CE Quiz

Original Article

Assessment of Midpalatal Suture Maturation by Cone-beam Computed Tomography in Circumpubertal Age Group

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Abstract

This study evaluated the prevalence of midpalatal suture maturation stages in 8 to 18 years old patients and the relationship between chronological age and the suture maturation stages in a Thai population. The cone-beam computed tomography (CBCT) images of the midpalatal suture from 240 subjects (110 males, 130 females) aged 8 to 18 years were classified into five stages (A-E). The distribution of the maturation stages was determined according to chronological age and sex. Chi-square test was used to compare the prevalence of maturation stages between male and female subjects. Spearman's rank correlation analysis was performed to investigate the relationship between the maturation stage and chronological age. The results showed that the fused stages (D-E) were not seen in the prepubertal age group (8-11 years old). In the postpubertal age group (12-18 years old), the prevalence of nonfused stages (A-C) and fused stages (D-E) was 82.3% and 17.7% respectively. Stage C was the most prevalent (62.6%) in the postpubertal age group. Female showed a significantly higher prevalence of fusion than male (χ^2 = 5.434, p=0.02). The correlation coefficient between chronological age and the suture maturation was 0.325 (p<0.001). In conclusion, fusion was not observed in females under 12 years old and males under 14 years old. Thus, CBCT might be recommended to verify the suture status before performing maxillary expansion in female ≥12 years old and males ≥14 years old. Overall, chronological age had a weak positive correlation with the suture maturation.

Keywords: Chronological age, Cone-beam computed tomography, Maturation stages, Midpalatal suture, Rapid maxillary expansion

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Introduction

Rapid maxillary expansion (RME) is an orthopedic procedure that is routinely used in orthodontic practice for many purposes, including correction of maxillary transverse deficiency[1-4], posterior crossbite, dental crowding[1,4] and facilitating Class III correction by facemask therapy.[5] The objective of RME is to increase the transverse width of the maxillary arch at the skeletal level by splitting the midpalatal suture.[2]

Treatment timing for RME is very important. The treatment effects of RME differ depending on the skeletal maturity of the patient.[6] As patients grow older, interdigitation of the midpalatal suture increases, making maxillary expansion more difficult.[7] Performing RME in a skeletally mature patient in which fusion of the midpalatal suture has occurred could lead to undesirable side effects such as buccal tipping of maxillary posterior teeth, alveolar bone bending, reduction of buccal bone thickness and marginal bone level, gingival recession, pain and increasing risk of relapse.[8-10] Hence surgically assisted rapid maxillary expansion (SARME) has been recommended in patients with advancing age.[11] However, there is no consensus in the literature about the time point to shift from RME to SARME.[11]

The start and the advance of fusion of the midpalatal suture vary greatly with age and sex.[12,13] There have been controversies regarding the age at which fusion of the midpalatal suture occurs. Understanding these variabilities is essential in treatment planning for RME.[7,13] For evaluation of the midpalatal suture, Angelieri *et al.*[13] classified the midpalatal suture into five stages using cone-beam computed tomography (CBCT) images. At stages A, B and C, the midpalatal suture was still open, and a conventional RME could be easily performed. At stages D and E, the midpalatal suture was partially or totally fused, hence patients in these stages might be better treated by SARME. This method has the potential to avoid undesirable effects of RME failure or unnecessary SARME, particularly in adolescents and young adults whom prognosis of RME is unpredictable. However, routine CBCT radiography of every patient is not recommended because of ethical concerns regarding unnecessary radiation exposure. Thus, a CBCT study of the midpalatal suture maturation could provide information and help in treatment planning for maxillary expansion. Unfortunately, there has been a lack of evidence regarding the maturation of the midpalatal suture and the relationship between chronological age and the midpalatal suture maturation in a Thai population. Furthermore, racial variations in the maturation have also been suggested. Therefore, the aims of this study were to evaluate 1. the prevalence of midpalatal suture maturation stages in 8 to 18 years old patients and 2. the relationship between chronological age and the suture maturation stages in a Thai population.

