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Research Article

CORRELATION OF CBCT MIDPALATAL SUTURE MORPHOLOGY WITH SECOND MOLAR CALCIFICATION, CVMI AND MP3 SKELETAL MATURITY INDICATORS

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A B S T R A C T

Background: Through assessment of the midpalatal suture morphology, it was found out that it is possible to minimize the failure of rapid maxillary expansion in adolescent and young adult patients. However, it is not possible to obtain routine CBCT of every patient, and especially those without any diagnostic need (e.g., impacted tooth, cyst). Hence the present study is taken up to correlate Angelieri et al CBCT classification of midpalatal suture morphology with routinely used various skeletal maturity indicators like Second molar calcification stages by Demirjian, CVMI stages by Hassel and Farman and MP3 stages by Hagg and Tarranger which are available as a part of the routinely obtained diagnostic records for patients requiring maxillary expansion.

Methods: The study was performed using CBCT of axial view of maxilla, Orthopantomograms, lateral cephalograms, Intra oral periapical radiographs of Middle phalanx of third finger obtained from 25 patients aged between 10 to 25 years seeking orthodontic treatment.

Results: The results showed that Correlation between Cervical vertebrae maturation stages and CBCT (midpalatal suture) stages values showed statistically highly significant correlation($p<0.001$). Correlation between middle phalanx of third finger stages and CBCT (midpalatal suture) stages values showed statistically highly significant correlation($p<0.001$). Correlation between second molar calcification stages and CBCT (midpalatal suture) stages values showed statistically significant corelation($p<0.008$)

Conclusion: Among developmental age indices, CVMI and MP3 Showed highly significant correlation, suggesting that they can be useful in assessing maturation of the midpalatal suture.

INTRODUCTION

Transverse growth of maxilla is the first to cease followed by anteroposterior and vertical dimensions, it stops when the first bridging of midpalatal suture begins. This usually means that by early adolescence, palatal width growth would normally end and to mechanically alter this later with appliance therapy, would require heavier forces. Hence it is important to know the patency of mid palatal suture.[16]

The increase in the maxillary arch transverse dimension by means of rapid maxillary expansion (RME) has been a routine treatment modality in present day orthodontic practice, it is an established and credible tool for treating maxillary transverse deficiency.[21]

Patency of midpalatal suture has been one of most important diagnostic criteria for the patients who undergo rapid maxillary expansion. There are conflicting views about the closure of midpalatal suture.[21]The chronological age does not seem to be a reliable indicator of morphological status of the midpalatal suture.[10]

Melson (1975) analysed palatal growth and midpalatal suture morphology in humans from 0 to 18 years of age. The morphological development was divided into three stages. In the first stage suture was short, broad, and y shaped, in the second more sinuous and in the third heavy inter digitation occurred.[10]

In a histologic study, Person and Thilander (1977) investigated palatal suture from 15 to 35 years of age. It was demonstrated that palatal suture may show obliteration during the juvenile period but a marked degree of closure was rarely found until the third decade of life.[4]

Revelo and fishman proposed individual assessment of midpalatal suture morphology with occlusal radiographs before RME therapy.[7] However occlusal radiographs are not reliable for analysing midpalatal suture morphology because vomer and structures of external nose overlay the midpalatal

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area and thus might lead to false radiographic interpretation of midpalatal suture fusion.[29]

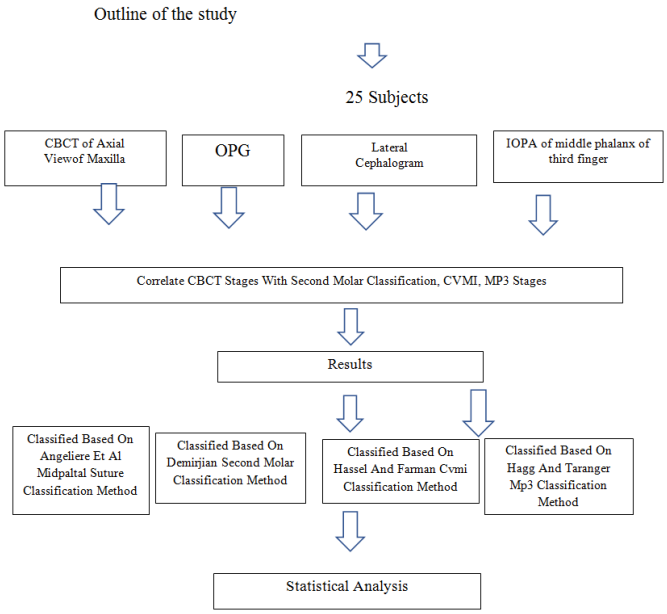
Cone-beam computed tomography (CBCT) provides 3-dimensional visualization of the oral and maxillofacial structures at relatively low cost, no superimposition of adjacent structures, easy accessibility, and low radiation exposure compared with multislice medical computed tomography.[20]

