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ASSESSMENT OF SKELETAL MATURATION IN DIFFERENT AGE GROUPS OF EGYPTIAN POPULATION USING CBCT SCANS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Objectives: This study aimed to assess the association between the MPS and CV maturation stages and age in a sample of Egyptian population using cone beam computed tomography scans.

Methodology: Sixty maxillofacial CBCT scans of individuals aged from 10 to 30 years were retrospectively gathered and visually analyzed for assessment of Mid-palatal suture and cervical vertebrae maturation stages and their association with age and with each other on corrected axial and sagittal views respectively. Two observers independently evaluated the CBCT images.

Results: There was a moderate positive association between age and MPS (rs=0.485). There were strong positive associations between (CVM-age) (rs=0.683) and (CVM-MPS) (rs=0.506). The study demonstrated excellent inter-observer and intra-observer agreement for MPS and CVM maturation stages assessment

Conclusion: Mid-palatal suture maturation stage identification does not strongly correspond with chronological age. However, cervical vertebrae maturation stage determination can provide an accurate idea about the chronological age range.

KEYWORDS: Midpalatal suture, cervical vertebrae, CBCT, skeletal maturation, Chronological age.

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INTRODUCTION

Skeletal maturation refers to the evaluation of the size, shape, and level of mineralization in the epiphyses and physeal plates of bones to determine how close they are to reach full development. This assessment is often used to diagnose and monitor conditions related to abnormal growth patterns, evaluate a child's growth potential, or track the effectiveness of medical treatments. It is important to note that skeletal maturation differs from skeletal growth. While growth refers to the quantitative increase in size or mass of bone, maturation describes the sequential changes that result in a fully developed and specialized bone structure. These distinctions make skeletal maturation a key measure in various clinical fields, such as orthodontics for planning interventions and pediatrics for managing growth-related conditions. [1]

The age of an individual can be assessed using various methods, including chronological, morphological, skeletal, biological, dental, circumpubertal, behavioral, and mental age. Among these, chronological age is the most straightforward to determine, calculated simply from the individual's date of birth. However, skeletal maturation does not always align with chronological age due to significant developmental differences among individuals of the same chronological age. [2]

A precise assessment of a person's developmental stage is crucial for accurate diagnosis and treatment planning. It helps to predict future growth patterns, craniofacial development, and the likelihood of post-treatment relapse. Additionally, this evaluation plays a vital role in Forensic Medicine and Dentistry. [3, 4]

Over time, several approaches have been developed to evaluate the maturation of facial sutures. Common approaches include evaluating sexual characteristics, dental examinations, and radiographic imaging. Among these, carpal radiography (Hand–wrist method) is widely used to determine skeletal age due to the strong association between mandibular growth and the bone maturation sequence of the hand and wrist. [5]

Another widely recognized method for evaluating skeletal maturation is the cervical vertebrae maturation (CVM) technique, first introduced by Lamparski in 1972. [6] This approach identified cervical vertebrae maturation stages using C2 through C6 as part of the diagnostic process. In 1995, Hassel and Farman [7] refined the CVM method, focusing on three vertebrae; C2, C3, and C4 because C3 and C4 could still be clearly observed even if during imaging, a protective thyroid collar was used. Later, in 2005, Baccetti et al. [8] presented a detailed schematic illustrating the six stages of CVM. Multiple studies conducted worldwide have validated the reliability of the CVM method, primarily by comparing it to the hand and wrist method. One of the key advantages of the CVM method is its simplicity in assessing the shapes of the cervical vertebrae and its high reproducibility, with trained examiners achieving classification accuracy of up to 98%. Additionally, the method is valuable in predicting the pubertal peak in mandibular growth. However, this relationship does not extend to the maxilla.

Assessing the ossification or maturation of the maxilla can be reached by surveying the fusion of the mid-palatal suture (MPS) using occlusal radiographs. This can be unreliable because the vomer and other nasal structures overlap the area of the suture, making it difficult to interpret the stage of fusion accurately. In contrast, cone beam computed tomography (CBCT) offers a reliable alternative. It allows for the individual evaluation of MPS maturation by isolating the suture without interference from overlapping anatomical structures. [9,10]

Different studies have been published discussing the possible association of different indicators of skeletal maturation with chronological age.[1-10]

However, not enough research has been formulated to appraise the maturation stages of the midpalatal suture and their possible association with chronological age. Therefore, this study was designed to investigate such association in a sample of Egyptian population with age ranging from 10 to 30 years using CBCT.