Materials and methods

The research protocol was approved by the Human Research Ethics Committee of Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2019-036). From 581 patients aged between 8 and 18 years old who underwent CBCT imaging at the Department of Radiology, Faculty of Dentistry, Chulalongkorn University between January 2013 and December 2018, 240 subjects (110 males, mean age 13.9± 2.8 y; 130 females, mean age 14.4±2.6 y) were consecutively selected based on the following inclusion criteria: good quality of CBCT images that displayed the entire midpalatal suture. The exclusion criteria were craniofacial syndromes, pathology in the maxilla that might affect the midpalatal suture, history of trauma in the maxillofacial region and orthodontic treatment. All CBCT images were taken for diagnosis purpose; therefore, no subjects received unjustified radiation exposure. The CBCT images were obtained using a 3D Accuitomo 170 machine (J. Morita, Kyoto, Japan) with 80-90 kV, 1-10 mA and 17.5 s exposure time. The field of view of the CBCT images was 8 x 8 or 10 x 10 cm with 0.165 or 0.25 mm voxel size. A 1-mm slice thickness was used. Infinitt® PACs software (Infinitt Healthcare Co., Ltd., Seoul, Korea) was used to adjust the patient's head position in three planes of space: in the coronal and axial views, the vertical reference line was positioned at the midsagittal plane; in the sagittal view, the horizontal reference line was adjusted so that it passed anteroposteriorly through the long axis of the palate, and positioned in the center of the supero-inferior dimension of the palate (Fig. 1).

The central cross-sectional axial slice of the midpalatal suture was used to determine the maturation stage. For subjects who exhibited a thick or curved palate, two or more axial cross-sectional slices were assessed. All slices were saved as JPG files and randomly arranged in a Powerpoint (Microsoft Corp., Redmond, WA) presentation file with a black background; only random identification numbers were visible.

Two examiners (NC, KM) were trained and calibrated for classification and any disagreement discussed until consensus was obtained. For the main evaluation, all CBCTs were classified blindly by the principal examiner (NC). The midpalatal sutures were classified into five stages of development according to the protocol described by Angelieri *et al.*[13] (Fig. 2).

To evaluate the intra-examiner and inter-examiner agreement, 30 CBCT images were randomly selected and reclassified by the principal examiner (NC) and the second examiner (KM) 2 months after the main evaluation.

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS 22.0; IBM Corp, Armonk, NY). Intra-examiner and inter-examiner agreements were evaluated using weighted kappa statistics, and defined using the scale of Landis and Koch[14] (<0, poor; 0-0.20, slight; 0.21-0.40, fair; 0.41-0.60, moderate; 0.61-0.80, substantial; 0.81-1.00, almost perfect agreement). The distribution of maturation stages of the midpalatal suture according to chronological age and sex was compiled as absolute and percentage frequencies in a cross-tabs table. Chi-square test was applied to compare the prevalence of maturation stages between male and female subjects. Spearman's rank order correlation analysis was used to investigate the relationship between chronological age and midpalatal suture maturation stages. The level of significance was set at $p<0.05$ for all statistical calculations.