Angelieri et al proposed, an individual evaluation method of midpalatal suture with Cone beam computed tomography. By observing the images of the suture in different stages of calcification, 5 maturational stages were determined: A, B, C, D, and E. Among these, treatment with RME would have less resistance and consequently greater skeletal effect in stages A and B than in stage C, where ossification areas are already observed along the suture. For patients in stages D and E, surgically assisted expansion is better indicated because at these stages fusion of the palatal suture has already occurred partially or totally.[29]

Through assessment of the midpalatal suture morphology, it was found out that it is possible to minimize the failure of rapid maxillary expansion in adolescent and young adult patients. However, it is not possible to obtain routine CBCT of every patient, and especially those without any diagnostic need (e.g., impacted tooth, cyst, and skeletal asymmetry).[36]

Hence the present study was taken up to correlate Angelieri et al CBCT classification of midpalatal suture morphology[29] with routinely used various skeletal maturity indicators like Second molar calcification stages by Demirjian[3], CVMI stages by Hassel and Farman[8] and MP3 stages by Hagg and Tarranger[9] which are available as a part of the routinely obtained diagnostic records for patients requiring maxillary expansion.

MATERIALS AND METHODS



Sample Size

The sample consists of CBCT images of maxilla, radiographs of middle phalanx of third finger and routinely obtained panoramic radiographs, Lateral cephalograms of 25 patients aged between 10 to 25 years seeking orthodontic treatment.

Inclusion Criteria

1. Chronological age ranging from 10 to 25 years
2. Normal overall growth and development

Exclusion criteria

1. Disease or medicine intake affecting bone metabolism
2. Previous history of trauma
3. Poor quality images that are difficult to distinguish

METHODOLOGY

The study was performed using CBCT of axial view of maxilla[29], Orthopantomograms[3], lateral cephalograms[8], Intra oral periapical radiographs of Middle phalanx of third finger[9] obtained from 25 patients.

15 patients CBCT taken from CBCT machine -J MORITA'S VERAVIEW X 800. Software used IDIXEL, images were taken using the following parameters: 105 kVp, 9.4 seconds scan time and field-of-view 80×80mm. (FIG-1,2,3)

10 patients CBCT taken from CBCT machine-CARESTREAM 8100. Software used CARE STREAM IMAGING SOFTWARE, images were taken using the following parameters: 105 kVp, 10.8 seconds scan time and field-of-view 80×80mm.

Each subject was standing in an erect position with the Frankfort horizontal plane (superior aspect of the external auditory canal to the infraorbital rim line) parallel to the ground during scanning process. The images were converted to Digital Imaging and Communication in Medicine (DICOM) format. DICOM files were reconstructed into a three-dimensional image by multiplanar reformatting and volume rendering using imaging software.

Tracings were made from lateral cephalogram, opg and middle phalanx x ray on a matte acetate tracing sheet and 0.3mm micro lead pencil.

Evaluation of midpalatal suture morphology using cone beam computerized tomography:

The evaluation of the mid palatal suture morphology using CBCT images were classified into five stages (stage A - E) as suggested by Angeliere et al[29]. (FIG-1)

Evaluation of dental maturity using panoramic radiograph

Calcification of second molar were evaluated according to the index described by Demirjian et al (Demirjian index DI), in which one of the eight stages of calcification (A to H) was assigned to the tooth[3]. (FIG-2)

Evaluation of skeletal maturity using Lateral Cephalogram

Cervical vertebrae maturity were evaluated by classifying C2, C3 and C4 into six groups depending on their maturation pattern on the lateral Cephalogram using the classification given by Hassel and Farman[8]. (FIG-3)

Evaluation of skeletal maturity using radiograph of middle phalanx of the third finger

The ossification of middle phalanx of the third finger of the hand (MP3) were evaluated by using Hagg and Tarranger method of classification[9]. (FIG-4)

CBCT, CVMI, MP3 and second molar calcification stages were recorded by examiner 1 and it was re-evaluated by examiner 2 to eliminate inter examiner bias.

