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Cone beam computed tomography evaluation of midpalatal suture maturation in adults

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Abstract. The aim of this study was to evaluate midpalatal suture maturation in adults, as observed in cone beam computed tomography (CBCT) images. CBCT scans from 78 subjects (64 female and 14 male, age range from 18 to 66 years) were evaluated. Midpalatal suture maturation was verified on the central cross-sectional axial slice in the superior–inferior dimension of the palate, using methods validated previously. Intra-examiner agreement was analyzed by weighted kappa test. Multinomial logistic regression was used to test whether sex and chronological age (adults $<$30 years or $\geq$30 years) could be used as a predictor for the maturational stages of the midpalatal suture. The majority of the adults presented a fused midpalatal suture in the palatine (stage D) and/or maxillary bones (stage E). However, the midpalatal suture was not fused in 12% of the subjects. Sex and chronological age were not significant predictors of the maturational stages of the midpalatal suture. The individual assessment of midpalatal suture maturation by way of CBCT images may provide reliable information critical to making the clinical decision between rapid maxillary expansion and surgically assisted rapid maxillary expansion for the treatment of maxillary atresia in adults.

Key words: CBCT; midpalatal suture; adult; rapid maxillary expansion.

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The concept that the maxilla can be expanded by opening the midpalatal suture was first introduced by Angell in 1860[1]. A century later, Haas published the results of a study on the rapid expansion of the maxillary dental arch by opening the midpalatal suture[2], and since then, rapid maxillary expansion (RME) has been utilized for the treatment of posterior crossbite and maxillary deficiency (primarily for the correction of crossbite), as well as to increase the maxillary arch perimeter in individuals with moderate crowding of the dental arches[3]. The routine use of this therapy has, however, been limited to growing patients, since clinical failure of RME is typically observed in adults. Complications include serious pain, accentuated buccal tipping and gingival recession in the posterior teeth, palatal tissue ulceration or necrosis[4–7], buccal root resorp-

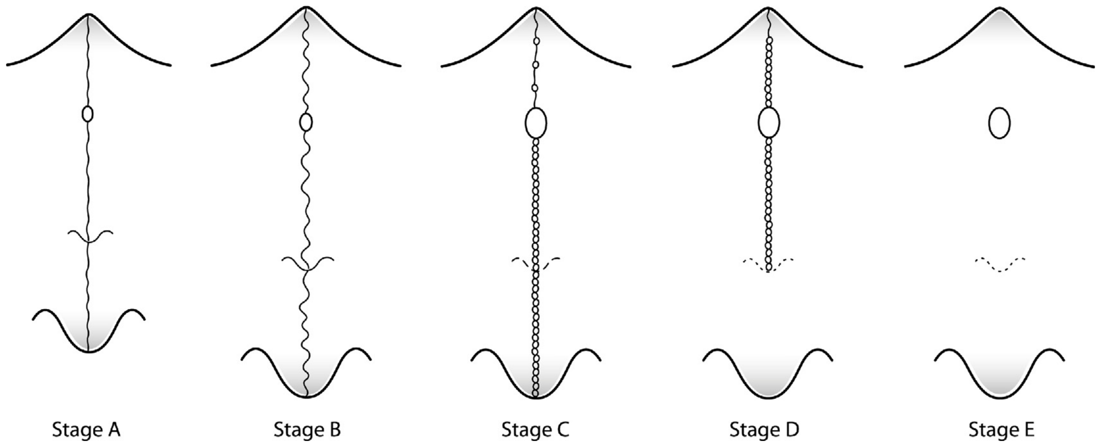

Fig. 1. Schematic drawing of the maturational stages of the midpalatal suture. Stage A of the morphology of the midpalatal suture is characterized by one relatively straight high-density midpalatal suture line. Stage B is observed as one scalloped, high-density line at the midline. Stage B may present some areas as two parallel, scalloped, high-density lines close to each other and separated by small low-density spaces. Stage C is visualized as two parallel, scalloped, high-density lines that are close to each other, separated in some areas by small low-density spaces. Stage D is visualized as two scalloped, high-density lines at the midline on the maxillary portion of the palate, but the midpalatal suture cannot be identified in palatine bone. At stage E, sutural fusion has occurred in the maxilla. The midpalatal suture cannot be identified, and the parasutural bone density is the same as in other regions of the palate. From Angelieri et al.[25].

