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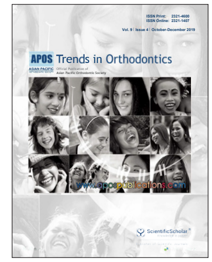

Original Article

Evaluation of the degree of fusion of midpalatal suture at various stages of cervical vertebrae maturation

Khyati Narula[1], Siddarth Shetty[1], Nandita Shenoy[2], N. Srikant[3]

Departments of [1]Orthodontics and Dentofacial Orthopedics, [2]Oral Medicine and Radiology, [3]Oral Pathology, Manipal College of Dental Sciences, Mangalore, Karnataka, India.

***Corresponding author:**
Khyati Narula,
Ex-Resident, Department of Orthodontics, Manipal College of Dental Sciences,
Light House Hill Road,
Mangalore-575001,
Karnataka, India.

orthokhyati@gmail.com

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ABSTRACT

Introduction: Rapid palatal expansion was initially done during circumpubertal age. However, the correct evidence suggests visualizing the patency of midpalatal suture (MPS) radiologically at different chronological age as there can be early or late fusion of suture in some cases.

Objective: This study was aimed at assessing the fusion of MPS at different stages of cervical vertebrae maturation and to find any correlation between them from the patients of two South Indian districts.

Design and Setting: A total of 144 subjects aged 10–20 years were included in our study.

Materials and Methods: Skeletal age based on cervical vertebrae was assessed from lateral cephalograms. MPS staging was done by two observers using cone-beam computed tomography at 2-time intervals. Inter- and intra-examiner reliability for suture staging was analyzed by kappa statistics. Correlation of skeletal age to sutural maturation was done using Kendall's tau-b test.

Results: A fair agreement was obtained by kappa test for inter (0.313) and intraexaminer reliability (0.219 for first and 0.451 for the second observer) for 144 subjects. Kendall's tau-b test showed a significant correlation between skeletal age and suture maturation, with the maximum association between CS 4 skeletal age and Stage C of MPS, with $P < 0.001$.

Conclusion: A strong correlation was found between skeletal age and sutural fusion. Predominantly, Stage C coincided with CS 4 with greater gender predilection toward females.

Keywords: Midpalatal suture, Cone-beam computed tomography, Cervical vertebrae, Skeletal maturity

INTRODUCTION

Maxillary transverse deficiency, one of the most common malocclusions in orthodontic patients, presents as a unilateral or bilateral posterior crossbite.[1] About 18% of mixed-dentition patients[2] and 30% adult patients[3] present with transverse maxillary constriction. It is evident that treatment onset timing is as critical as implementing a treatment protocol.

The closure of midpalatal suture (MPS) usually occurs at a certain age, i.e., 11–13 years in girls and 14–16 years in boys. Hence, understanding MPS maturation and its individual variability are essential to predict the effect of rapid maxillary expansion (RME) on adolescents and adults. Palatal suture ossification depicted by formation of mineralized bridges from posterior to anterior usually coincides with the skeletal age.[4]

The study aims to assess the degree of maturation of the MPS at various stages of skeletal maturation among two South Indian district's population.

MATERIALS AND METHODS

This is a clinical retrospective study which was conducted after getting Institutional Ethics Committee approval. All pretreatment diagnostic ultra-low-dose cone-beam computed tomography (CBCT) scans and lateral cephalograms were acquired from a sample of 144 subjects (67 males, and 77 females) aged between 10 and 20 years. The subjects were selected irrespective of malocclusion. The age limit was the only inclusion factor in our study whereas those excluded were if they had (a) any previous orthodontic treatment (b) any impacted supernumerary tooth in the upper anterior (c) any developmental or genetic anomaly related to craniofacial region (d) poor quality of CBCT images and lateral cephalograms.