RESULTS

The present study was taken up to correlate Angelieri et al CBCT classification of midpalatal suture morphology with routinely used various skeletal maturity indicators like Second molar calcification stages by Demirjian, CVMI stages by Hassel and Farman and MP3 stages by Hagg and Tarranger in 25 patients aged between 10 to 25 years seeking orthodontic treatment.

Demographics of the sample

The distribution of the total sample and its gender related to each developmental age index according to CBCT stage (maturation of midpalatal suture) are presented. (Table 1, 2 , 3)

Table 1 Age and Gender Distribution among Study Subjects

Age and Gender Distribution among Study Subjects			
Variables	Category	n	%
Age	10-15 years	14	56%
	16-20 years	6	24%
	21-23 years	5	20%
Gender	Males	11	44%
	Females	14	56%

Table 2 Demographics of The Sample Subjects

Demographics of the sample subjects of all Indices			
Indices	Stages	n	%
CVMI Stage	Stage 2	7	28%
	Stage 3	1	4%
	Stage 4	5	20%
	Stage 6	12	48%
II Molar Calcification Stage	Stage D	1	4%
	Stage E	2	8%
	Stage F	7	28%
	Stage G	6	24%
	Stage H	9	36%
MP3 Stage	Stage F	3	12%
	Stage FG	3	12%
	Stage G	2	8%
	Stage H	5	20%
	Stage I	12	48%
CBCT Mid Palatal Suture Stage	Stage A	2	8%
	Stage B	6	24%
	Stage C	11	44%
	Stage D	5	20%
		1	4%

Table 3 Gender Based Comparison of Different Indices

Gender based comparison of different Indices using Chi Square Test							
		Males		Females			
Indices	Stages	n	%	n	%	χ^2 Value	P-Value
CVMI Stage	Stage 2	4	36.4%	3	21.4%	2.959	0.39
	Stage 3	1	9.1%	0	0.0%		
	Stage 4	1	9.1%	4	28.6%		
	Stage 6	5	45.5%	7	50.0%		
II Molar Calcification Stage	Stage D	1	9.1%	0	0.0%	4.515	0.34
	Stage E	2	18.2%	0	0.0%		
	Stage F	3	27.3%	4	28.6%		
	Stage G	2	18.2%	4	28.6%		
	Stage H	3	27.3%	6	42.9%		
MP3 Stage	Stage F	3	27.3%	0	0.0%	6.196	0.19
	Stage FG	2	18.2%	1	7.1%		
	Stage G	1	9.1%	1	7.1%		
	Stage H	1	9.1%	4	28.6%		
	Stage I	4	36.4%	8	57.1%		
CBCT Mid Palatal Suture Stage	Stage A	1	9.1%	1	7.1%	0.945	0.92
	Stage B	3	27.3%	3	21.4%		
	Stage C	5	45.5%	6	42.9%		
	Stage D	2	18.2%	3	21.4%		
	Stage E	0	0.0%	1	7.1%		

Correlation between indices using a rank order correlation analysis

Correlation between Cervical vertebrae maturation stages and CBCT (mid palatal suture) stages were investigated.All values showed statistically significant correlation($p<0.001$).The same analysis was performed according to gender.Statistically significant correlation was found in both male and female subjects ($p<0.001$).(Table 4)

Table 4 Correlation between CVMI and CBCT Midpalatal Suture Morphology

spearmans correlation statistics to assess the relationship between cvmi stages and CBCT Mid palatal suture stages								
		CBCT Mid Palatal Suture Stage						
Samples	CVMI Stage	Stage A	Stage B	Stage C	Stage D	Stage E	rho Value	P-Value
Overall	Stage 2	2	3	2	0	0	0.73	<0.001*
	Stage 3	0	0	1	0	0		
	Stage 4	0	3	2	0	0		
	Stage 6	0	0	6	5	1		
Males	Stage 2	1	2	1	0	0	0.73	<0.001*
	Stage 3	0	0	1	0	0		
	Stage 4	0	1	0	0	0		
	Stage 6	0	0	3	2	0		
Females	Stage 2	1	1	1	0	0	0.75	<0.001*
	Stage 3	0	0	0	0	0		
	Stage 4	0	2	2	0	0		
	Stage 6	0	0	3	3	1		

