Original Article

Quantitative Evaluation of Midpalatal Suture Opening and Its Relation with Zygomaticomaxillary Suture Status in Patients Aged 7–25 Years Using Cone Beam Computed Tomography Images: In an Iranian Population

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Abstract

Objective: The purposes of this study were to determine the midpalatal suture (MPS) opening depth and to assess its relation with the zygomaticomaxillary suture (ZMS) by age with using cone beam computed tomography (CBCT). **Materials and Methods:** In this cross-sectional study, 167 CBCT scans of patients aged 7–25 years (mean age: 16.04 ± 5.17 years) were selected based on predefined criteria and categorized into four age groups. The mean percentages of the depth of MPS opening at anterior, middle, and posterior regions in the coronal and closure status of ZMS in axial views were determined by a maxillofacial radiologist. **Results:** The mean percentages of MPS opening depth at anterior, middle, and posterior regions were 98.20%, 89.27%, and 71.44%, respectively. In these regions, 20–25-year age group showed a significant difference compared with first- and second-age groups. A significant difference was observed in the frequencies of complete MPS opening in different age groups in the middle (P = 0.017) and posterior (P = 0.001) regions. About 80.20% patients had open ZMS bilaterally. The percentages of opening depth in the three regions were 97.8%, 91.8%, and 75.6%, respectively, when ZMS was open on both sides. **Conclusion:** Percentage of opening depth of this suture decreased by age. MPS closure starts from the posterior region. ZMS in younger people is usually open on both sides; however, it can be closed on one or both sides by age. An association was observed between bilateral closure or opening of ZMS and mean percentage of MPS opening in the middle and posterior regions.

Keywords: *Cone beam computed tomography, cranial suture, development, growth, maxilla, orthodontics*

Introduction

Constricted maxillary arch is a transverse maxillary deficiency that is common among orthodontic patients. Deep palate, posterior crossbite, crowding of the teeth, and difficulty in nasal breathing, as well as mandibular shift, are accompanied with this disturbance.[1] Patients' age and the pattern of the obliteration of midpalatal suture (MPS) have an important role on the selected type of treatment in this skeletal abnormality. Early maxillary expansion is promoted in children and very young adults having maxillary constriction.[2] Surgically assisted rapid maxillary expansion (SARME) is the treatment of choice to correct this deficiency in older adults. These treatments result in redirecting the developing teeth into more normal positions and eliminating untoward temporomandibular joint positions and mandibular closure patterns. Overall using the available opportunity during growth periods reduced treatment complexity and time.[3,4] After sutural closure, conventional orthopedic maxillary expansion is unsuccessful, and the expansion resulted in alveolar or dental tipping, with no significant basal skeletal changes. Thus, evaluation of MPS before treatment is very important, and the degree of obliteration of this suture determines the type of treatment. In orthodontics, the common method in the assessment of MPS, before and throughout RME, is using occlusal radiograph; however, this diagnostic method assesses the two-dimensional aspect of a three-dimensional structure.[5-7] Overall, conventional radiography seems to have limited value in the evaluation of facial sutures because of the complexity of

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the facial skeleton. Three-dimensional volumetric imaging, such as cone beam computed tomography (CBCT), allows the orthodontist to evaluate facial skeletal sutures three-dimensionally with minimal image distortion.[8,9] There are several studies on limited histological specimens of human MPSs;[10-12] however, they give no enough reliable documentation on the start of physiologic obliteration and on the advance of closure with age. We also found a limited study[13-15] on computed tomography examination of MPS closure. Angelieri *et al*. presented a new classification method for the evaluation of MPS maturation using CBCT.[14] Kwak *et al*. suggested that fractal analysis in CBCT could be a useful method in this evaluation.[15]

It seems that the other facial sutures, such as the zygomaticomaxillary, frontomaxillary sutures, and also spheno-occipital synchondrosis as well as MPS, are affected in the process of the RME,[16] Thus, the maturational stage and the amount of closure of the adjacent sutures to the MPS could be effective on the success rate of maxillary expansion.