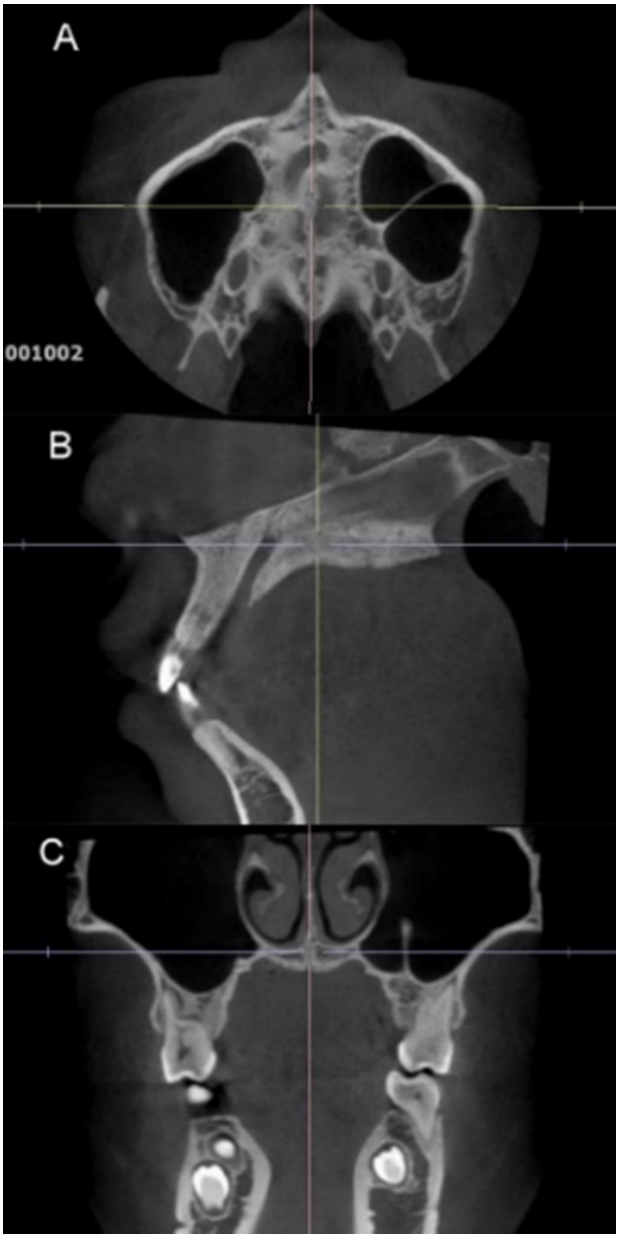

Figure 1 *Orientation of head position in three planes of space. A, axial; B, sagittal; and C, coronal views. Note that in B, the sagittal view, the horizontal line that indicates the position of the axial plane view is positioned through the center of the supero-inferior dimension of the hard palate (Infinitt® PACs software)*

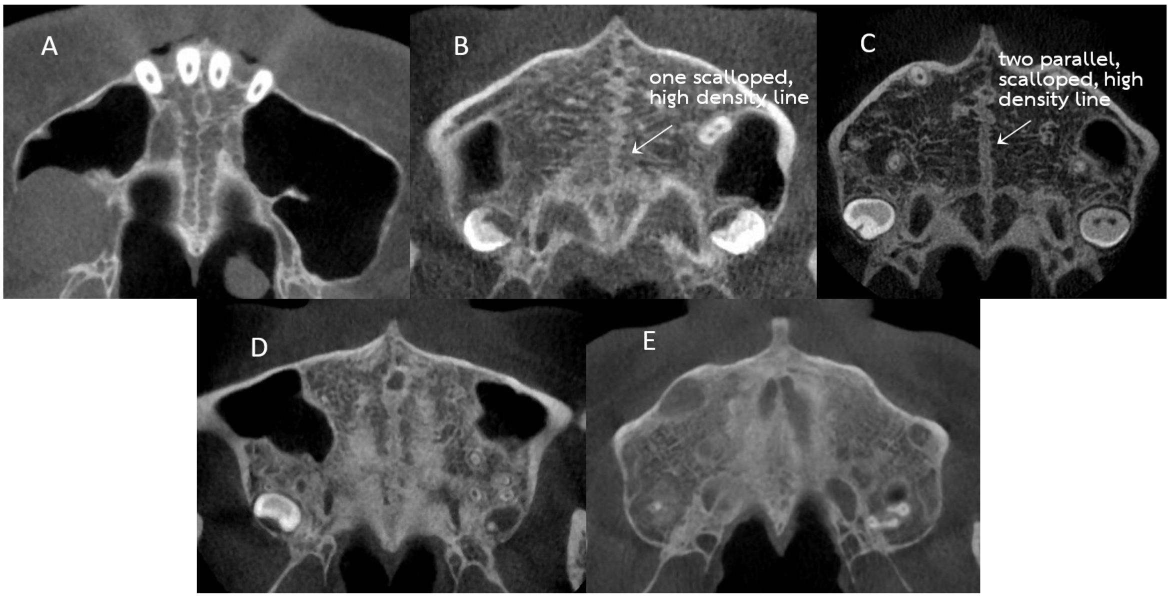

Figure 2 *Maturation stages of midpalatal suture. A) stage A, the suture is characterized by one relatively straight high-density line; B) stage B, the suture is observed as one scalloped, high density line at the midline. Stage B may present as two parallel, scalloped, high-density lines close to each other and separated by small low-density spaces in some areas. C) stage C, the suture is visualized as two parallel, scalloped, high density lines that are close to each other, separated by small low density spaces; D) stage D the suture is visualized as two scalloped, high density lines on the maxillary portion of the palate (anterior to the transverse palatine suture), but the suture cannot be identified in palatine bone (posterior to the transverse palatine suture); E) stage E, the suture cannot be identified along the maxillary and palatine bones, indicating the sutural fusion has occurred. Stage A-C (Nonfused midpalatal suture). Stage D-E (Fused midpalatal suture)*

Results

The weighted kappa coefficients for both intra-examiner and inter-examiner agreements were 0.94, demonstrating almost perfect intra-examiner and inter-examiner agreement. The distribution of the stages of midpalatal suture maturation are summarized in Table 1. The most prevalent in the study population was stage C (62.1%), followed by stage B (21.7%), stage D (10.8%), stage E (3.8%) and stage A (1.7%), respectively. The midpalatal suture was not fused in 85.4% of the total subjects. Both sexes had a higher prevalence of stage C, which was more frequent in females (females, 63.1%; males, 60.9%). Furthermore, in females, higher frequencies of stages D and E were observed (stage D, 16.2% in females, 4.5% in males; stage E, 3.8% in females, 3.6% in males). Neither females under 12 years old nor males under 14 years old had fusion of the suture. In general, the percentage of subjects who had fused midpalatal suture (stages D and E) increased with age.