Correlation between middle phalanx of third finger stages and CBCT (mid palatal suture) stages were investigated.All values showed statistically significant correlation($p<0.001$).The same analysis was performed according to gender. Statistically significant correlation was found in both males($p<0.03$) and females($p<0.04$).(Table 5)

Table 5 Correlation between Mp3 and CBCT Midpalatal Suture Morphology

Spearman's Correlation Statistics to assess the relationship between MP3 Stages and CBCT Mid Palatal Suture Stages								
		CBCT Mid Palatal Suture Stage						
Samples	MP3 Stages	Stage A	Stage B	Stage C	Stage D	Stage E	rho Value	P-Value
Overall	Stage F	0	2	1	0	0	0.61	0.001*
	Stage FG	1	0	2	0	0		
	Stage G	0	2	0	0	0		
	Stage H	1	1	3	0	0		
	Stage I	0	1	5	5	1		
Males	Stage F	0	2	1	0	0	0.66	0.03*
	Stage FG	1	0	1	0	0		
	Stage G	0	1	0	0	0		
	Stage H	0	0	1	0	0		
	Stage I	0	0	2	2	0		
Females	Stage F	0	0	0	0	0	0.54	0.04*
	Stage FG	0	0	1	0	0		
	Stage G	0	1	0	0	0		
	Stage H	1	1	2	0	0		
	Stage I	0	1	3	3	1		

Table 6 Correlation between II Molar Calcification Stages and CBCT Midpalatal Suture Morphology

Spearman's Correlation Statistics to assess the relationship between II Molar Calcification Stages and CBCT Mid Palatal Suture Stages								
		CBCT Mid Palatal Suture Stage						
Samples	II Molar Calcification	Stage A	Stage B	Stage C	Stage D	Stage E	rho Value	P-Value
Overall	Stage D	0	0	1	0	0	0.52	0.008*
	Stage E	1	1	0	0	0		
	Stage F	1	3	2	1	0		
	Stage G	0	1	4	1	0		
	Stage H	0	1	4	3	1		
Males	Stage D	0	0	1	0	0	0.62	0.04*
	Stage E	1	1	0	0	0		
	Stage F	0	2	1	0	0		
	Stage G	0	0	1	1	0		
	Stage H	0	0	2	1	0		
Females	Stage D	0	0	0	0	0	0.40	0.16
	Stage E	0	0	0	0	0		
	Stage F	1	1	1	1	0		
	Stage G	0	1	3	0	0		
	Stage H	0	1	2	2	1		

Correlation between second molar calcification stages and CBCT (mid palatal suture) stages were investigated.All values showed statistically significant corelation($p<0.008$).The same

analysis was performed according to gender. Statistically significant correlation was found in males($p<0.04$) and in females it is not significant .(Table 6)

Association between indices using contingency coefficients

The results of crosstab analysis between CBCT stage and Second molar calcification stage,CVMI,MP3 stage are shown in table 7. All measurements showed significant correlation ($p<0.001$).

Table 7 Association between CBCT Stage and Maturation Indices

Analysis of associations between CBCT stage and maturation indices using crosstabs							
		Total		Males		Females	
CBCT Stage	Other Indices	γ	τ-b	γ	τ-b	γ	τ-b
Mid Palatal Suture Stages	CVMI	0.89	0.65	0.87	0.65	0.92	0.67
		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
	II Molar Calcification	0.61	0.45	0.66	0.52	0.50	0.36
		0.002*	0.002*	0.14	0.14	0.003*	0.003*
	MP3 Stages	0.69	0.51	0.71	0.56	0.67	0.46
		<0.001*	<0.001*	<0.001*	<0.001*	0.002*	0.002*

Cross tab analysis by contingency coefficients showed that CVMI and MP3 both showed significantly high correlation($p<0.001$) but the MP3 values in female subjects($p<0.002$) showed a slightly low correlation values compared to CVMI($p<0.001$).