Based on our current knowledge, there are limited CT studies on the MPS and its status by considering the critical age groups, particularly in an Iranian population. Thus, the purpose of this study was to evaluate quantitatively the status of MPS closure or opening depth in critical age groups using CBCT images of orthodontic patients in an Iranian population. Another aim of this study was to answer this question "is there any relation between the status of zygomaticomaxillary suture (ZMS) with the percentage of opening depth of MPS?" These may be the useful indices to use nonsurgical RME approach not only based on patient age but also CBCT findings of these sutures.

Materials and Methods

In this descriptive cross-sectional study, 167 CBCT scans of patients aged <25 years (mean age: 16.04 ± 5.17 years), including 90 females and 77 males, were selected from the archives of CBCT images of a maxillofacial radiology clinic located in the north part of Iran from 2015 to 2017. These patients had no syndrome or systemic problems. They were not cases of trauma. The CBCT images having motion artifact are not included in this study. Thus, the inclusion criteria were the age <25 years and the absence of systemic disease and syndrome. The exclusion criteria were the history of facial trauma and central bone lesion in maxilla and the presence of motion blurriness of CBCT images. An assigned code of Ethical Committee of Guilan University of Medical Sciences for this research was IR. GUMS. REC.1394.539. "All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Declaration of Helsinki". Informed consent was obtained from all patients for being included in the study. Selected patients were allocated into four age groups: <10 (30 cases), 10–15 (44 cases), 15–20 (52 cases), and 20–25 (41 cases) years. The CBCT images were taken by NewTom VG (QR Srl Company, Verona, Italy) by selecting a 4- or 9-inch field of view and "zoom" mode. Study images were reconstructed from volumetric images in such a way that the reconstructed plane was parallel to the palate. CBCT images depicting the dentoalveolar portion of maxilla to midportion of maxillary sinus were included in this study. Axial images having 0.5 mm thickness and distance was regenerated from selected volumetric data. A maxillofacial radiologist having >10 years of experience selected an axial view from maxillary axial series in which the MPS was clearly visible in the image. Then, on this selected axial view, coronal images having 1 mm thickness and 2 mm distance were reconstructed on a line in the direction of MPS from behind the nasopalatine foramen to the transverse palatal suture. The width of the generated coronal image was 100 mm. The coronal images were divided into three groups of anterior, middle, and posterior sections. Overall, three to four cuts in each section were evaluated [Figure 1]. The percentage of opening depth of the MPS in all cuts of every region was reported in such a way that the opening depth of MPS was divided to total visible depth of MPS (from palatal portion of oral side to base of nasal cavity) in each cut [Figure 2]. Mean percentages of three or four cuts in each section were calculated. Then, the mean percentage of opening of the MPS depth in each section was reported as the final opening percentage. The opening of suture was defined as the presence of radiolucent line or band between the right and left side of maxilla in the location of suture. In addition, upper axial cuts were evaluated to assess whether the right and left ZMSs are open or not [Figure 3]. The mean percentage of opening depth of the MPS in 20 samples was evaluated again by the same maxillofacial radiologist 2 weeks later. Intraobserver agreement was reported as 96.8%.

Statistical analysis

Data were entered in SPSS, version 21 (IBM Corporation, Armonk, NY, USA). Kolmogorov–Smirnov was used for the evaluation of normal distribution of data. To compare the mean percentage of opening depth of MPS in different age groups, Mann–Whitney U-test was used. Chi-square test was applied to compare the frequency of the opening

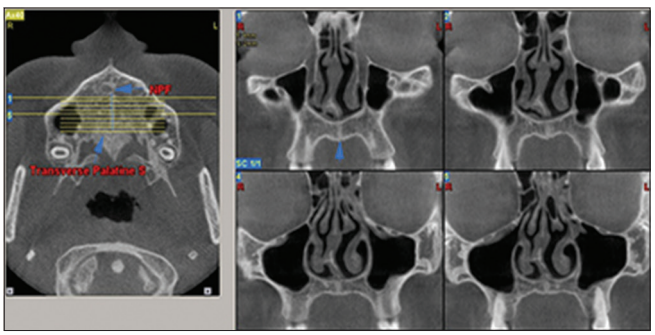

Figure 1: Reconstructed coronal views of maxilla for evaluation of midpalatal suture