Null hypothesis is that there is not an association between maturation of the midpalatal suture and the chronological age.

MATERIALS AND METHODS

Study size

A retrospective cross section study was performed on sixty maxillofacial CBCT scans belonging to Egyptian individuals and collected from the CBCT database available at Oral and Maxillofacial Radiology department, Faculty of Dentistry, Cairo University based on a strict eligibility criteria.

Based on the results of Jimenez-Valdivia et al. 2019 [11] adopting an alpha (α) level of 0.05 (5%), power=80%, the predicted sample size (n) was a total of 15 patients per age group for a total of 60 patients in the four tested age groups. Sample size was calculated using G*Power version 3.1.9.6 for windows using Z test. Sample size calculation was approved by the Medical Biostatistics Unit at Faculty of Dentistry, Cairo University under the date 19/3/2023.

Inclusion criteria:

CBCT scans of Egyptian patients, males and females with ages starting from 10 to 30 years.

CBCT scans with maxilla, mandible and cervical vertebra CS4 are visible.

CBCT images of good quality without artifacts that could interfere with visual assessment of maxilla, mandible and cervical vertebrae.

Exclusion criteria:

Patients undergoing or with a history of previous orthodontic treatment, any pathological conditions or lesions affecting the normal bony architecture, history of past surgeries involving the maxillofacial and/or cervical region, history of chemotherapy or radiotherapy and patients with labial and palatal cleft.

Our study was approved by the Research and Ethics Committee at Faculty of Dentistry, Cairo University **(No. of approval 7-4-23).**

To represent various maturation stages of the midpalatal suture, the study selected individuals aged 10 to 30 years, covering both children and adults in the Egyptian population. This range was divided into four age groups: Group 1 (10–15 years), Group 2 (16–20 years), Group 3 (21–25 years), and Group 4 (26–30 years). Image analysis and interpretation was performed using Planmeca Romexis software viewer (Planmeca OY, Helsinki, Finland).

Assessment of Midpalatal suture

Midpalatal suture was assessed using corrected axial CBCT images (Figure 1) for evaluation of its maturation stage and was classified following ***Angelieri et al., 2013*** [12] as a stage of A, B, C, D, or E as follows:

Stage A: The suture is seen as a somewhat straight line of high density.

Stage B: The suture presents as a scalloped radiopaque line.

Stage C: The suture presents as two lines that are radiopaque, scalloped, parallel and separated by areas of low radiographic density.

Stage D: The palatine bones appear more radiodense, and the suture in this area is no longer visible except as two lines that are scalloped and dense along the midline of the palatine bone.

Stage E: Along the maxillary and palatine bones, the suture is no longer visible, signifying fusion.