tion[8,9], alveolar bone bending[10], fenestration of the buccal cortex[8], and instability of the expansion[10–12]. Surgical procedures have been recommended for the treatment of maxillary transverse deficiency in adults, such as multi-segment Le Fort I osteotomies or surgically assisted rapid maxillary expansion (SARME)[13].

Chronological age has been considered a fundamental factor for making the choice between RME and SARME/Le Fort osteotomy to treat maxillary deficiency. However, SARME for the treatment of maxillary deficiency has been recommended for patients older than 14 years[14], 16 years[15], 20 years[16], or 25 years of age[17]. Alpern and Yurosko have suggested a difference in chronological age between male and female patients, with SARME indicated in females older than 20 years of age and in males older than 25 years of age[18].

In addition to the absence of a well-defined chronological age threshold for the indication of SARME, many case reports have shown the possibility of successful sutural expansion with RME alone in much older adult patients[18–21]. Surgically assisted maxillary expansion, however, increases morbidity, treatment costs, and the number of days required for the patient to make a full recovery and to resume routine activities.

The variability in clinical outcomes of RME in late adolescent and young adult patients has also been highlighted in histological studies evaluating the maturation of the midpalatal suture in cadavers. No fusion of the midpalatal suture was observed in subjects aged 27 years, 32 years[22], 54 years[23], and even 71 years[24]. On the other hand, Persson and Thilander verified fusion of the midpalatal suture in adolescents ranging from 15 to 19 years of age[22].

Angelieri et al. have proposed a method of individual evaluation of midpalatal suture maturation with cone beam computed tomography (CBCT) as a way of providing more reliable clinical data when making the decision between RME only and surgically assisted maxillary expansion for adolescent and young adult patients[25]. CBCT has the advantage of being able to isolate the midpalatal suture without the overlapping of other anatomical structures, as occurs when occlusal radiographs are obtained[26].

Angelieri et al. also reported sex differences in the minimum age of fusion of the midpalatal suture[25]. The midpalatal suture was fused in the palatine (stage D) or/and maxillary bones (stage E) in female subjects older than 11 years of age and in male subjects older than 14 years of age (Fig. 1). Nevertheless, that study also described great variability in the distribution of the maturational stages of the midpalatal suture in subjects older than 11 years.

The aim of this study was to evaluate the maturation of the midpalatal suture in adults as viewed in CBCT images, as chronological age has been shown to be an unreliable parameter for making the clinical decision between RME alone and SARME/Le Fort I segmentation for these patients.

Subjects and methods

Baseline diagnostic CBCT images from 78 subjects were examined. Sixty-four were female and 14 were male, and they ranged in age from 18 to 66 years (Table 1). The sample was divided into two age groups: younger adults and older adults, i.e. younger or older than 30 years of age. The cut-off value of 30 years for the definition of young adulthood has been proposed in forensic radiology[27]. The CBCT images were obtained from the archives of the private practice of one oral and maxillofacial surgeon. These images had been required for diagnosis and treatment planning by the surgeon. This was a descriptive and retrospective study and was approved by the Institutional Review Board of Methodist University of São Paulo.

The inclusion criteria were age older than 18 years, malocclusion of any Angle class, any skeletal deformities, and good quality CBCT images. The exclusion criteria were craniofacial syndromes, systemic diseases, previous orthognathic surgery, and the presence of noise on the CBCT images or blurred images.

The CBCT images evaluated in the current study were obtained using an

Table 1. Demographic characteristics of the sample.