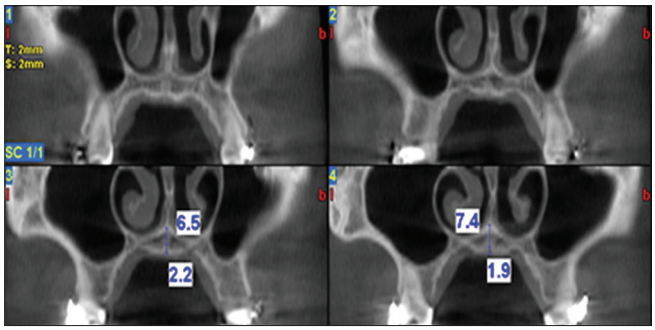

Figure 2: The measurement of opening depth of midpalatal suture and its total depth

of ZMS in different age groups. Finally, Kappa test was performed to determine the relation between the opening status of ZMS and the mean percentage of opening depth of MPS. The level of significance was ≤ 0.05.

Results

The mean percentages of opening of the MPS depth in anterior, posterior, and middle sections were 98.20 ± 13.29%, 89.27 ± 30.93%, and 71.44 ± 45.09%, respectively. These data from different age groups are shown in Table 1. There was a statistically significant association between the opening of MPS depth and the age groups in the middle ($P = 0.008$) and posterior ($P = 0.001$) sections of the suture. The percentage of suture opening decreased with increasing age and also from the anterior to the posterior region of MPS.

Table 2 shows that the results of pairwise comparisons of MPS opening depth in different age groups. Overall, a statistically significant difference was found between the 20- and 25-year age group and other age groups in the middle and posterior regions.

The frequencies of the complete opening of MPS are presented in Table 3. According to these data, there were significant differences between the age groups in the frequencies of complete MPS opening in the middle and posterior regions.

This study demonstrated that in 19.75% of the evaluated images, the ZMS was closed; in 5.98%, the ZMS was closed only in one side; and in 13.77%, it was closed on both sides. In addition, Table 4 demonstrates the frequencies of open and closed ZMS among different age groups. A significant difference was found in the opening of ZMS among the different age groups. Table 5 shows the relation between the mean percentage of MPS opening and closure of ZMS. We found an association between bilateral closure or opening of ZMS and the mean percentage of MPS opening in the middle and posterior regions of MPS.

Discussion

This study showed that a general decrease in the percentage of MPS opening depth in all three regions with age, which

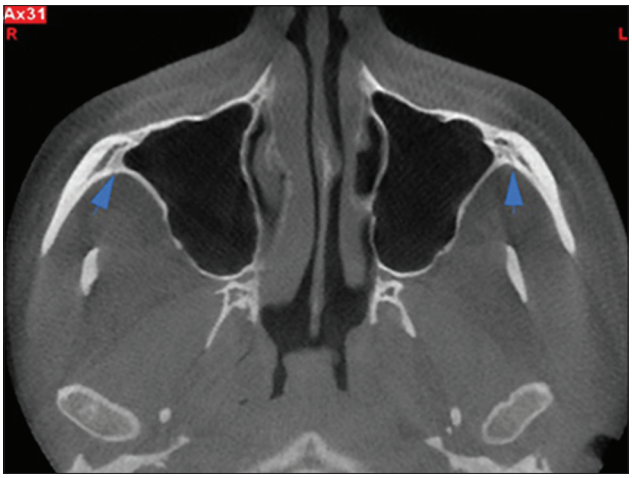

Figure 3: It reveals bilateral open zygomaticomaxillary sutures

Table 1: The mean percentage of midpalatal suture depth opening at anterior, middle, and posterior third regions of in different age groups

Locations	Age	*n*	SD±mean	*P**
Anterior 3rd of MPS	<10	30	100±0	0.31
	10-15	44	100±0	
	15-20	52	98.08±13.83	
	20-25	41	95.13±21.76	
Middle 3rd of MPS	<10	30	96.67±18.20	0.008
	10-15	44	95.48±20.91	
	15-20	52	90.44±29.60	
	20-25	41	75.73±43.26	
Posterior 3rd of MPS	<10	30	93.36±25.26	0.001
	10-15	44	79.86±40.18	
	15-20	52	65.56±47.78	
	20-25	41	53.83±50.20	

*Kruskal-Wallis. SD: Standard deviation; MPS: Midpalatal suture

was statistically significant between-age groups in the middle and posterior regions but not in the anterior region. This finding demonstrated that in the anterior region, the MPS depth of opening in all age groups was similar and actually up to 95%. In contrast, in the middle and posterior regions, there were significant differences among age groups. Persson and Thilander[11] in their histological study found the highest obliteration index in the posterior part of this suture. They showed slender bony bridges, which appear across the sutures and become more numerous with age. Rapid progress in the obliteration or the degree of suture closure occurred during the third decade. No significant difference in suture closure stages based on sex was found in their study.