Lateral cephalograms were taken in natural head position. Those scans where mild slouching of the neck was seen were not considered. The cephalograms were taken on Planmeca Promax machine with its calibration: 68 kV, 12 mA for 0.6–0.9 s depending on the body build of the patient. To assess the skeletal maturity using cervical vertebrae method was based on the Baccetti *et al.*[5] criteria. C2, C3, and C4 were traced to identify the shape of vertebrae; however, for C2 no shape was followed.

Ultra-low-dose full field of view (FOV) CBCT were taken on Planmeca Promax 3D MID Pro-Face machine (Helsinki Finland; 0.6 mm layer and voxel size of 0.6×0.6×0.6) machine having the voltage of 90 kVp, current of 5.6 mA and exposure time of 16–18 s in the department of oral medicine and radiology. All CBCT scans were taken in an upright position,with patient's head in confluence with machine's laser light for planar orientation. The data were saved as DICOM files which were later exported to Romexis 4.1 software for analyzing the images. In the sagittal section, the subject's head was adjusted such that palatal bone was assessed at the central incisor region with the horizontal reference line in the median region of the palate, which is the cancellous bone between the upper and lower cortical bones. In most of the scans, the palate appeared as a single thin radio-opaque line; hence, every effort was made to keep the horizontal reference line as close to the center of the radio-opaque palate or in the upper margin of the lower cortical plate of it. Axial section of the CBCT was used for the classification of staging. The axial orientation in an ultra-low dose CBCT is cumbersome hence, samples with curved palates were not considered.

All the images were scanned and saved in JPEG format by the first observer (principal investigator) and were arranged in the Microsoft PowerPoint 2016 on a white background, with no change in brightness and contrast of the images. There were two observers in this study, and the second observer (radiologist) was blinded. The staging was done by both the observers and in case of different results for few samples the final decision of the second observer was considered. The staging was again reevaluated after 1 month by both the observers for intra- and inter-examiner reliability. At the end of both assessments if mismatch in staging was found, again the readings of the second observer were considered final. The classification of sutural staging was done using Angelieri *et al.*[6] method [Table 1 and Figure 1].

Statistical analysis

The statistical analysis was carried out using SPSS 20.0 version. Chi-square test was used to calculate the gender-based sample distribution in cervical vertebrae maturity index (CVMI) and MPS staging at both the assessments. Kendall's Tau-b test was used for correlating the skeletal

Table 1: Skeletal maturation stages of midpalatal suture description.

Stages	Description
Stage A	Relatively straight high-density line at the midline
Stage B	A scalloped high-density line at the midline
Stage C	Two parallel, scalloped, high-density lines close to each other, and separated in some areas by small low-density spaces
Stage D	Two scalloped, high-density lines at the midline on the maxillary portion of the palate that cannot be visualized in palatine bone
Stage E	The suture cannot be identified

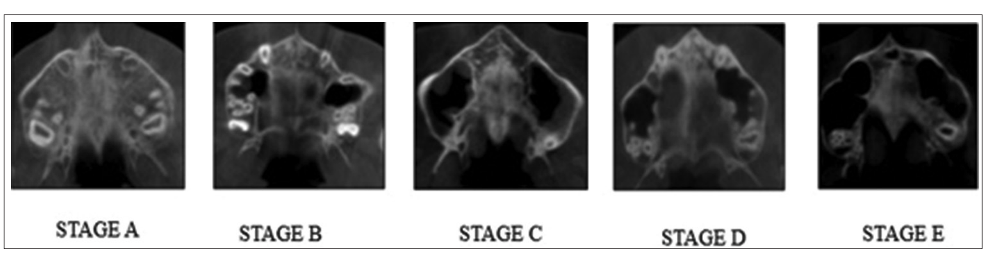

Figure 1: Stages of Mid Palatal Suture Maturation.

age with MPS staging. *P*-value was kept at <0.05, which was considered as statistically significant. Kendall's tau-b test was used for correlation as the parameters (ordinal). To obtain inter-examiner reliability between principal investigator and second observer, Kappa test was used. The intraexaminer reliability was done and since it was found that the results of the second observer were more consistent hence, readings of the second observer were used for correlation analysis.

