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Original Article

Relationship of the Fusion Stage of Spheno-Occipital Synchondrosis with Midpalatal and Zygomaticomaxillary Sutures on Cone-Beam Computed Tomography Scans of Patients Aged Between 7 and 21 Years

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Main Points
- The grades I-III of SOS predicts the higher percentage of MPS opening and the higher chance of opening of ZMS.
- With each one year increase in age, MPS opening percentage decreased by 1.07% in the anterior half and by 1.30% in the posterior half.
- There was a correlation between the fusion of SOS (cranial compartment) and ZMS (facial suture) in all age groups.

ABSTRACT

Objective: This study assessed the relationship of the fusion stage of spheno-occipital synchondrosis (SOS) with midpalatal (MPS) and zygomaticomaxillary (ZMS) sutures on cone-beam computed tomography (CBCT) scans of 7 to 21-year-old patients.

Methods: This cross-sectional study evaluated the CBCT scans of 176 patients between 7 and 21 years presenting to a maxillofacial radiology clinic. The fusion stage of SOS was determined using a five-stage classification system. The percentage of opening depth of MPS was measured on two middle coronal cuts in the anterior and posterior half of the palate. To assess ZMS, suture fusion was evaluated in four age groups in the axial cut visualizing its maximum length. Data were analyzed using the Kruskal-Wallis, Mann-Whitney U, and Bonferroni tests and regression models.

Results: The percentage of MPS opening significantly decreased in both the anterior and posterior halves with age ($p<0.002$). With an increase in SOS grade, the percentage of MPS opening in both the anterior and posterior halves significantly decreased ($p<0.001$). By an increase in the ZMS stage, the SOS grade significantly increased ($r=0.565$, $p<0.001$).

Conclusion: The MPS opening percentage in the anterior and posterior halves decreased with age, with a greater reduction in the posterior half. A significant inverse correlation exists between the SOS fusion stage and the percentage of MPS opening. In SOS grades I-III, the mean percentage of MPS opening was 100% in all age groups (with the highest frequency of ZMS stage I), indicating a higher chance of success for orthodontic treatments such as rapid maxillary expansion in these individuals.

Keywords: Sphenoid bone, occipital bone, cranial sutures, cone-beam computed tomography, orthodontics

INTRODUCTION

Synchondrosis refers to a cartilaginous joint between two bones. Spheno-occipital synchondrosis (SOS) is a longitudinal suture extending from the clivus to the pharyngeal surface of the cranial base, fusing the sphenoid and occipital bones.[1] Due to the effect of SOS on the elongation of the cranial base and the provision of space for dentoalveolar growth and development, SOS is an important area in growth and development of the craniofacial

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skeleton.[2,3] The development of SOS shifts the maxilla anteriorly and inferiorly, resulting in an increase in facial height and depth.[4-7] Cranial base growth's effect on the maxillomandibular complex makes it an interesting topic of research for orthodontists.[8] In patients with craniofacial syndrome, the initiation of ossification of SOS causes severe midface hypoplasia.[5] Some researchers believe that the cranial base serves as a guide for the development of the maxilla, midface, and inferior facial complex. Spheno-occipital synchondrosis is of particular interest among synchondroses because it can be observed on lateral skull radiographs taken during the adolescence period.[9] On the other hand, intersphenoid synchondrosis is ossified immediately after birth, whereas ethmoid synchondrosis is ossified at 7 years of age.[10] Due to the ossification of SOS at a relatively later stage in life compared with synchondroses of the skull base, SOS is commonly used for age estimation in forensic medicine.[11,12]

Age estimation is particularly important in orthodontics to determine the pubertal status of patients. Recently, SOS has attracted the attention of researchers as a beneficial index for age estimation alone or in combination with other skeletal age indices, especially for legal and forensic purposes.[8,13-17] It appears that the SOS fusion stages can serve as an efficient index for the assessment of development and puberty because the time of SOS fusion and cervical vertebral maturation stages are closely correlated. Thus, assessment of SOS fusion may help in orthodontic treatment planning and decision-making regarding surgical or nonsurgical treatment plans.[3,13] Clinically, orthodontic treatments such as rapid maxillary expansion (RME) affect the zygomaticomaxillary (ZMS) and frontomaxillary sutures as well as SOS. Thus, the level of the maturation and fusion of the sutures adjacent to the midpalatal suture (MPS) can affect the success rate of maxillary expansion.[18] A previous study on early treatment of Class III patients with RME and maxillary protraction indicated that a combination of these modalities increased the SOS width by 0.5 to 1 mm and yielded more favorable results. Therefore, it may be concluded that combined application of RME and maxillary protraction would have a higher success rate if performed before the complete fusion of the SOS.