Table 1 *Distribution of the midpalatal suture maturation stage by chronological age and sex*

Age (y)	Sex	MPS stage										Total
		A		B		C		D		E		
		n	%	n	%	n	%	n	%	n	%	
8	M			2	50	2	50					4
	F			1	50	1	50					2
	M+F			3	50	3	50					6

Table 1 *Distribution of the midpalatal suture maturation stage by chronological age and sex (cont.)*

Age (y)	Sex	MPS stage										Total
		A		B		C		D		E		
		n	%	n	%	n	%	n	%	n	%	
9	M			2	33.3	4	66.7					6
	F			1	20	4	80					5
	M+F			3	27.3	8	72.7					11
10	M	1	16.7	2	33.3	3	50					6
	F			2	40	3	60					5
	M+F	1	9.1	4	36.4	6	54.5					11
11	M			5	62.5	3	37.5					8
	F	1	16.7			5	83.3					6
	M+F	1	7.1	5	35.7	8	57.1					14
12	M			3	33.3	6	66.7					9
	F			4	26.7	10	66.7	1	6.7			15
	M+F			7	29.2	16	66.7	1	4.2			24
13	M			5	55.6	4	44.4					9
	F			4	36.4	6	54.5	1	9.1			11
	M+F			9	45	10	50	1	5			20
14	M	1	5.9	4	23.5	11	64.7	1	5.9			17
	F			2	9.5	15	71.4	4	19			21
	M+F	1	2.6	6	15.8	26	68.4	5	13.2			38
15	M					8	80	2	20			10
	F			1	6.3	13	81.3	2	12.5			16
	M+F			1	3.8	21	80.8	4	15.4			26
16	M			3	15.8	14	73.7			2	10.5	19
	F			2	14.3	7	50	5	35.7			14
	M+F			5	15.2	21	63.6	5	15.2	2	6.1	33
17	M			3	25	8	66.7	1	8.3			12
	F			2	12.5	8	50	4	25	2	12.5	16
	M+F			5	17.9	16	57.1	5	17.9	2	7.1	28
18	M	1	10	2	20	4	40	1	10	2	20	10
	F			2	10.5	10	52.6	4	21.1	3	15.8	19
	M+F	1	3.4	4	13.8	14	48.3	5	17.2	5	17.2	29
8-18	M	3	2.7	31	28.2	67	60.9	5	4.5	4	3.6	110
	F	1	0.8	21	16.2	82	63.1	21	16.2	5	3.8	130
	M+F	4	1.7	52	21.7	149	62.1	26	10.8	9	3.8	240

MPS, midpalatal suture; M, male; F, female

The distribution according to the midpalatal suture maturation stage is shown in Figure 3. Stage A was observed in subjects aged 10, 11, 14 and 18 years old. Stage B was observed at all ages, and the distribution tended to increase from 8 to 13 years of age, then decreased. Stage C was observed at all ages and tended to increase from 8 to 14 years of age, then decreased. Stage D was observed from 12 to 18 years of age, the distribution mainly being in the range of 14 to 18 years old. Stage E was observed from 16 to 18 years of age, mostly at 18 years of age. The distribution of stages D and E was notably in the older age group.