RESULTS

Sample distribution

Gender	Frequency	Percent
Male	67	46.5
Female	77	53.4
Total	144	100.0

A total of 144 subjects met the inclusion criteria out of which 46.5% ($n = 67$) were males and 53.4% ($n = 77$) were females.

CVMI staging

Descriptive distribution of CVMI in each gender for a sample of 144 subjects using Chi-square test showed that in CS 2 and CS 3 stages there were more males ($n = 10$, $n = 26$) as compared to females ($n = 1$, $n = 20$). While there were more number of females in CS 4 ($n = 18$), CS 5 ($n = 31$), and CS 6 ($n = 7$), as compared to their male counterparts with CS 4 ($n = 17$), CS 5 ($n = 8$), and CS 6 ($n = 6$).

MPS staging at 1st assessment (A1)

Descriptive distribution of MPS in each gender for a sample of 144 subjects using Chi-square test showed that in Stage A of sutural maturation males ($n = 7$) presented in more number as compared to females ($n = 5$) while there were equal samples of females ($n = 14$) and males ($n = 14$) in Stage B. Females ($n = 43$) were found in more number in Stage C followed by males ($n = 28$). In Stage D males ($n = 15$) presented in more number than females ($n = 11$). Females ($n = 4$) were in more number in Stage E than males ($n = 3$) [Table 2].

MPS staging at 2nd assessment (A2)

Descriptive distribution of MPS in each gender for a sample of 144 subjects using Chi-square test showed that in Stage A of sutural maturation males ($n = 8$) presented in more number as compared to females ($n = 1$) while there were more males ($n = 11$) as compared to females ($n = 7$) in Stage B. Females ($n = 49$) were found in more number in Stage C followed by males ($n = 31$). In Stage D females ($n = 17$) presented in more number than males ($n = 15$). Females ($n = 3$) were in more number in Stage E than males ($n = 2$) [Table 3].

Table 2: Midpalatal suture staging at 1st assessment (A1) (*$P \le 0.05$).

Chi-square tests	Value	Df	*P* value*
Pearson Chi-square	4.386	4	0.356
n of valid cases	144		

Table 3: Midpalatal suture staging at 2nd assessment (A2) (*$P \le 0.05$).

Chi-square tests	Value	Df	*P* value*
Pearson Chi-square	10.062	4	0.039
n of valid cases	144		

Correlation of skeletal age to sutural staging

For all 144 samples

Kendal tau-b test is used to test the correlation in final scoring of MPS maturation with the skeletal age of the patient. With cumulative staging of both time assessments as classified by the second observer gave us the final MPS.

There was a significant association between the skeletal age and sutural maturation. It was seen that the maximum association of Stage C of MPS ($n = 28$) was found in CS 4 of skeletal age with followed by the CS 3 ($n = 22$). Out of 144 cases, maximum cases ($n = 46$) were found in CS 3 stage of CVMI with varying stages of sutural maturation, followed by CS 5 ($n = 39$) and CS 4 ($n = 35$) stages, respectively. In CS 6 of cervical vertebrae, we could appreciate three different stages in suture maturation, i.e., Stage C ($n = 8$), Stage D ($n = 4$), and Stage E ($n = 1$) [Table 4 and Figure 2].

In each gender

There was a significant association between the skeletal age and sutural maturation as seen in females ($n = 16$). In males, it was found that there was an overlap of sutural staging with skeletal age as ($n = 12$) for Stage C was found with CS 3 and CS 4. The results showed that the predominant stage of the samples evaluated was in CVMI 4 with MPS in Stage C in both the genders, found significant. However, only in 1 case at the CS 2 stage in females, it was found Stage D of sutural maturation which means that females do mature early than males and sutural staging would not always coincide with skeletal stage [Table 5 and Figure 3].

