doses, so scans could not be obtained for all orthodontic patients unless clinically indicated.²¹

The distribution of MPSMS stages according to CVMS (Table 2.) also aligns with the studies of Liu et al., Luz et al., and Jang et al.,²⁴ all of which demonstrated a gradual progression of midpalatal suture maturation and fusion along with advancing cervical vertebral stages. While Liu et al., Luz et al., and Jang et al., used the CVMS classification system with stages CS1-CS6, the present study used a more recent five-stages version (CS1-CS5) proposed by Baccetti. This updated classification offers clearer morphological transitions between stages, which helps reduce ambiguity in inter-rater interpretation.²¹

The distribution of CVMS and MPSMS by gender (Table 3.) is in agreement with Jang et al.,²⁴ who also observed a balanced distribution of male and female participants. Statistical analysis using the Spearman rank correlation test demonstrated a strong correlation between CVMS and MPSMS, with a correlation coefficient value of $r=0.640$ (Table 4), confirming a significant relationship between two variables.²² This finding is consistent with previous research by Luz et al.⁹ with a value of $r=0.6916$; Mahdian et al.,²³ reports the value of $r=0.691$ in

female and $r=0.754$ in male participants. However, Mahdian et al.,²³ did not report the overall correlation for all samples.

This study is also in line with research by Liu et al.⁶, who found a strong correlation with a value of $r=0.867$ using a larger sample size and a different classification strategy. They grouped CS1-CS6 into three broader categories (prepubertal stage, pubertal stage, and postpubertal stage) and the midpalatal suture stages A-E into no fusion of the midpalatal suture stage, partial or complete fusion of the midpalatal suture, and transitional stage as it implies the beginning of fusion of the midpalatal suture. Jang et al.,²⁴ reported an even higher correlation ($r=0.874$) with a larger sample size and used a different CVMS classification system (CS1-CS6). It is important to note that racial and ethnic variations were present across all studies.²⁴

This study confirms that there is a strong relationship between CVMS and MPSMS, suggesting that CVMS potentially can be used as a reliable indicator for predicting MPSMS. The Spearman rank correlation revealed stronger correlations in male participants than in females, consistent with previous studies. The difference in correlation results between males and females may be attributed to biological differences in growth patterns. Since individuals in active growth phases have a greater chance of success in RME treatment because their bones are more responsive to expansion.^{25,26}

The limitation of the study is the use of a non-probability sampling method with a cross-sectional design. Future research should adopt a prospective study design and consider simplifying MPSMS stages into two categories such as pre-fusion and fusion, as this may enhance clinical applicability.

CONCLUSION

There is a strong correlation between CVMS and MPSMS in the population aged 8–19 years. The implication of this study in the clinic is that RME is recommended during CVMS stages CS1 to CS3, with CS2 being the most optimal stage. However, RME is not recommended for patients in CVMS stages CS4 and CS5.

Author Contributions: Conceptualization, S.N. and H.W.; methodology, S.N., H.W., S.P.A.A.; software, S.P.A.A.; validation, S.N., H.W., S.P.A.A.; formal analysis, S.N.; investigation, S.N.; resources, S.N., H.W., S.P.A.A.; data curation, S.N.; writing original draft preparation, S.N.; writing review and editing, S.N.; visualization, S.N.; supervision, H.W. and S.P.A.A.; project administration, S.N.; funding acquisition, S.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no funding.

Institutional Review Board Statement: The ethic of this research was approved by Komisi Etik Penelitian Kesehatan FKG Universitas Trisakti (804A/S1/KEPK/FKG/11/2024 and 29 November 2024).

Informed Consent Statement: Patient consent was waived due to the use of secondary data.

Data Availability Statement: Data are available on valid request by contacting the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Informed Consent Statement: Patient consent was waived due to the use of secondary data.

Data Availability Statement: Data are available on valid request by contacting the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

1. Ghodasra R, Brizuela M. Orthodontics, Malocclusion. Treasure Island (FL): StatPearls. 2023. p.23.
2. Mathew R, Sathasivam HP, Mohamednor L, Yugarai P. Knowledge, attitude and practice of patients towards orthodontic treatment. BMC Oral Health. 2023 8;23(1):132. <https://doi.org/10.1186/s12903-023-02780-y>
3. Irano-Cortés JE, Montiel-Company JM, Bellot-Arcis C, Almerich-Torres T, Acevedo-Atala C, Ortolá-Siscar JC, et al. Factors related to the psychological impact of malocclusion in adolescents. Scientific Reports. 2020;10(1):13471. <https://doi.org/10.1038/s41598-020-70482-4>

