Nigerian Medical Journal
NIGERIA MEDICAL ASSOCIATION
Print ISSN 0300-1652, E-ISSN 2229-774X

Original Research

Evaluation of Mid-Palatal Suture Maturation Stage in Adolescents and Adults Using Cone Beam Computed Tomography (CBCT)- A Comparative Study

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Abstract

Background: Several methods have been described in orthodontics for the evaluation of the skeletal age. These include hand-wrist radiography and cervical vertebral maturation (CVM) based on lateral cephalogram. Computed tomography (CT) scan has emerged as an effective tool for image diagnosis in situ. The present study was done to assess the stages of the mid-palatal suture in adolescents and adults utilizing cone beam computed tomography (CBCT).

Methodology: A descriptive and prospective study was done on 110 CBCT scans of individuals aged between 10-30 years, who visited the Department of Oral Medicine and Radiology, MMCDSR, Ambala, Haryana. The visualization and classification of the stage of maturation of the mid-palatine suture was done as per Angelieri's method using a cross-sectional axial slice.

Results: Stage C was found to be the most prevalent (29.1%) with the majority of cases occurring in the 16–20 age range. Males were more likely to have Stage B, while females had Stage C. In 60 cases (54.5 percent of the overall sample), the mid-palatine suture was found to be open. The Chi-Square test results for each examiner were highly significant ($p < 0.01$), indicating a statistically significant association between age group and Stage distribution.

Conclusion: There is a higher chance that post-adolescents and adults will have an open mid-palatal suture. When maxillary expansion is necessary, orthodontists may take these consequences into account. Furthermore, the middle palatal suture's ossification varies, hence using CBCT to rule out this possibility may be advised.

Keywords: Mid-Palatine Suture Maturation; CBCT; Maxillary Expansion.

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How to cite: Singh R, Gupta D, Garg A, Dahiya V, Gupta P, Gambhir RS. Evaluation of Mid-Palatal Suture Maturation Stage in Adolescents and Adults Using Cone Beam Computed Tomography (CBCT)- A Comparative Study. Niger Med J 2025;66(1):347-356.https://doi.org/10.71480/nmj.v66i1.744.

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Introduction

Skeletal variations involving the maxilla fall into three categories: transverse, horizontal, and vertical. Transverse variations are the most common type of these and can occur alone or in conjunction with other modifications. The most frequent of these transverse alterations is a decrease in transverse distance. This is also frequently known as a transverse maxillary deficit (TMD).[1] Nonetheless, TMD has a substantial impact on the individuals' jaw functions and appearance, just like many various kinds of malocclusions. Orthodontists have determined that a significant percentage of all malocclusions consist of these types of TMDs.[2]

A number of problems including cross-bite in the posterior region (dental and/or skeletal), crowding, narrowing of the airway, changes in the posture of the tongue, mouth breathing, and occlusal disharmony are linked to transverse maxillary constriction. These issues can have a significant impact on both muscle performance and appearance. Maxillary expansion is used in orthodontics to rectify maxillary transverse constriction along with the tooth axis of the posterior teeth, to relieve dental crowding, and to establish a desirable maxilla-mandibular connection.[3]

The most successful orthopaedic method for enlarging and enhancing the transverse length and resolving transverse discrepancies is rapid expansion of the maxilla (RME), which involves using strong forces to open the mid-palatal suture, increasing the inter-molar width, and separating the two halves of the maxillary bone.[5,6] The maxillary bone's two halves gradually inter-digitated to the point where they are now irreversibly joined, despite force and in-office appliances. Surgery or surgically supported rapid maxillary expansion (SARME) is the only method for separating the mid-palatine suture. [7,8] RME has been recommended for developing individuals within the clinical setting because adults typically experience therapeutic failure due to suture fusion.[9]

The mid-palatal suture in humans is unique among cranial sutures due to the fact it may not close up with age. Consequently, the choice of whether to perform SARME or RME is not to be solely centred on the patient's age. [10,11] Age and sex have a major impact on when the mid-palatal suture fuses and advances.

The assessment of the intermaxillary suture was previously done using maxillary occlusal images; however, because the picture is a 2D depiction of a 3D structure, it is challenging to perform an anteroposterior examination of the suture on these views. Alternative methods that can produce 3D, high-resolution pictures include computed tomography (CT) and cone beam computed tomography (CBCT). These methods also have the advantage of lacking superimposition of anatomic structures and having superior accuracy as well as reliability for assessing inter-maxillary sutures.[12,13] Therefore, the aim of this study was to assess the maturation grades of the mid-palatal suture in adolescents and adults utilizing CBCT in a north Indian population.