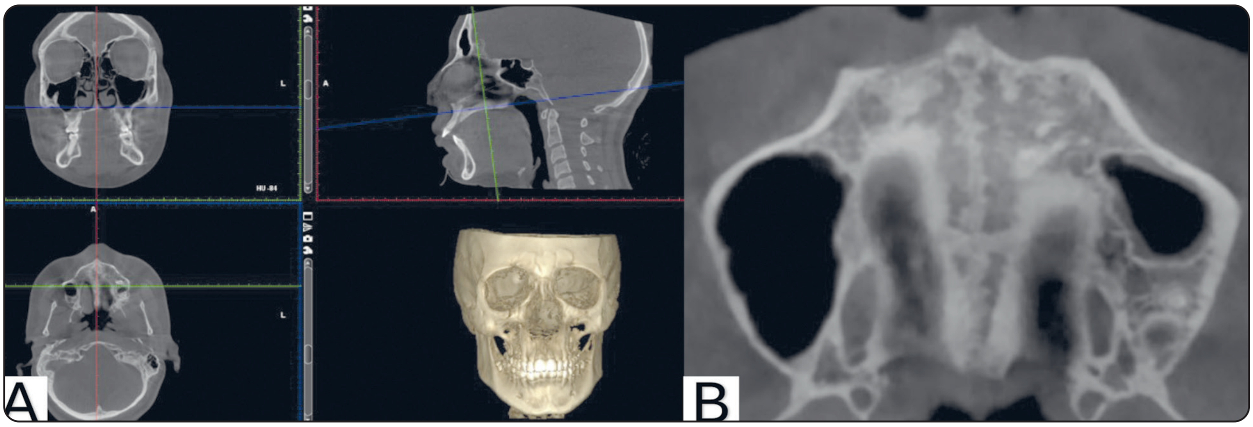

Fig. (1) CBCT images showing the adjustment of the scan for the midpalatal suture assessment: (A) Adjustment of the position indicator of the image which is positioned at the patient's midsagittal plane in both the coronal and axial views (red lines) and parallel to the antero-posterior long axis of the palate in sagittal image (blue line). (B) A central axial CBCT image showing MPS maturation stage (C) where the suture presents as two lines that are radiopaque, scalloped, parallel and separated by areas of low radiographic density according to Angelieri et al., 2013. [12]

Assessment of Cervical vertebrae

Cervical vertebrae: C2, C3 and C4 were assessed using corrected sagittal cuts (Figure 2) for evaluation of its maturation stage (CS1, CS2, CS3, CS4, CS5 and CS6) following the classification of ***Bacette et al., 2005*** [8] as follows:

CS1: C2, C3 and C4 are seen with flat lower borders. The bodies of both C3 and C4 are trapezoid in shape where the superior border of the vertebral body is tapered postero-anteriorly.

CS2: A concavity is seen at the lower border of C2, while both C3 and C4 are still seen with trapezoidal bodies.

CS3: Both C2 and C3 are seen with concavities at their lower borders. The bodies of C3 and C4 may remain trapezoid in shape or seen as rectangular horizontal.

CS4: The lower borders of C2, C3, and C4 now are seen with concavities. The bodies of C3 and C4 take on a horizontally rectangular shape.

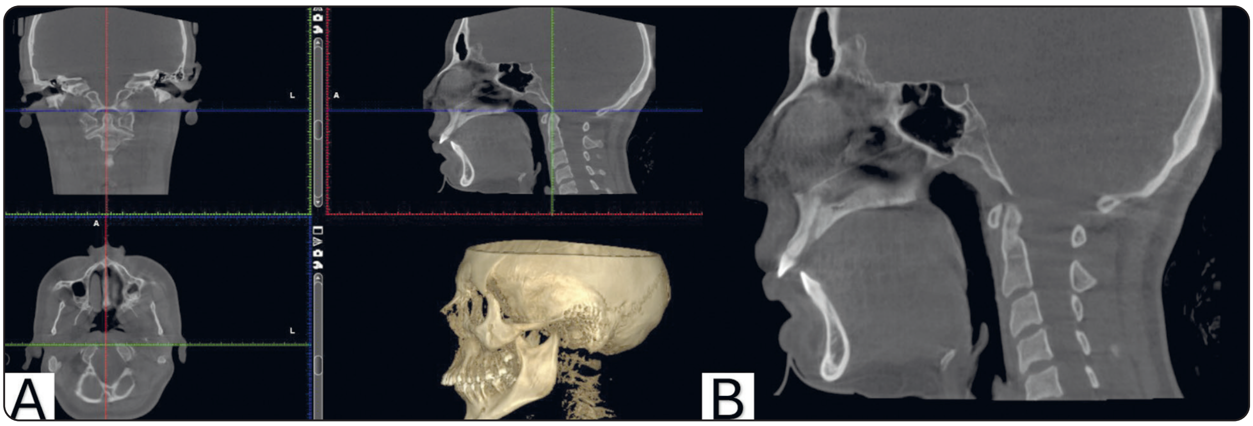

Fig. (2) CBCT images showing the adjustment of the scan for cervical vertebrae maturation: (A) CBCT images showing the adjustment of mid-sagittal sections that were used for identification and classification of the cervical vertebrae maturation stages. (B) Sagittal image showing cervical vertebrae maturation stage (CS4) according to Bacette et al., 2005 [8]; as concavities can be clearly noticed at the lower borders of C2, C3, and C4 with the bodies of C3 and C4 being horizontally rectangular in shape.

CS5: The concavities at the lower borders of C2, C3, and C4 persist. One of the bodies of C3 and C4, at least, appears squared in shape.

CS6: The concavities at the lower borders of C2, C3, and C4 still remain noticeable, with one of the bodies of C3 and C4, at least, appearing rectangular vertical in shape.

CBCT images were independently analyzed by two oral radiologists, who were blinded to the patients' demographic data and each other's findings. The first radiologist assessed the scans to determine the maturation stages of the midpalatal suture and cervical vertebrae. The second radiologist re-evaluated the images, with a two-week interval between their two reading sessions. Intra-observer and inter-observer variability were then assessed based on the results.