Sex	Age, years		Total
	<30	>30	
Female	30	34	64
Male	6	8	14
Total	36	42	78

iCAT Cone Beam 3D Imaging system scanner (Imaging Science International, Hatfield, PA, USA); the scan time was 17.8 s and the resolution was 0.30 mm. Invivo5 software (Anatomage, San Jose, CA, USA) was used to adjust the patient's head in three planes of space and to select the slice for the evaluation of midpalatal suture maturation. These procedures were performed according to the protocol described previously by Angelieri et al.[25]. The maturational stage of each midpalatal suture was determined by evaluating the central cross-sectional axial slice in the superior–inferior dimension of the palate (i.e., from the nasal to the oral surface).

For the classification of midpalatal suture maturation, all axial central cross-sectional slices were arranged by the principal investigator in a PowerPoint presentation with a black background, using codes that were displayed sequentially on a high-definition computer monitor. Two axial cross-sectional slices were used when subjects presented with a thick or a curve palate[25]. No adjustments in contrast or brightness of these images were undertaken. All images of the midpalatal suture were classified blindly by one expert examiner (F.A.) in a darkened room, according to the maturational stages described by Angelieri et al.[25] (Fig. 1).

Method error

Thirty images of the midpalatal sutures were selected randomly from the total sample and reclassified by the same examiner a month later.

Statistical analysis

A weighted kappa coefficient was calculated for evaluation of the intra-examiner agreement. The statistical software used was MedCalc ver. 12.3.0 (MedCalc Software bvba, Mariakerke, Belgium). The agreement was defined using the scale of Landis and Koch[28].

The sample size was estimated using the sample size tables for logistic regression[29], with $\alpha = 0.05$, a power of 80%, a percentage of patients with suture E of 60%[25], a standard deviation for age of 15 years, and an odds ratio (OR) for 15 years of age of 2.0 (corresponding to an OR of 1.05 for each year). Considering these parameters, a sample size of at least 76 patients was necessary. All available CBCT scans of adult patients matching the inclusion criteria were included in the study.

With regard to chronological age, two age groups were considered: younger and older than 30 years[27]. For the statistical analysis, stages B and C (indicating that the midpalatal suture was still present) were grouped together, as there were too few cases for these to be considered as separate stages. The prevalence rates of the maturational stages of the midpalatal suture in the two age groups were compared by χ^2 tests with Yates' correction ($P < 0.05$).

Table 2. Distribution of the maturational stages of the midpalatal suture.

Stage	Age <30 years		Age >30 years		Total
	Female	Male	Female	Male	
A	0	0	0	0	0
B	1	0	2	0	3
C	2	1	2	1	6
D	9	2	6	2	19
E	18	3	24	5	50
Total	30	6	34	8	78

An ordinal logistic regression model was performed using maturational stages of the midpalatal suture as an outcome variable. The ranks of the outcome variable were codified as 1 (B and C), 2 (D), and 3 (E). The primary predictor variable was age (in years). The other predictor variable was sex (the code was 0 for female and 1 for male). The impact of each factor on the outcome variable was expressed as an OR with its 95% confidence interval (95% CI). The analysis was performed using Stata version 11 (StataCorp LP, College Station, TX, USA).

Results

The weighted kappa coefficient for the evaluation of the intra-examiner agreement was 0.802 (95% CI 0.605–0.999), demonstrating substantial agreement according to the scale of Landis and Koch[28].

The distribution of the maturational stages of the midpalatal suture in the sample is shown in Table 2. The mean ages and prevalence rates of male and female subjects for each maturational stage are reported in Table 3. The midpalatal suture was not fused in nine out of 78 patients (12% of the total sample with stages B or C) and this was observed in both age ranges with similar prevalence rates. The comparison between the two age groups for the prevalence rate of stage B + C showed no statistically significant difference ($\chi^2 = 0.000$, $P = 1.000$). In the majority of the sample in both age groups, the midpalatal suture was at least partially fused. The prevalence rate of stage D decreased from 31% (11 subjects) in the younger adult group to 19% (eight subjects) in the older adult group. There was no statistically significant difference between the two age groups with regard to the prevalence rate of stage D ($\chi^2 = 0.839$, $P = 0.360$). In contrast, stage E increased over time, from 58% (21 subjects) in the younger adults to 69% (29 subjects) in the older adults. Once again the comparison of the prevalence rate for stage E between the two age groups was not statistically significant ($\chi^2 = 0.557$, $P = 0.455$).