Methodology

Ethical clearance and informed consent

This descriptive prospective study was conducted in the Department of Oral Medicine and Radiology of M.M College of Dental Sciences and Research, Mullana, Ambala. Prior approval was taken from the Institutional Ethical Committee (IEC-2273) and the patients who showed willingness to participate in the study were made to sign an informed consent before the start of the study.

Study population and study sample.

Only those patients who visited the Department of Oral Medicine and Radiology and underwent CBCT for the evaluation of the maxillary region for various diagnostic and treatment purposes were enrolled for the study. No patient was deliberately subjected to CBCT only for the purpose of this study. The sample size was estimated by using the below-mentioned formula-

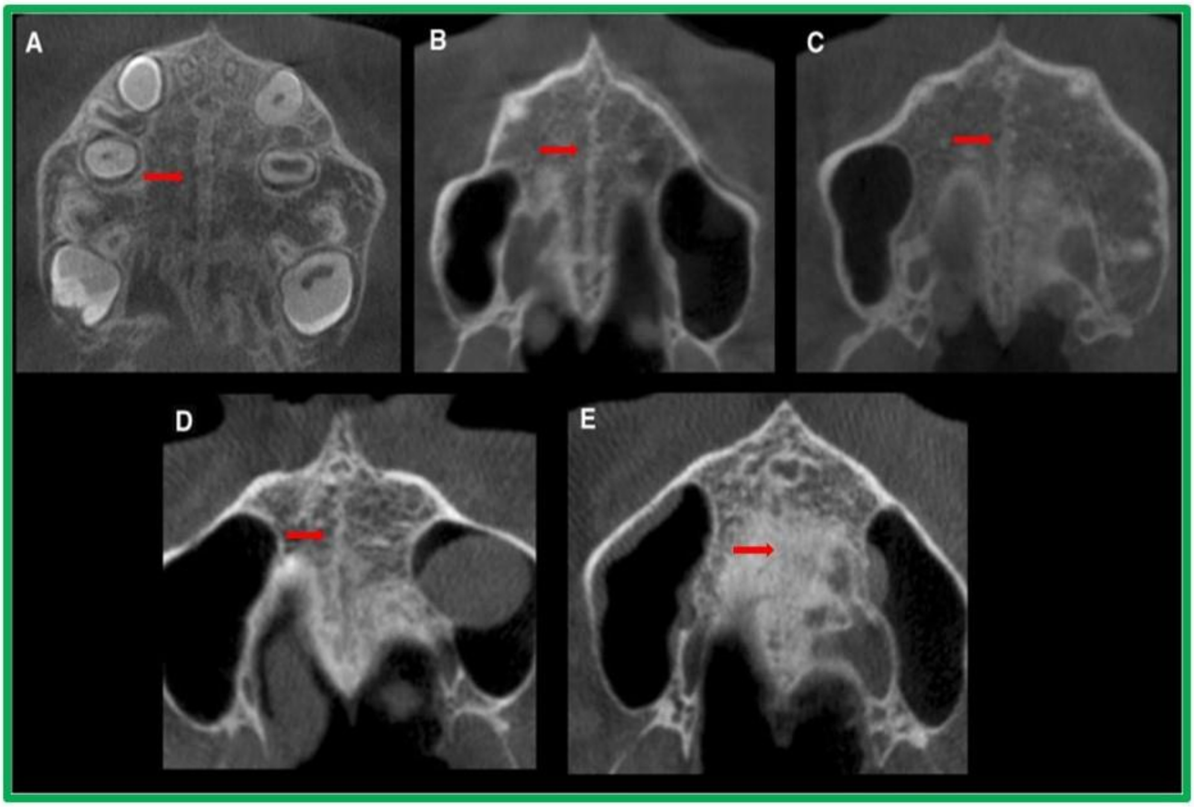
n = Z2p (1 – p) / d2

n = sample size, z = level of confidence 95% = 1.96, p = expected highest Prevalence-70.8%,[4] d= Precision (5% = 0.05).
With an attrition rate of 5%, the sample size calculated was 110.

Examination
Only those patients between the ages of 10 years and 30 years were included in the study according to the inclusion criteria. Subjects with a history of orthodontic therapy, maxillofacial conditions or injuries, cleft lip and palate, syndromic disorders, and noisy or fuzzy images on CBCT scans were excluded. The CBCT (NEW-TOM GIANO HR, Italy) generates a volume with a field of view (FOV)upto 16x18cm with a resolution of upto 75micrometres at 110Kvp. The scans were analysed on a 21.5-inch flat panel TFT screen (Hewlett Packard HP22yh) with 1920x1080 at 60 Hz.