Orthodontists can guide/modify facial growth and development to further benefit their patients. However, comprehensive knowledge about the normal growth pattern and the underlying mechanisms is required.[19] Precise knowledge about the fusion pattern of MPS and SOS at different ages can greatly help orthodontists and oral and maxillofacial surgeons in treatment planning and decision-making. Maxillary expansion procedures affect not only the MPS but also other sutures. Thus, the expansion status highly depends on the maturity status of other sutures such as the SOS. Also, SOS may serve as a suitable index for the estimation of skeletal age.[2] This study aimed to assess the relationship of the fusion stage of SOS with MPS and ZMS on cone-beam computed tomography (CBCT) scans of patients aged between 7 and 21 years.

METHODS

This cross-sectional study was conducted on 176 CBCT scans of patients aged between 7 and 21 years referred to an oral and maxillofacial radiology clinic in Rasht, Iran between 2019 and 2021. The study protocol was approved by the Ethics Committee of Gulian University of Medical Sciences (IR.GUMS.REC.1400.413). The minimum sample size was calculated as 50 in each group assuming four age groups with a mean midpalatal suture (MPS) score of 93.36 in the age group <10 years, 79.86 in those 10-15 years, 65.56 in those 15-20 years, and 53.83 in those between 20 and 25 years, study power of 0.95, error rate of 0.05, and standard deviation of 50.20 according to a previous study[20] using PASS 11. During this period (2019-2021), the number of eligible and available cases in the age range of 7 to 10 years was 26.

CBCT scans taken for purposes not related to this study, such as assessment of paranasal sinuses or the midface that visualized the maxilla, base of skull, and spheno-occipital region, were selected for this study. Images with motion artifacts, CBCT scans of patients with a mass or fracture at the aforementioned sites, and CBCT scans of patients with systemic diseases or syndromic conditions with significant effects on bone density or cortex of maxillofacial bones were excluded. After the selection of eligible CBCT scans of patients by convenience sampling, they were divided into four groups based on the age range of the patients as follows:

Group I: 7-10-years-old (n=26), Group II: 11-14-years-old (n=50), Group III: 15 to 17-years-old (n=50), and Group IV: 18 to 21-years-old (n=50).

All CBCT scans were obtained in full mode by a NewTom (SRL, Verona, Italy) CBCT scanner with patients in the standing position. The exposure settings were automatically adjusted by the scanner and software. Two oral and maxillofacial radiologists with over 10 years of clinical experience independently assessed the ossification pattern of SOS on reconstructed sagittal images with 1 mm slice thickness and 2 mm slice interval at the midline. The SOS and clivus area were clearly visible on the reconstructed sagittal images. In the case of disagreement between the two observers, the images were evaluated by an independent third radiologist. Also, 20 CBCT images were randomly selected and re-evaluated by the examiners after a 2-week interval to assess intraobserver reliability.

The fusion stages of SOS were classified using a 5-point classification scale introduced by Bassed et al.[13] (Figure 1A-E):

Stage I: The joint is completely open.

Stage II: The superior part of the joint is fused.

Stage III: Half of the joint length is fused.

Stage IV: The joint is completely fused and a scar line is evident.

Stage V: The joint is completely fused and there is no scarring.

To assess the MPS, axial images with a 1 mm slice thickness that visualized the MPS path properly were selected. A reconstruction line was drawn posterior to the nasopalatine foramen extending to the transverse palatine suture. Based on the predetermined area by reconstruction line in software, coronal images were reconstructed with 1 mm slice thickness and 2 mm slice interval with 100 mm image width. Next, the cuts were divided into two groups (anterior and posterior half), and the two middle cuts in each group were selected. In each cut, if the MPS depth was entirely open, the percentage of opening was reported as 100%, and if part of it was open, the entire suture height and the depth of the opening were measured to 0.1 mm accuracy, and then the value was reported as the percentage of opening in the respective cut by dividing the depth of suture opening to the entire suture height. Subsequently, the mean percentage of suture opening was calculated for each of the anterior and posterior halves based on the mean values of the two middle cuts (Figure 2).