The results of ordinal logistic regression confirmed that there was no significant association between chronological age or sex and the maturational stages of the midpalatal suture (Table 4). In fact, neither chronological age (OR 1.03, $P = 0.090$) nor sex (OR 0.75, $P = 0.621$) was a significant predictor of the maturational stage of the midpalatal suture.

Table 3. Descriptive statistics for age and sex at the different maturational stages of the midpalatal suture.

Rank	Maturational stage	Number	Age (years) Mean ± SD	Female *n* (%)	Male *n* (%)
1	BC	9	32.5 ± 13.2	7 (11)	2 (14)
2	D	19	32.3 ± 14.2	15 (23)	4 (29)
3	E	50	38.7 ± 15.4	42 (66)	8 (57)
All	BCDE	78	36.4 ± 15.0	64	14

SD, standard deviation.

Table 4. Results of the ordinal logistic regression model with the maturational stages of the midpalatal suture as outcome variable and age and sex as predictors.

Variable	Coefficient	SE	OR (95% CI)	*P*-value
Intercept 1	−1.145	0.661		
Intercept 2	0.353	0.627		
Sex (male = 1, female = 0)	−0.290	0.586	0.75 (0.24–2.36)	0.621
Age (years)	0.028	0.017	1.03 (1.00–1.06)	0.090

SE, standard error; OR, odds ratio; CI, confidence interval.

Discussion

The clinical decision between RME alone or SARME/Le Fort osteotomy to treat maxillary deficiency has traditionally been based in great part on the chronological age of the patient. However, this decision can be difficult for the clinician to make, as there is no consensus in the literature regarding the minimum age for surgical assistance for treating transverse maxillary problems. Some clinicians have recommended this type of surgical intervention in patients older than 14 years[14], 16 years[15], 20 years[16], or 25 years[17]. To add to the confusion, many case reports have shown that RME is possible in older adult patients[18–21].

As mentioned earlier, attempting to expand the maxilla without surgical assistance in older individuals can be frustrating; many problems have occurred when RME alone is used (e.g., significant pain, gingival recession and buccal tipping of the posterior teeth, palatal mucosal ulceration or necrosis[4–7], buccal root resorption[8,9], alveolar bone bending[10], fenestration of the buccal cortex[8], and instability of the expansion)[10–12]. On the other hand, the SARME/Le Fort osteotomy for maxillary expansion increases morbidity, treatment costs, and the number of days required for the patient to make a full recovery and to resume routine activities.

The individual evaluation of midpalatal suture maturation on CBCT scans has been proposed by Angelieri et al., in order to identify the morphology of the midpalatal suture prior to intervention with one of the two treatment options discussed previously for adolescent and young adult patients[25]. These researchers have reported great variability in the distribution of the maturational stages of midpalatal suture according to chronological age, with the fusion of the midpalatal suture in some female subjects older than 11 years and in some male subjects older than 14 years[25].

The present study evaluated midpalatal suture maturation as viewed in CBCT images in a sample of 78 adult subjects. Confirming clinical experience, the majority of the subjects presented with fusion of the midpalatal suture in the palatine or/and maxillary bones. Interestingly, in terms of the percentage in each age interval, the prevalence of stage D decreased with age, while stage E increased in prevalence with age (Fig. 1). Despite these results, chronological age was not a statistically significant predictor of the maturational stages of the midpalatal suture, indicating the need for the assessment of midpalatal suture maturation in CBCT scans in adults at any age before making the clinical decision between RME only or SARME/Le Fort osteotomy for maxillary expansion. Similarly, the maturation of the midpalatal suture was not influenced significantly by sex. Skeletal maturity is usually reached earlier in girls than in boys in the pubertal ages[30,31]. Nevertheless, males and females present similar bone density until 50 years old. After this age, the bone density in females starts to decrease[32,33]. There are no data regarding sexual dimorphism in the maturation of facial sutures in adulthood.