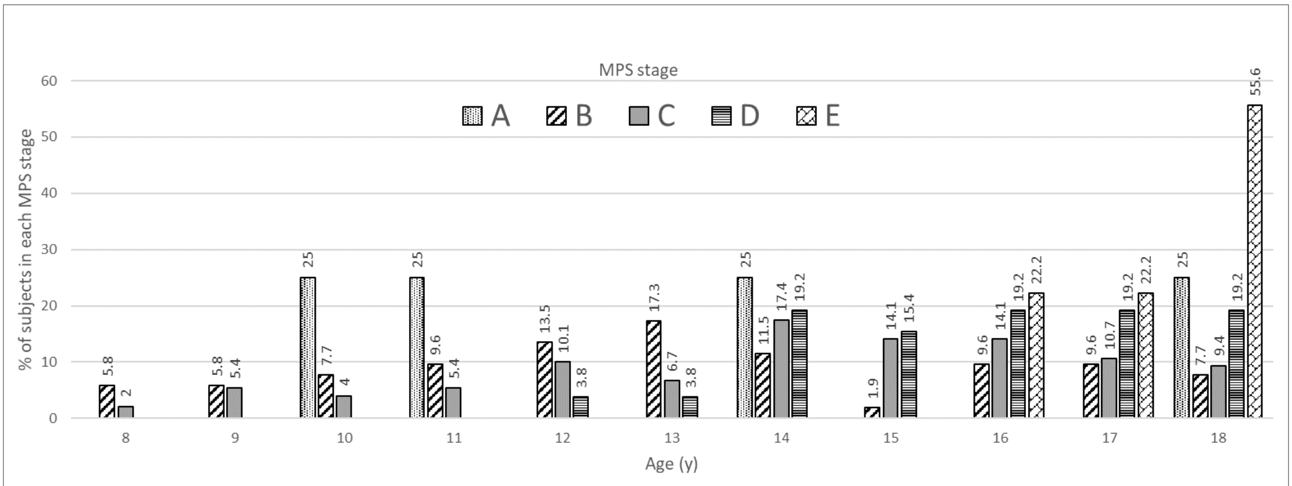

Figure 3 *Sample distribution according to the midpalatal suture maturation stage; MPS, midpalatal suture*

The comparison of the prevalence of fusion of the midpalatal suture by sex in the postpubertal age group (12-18 years old) is given in Table 2. There was a significant difference in the prevalence of fusion of the suture between the sexes. Females had a higher prevalence of fusion than males (23.2% and 10.5% in females and males respectively, χ^2 = 5.434, p=0.02).

Table 2 *Comparison of the prevalence of fusion of the midpalatal suture between the sexes in the postpubertal age group*

Sex	MPS stage		Total	Chi-square test, *p*-value
	Nonfused MPS (stage A, B, C)	Fused MPS (stage D, E)		
Male	77 (89.5%)	9 (10.5%)	86	χ^2 = 5.434,
Female	86 (76.8%)	26 (23.2%)	112	p = 0.02
Total	163 (82.3%)	35 (17.7%)	198	

MPS, midpalatal suture

In the study population, there was a weak correlation between chronological age and the midpalatal suture maturation stages (r=0.325, *p*<0.001). Females showed a slightly higher correlation coefficient than males (r=0.348, *p*<0.001 and 0.276, *p*=0.003 for females and males respectively).

Discussion

This study was performed to evaluate 1. the prevalence of midpalatal suture maturation stages in 8 to 18 years old patients and 2. the relationship between chronological age and the suture maturation stages in a Thai population. The results showed that fusion was not observed in females under 12 years old and males under 14 years old, however, it was possible to find nonfused midpalatal suture in individuals older than these ages. Overall chronological age had a significant, but weak positive correlation with the maturation stage of the midpalatal suture.

Determining maturation stage of the midpalatal suture is important for RME therapy.[13,15] Many methods for assessment of the midpalatal suture have been proposed in the literature, including histological studies[7,12,16], evaluation of occlusal radiographs[17], micro-CT of autopsy material[18] and CBCT.[13] Histological and micro-CT evaluations require an invasive biopsy material, precluding its use in orthodontic patients.[15] Revelo and Fishman[17] used occlusal radiographs to assess the fusion of midpalaltal suture before RME therapy. However, the study by Wehrbein *et al.*[19] showed that an occlusal radiograph was unreliable to assess the fusion of the midpalaltal suture due to the superimposition of nearby anatomical structures. The diagnostic advantages of CBCT are its ability to visualize the midpalatal suture without such superimposition, allowing a reliable assessment of suture maturation.[20] In this study, we classified the midpalatal suture into five stages of maturation according to the method of Angelieri *et al.*[13] Although this classification method has the potential reliability and reproducibility for diagnostic purposes, it requires an extensive training program before it can be applied.[21,22] In the current study, the two examiners (NC, KM) were trained and calibrated before using this classification method, which was validated by the almost perfect intra-examiner and inter-examiner agreement.