The present study showed that the lowest amount of MPS depth opening was in the 20- to 25-year age group. Persson and Thilander[11] also reported a significant activity in the sutural closure in the 20–25-year age group. Knaup *et al*. in a histomorphological study demonstrated that early ossification of MPS occurred in a 21-year-old male. They

also reported a 54-year-old male as the oldest subject with no obliteration in the entire MPS. The obliteration index in the younger age group (≤25 years) was below 5%.[17]

RME is one of the suggested treatments to correct transverse maxillary deficiencies. It seems that using nonsurgical conventional RME in adults is rarely successful because the articulation of MPS begins to complete by late adolescence and becomes more rigid with age. Thus, SARME has been frequently used to release the closed sutures in adults. Furthermore, the cost and the surgical complications are the disadvantages of this method. Thus, patients' request for nonsurgical treatment has been increasing.[18,19] Miniscrew-assisted rapid palatal expansion (MARPE) as a nonsurgical technique could be considered an alternative method to correct transverse discrepancy and expand maxilla to increase upper arch length for crowding correction.[20,21] Thus, the results of this study confirmed that the evaluation of MPS based on CBCT finding is helpful to choose the best treatment planning.

Table 2: Pairwise comparisons of midpalatal suture opening depth in different age groups

Locations	Age (I)	Age groups (J)	Mean difference (I-J)	*P**
Anterior 3rd of MPS	<10 (1)	10-15 (2)	0.00	1, 2: 1.000
		15-20 (3)	1.92	1, 3: 0.529
		20-25 (4)	4.87	1, 4: 0.129
	10-15 (2)	15-20 (3)	1.92	2, 3: 0.489
		20-25 (4)	4.87	2, 4: 0.093
	15-20 (3)	20-25 (4)	2.95	3, 4: 0.289
Middle 3rd of MPS	<10 (1)	10-15 (2)	1.19	1, 2: 0.869
		15-20 (3)	6.24	1, 3: 0.368
		20-25 (4)	20.95	1, 4: 0.004
	10-15 (2)	15-20 (3)	5.05	2, 3: 0.415
		20-25 (4)	19.76	2, 4: 0.003
	15-20 (3)	20-25 (4)	14.71	3, 4: 0.021
Posterior 3rd of MPS	<10 (1)	10-15 (2)	30.50	1, 2: 0.190
		15-20 (3)	27.79	1, 3: 0.006
		20-25 (4)	39.53	1, 4: 0.001
	10-15 (2)	15-20 (3)	14.30	2, 3: 0.511
		20-25 (4)	26.03	2, 4: 0.005
	15-20 (3)	20-25 (4)	11.74	3, 4: 0.145

*Mann-Whitney U-test. MPS: Midpalatal suture

We found nonobliterated MPS in some of the patients in 20–25 age group. This finding is in agreement with Kwak *et al*.[15] in this idea that "age should not be the only factor used to determine whether SARME can be performed and that conventional RME may be possible in adults. Indeed, in some studies RME has been performed in adults." Thus, at least CBCT could be performed for patients that have a surgical approach in their treatment plan.

We detected the obliteration of MPS beginning from the nasal side in all CBCT images in contrast to other studies,[7,11] which have mentioned about more obliteration progress in the oral side of the suture than the nasal side.

The results of present study are in agreement with those of other studies[7,11] in that the intermaxillary suture begins to obliterate earlier in its posterior region than in its anterior region. It seems that factors other than skeletal maturity could significantly influence the variations in order of closure between different regions of the palatal suture.[22] N'Guyen *et al*.[13] mentioned that obliteration of MPS begins in the anterior as well as in the superior regions. The last part of the suture to be obliterated is the inferior part of the suture.