Statistical analysis:

Categorical and ordinal data were presented as frequencies and percentages. Categorical data were analysed using Fisher's exact test. Numerical data were expressed as mean and standard deviation (SD) values. Normality was assessed by examining the distribution and performing Shapiro-Wilk's test, which confirmed that the data were normally distributed. They were analysed using an independent t-test. Correlation analysis was made using Spearman's rank-order correlation coefficient. Inter- and intra-observer reliability for numerical data were analysed using the Intra-class correlation coefficient (ICC), and ordinal data were analysed using the weighted Kappa coefficient. Age and the possibility of suture closure were predicted using multivariable linear and binary logistic regression models, respectively. Model selection for the stepwise procedure was based on the Akaike Information Criterion (AIC), choosing the model with the lowest AIC value. A significance level of $p<0.05$ was established for all tests. Statistical analysis was conducted using R statistical software, version 4.4.1 for Windows.

RESULTS

Summary statistics for demographic data and radiographic characteristics are presented in Table (1) and Figure (3).

TABLE (1) Summary statistics for demographic data and radiographic characteristics.

Parameter		Value
Age (years) (Mean±SD)		20.75±6.07
Mid-palatine sutures stage [n(%)]	**A**	4 (6.67%)
	B	12 (20.00%)
	C	40 (66.67%)
	D	3 (5.00%)
	E	1 (1.67%)
Possibility of open suture [n(%)]	**Yes**	56 (93.33%)
	No	4 (6.67%)
Cervical vertebrae maturation stage [n(%)]	**CS1**	10 (16.67%)
	CS2	3 (5.00%)
	CS3	4 (6.67%)
	CS4	34 (56.67%)
	CS5	9 (15.00%)

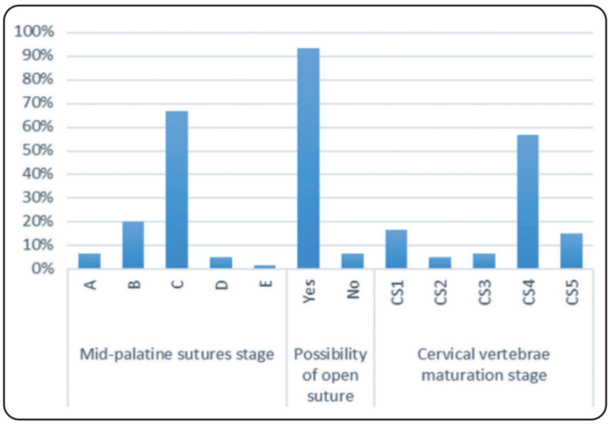

Fig. (3) Bar chart showing demographic data.

Associations with age are presented in Table (2).

There was a moderate positive association between age and MPS. There was strong positive association between (CVM-age) and (CVM-MPS).

TABLE (2) Correlation matrix.

Variable	Correlation coefficient	
	MPS	**CVM**
Age	0.485*	0.683*
MPS		0.506*

** Significant*

The association between age and the possibility of suture closure is presented in Table (3) and Figure (4). The association was statistically significant with cases with no possibility of suture closure (27.00±2.94) years having significantly higher ages than those with the possibility of closure (20.30±6.01) years (p=0.010).

TABLE (3) Association between age and the possibility of suture closure.

Age (years) (Mean ± SD)		p-value
Possibility of closure	**No possibility of closure**	
20.30±6.01	27.00±2.94	**0.010***

** Significant.*

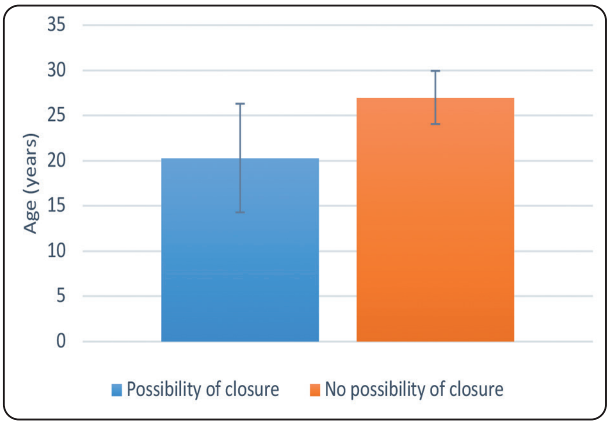

Fig. (4) Bar chart demonstrating mean and standard deviation values (error bars) for age according to the possibility of suture closure.