The results of this study showed that there was a high prevalence (85.5%) of nonfused midpalatal sutures (stages A, B and C) in patients aged 8 to 18 years, consistent with the previous study by Angelieri *et al.*[13], who observed that 81.5% of subjects aged 5 to 18 years had nonfused midpalatal sutures. Furthermore, it should be noted that patients at prepubertal age (8-11 years old) had no stages D and E, indicating an absence of midpalatal suture fusion in this age group. These results are consistent with those of Angelieri *et al.*[13] and Tonello *et al.*[23], who observed a lack of subjects under 12 years of age in stages D and E. Furthermore, these findings support a previous study, which reported greater and more stable orthopedic changes when performing RME in patients under 12 years of age.[3] However, Jang *et al*.[24] observed stages D and E in some females aged 10 and 11 years old, probably because of the racial difference and the difference in classification method used in their study, in that they additionally investigated the suture on a coronal cross-sectional planar view and on volume-rendered images.

The findings of this study illustrate great variability in distribution of the maturation stages of the midpalatal suture, especially in the postpubertal age group, as subjects 12 years of age and above presented all stages of maturation. These results are consistent with Angelieri *et al.*[13], who observed all stages of maturation in subjects older than 11 years, and Ladewig *et al.*[25], who observed all stages in subjects aged 16 to 20 years. In addition, previous histological studies have also shown great variations in the ages of midpalatal suture fusion.[7,12,16,18] In the postpubertal age group (12-18 years old), it was observed that the nonfused stages (stages A, B and C) were seen in 82.3% of the subjects; this is quite similar to the study by Angelieri *et al.*[13] who observed that 75% of subjects aged 11 to 18 years were in the nonfused stages. These results demonstrated that there was a high possibility to find nonfused midpalatal suture in the postpubertal age group. Furthermore, we observed that the prevalence of fused midpalatal suture (stages D and E) gradually increased with increasing age, especially from 14 to 18 years of age, which is consistent with previous studies.[13,23,24]

The maturation of the midpalatal suture occurs earlier in females than in males, as verified in this study in which stage D was present in females from 12 years and in males from 14 years of age. These findings are consistent with previous studies[13,24] and correspond with the sex differences in the pubertal growth spurt that occurs approximately 2 years earlier in females than in males.[26] Furthermore, in the postpubertal age group, female subjects had a significantly higher prevalence of fusion compared with male subjects. Other studies[13,24,25], although not statistically significant, also observed higher prevalence of fusion in female subjects than in male subjects. These findings have clinical relevance in that performing RME in the postpubertal age group might not be successful in some patients, particularly in female subjects. Thus, individual assessment of the suture might be considered in this age group.

In the present study, the correlation between chronological age and suture maturation stage was weak in both male and female subjects. Previous studies reported that the suture maturation stages were more consistent with skeletal age, such as hand-wrist bone age[24] and cervical vertebrae maturation (CVM)[24,27], rather than with chronological age. These indicated that the midpalatal suture maturation stages might not be reliably determined on the basis of the chronological age. However, chronological age may be a viable alternative to predict the maturation of the suture when the skeletal age cannot be assessed.[27] Shin *et al.*[28] also found that the midpalatal suture opening ratio had significant negative correlations with age, palate length, and midpalatal suture maturation stage in young adults and suggested that these parameters can be predictors of suture expansion.

Based on the results of this study, fusion of the midpalatal suture was not observed in females under 12 years old and males under 14 years old. However, the suture has not been fused in some older individuals. Thus, in order to reduce the risk of RME failure or unnecessary SARME, it would be useful to individualize assessment of the suture before performing maxillary expansion in females from the age of 12 and males from the age of 14. Female showed a significantly higher prevalence of fusion than male in the postpubertal age group. The correlation between chronological age and suture maturation stage was weak in both male and female subjects.

This study included a large sample in circumpubertal age group, i.e., from 8 to 18 years old. However, the limitation of our study was the small samples in the younger age group (8 to 11 years old), and further studies could include a larger sample size in this group. Furthermore, a longitudinal clinical study would be necessary to evaluate the clinical effectiveness of this classification method on predicting the treatment outcomes of RME. In addition, consideration should also be given to other features of anatomical resistance to maxillary expansion, such as zygomaticomaxillary, zygomaticotemporal and pterygopalatine sutures when performing RME therapy.[29,30]

Conclusions

Fusion of the midpalatal suture was not observed in females under 12 years old and males under 14 years old. However, the suture was not fused in some older individuals. Thus, from the age of 12 in females and 14 in males, CBCT might be recommended to verify the suture status before performing maxillary expansion. In the postpubertal age group, the possibility to find fusion of the suture was higher in females than in males. Overall, chronological age showed a weak correlation with the maturation stage of the midpalatal suture.

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