The axial CBCT slice was used to visualize the skeletal maturation grade of the mid-palatine suture, which was classified using the Angelieri et al. technique.[11] Three examiners were calibrated in the department to examine the images. The intra- and inter-examiner measurement was evaluated using the weighted kappa coefficients. It showed values ranging from 0.872 to 0.915. The images were divided into five categories based on the stages of development. The open mid-palatal suture was taken into consideration for Stages A, B, and C, while the closed suture was taken into consideration for Stages D and E (Figure 1).

Figure 1: Developmental Stages of mid-palatine suture according to Angelieri et al. Method



Stage A –The mid-palatal suture is seen as a relatively straight radiopaque line.

Stage B - The mid-palatal suture appears as a scalloped line of high density.
Stage C -Two radiopaque, scalloped, and parallel lines are separated by areas of low radiographic density.
Stage D -The palatine bones become more radiopaque, and the suture is not properly visualized. It is only visualized as two scalloped high-density lines at the midline on the palate bone.
Stage E -It is no longer possible to see the suture along the maxillary and palatine bones, indicating fusion has occurred in the maxilla.

Statistical analysis

The statistical techniques were all conducted using Statistical Package for Social Sciences (SPSS, Chicago, Illinois, USA) version 20. Age (measured in years) and sex (coded as 0 for men and 1 for women) were the predictor variables. Each factor's influence on the outcome variable was expressed using 95% CI (confidence interval). $P<0.05$ was used to indicate statistical significance for all statistical tests.

Results

The majority of subjects were found to be in Stage C of maturation of mid-palatine suture (29.1% of subjects) which was followed by Stage B (24.5%). Stage A was found to be least prevalent among the sample size (6.4%) (Figure 2). The mid-palatine suture was found to be open in 60% (66) of study subjects.