Regression analyses predicting age are presented in Table (4). Results showed that the increase in CVM was significantly associated with older age (p<0.001). The stepwise model was similarly statistically significant (p<0.001) and explained 44.6% of the variance and contained only CVM.

TABLE (4) Regression analyses for age (stepwise).

Variable	Coefficient	95% CI		Test statistic	p-value	R^2
		Lower	Upper			
CVM	3.16	2.25	4.07	**6.96**	**<0.001***	**0.446**

*CI Confidence interval, * significant (p<0.05).*

The current study demonstrated excellent inter-observer and intra-observer agreement for MPS and CVM maturation stages assessment represented in tables (5) and (6).

TABLE (5) Inter-observer reliability

Measurement	Reliability coefficient (95% CI)	p-value
Mid-palatine sutures stage	0.976 (0.928:1.000)	**<0.001***
Cervical vertebrae maturation stage	1.000 (1.000:1.000)	**<0.001***

*CI Confidence interval, * significant (p<0.05).*

TABLE (6) Intra-observer reliability

Measurement	Reliability coefficient (95% CI)	p-value
Mid-palatine sutures stage	0.908 (0.772:1.000)	**<0.001***
Cervical vertebrae maturation stage	0.845 (0.549:1.000)	**<0.001***

*CI Confidence interval, * significant (p<0.05).*

DISCUSSION

Since individuals vary in the timing, span, and pace of growth, assessing skeletal age is crucial for creating effective treatment plans and ensuring treatment outcomes and stability. Chronological age alone does not reliably indicate a child's growth stage, as children of the same chronological age often display differing levels of skeletal development. To address this limitation, several alternative markers of maturity have been proposed, including dental eruption, stages of dental calcification, hand and wrist development, height, weight, sexual maturation, frontal sinus development, cervical vertebrae and midpalatal suture maturation. [13, 14]

An innovative method of assessment was introduced by ***Angelieri et al., 2013*** [12] to assess the midpalatal suture (MPS) maturation using CBCT images. This study was conducted to assess the evidence of an association between the midpalatal suture maturation and the chronological age using CBCT scans of Egyptian population with age (10-30) years old. The sample was divided into four groups with the youngest group age (10-15) and the oldest one (26-30). The second aim of the current study was to assess the possible association between cervical vertebrae maturation (CVM) and chronological age. The possible association between CVM and age was assessed following a well-established method of ***Bacetti et al., 2005***[8]. The possible association of cervical vertebrae maturation stages with the MPS maturation stages was also assessed.

The current study results showed that the distribution of mid-palatal suture was as follows; the majority of participants were in stage C (66.67%), followed by stage B (20.00%), stage A (6.67%), stage D (5.00%), and stage E (1.67%). Open sutures were observed in 56 participants (93.33%), while 4 participants (6.67%) did not exhibit this characteristic. In terms of cervical vertebrae maturation stages, most participants were in CS4 (56.67%), with smaller groups in CS1 (16.67%), CS5 (15.00%), CS3 (6.67%), and CS2 (5.00%).

Regarding the possible association between MPS and CMV with age and with each other, there was a moderate positive association between age and MPS, while CMV showed a strong association with age. A strong association was also found between the MPS and CMV.

In agreement with the current study results, ***Tonello et al., 2017*** assessed midpalatal suture maturation in 84 children with more restricted age group range (11–15) years old in association with the age. They found that 90.3% of the subjects in the 11–13 age group had the unfused stages (A, B, and C), 13.1% of the sample had stage D and 10.7% had stage E. They reported that there was an association between the prevalence of the different maturation stages and chronological age. [15]

Similarly, in a study conducted by ***Ladewig et al., 2018***, midpalatal suture maturation was assessed in a larger sample of 112 patients within the narrow age range of 16–20 years. The study found that stage A was absent in all participants, while stage B was observed in 16 individuals. Stage C was identified in 50 participants, whereas stages D and E were noted in 26 and 27 individuals, respectively. These results demonstrated the relation between MPS maturation and age. [10]