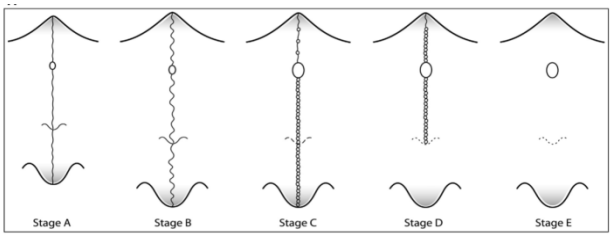


Fig 1 Angeliere Et Al Cbct Classification of Midpalatal Suture Morphology (Stage A to E)

Stage A, straight high-density sutural line, with no or little interdigitation
Stage B, scalloped appearance of the high-density sutural line
Stage C, 2 parallel, scalloped, high-density lines that were close to each other, separated in some areas by small low-density space
Stage D, fusion completed in the palatine bone, with no evidence of a suture
Stage E, fusion anteriorly in the maxilla.

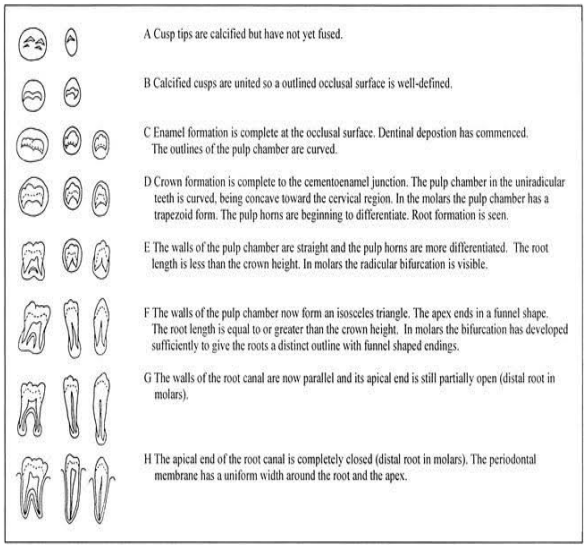


Fig 2 Second Molar Calcification Stages By Demirjian

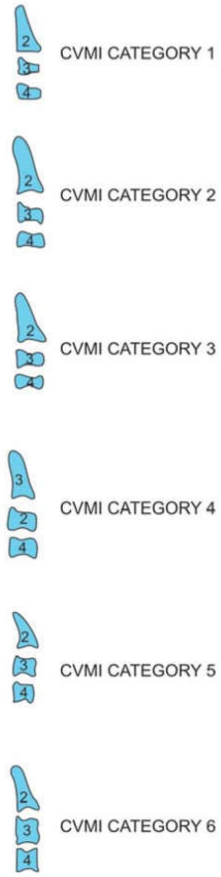


Fig 9 CVMI Stages by Hassel and Farman

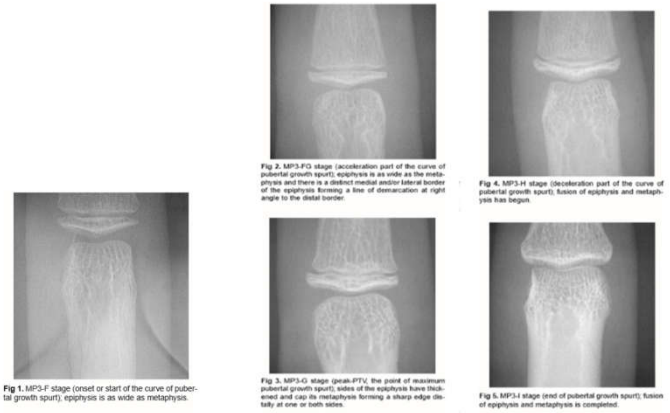


Fig 11 Middle Phalanx of Third Finger Stages By Hagg Andtaranger

DISCUSSION

Transverse discrepancy of maxilla is one of the most common skeletal problems in the craniofacial region. It is characterised by presence of unilateral or bilateral posterior crossbite, deep or high arched palate, dental crowding, dark spaces in the buccal corridors etc[30].

Maxillary transverse arch width deficiency normally do not present an orthodontic challenge if they are detected before or during the adolescent growth spurt. Correction of these deficiencies can be done with a maxillary rapid palatal expander[12].

According to Proffit by the late teens interdigitation and areas of bony bridging across the suture develop to the point that maxillary expansion becomes impossible. The palatal suture reportedly close as when a patient reaches 12 to 13 years of age[12].

Revelo and Fishman in their study on midpalatal suture ossification found that by the end of skeletal maturation only 50% of the midpalatal suture was ossified[7].