The opening percentage of the MPS depth in all cuts was calculated using the following formula:

$$\frac{\textit{MPS opening depth}}{\textit{Visible entire MPS depth (from the palate to the base of nasal cavity)}}$$

To assess the ZMS, axial images with 1 mm slice thickness were evaluated. Among the axial cuts, the cut with the greatest length of the ZMS was evaluated and assigned to one of the following four groups (Figure 3A-D):

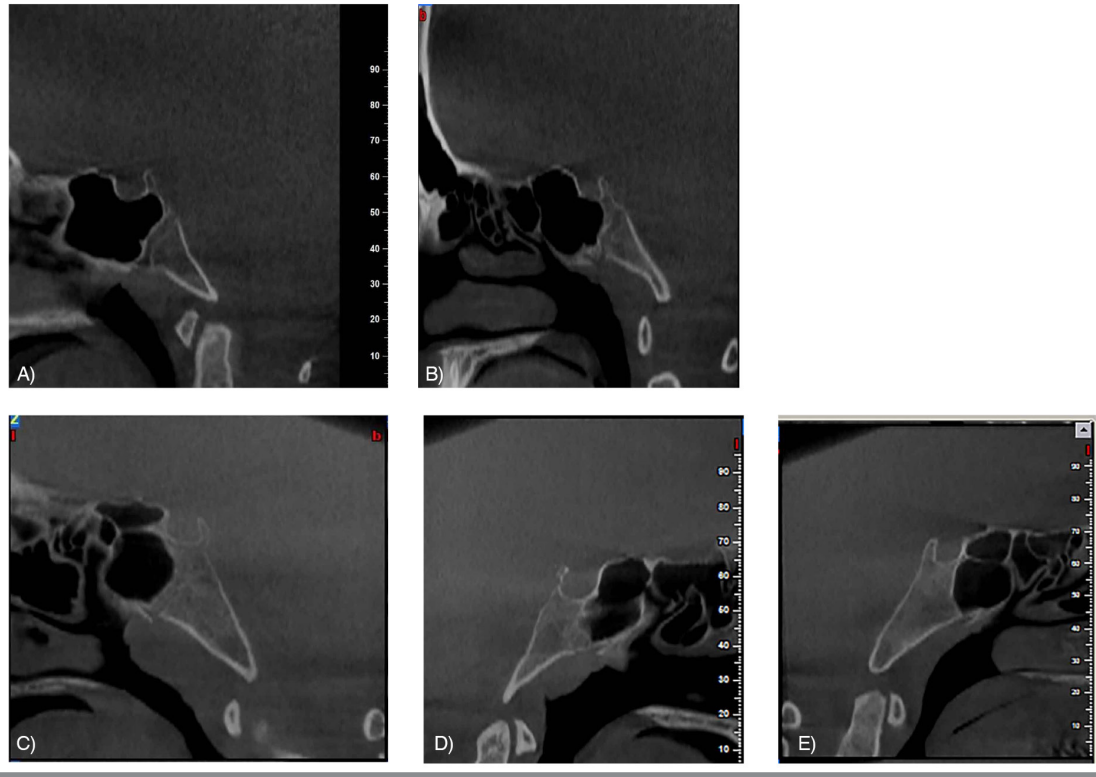

Figure 1. Fusion stages of SOS: A) Stage 1 (the joint is completely open); B) Stage 2 (superior part of the joint is fused); C) Stage III (half of the joint length is fused); D) Stage IV (the joint is completely fused and a scar line is evident), E) Stage V (the joint is completely fused and there is no scarring)