A study by ***Jimenez-Valdivia et al., 2019*** evaluated the potential association between age and midpalatal suture (MPS) maturation using a larger and more diverse sample population. Following Angieleri's method, the study assessed maturation stages of MPS in juveniles and young adults through CBCT scans. Their Sample included 200 CBCT scans of individuals aged between 10 and 25 years, categorized into three groups: adolescents, post-adolescents, and young adults. Five maturation stages were identified: stages A, B, and C indicated an open midpalatal suture, while stages D and E reflected a fused suture. The findings revealed that the likelihood of observing an open midpalatal suture was 70.8% in individuals aged 10 to 15 years, 21.2% in those aged 16 to 20 years, and 17% in the 21 to 25-year age group. These results confirmed a significant association between age and MPS maturation. (11)

A wider age group was assessed by ***Katti et al., 2020*** who evaluated the midpalatal suture maturation in 200 cases aged between 11 to 50 years, which was close to the current study's age range but with a significantly higher sample size. The authors discovered that 15 subjects (those under 20) had stage A. Forty subjects (15 of whom were over 20 years old) had stage B, 70 subjects (60 of whom were over 20 years old) had stage C, 25 had stage D, and 40 had stage E (all over 20 years old). (16)

A more novel study by ***Silva-Montero et al., 2022*** intended to estimate the frequency of different stages of midpalatal suture maturation in young adults aged 15 to 30 years. The study also utilized CBCT scans to analyze the potential association between maturation stages and variables such as sex and age groups. The results revealed a statistically significant association between age and midpalatal suture maturation across the different age groups in the sample. (17)

The results reported by the current study, ***Tonello et al., 2017, Ladewig et al., 2018***, ***Jimenez-Valdivia et al., 2019, Katti et al. 2020*** and ***Silva-Montero et al., 2022*** were consistent with the results reported by Angelieri et al., 2013 who reported that the stages A,B,C were found in the young age group with corroboration with the histologic findings of ***Melsen and Melsen, 1982,*** who described the development of the midpalatal suture (MPS) at the juvenile stage as following a tortuous path, with the development of "bone islands" scattered along the suture. (10, 11, 15-18)

However, a group of authors conducted some research questioning the reliability of this method. ***Coşkuner et al., 2018*** evaluated the stages of midpalatal suture maturation in patients older than 15 years, the aim of their study was to determine the association between the stage of MPS maturation, CVM and age. The study deduced that neither CVM nor chronological age serves as a reliable indicator to determine the stage of MPS maturation in 15–30-year-old patients. The reason for this could be the small sample size of the study. (19)

Barbosa et al., 2019 assessed the reliability and reproducibility of individually evaluating midpalatal suture maturation using Angieleri's method for potential diagnostic applications. Two groups of examiners were established, each of which examined 60 CBCT/CT axial images and independently assessed the midpalatal suture maturation stage twice, with a 21-day interval between evaluations. The study concluded that Angieleri's method showed potential for reliability and reproducibility. However, the observed agreement rate was not high enough to support its use as a routine clinical tool. This lower agreement rate may have been due to the complex methodology, which involved both CBCT and CT cases, as well as the lack of a standardized voxel size for visual analysis. (20)

Regarding the possible association between CVM and age, most research was in agreement with our results. ***Madhu, 2017*** conducted a study aiming to ascertain the association between cervical vertebrae maturation and chronological age. Lateral cephalograms of 67 patients were obtained with high clarity and good contrast, and visually assessed to determine the maturation stage. The results, though arguable by the small sample size, marked that chronological age could be reliably concluded using the CVM index. (21)

A more recent study by ***Schoretsaniti et al., 2021*** investigated a sample consisting of 474 lateral cephalometric radiographs. Six examiners were trained in the CVM method, and all images were analyzed twice. The results demonstrated that the CVM method exhibited high reliability. Additionally, a noticeable association was observed between the maturation stages and chronological age. (22)

On the contrary, ***El-Bakary & Abo El-Atta, 2018*** studied 149 lateral cephalograms of Egyptians and claimed that CVM staging is not accurate to depend on solely for age estimation and accuracy will be enhanced if combined with another maturation index like dental age estimation. [23]

The current study also demonstrated a strong association between MPS and CVM. ***Lee & Mah, 2019*** assessed a total of 480 CBCT scans of patients aged 7-15 years utilizing a similar methodology to the current study. The results obtained indicated that CVM can be reliably used to predict the maturity of MPS. [24]