The "V-shaped" opening of MPS during RME[23] is compatible with the pattern of MPS closure that we found in CBCT images, and this indicates that the maxilla articulates superiorly and posteriorly with the rest of the midface.

It seems that the structural resistance of the middle face caused by ZMS and pterygomaxillary sutures could be an anatomical barrier that interferes with the transverse expansion of the maxilla in older patients and not just the irregularities and interdigitation that are present in the MPS.[7] This study showed that in participants aged ≤10 and 10–15 years, the ZMS was open on both sides in almost all images. The frequency of open ZMS was largely decreased in the 20–25-year age group. In other words, increasing age has the same effect on both ZMS and MPS closure.

However, the results of this study indicate that bilateral opening of ZMS has a relation with MPS opening. This implies that no closure of ZMS bilaterally could be a predictor for >90% opening of MPS depth in anterior and

Table 3: The frequencies of complete opening of midpalatal suture in different regions; anterior, middle, and posterior regions

Regions	Complete opening of MPS	<10, *n* (%)	10-15, *n* (%)	15-20, *n* (%)	20-25, *n* (%)	Total, *n* (3%)	*P**
Anterior 3rd of MPS	No	0	0	1 (1.9)	2 (4.9)	3 (1.8)	0.42
	Yes	30 (100.0)	44 (100.0)	51 (98.1)	39 (95.1)	164 (98.2)	
Middle 3rd of MPS	No	1 (3.3)	2 (4.5)	5 (9.6)	10 (24.4)	18 (10.8)	0.017
	Yes	29 (96.7)	42 (95.5)	47 (90.4)	31 (75.6)	149 (89.9)	
Posterior 3rd of MPS	No	2 (6.7)	9 (20.5)	18 (34.6)	19 (46.3)	48 (28.7)	0.001
	Yes	28 (93.3)	35 (79.5)	34 (65.4)	22 (53.7)	119 (71.3)	

*Chi-square test. MPS: Midpalatal suture

Table 4: The frequencies of open and closed zygomaticomaxillary sutures among different age groups

ZMS	Status	Age groups				*P**
		<10 (%)	10-15 (%)	15-20 (%)	20-25 (%)	
Right	Open	30 (100.0)	44 (100.0)	43 (82.7)	21 (51.2)	0.0001
	Close	0	0	9 (17.3)	20 (48.8)	
Left	Open	29 (96.7)	44 (100.0)	45 (86.5)	22 (53.7)	0.0001
	Close	1 (3.3)	0	7 (13.5)	19 (46.3)	
Total	Open	29 (96.7)	44 (100.0)	42 (80.8)	19 (46.3)	0.0001
	Close	1 (3.3)	0	10 (19.2)	22 (53.7)	

*$P \leq 0.05$ Chi-square test. ZMS: Zygomaticomaxillary suture

Table 5: The relation between the mean percentage of midpalatal suture opening and closure of zygomaticomaxillary suture

Status of ZMS in right and left side	Mean percentage of MPS depth opening		
	Anterior 3rd	Middle 3rd	Posterior 3rd
Open	97.8±14.8	91.8±27.4	75.6±42.9
Close	100±0	78.9±41.3	54.7±50.4
P	0.39	0.03	0.001

MPS: Midpalatal suture; ZMS: Zygomaticomaxillary suture

middle regions of the suture. Thus, the opening of ZMS contributes to lower orthopedic forces to expand MPS. This finding is in agreement with the study of Revelo and Fishman[24] that demonstrated maxillary skeletal articulation, particularly zygomatic buttress effects on closure of palatine bony segments.

However, radiation dose for the patient must be considered in the evaluation of MPS using CBCT. It appears not be a problem because the radiation dose and the small field of view of CBCT are comparable to a full mouth series of periapical radiographs.[25]

Conclusion

The percentage of MPS opening depth and also the frequency of ZMS opening decreased by age. In all age groups, the lowest percentage of MPS opening depth was observed in the posterior region of the palate. The middle portion of MPS is a good place for evaluating the effect of increasing age on the opening depth of MPS. After 20 years of age, the opening depth decreased to <90%. We found that bilateral opening of the ZMS has a positive relation with effective opening depth of MPS at the posterior and middle portions of MPS. Thus, CBCT evaluation for evaluation of MPS before surgical approach is suggested.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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