The relatively high prevalence of stage D in subjects younger than 30 years (31%) may explain the satisfactory results obtained by Alpern and Yurosko[18]. Capelozza Filho et al. also reported successful RME in over 80% of non-growing patients[19]. As RME was deemed successful by the creation of a maxillary interincisor diastema, many of those patients could have been at stage D, a stage that is characterized by fusion of the midpalatal suture only in the palatine bone.

It should be noted that in the studies mentioned above, most of the patients were younger than 25 years, with females older than 15 years[18] and males older than 17 years[19]. On the other hand, some of those adult patients who were treated successfully with RME could have presented with no fusion of the midpalatal suture[18,19]. According to the results of the present study, 12% of the total sample exhibited midpalatal suture maturational stages B and C, demonstrating interdigitation (stage B) or some bone bridges along the suture (stage C) (Fig. 1). These results corroborate those of histological studies in cadavers, in which no fusion of the midpalatal suture was observed in subjects of ages 27 years, 32 years[22], 54 years[23], and even 71 years[24].

The results of this study lead to the obvious question: if an adult patient presents with no fusion of the midpalatal suture on CBCT analysis, can RME be successful without a surgical assist? Previous studies have demonstrated that besides the midpalatal suture, other circummaxillary sutures such as the zygomaticomaxillary, zygomaticotemporal, and pterygopalatine sutures represent the primary anatomical resistance to SARME[17,34,35]. However, significant maxillary expansion has been observed in patients treated by means of SARME with or without pterygopalatine disjunction[36].

In a finite element analysis study, SARME with only separation of the midpalatal suture demonstrated the same results in terms of the quantity of maxillary expansion as SARME with separation of the pterygopalatine suture or Le Fort I corticotomy[37]. The authors suggested that after the separation of the midpalatal suture had occurred, low amounts of loading remained in the anatomical structures. The positive results verified in clinical studies on RME in adults may signify favorable responses[18,19]. However, future studies must be performed to clarify whether or not the circummaxillary sutures offer significant resistance to RME in the presence of a midpalatal suture that is not fused.

The findings of this study encourage the taking of CBCT images from adult patients in whom the adaptability of the midpalatal suture is in question to identify the maturational stage of the midpalatal suture. However, the imaging selection recommendations for the use of CBCT in transverse discrepancies have been described as possibly indicated at the pretreatment phase[38]. Thus, it is an essential clinical procedure to follow the guidelines of imaging proposed by the American Academy of Oral and Maxillofacial Radiology appropriately[38], according to the clinical condition and assessing the radiation dose risk.

Therefore, the individual evaluation of midpalatal suture maturation on CBCT images in adults may provide reliable parameters for the clinical decision between RME alone and surgical assistance for the treatment of maxillary deficiency. Fusion of the midpalatal suture in the palatine or maxillary bones was present in the majority of the adults, corroborating clinical experience. Nevertheless, the midpalatal suture was not fused in 12% of the adults. Identifying this subgroup of patients before treatment is the clinical challenge.

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Competing interests

We do not have any conflicts of interest.

Ethical approval

This study was approved by the Ethics Committee of Universidade Metodista de São Paulo (Methodist University of São Paulo); reference number 1.118.156. Ethical approval was obtained on 18 June

2015. The reference number of the General Ethics Commission site of the Brazilian Government is CAAE 45795715.0.0000.5508 (http://aplicacao.saude.gov.br/plataformabrasil/login.jsf).

Patient consent

Not required.

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