Luz et al., 2022 conducted a retrospective study with the objective of evaluating whether the CVM method could predict the stage of maturation of the midpalatal suture in patients aged 11 to 14 years. The study came to the conclusion that the CVM method has a powerful association with midpalatal suture maturation and can be used to predict it during the **early** stages of maturation. [25]

Munusamy et al., 2024 assessed MPS and CVM stages in 100 subjects with age range of 4–24 years. The study showed a highly significant and positive association between MPS stage and CVM stage. These results can also be attributed to the young age range of the sample. [26]

On the other hand, ***Yang et al., 2023*** conducted a study similar to the current one, investigating the association between chronological age, cervical vertebral maturation (CVM) stage, and midpalatal suture (MPS) maturation stage. They divided 109 participants, aged 7–43 years, into three age groups: under 15 years, 15–25 years, and over 25 years. The MPS maturation stages were classified according to Angeliere's method, while the CVM stages were categorized based on Baccettei's classification. The results concluded that MPS maturation stage may not be accurately predicted from chronological age and CVM stage. This finding was consistent with previous research involving samples with a higher proportion of older patients. [27]

When comparing our results to the existing literature, we recommend that further research on the maturation stages of the midpalatal suture be conducted with larger sample sizes of Egyptians and a broader age range. This will help to gain a better understanding of its association with age and other recognized maturation indices, and to determine whether it can truly be established as a reliable method for age estimation.

CONCLUSION

Mid-palatal suture maturation stage identification does not strongly correspond with chronological age. However, cervical vertebrae maturation stage determination can provide an accurate idea about the chronological age range.

REFERENCES

1. Mora, S., & Gilsanz, V. (2010). Pubertal growth of the male skeleton. In Osteoporosis in Men (pp. 95-103). Academic Press.
2. Macha, M., Lamba, B., Avula, J. S. S., Muthineni, S., Margana, P. G. J. S., & Chitoori, P. (2017). Estimation of correlation between chronological age, skeletal age and dental age in children: a cross-sectional study. Journal of clinical and diagnostic research: JCDR, 11(9), ZC01.
3. Rai, V., Saha, S., Yadav, G., Tripathi, A. M., & Grover, K. (2014). Dental and skeletal maturity- a biological indicator of chronologic age. Journal of clinical and diagnostic research: JCDR, 8(9), ZC60–ZC64.
4. Uslu-Akcam, O. (2017). Diagnostic value of cervical vertebral maturation stages for skeletal age estimation in orthodontic patients. Progress in Orthodontics, 18(1), 1–8.
5. Ozturk, T., Gumus, H., & Ozturk, G. (2020). Are Dental Maturation, Skeletal Maturation, and Chronological Age Associated With Complete Cleft Lip and Palate? The Cleft Palate-Craniofacial Journal, 105566562094477.
6. Lamparski, D.G. (1975). Skeletal age assessment utilizing cervical vertebrae. American Journal of Orthodontics, 67, 458-459.
7. Hassel, B., & Farman, A. G. (1995). Skeletal maturation evaluation using cervical vertebrae. American Journal of Orthodontics and Dentofacial Orthopedics, 107(1), 58-66.

8. Baccetti, T., Franchi, L., & McNamara Jr, J. A. (2005, September). The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. In Seminars in Orthodontics (Vol. 11, No. 3, pp. 119-129). WB Saunders.

9. Angelieri, F., Franchi, L., Cevidanes, L. H. S., Gonçalves, J. R., Nieri, M., Wolford, L. M., & McNamara Jr, J. A. (2017). Cone beam computed tomography evaluation of midpalatal suture maturation in adults. International journal of oral and maxillofacial surgery, 46(12), 1557-1561.

10. Ladewig, V. de M., Capelozza-Filho, L., Almeida-Pedrin, R. R., Guedes, F. P., de Almeida Cardoso, M., & de Castro Ferreira Conti, A. C. (2018). Tomographic evaluation of the maturation stage of the midpalatal suture in postadolescents. American Journal of Orthodontics and Dentofacial Orthopedics: Official Publication of the American Association of Orthodontists, Its Constituent Societies, and the American Board of Orthodontics, 153(6), 818–824.

11. Jimenez-Valdivia, L. M., Malpartida-Carrillo, V., Rodríguez-Cárdenas, Y. A., Dias-Da Silveira, H. L., & Arriola-Guillén, L. E. (2019). Midpalatal suture maturation stage assessment in adolescents and young adults using cone-beam computed tomography. Progress in orthodontics, 20, 1-7.