DISCUSSION

The chronological age is not a reliable predictor of skeletal maturity; hence, hand wrist and cervical vertebrae are being used as reliable markers for skeletal maturity.[7] The progression of MPS ossification with advancing skeletal maturation impedes the skeletal response to RME thereby leading to a failure of separation of the hemi-maxillae. Hence, the success of RME demands, an individualized assessment for the stage of ossification of this area.[8]

To assess the MPS ossification, maxillary occlusal radiographs are most frequently used, but it had its own inherent technological limitations and the histological methods used in the past were mostly limited to experimental methods.[9,10] The age group in our study was selected according to the recommendations of Angelieri *et al.*[6] and Tonello *et al.*[11] Hellsing[12] found that by the age of 15 years cervical vertebrae reach their full adult dimensions. Revelo and Fishman[13] found that only 50% of MPS was ossified at the end of skeletal maturation. Various studies have been done in the past regarding sutural maturation using CBCT,[6,11] histological measures to identify sutural maturation,[4,14] and correlation of sutural maturation to different skeletal maturity indicators using CT scans.[15] However, our study was different from others as it was a retrospective study where we were finding the correlation between skeletal age and sutural maturation using CBCT and assessing the fusion of MPS at different skeletal ages. CBCT imaging overcomes the pitfalls of 2D imaging thereby enabling 3D visualization of whole craniofacial complex and helps in measuring the changes caused by RME.[16,17]

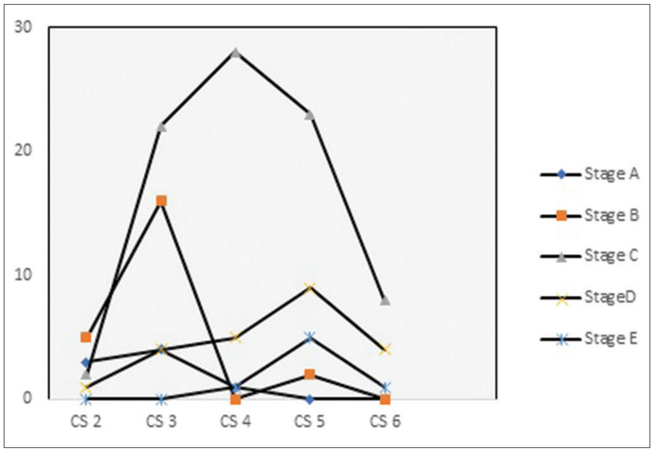

Figure 2: Correlation of Skeletal Age to Sutural Staging.

The radiologist being more experienced in reading the scans; hence, their readings were validated and used for the final correlation. The results of the present study in relation to the

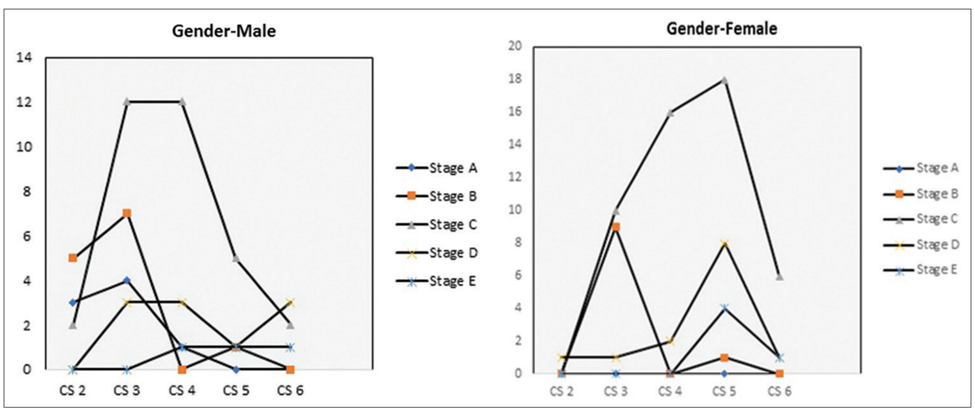

Figure 3: Correlation of Skeletal age to Sutural Staging in Males and Females.