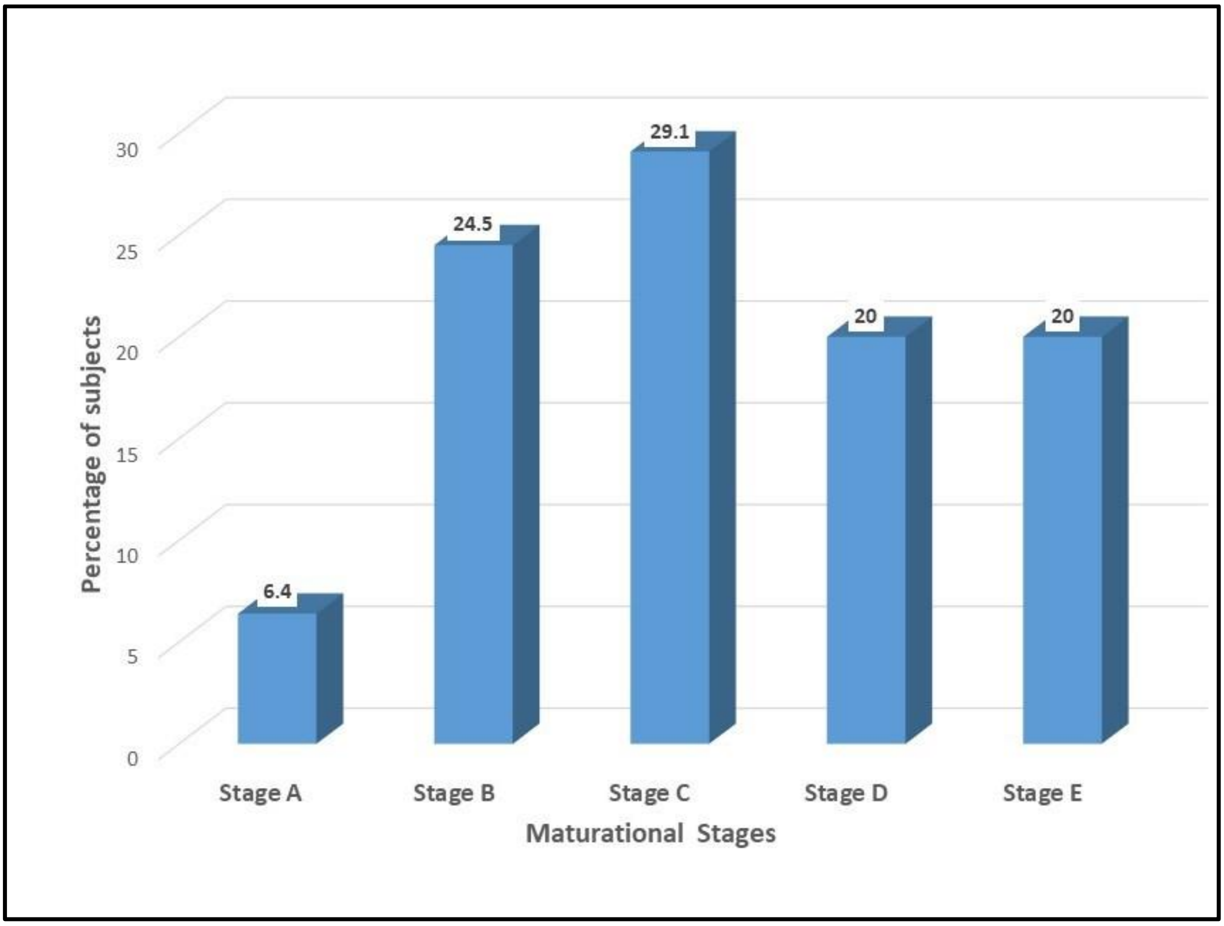


Figure 2: Prevalence rate of various maturational Stages among study subjects

Distribution of the MPS maturational stages by age group and gender is shown in Table 1 and Table 2 respectively. For all examiners, younger subjects (11–15 years) predominantly were in Stage B (73.1%) and Stage A (26.9%). In contrast, older subjects in the age group of 16–20 years and 21–25 years primarily were in Stage C, with proportions ranging from 66.7% to 83.3%. For the oldest group (26–30 years), there is a notable shift, with most subjects in Stage E (50.0%) or Stage D (35.7%).

Table 1: Distribution of the MPS maturational Stages by age group

		Age										**Chi-Square**	**p-value**
		11-15 year		**16-20 year**		**21-25 year**		**26-30 year**		**Total**			
		N	%	N	%	N	%	N	%	N	%		
Examiner1	Stage-A	7	26.9	0	0.0	0	0.0	0	0.0	7	6.4	123.40	.0001 **
	Stage-B	19	73.1	0	0.0	4	12.5	4	14.3	27	24.5		
	Stage-C	0	0.0	16	66.7	16	50.0	0	0.0	32	29.1		
	Stage-D	0	0.0	8	33.3	4	12.5	10	35.7	22	20.0		
	Stage-E	0	0.0	0	0.0	8	25.0	14	50.0	22	20.0		
Examiner 2	Stage-A	7	26.9	0	0.0	0	0.0	0	0.0	7	6.4	129.49	.0001 **
	Stage-B	19	73.1	0	0.0	4	12.5	4	14.3	27	24.5		
	Stage-C	0	0.0	20	83.3	12	37.5	0	0.0	32	29.1		
	Stage-D	0	0.0	4	16.7	8	25.0	10	35.7	22	20.0		
	Stage-E	0	0.0	0	0.0	8	25.0	14	50.0	22	20.0		
Examiner 3	Stage-A	7	26.9	0	0.0	0	0.0	0	0.0	7	6.4	141.65	.0001 **
	Stage-B	19	73.1	0	0.0	4	12.5	4	14.3	27	24.5		
	Stage-C	0	0.0	20	83.3	20	62.5	0	0.0	40	36.4		
	Stage-D	0	0.0	4	16.7	0	0.0	14	50.0	18	16.4		
	Stage-E	0	0.0	0	0.0	8	25.0	10	35.7	18	16.4		
	Total	26	100.0	24	100.0	32	100.0	28	100.0	110	100.0		

		Age										**Chi-Square**	**p-value**
		11-15 year		**16-20 year**		**21-25 year**		**26-30 year**		**Total**			
		N	%	N	%	N	%	N	%	N	%		
Examiner1	Stage-A	7	26.9	0	0.0	0	0.0	0	0.0	7	6.4	123.40	.0001 **
	Stage-B	19	73.1	0	0.0	4	12.5	4	14.3	27	24.5		
	Stage-C	0	0.0	16	66.7	16	50.0	0	0.0	32	29.1		
	Stage-D	0	0.0	8	33.3	4	12.5	10	35.7	22	20.0		
	Stage-	0	0.0	0	0.0	8	25.0	14	50.0	22	20.0		