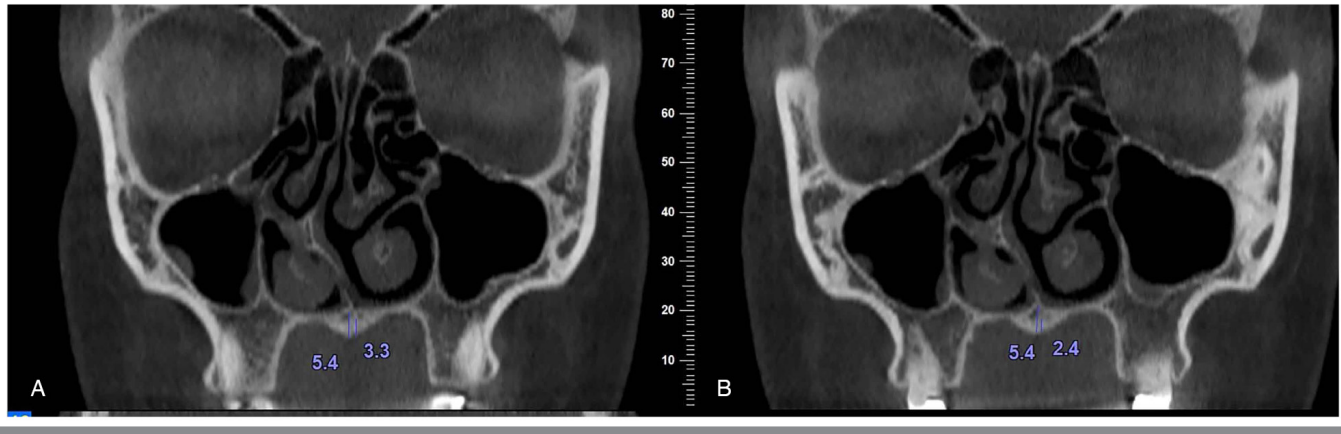

Figure 2. The measurement of the total height of MPS and opening portion in the coronal images of anterior MPS

I) The suture is completely open.

II) Over half of the suture length is open.

III) Less than half of the suture length is open.

IV) The suture is completely fused.

The percentage of the opening of MPS and the fusion stage of ZMS were determined by a postgraduate student (N.T.) of oral and maxillofacial radiology under the supervision of an oral and maxillofacial radiologist (Z.D.K.) irrespective of the observers (F.O. and N.K.H.) who evaluated the SOS.

Statistical Analysis

The normal distribution of data was evaluated using the Shapiro-Wilk test. The homogeneity of variances was analyzed using Levene's test. Accordingly, the Spearman correlation test, linear and ordinal regression models, Kruskal-Wallis test, Mann-Whitney U test, and Bonferroni adjustment were applied for statistical analysis of the data using SPSS version 26. The significance was set at ≤0.05.

RESULTS

CBCT scans of 81 males (46%) and 95 females (54%) were evaluated. Of all, 26 (14.8%) were between 7and10 years. Other age groups included 50 patients (28.4%) each. The mean age of all participants was 14.93±4.16 years. The intraobserver agreement for the evaluation of SOS was calculated as 92%.

Table 1 presents the mean percentage of MPS opening in the anterior and posterior halves in different age groups. The Kruskal-Wallis test showed that the mean percentage of MPS opening in the anterior and posterior halves significantly differed among the three age groups (p=0.005 and p=0.004, respectively). The mean percentage of MPS opening decreased in the anterior and posterior halves with age; the percentage of opening in the posterior half was lower than that in the anterior halves in all age groups. Pairwise comparisons of the age groups regarding the anterior half of MPS showed no significant difference in the percentage of opening between 11 and 14 and 15-17-years-old (p>0.999). However, the difference between 18 and 21 and 11-14-years-old (p=0.006) and 18-21 and 15-17-years-old (p=0.040) was statistically significant. Pairwise comparisons of the age groups regarding the percentage of opening of MPS in the posterior half showed a significant difference only between 18-21-year-olds and 11-14-year-olds (p=0.003). Other differences were not found significant (p>0.05).

Table 2 presents the frequency of different grades of SOS fusion in each age group. A significant difference was noted in frequency of all grades, except for grade III, among different age groups such that higher grades had a higher frequency in older age groups (p<0.05).

Table 3 presents the frequency of ZMS grades in different age groups. The frequency of ZMS grades I and III significantly differed in different age groups (p<0.05).