12. Angelieri, F., Cevidanes, L. H., Franchi, L., Gonçalves, J. R., Benavides, E., & McNamara Jr, J. A. (2013). Midpalatal suture maturation: classification method for individual assessment before rapid maxillary expansion. American Journal of Orthodontics and Dentofacial Orthopedics, 144(5), 759-769.

13. Hashim, H. A., Mansoor, H., & Mohamed, M. H. H. (2018). Assessment of skeletal age using hand-wrist radiographs following Bjork system. Journal of International Society of Preventive and Community Dentistry, 8(6), 482-487.

14. Mahmood, H. T., Shaikh, A., & Fida, M. (2016). Association between frontal sinus morphology and cervical vertebral maturation for the assessment of skeletal maturity. American Journal of Orthodontics and Dentofacial Orthopedics, 150(4), 637-642.

15. Tonello, D. L., de Miranda Ladewig, V., Guedes, F. P., Conti, A. C. D. C. F., Almeida-Pedrin, R. R., & Capelozza-Filho, L. (2017). Midpalatal suture maturation in 11-to 15-year-olds: A cone-beam computed tomographic study. American journal of orthodontics and dentofacial orthopedics, 152(1), 42-48.

16. Katti, G., Shahbaz, S., Katti, C., & Rahman, M. S. (2020). Evaluation of midpalatal suture ossification using cone-beam computed tomography: a digital radiographic study. Acta Medica, 63(4), 188-193.

17. Silva-Montero, J. C., Faus-Matoses, I., Ribas-Pérez, D., Pourhamid, H., & Solano-Mendoza, B. (2022). Analysis of the Frequency and Correlated Factors of Midpalatal Suture Maturation Stages in Young Adults, Based on Cone Beam Computed Tomography Imaging. Journal of Clinical Medicine, 11(23), 6959.

18. Melsen, B., & Melsen, F. (1982). The postnatal development of the palatomaxillary region studied on human autopsy material. American journal of orthodontics, 82(4), 329-342.

19. Coşkuner, H. G., Atik, E., & Taner, T. (2018). Relationship between midpalatal suture maturation and age and maturation of cervical vertebrae: radiographic evaluation. Acta Odontologica Turcica, 35(3), 69-74.

20. Barbosa, N. M. V., Castro, A. C. D., Conti, F., Capelozza-Filho, L., Almeida-Pedrin, R. R. D., & Cardoso, M. D. A. (2019). Reliability and reproducibility of the method of assessment of midpalatal suture maturation: A tomographic study. The Angle Orthodontist, 89(1), 71-77.

21. Madhu, S. (2017). Correlation between cervical vertebrae maturation and chronological age: a radiographic study. World J Dent, 8(5), 382-385.

22. Schoretsaniti, L., Mitsea, A., Karayianni, K., & Sifakakis, I. (2021). Cervical vertebral maturation method: reproducibility and efficiency of chronological age estimation. Applied Sciences, 11(7), 3160.

23. El-Bakary, A. A., & Abo El-Atta, H. M. (2018). Skeletal maturation using cervical vertebrae versus dental age for age estimation. Mansoura Journal of Forensic Medicine and Clinical Toxicology, 26(1), 13-21.

24. Lee, Y., & Mah, Y. (2019). Evaluation of midpalatal suture maturation using cone-beam computed tomography in children and adolescents. Journal of the Korean Academy of Pediatric Dentistry, 46(2), 139-146.

25. Luz, C. N., Pasqua, B. D. P. M., Paiva, J. B., & Rino-Neto, J. (2022). Cervical vertebrae maturation assessment as a predictive method for midpalatal suture maturation stages in 11-to 14-year-olds: retrospective study. Clinical and Investigative Orthodontics, 81(1), 43-49.

26. Munusamy, N., Tandon, P., Singh, G., Singh, G., Nagar, A., & Patil, R. (2024). Evaluation of the Midpalatal Suture and its Correlation with the Cervical Vertebral Maturation Stages and Second Molar Mineralization Stages: A CBCT Study. Journal of Indian Orthodontic Society, 58(3), 236-244.

27. Yang, Chin-Chen & Chen, Meng-Yen & Liu, Jia-Kuang & Chang, Chen-Jung. (2023). Investigation of the correlation of midpalatal suture maturation stage with chronological age and cervical vertebral maturation stage. APOS Trends in Orthodontics. 14. 1-6. 10.25259/APOS_86_2023.