	E												
Examiner 2	Stage-A	7	26.9	0	0.0	0	0.0	0	0.0	7	6.4	129.49	.0001**
	Stage-B	19	73.1	0	0.0	4	12.5	4	14.3	27	24.5		
	Stage-C	0	0.0	20	83.3	12	37.5	0	0.0	32	29.1		
	Stage-D	0	0.0	4	16.7	8	25.0	10	35.7	22	20.0		
	Stage-E	0	0.0	0	0.0	8	25.0	14	50.0	22	20.0		
Examiner 3	Stage-A	7	26.9	0	0.0	0	0.0	0	0.0	7	6.4	141.65	.0001**
	Stage-B	19	73.1	0	0.0	4	12.5	4	14.3	27	24.5		
	Stage-C	0	0.0	20	83.3	20	62.5	0	0.0	40	36.4		
	Stage-D	0	0.0	4	16.7	0	0.0	14	50.0	18	16.4		
	Stage-E	0	0.0	0	0.0	8	25.0	10	35.7	18	16.4		
	Total	26	100.0	24	100.0	32	100.0	28	100.0	110	100.0		

** p<0.01, Statistically significant

Table 2: Shows gender-based age and grade distribution among study subjects.

Age		Gender						Chi-Square	p-value
		Male		Female		Total			
		N	%	N	%	N	%		
								2.884	0.410
11-15 year		19	27.5	7	17.1	26	23.6		
16-20 year		12	17.4	12	29.3	24	21.8		
21-25 year		20	29.0	12	29.3	32	29.1		
26-30 year		18	26.1	10	24.4	28	25.5		
Total		69	100.0	41	100.0	110	100.0		
Examiner 1	Grade-A	4	5.8	3	7.3	7	6.4	22.382	.0001**
	Grade-B	23	33.3	4	9.8	27	24.5		
	Grade-C	16	23.2	16	39.0	32	29.1		
	Grade-D	7	10.1	15	36.6	22	20.0		
	Grade-E	19	27.5	3	7.3	22	20.0		
Examiner 2	Grade-A	4	5.8	3	7.3	7	6.4	22.382	.0001**
	Grade-B	23	33.3	4	9.8	27	24.5		
	Grade-C	16	23.2	16	39.0	32	29.1		
	Grade-D	7	10.1	15	36.6	22	20.0		
	Grade-E	19	27.5	3	7.3	22	20.0		
Examiner 3	Grade-A	4	5.8	3	7.3	7	6.4	18.044	.001**
	Grade-B	23	33.3	4	9.8	27	24.5		
	Grade-C	16	23.2	24	58.5	40	36.4		
	Grade-D	11	15.9	7	17.1	18	16.4		
	Grade-E	15	21.7	3	7.3	18	16.4		
	Total	69	100.0	41	100.0	110	100.0		

** p<0.01, Statistically significant

The Chi-Square test results for each examiner were significant ($p < 0.01$), indicating a statistically significant association between age group and Stage distribution. While the patterns across observers were consistent, slight variations in the specific distributions can be observed, particularly in the allocation of Stages, D, and E for the older age groups.

Examiner 1 and Examiner 2 show identical grading patterns, where the majority of males were in Stage B (33.3%) and Stage E (27.5%), while most females were in Stage C (39.0%) and Stage D (36.6%) (Table 2). Evaluation of examiner 3 differs slightly, with a higher percentage of females (58.5%) in Stage C compared to males (23.2%). The Chi-Square test results are presented for each observer, with significant Chi-Square values ($p < 0.01$) observed across all three observers. This indicates a statistically significant association between gender and Stage distribution in the evaluations (Table 2).

Discussion

Treating patients with transverse deficiency of the maxilla is a crucial topic for orthodontists as the perspective regarding the youngest age needed for accurate palate expansion varies among different orthodontists. This is particularly challenging for patients who are late-stage adolescents and young adults. A few years ago, it was thought that a maxillary separation could only be performed on patients who were 16 or older due to the risk of finding a mid-palatine suture opening. Furthermore, if older people are treated with RME, it may result in significant discomfort, receding gingival tissue, inflammation or necrosis of the mucosa of the palate, buccal tipping of the posterior teeth, decrease in the thickness of buccal bone, alveolar bone bending, resorption of buccal roots, and fenestration of the buccal cortex.