According to Melson, response to orthopaedic maxillary expansion differ depending on the age and maturation of the patient. The interdigitation of the midpalatal suture increases as it matures, making skeletal expansion more difficult. As a result, expansion of maxilla leads to a tipping movement of teeth, which increases the risk of relapse because of dental expansion is greater than that of orthopaedic expansion. It is possible to expand the maxilla using a removable or fixed appliance such as HYRAX (Hygienic Rapid Palatal Expander) in young patients because structure of the suture is simple. However, with increased complexity of the suture, as occur in adults, different treatment methods such as surgically Assisted Rapid Palatal Expansion (SARPE) should be used. Recently a new method that can load orthopaedic pressure directly to the bone (i.e. Miniscrew Assisted Rapid Palatal Expansion) MARPE has been introduced in clinical practice[36].

Assessing Patency of midpalatal suture has been one of most important diagnostic criteria for the patients who undergo rapid maxillary expansion. Angeliere et al presented a novel classification method for individual assessment of midpalatal suture morphology. Cone-beam computed tomography images from 140 subjects (ages, 5.6-58.4 years) were examined to define the radiographic stages of midpalatal suture maturation. Five stages of maturation of the midpalatal suture were identified and defined: stage A, straight high-density sutural line, with no or little interdigitation; stage B, scalloped appearance of the high-density sutural line; stage C, 2 parallel, scalloped, high-density lines that were close to each other, separated in some areas by small low-density spaces; stage D, fusion completed in the palatine bone, with no evidence of a suture; and stage E, fusion anteriorly in the maxilla[29].

In the present study three different skeletal maturity indicators (Cervical Vertebrae Maturity Index (CVMI), Second molar calcification, MP3) were used to correlate them with midpalatal suture ossification as seen in CBCT, in subjects having transverse maxillary deficiency.

To evaluate the morphology of the midpalatal suture according to maturation, CBCT images were assessed according to classification done by Angeliere et al. In the study done by Angeliere et al, Stages A and B typically were observed up to 13 years of age, whereas stage C was noted primarily from 11 to 17 years but occasionally in younger and older age groups. Fusion of the palatine (stage D) and maxillary (stage E) regions of the midpalatal suture was completed after 11 years only in girls. From 14 to 17 years, 3 of 13 (23%) boys showed fusion only in the palatine bone (stage D)[29]. These results were similar to those in present study also. Stage A and B was observed mostly in ages 10 to 13 years. In this study fusion of midpalatal suture below age 11 was not seen; compared with Angeliere et al. Stage C had relatively more dense distribution from 10 years to 17 years.

The correlation analysis in this study showed statistical significance for all index values. Among them the CVMI and MP3 stage showed strong correlation with CBCT stage ($p<0.001$). This result was similar to the findings of other studies showing strong correlations between facial skeletal growth and skeletal age. Difference being, previous studies evaluated facial size by linear growth of the mandible, but the current study evaluated maturation of the midpalatal suture.

The crosstab analysis using a contingency coefficient was performed additionaly (Table 7). when crosstab analysis was performed with CBCT stages, the CVMI and MP3 showed higher significant values($p<0.001$) than Second molar calcification stages. This means that maturation based on the morphology of the midpalatal suture was more consistent with skeletal age than with dental age. This further demonstrates that when predicting the morphology of midpalatal suture it can be expected that skeletal age (CVMI and MP3) is a more useful index than dental age.

A shortcoming that must be considered in maxillary expansion is other anatomical structures that resist expansion force. It is well known that resisting anatomical structures include not only the midpalatal suture, but also the zygomaticotemporal suture, zygomaticofrontal suture, and zygomaticomaxillary suture, among others.[26] Only the midpalatal suture was considered in this study[29].

In the present study among developmental age indices, the CVMI and MP3 showed strong correlations and high associations with the maturation stage of the midpalatal suture on CBCT images

CONCLUSION

In this study, we evaluated maturation stage based on the morphology of the midpalatal suture on CBCT images, and investigated correlations and associations between the maturation stage of the midpalatal suture and developmental age indices.

Among developmental age indices, the CVMI and MP3 showed strong correlations and high associations with the maturation stage of the midpalatal suture on CBCT images, meaning that these methods can be used to speculate on the maturation of the midpalatal suture according to its morphology.

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