Table 4: Correlation of skeletal age to sutural staging for all 144 samples (*$P \leq 0.05$).

Symmetric measures		Value	Asymp. SE[a]	Approx. T[b]	*P* value*
Ordinal by ordinal	Kendall's tau-b	0.445	0.058	6.945	<0.001
n of valid cases		144			

[a]not assuming null hypothesis stands for asymptotic error. [b]Using the asymptotic standard error assuming the null hypothesis

Table 5: Correlation of skeletal age to sutural staging in each gender (*$P=0.05$).

Gender			Value	Asymp. SE[a]	Approx. T[b]	*P* value*
Female	Ordinal by Ordinal	Kendall's tau-b	0.353	0.092	3.606	<0.001
	n of valid cases		77			
Male	Ordinal by ordinal	Kendall's tau-b	0.485	0.074	5.962	<0.001
	n of valid cases		67			

[a]not assuming null hypothesis stands for asymptotic error. [b]Using the asymptotic standard error assuming the null hypothesis

degree of ossification of the suture showed that ossification increased with skeletal age. However, some cases of incomplete ossification were still observed in the 17–19 years age groups and few samples at lower skeletal age had higher stages of sutural fusion, which depicts that those cases were early maturing in regard to suture maturation. This features that sutural fusion is not solely dependent on the skeletal or chronological age, the rate and intensity of ossification are also influenced by the race, diet, gender, and genetics.[18-21] Angelieri *et al.*[6] in their CBCT study of 140 subjects found that above 11 years of chronological age there can be different stages of MPS maturation. The results of our study also hold the same results.

As for the clarity in the timing of MPS development is considered, there are no proper data which depict by what age suture totally matures and studies carried on MPS assessment for its ossification thus have a lot of inter-individual variabilities.[22] In 20 male cadavers aging more than 70 years N'Guyen *et al.*[18] reported that suture that might not close completely even in the elderly as the suture was ossified in the anterior thirds and persistence of conjunctive tissue in the posterior third was noticed. He correlated this finding to the mastication forces acting on the maxillary bones during the entire life which he referred to it as the Functional hypothesis. We also found similar results where we could appreciate lower stages of suture maturation even though the subject is skeletally mature. There lies some controversy in the direction of maturation of sutural fusion as Schlegel *et al.*[19] and Persson and Thilander[4] believed that ossification occurs more in the posterior region then traverses in the anterior region of the palatal suture while N'Guyen *et al.*[18] stated that ossification process was completed only in the anterior region and the posterior region was still under various stages of maturation. Contrary to N'Guyen *et al.*,[18] in our sample distribution, we found similar results to Schlegel *et al.*[19] and Persson and Thilander[4] with more number of Stage D in both the genders at 1st assessment as compared to Stage E and also at 2nd assessment Stage D and Stage E. Kappa values showed varied results at both time assessments which show there can be some bias in reading the CBCT images at 2 time assessments. We came across two limitations in our study. First, as the suture margins are not well appreciated in low dosage; hence, there can be over or underestimation of sutural staging which holds the biggest limitation in our study. If it had been a normal dose medium FOV of the same region, the results could have been consistent throughout the period of assessment. However, we would appreciate more studies to be carried on sutural patency using CBCT as a diagnostic aid. The second limitation was for the reliability of agreement between both the observers; hence, we advise a radiologist who should always be involved in assessing sutural maturation or special training for reading CBCTs should be given to all orthodontists.

CONCLUSION

In our study, a strong correlation was found between skeletal age and sutural fusion, i.e., predominantly Stage C of MPS coincided with CS 4 with greater gender predilection towards females.

Staging of the MPS to initiate RME treatment in a non-growing child will be more validated if a prior thorough inspection of MPS anatomy has been done, but its use as a skeletal maturity indicator is questionable.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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