An occlusal image is a crucial technique recommended by Lehman et al [14] , for assessing the ossification of mid-palatal suture.[14] Nevertheless, being unable to view the posterior intermaxillary suture properly and the superposition over the suture as well as additional bony structures render this method generally unreliable. Postero-anterior (PA) cephalograms are the most reliable and easily accessible method for detecting and assessing longitudinal disparities of a bony origin in the lower and upper jaw.[15,16] Still, there are many who criticize this approach as PA cephalograms provide a 2D representation of a 3D structure, leading to distortion, projection errors, and difficulty in accurately assessing asymmetries.[1] This study shows that CBCT is a useful method for determining the Stages of mid-palatal suture maturation in young adults and adolescents. The findings indicate that there is an overall tendency favouring higher levels of suture maturation with advancing age, which is evidenced by improved bone continuity and less apparent suture line. The results demonstrate the considerable individual variation while also supporting the well-established notion that suture maturation advances with age.

Similar findings to our study, where in Stage A and B were noted in the age spectrum of 11–15 years old, have been reported by Angieleri et al, with Stage A being noticed from 5 to 11 years old and Stage B mostly seen up to 13 years old.[11] On the other hand, our investigation revealed an opened suture even among the age group of 21–25 years, despite the fact that the fusion of the MPS was seen for 15 years.

Ladewig et al, analyzed gender distribution across different age groups and reported that the mid-palatal suture maturation process follows distinct patterns in males and females.[17] Our findings align with this observation, as the prevalence of Stage C was higher in females across multiple age groups, suggesting that women tend to reach mid-palatal suture maturation earlier than men. Additionally, in younger age groups, male subjects were frequently found in earlier maturation stages, reinforcing the idea that suture closure occurs later in males compared to females. Reports of another study revealed that males aged 16 to 25 years were more likely to exhibit an open suture than females, indicating delayed maturation in males.[4] Additionally, research done by Festa F et al.[19] analyzing mid-palatal suture maturation in relation to age, sex, and skeletal growth patterns found that males tended to have lower maturation stages, suggesting delayed suture maturation compared to females.Notably, these findings align with clinical observations that RME failures are more common in late adolescence, especially in adults and female patients.

Another study observed Stage A in only one 11-year-old girl, while in our study, all individuals with Stage A were within the 11-15 age group.[19] Furthermore, we found that Stages D and E were present in 40% of our subjects, a notably higher prevalence as compared to the above study. This discrepancy may be due to various reasons such as reasons such as demographics (ethnic and genetic variation), assessment methodology, selection bias, and environmental factors. Angieliere et et al. [20] found that in their study, only 12% of subjects had unfused mid-palatal sutures. In contrast, our study revealed that 60% of the overall sample had open mid-palatal sutures. This significant difference could be attributed to variations in the sample characteristics. Similarly, reports of another study revealed that MPS maturation increases with age, with males tending to have lower maturation stages than females.[21]

Findings of a systematic review further support these findings, showing that stages A and B are more prevalent in individuals below 11 years, while stage C dominates the 11–14 years cohort, and stage D becomes more common in older adolescents.[22] Across all age groups, females tend to have higher maturation stages than males. Another study conducted by Reis LG et al. [23] reported stage E as the most prevalent (48.25%), with males in stages D and E being significantly older than those in lower stages ($p = 0.0001$). Although a weak correlation was observed between age and maturation.

The ability to accurately assess the mid-palatal suture maturation Stage has direct clinical implications, particularly for orthodontic procedures. Our study reinforces the notion that CBCT should be integrated into the diagnostic workflow to ensure that interventions are timed appropriately, thereby minimizing the risk of complications associated with late or inappropriate expansion attempts. Despite the strengths of this study, including the use of high-resolution CBCT imaging, there are limitations that must be considered. The cross-sectional nature of the study limits our ability to observe the progression of suture maturation over time. Moreover, the radiation exposure associated with CBCT, though low, remains a concern, especially in younger patients. Future research should focus on longitudinal studies to track the maturation of the midpalatal suture over time in the same individuals. This approach would provide deeper insights into the timing and progression of suture fusion, which could further refine treatment protocols for RME.

Conclusion

Cone-beam computed tomography (CBCT) is a useful diagnostic tool for assessing the maturity of the mid-palatal suture in young adults and adolescents. Although most individuals are in the intermediate Stages, there is a notable degree of variety as some have either fully fused sutures or open sutures. This variation highlights the necessity for individualized assessments and shows that relying solely on age to schedule orthodontic therapy is insufficient. Transverse dental malocclusion assessment is even more complicated than evaluating vertical or sagittal discrepancies, which emphasizes the necessity of sophisticated diagnostic instruments like CBCT for providing precise diagnosis and treatment planning.

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