4. Alyami D, Alharbi A, Hatan Y, Asiri YM, Alharthy H, Alogaibi YA. Prevalence of malocclusion and orthodontic treatment needs among adolescents in Najran City, Saudi Arabia. *J Orthod Sci.* 2023;4;12:60. p.3-5. <https://doi.org/10.4103/jos.jos.51.23>.
5. Ledra IM, Papadopoulou AK, Papadopoulou AK, et al. Comparison of the 3-dimensional force system produced by transpalatal arch and continuous arch mechanics in maxillary expansion. *J Clin Exp Dent.* 2020;12(7):e652-e658. <https://doi.org/10.4317/jced.56934>
6. Liu H, Feng L, Wang L. Diagnostic value of cervical vertebral maturation stages for midpalatal suture maturation assessment: a study in the Chinese population. *BMC Oral Health.* 2023;23(1):504. <https://doi.org/10.1186/12903-023-03220-7>.
7. Venkateshwara K, Soni S, Prashar A. Rapid maxillary expansion: A review. *Int J Health Sci.* 5(S2), 2021. p.244-5. <https://doi.org/10.53730/ijhs.v5nS2.5767>
8. Bhanotia D, Borah MJ, Kumar AS. Rapid maxillary expansion — a review. *IJDMSR.* 2022;4(4):174-185. <https://doi.org/10.35629/5252-0404174185>
9. Luz CN, Pasqua B, de PM, Paiva JB, Ring-Neto J. Cervical vertebrae maturation assessment as a predictive method for midpalatal suture maturation stages in 11- to 14-year-olds: retrospective study. *Clin Investig Orthod.* 2022; 81(1): 43-49. <https://doi.org/10.1080/13440241.2022.2042036>
10. Milani OH, Mills L, Nikho A, Tliba M, Allareddy V, et al. Automated classification of midpalatal suture maturation stages from CBCTs using an end-to-end deep learning framework. *Scientific Reports.* 2025;29;15(1):18783. <https://doi.org/10.1038/s41598-025-03778-y>
11. Shayani A, Merino-Gerlach MA, Garay-Carrasco IA, Navarro-Cáceres PE, Sandoval-Vidal HP. Midpalatal suture maturation stage in 10 to 25 year olds using cone-beam computed tomography—a cross-sectional study. *Diagnostics.* 2023; 13(8):1449. <https://doi.org/10.3390/diagnostics13081449>
12. Alshomrani F. Cone-beam computed tomography (cbct)-based diagnosis of dental bone defects. *Diagnostics.* 2024; 14(13):1404. <https://doi.org/10.3390/diagnostics14131404>
13. Thirunavukkarasu R, Mani B, Nirupama C, Muralidharan D, Tamizhman J, Prasanth C. CBCT in orthodontics: A boon for the millennial generation. *Int. J. Health Sci.* 6(S1), 2022. p.676-81. <https://doi.org/10.53730/ijhs.v6nS1.4814>
14. Ghodasra R, Brizuela M. Orthodontics, Cephalometric Analysis. Treasure Island (FL): StatPearls Publishing. 2023. <https://www.ncbi.nlm.nih.gov/books/NBK594272/>
15. Manabe A, Ishida T, Kanda E, Ono T. Evaluation of maxillary and mandibular growth patterns with cephalometric analysis based on cervical vertebral maturation: A Japanese cross-sectional study. Al-Moraissi E, editor. *PLoS One.* 2022. p.1-14. <https://doi.org/10.1371/journal.pone.0265272>.
16. Putridwita AF, Sahelangi OP. Factors associated with skeletal maturation at the growth spurt period using a cervical vertebrae maturation stage. *JIDA.* 2023;6(1):23-3. <https://doi.org/10.32793/jida.v6i1.977>
17. Schoretsaniti L, Mitsea A, Karayianni K, Sifakakis I. Cervical vertebrae maturation method: reproducibility and efficiency of chronological age estimation. *Appl Sci.* 2021; 11(7): 3160. <https://doi.org/10.330/app11073160>
18. Angelieri F, Franchi L, Cevindanes LH, McNamara JA Jr. Diagnostic performance of skeletal maturity for the assessment of midpalatal suture maturation. *Am J Orthod Dentofacial Orthop.* 2015;148(6):1010-6. <https://doi.org/10.1016/j.ajodo.2015.06.016>.
19. Mardiaty E, Komara I, Halim H, Maskoen AM. Determination of pubertal growth plot using hand-wrist and cervical vertebrae maturation indices, dental calcification, peak height velocity, and menarche. *The Open Dent J.* 2021;15(1): 228-40. <https://doi.org/10.2174/1874210602115010228>
20. Kulshrestha R. Growth and growth studies in orthodontics -a review. *JDOC.* 2016;2(4):1-5.
21. Benavides E, Krecioch JR, Connolly RT, Allareddy T, Buchanan A, Spelic D, et al. Optimizing radiation safety in dentistry: Clinical recommendations and regulatory considerations. *J Am Dent Assoc.* 2024;155(4). <https://doi.org/10.1016/j.adaj.2023.12.002>
22. Papageorgiou SN. On correlation coefficients and their interpretation. *J Orthod.* 2022;49(3):359-61.
23. Mahdian A, Safi Y, Dalaie K, Kavousinejad S, Behnaz M. Correlation assessment of cervical vertebrae maturation stage and mid-palatal suture maturation stage in an Iranian population. *J World Fed of Orthod.* 2020;9(3):112-6. <https://doi.org/10.1016/j.ejwf.2020.05.004>
24. Jang HI, Kim SC, Chae JM, et al. Relationship between maturation indices and morphology of the midpalatal suture obtained using cone-beam computed tomography images. *Korean J Orthod.* 2016;46(6):345-55. <https://doi.org/10.4041/kjod.2016.46.6.345>
25. Bashir NZ, Tanaka M, Tanaka M, et al. Removable partial dentures and mortality among older adults: A 10-year cohort study. *J Prosthet Dent.* 2022;128(1):1-7. <https://doi.org/10.1016/j.prosdent.2021.02.019>
26. Liang C, Angelieri F. Assessment of midpalatal suture maturation using cone-beam computed tomography: a systematic review. *AJODO.* 2020;158(3):327-36.