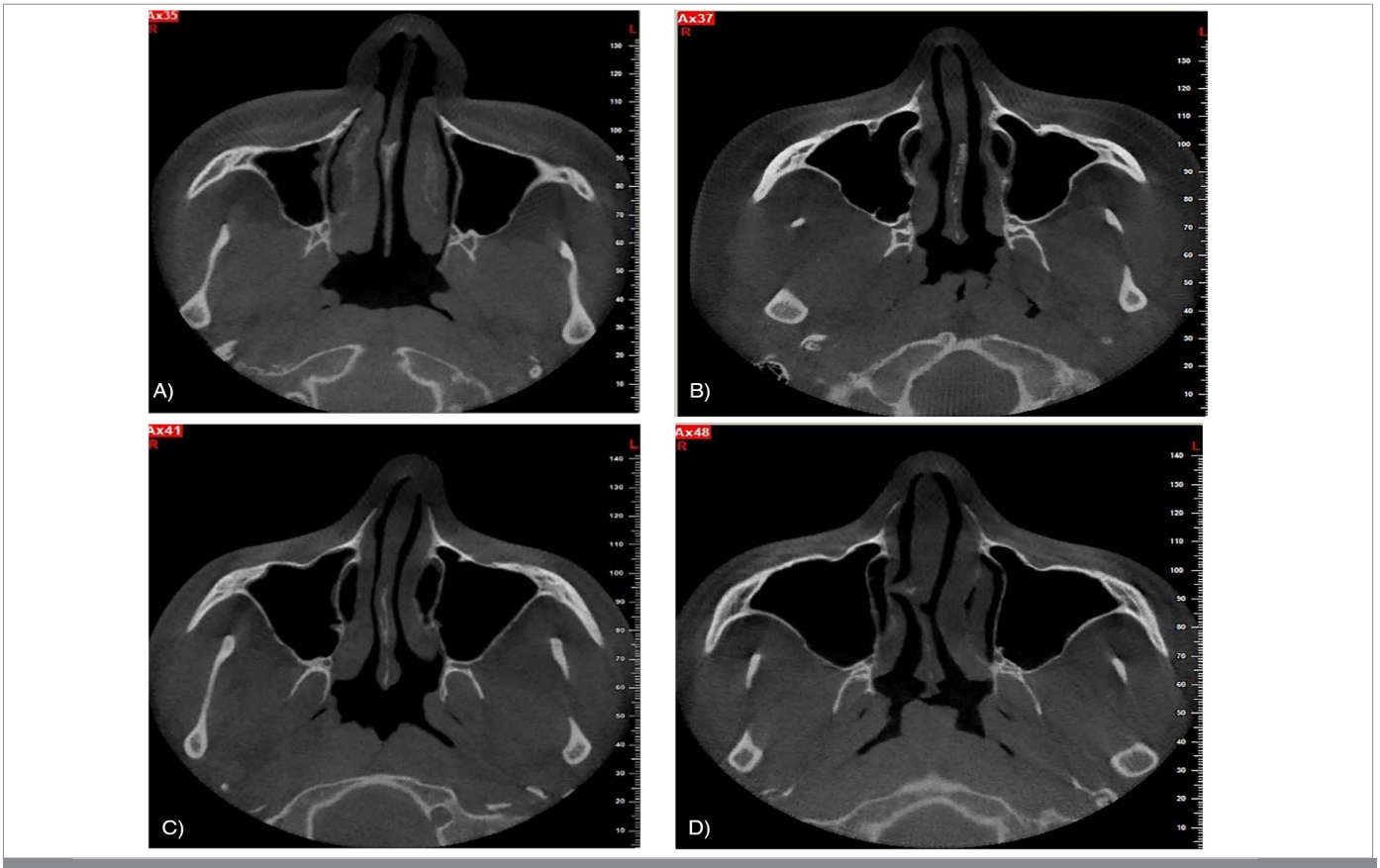

Figure 3. Fusion stages of ZMS: A) Stage 1 (suture is completely open); B) Stage II (over half of the suture length is open); C) Stage III (less than half of the suture length is open); D) Stage IV (suture is completely fused)

Table 1. Mean percentage of MPS opening in the anterior and posterior halves in different age groups

	Percentage of MPS** opening			p value*
Age groups	11-14	15-17	18-21	
	(n=50)	(n=50)	(n=50)	
Anterior half	98±9.90	96.08±13.60	87.88±22.29	0.005
Posterior half	95.42±16.66	91.12±20.88	74.34±22.37	0.004

*Kruskal-Wallis test; p≤0.05, **MPS: Mid Palatal suture.

Table 2. Frequency of different SOS fusion grades in each age group

SOS**	Age groups				p value*
	7-10	11-14	15-17	18-21	
	n (%)	n (%)	n (%)	n (%)	
1	26 (60)	14 (35)	2 (5)	0 (0)	<0.001
2	15 (5.6)	16 (88.9)	1 (5.6)	0 (0)	<0.001
3	0 (0)	7 (53.8)	5 (38.5)	1 (7.7)	0.116
4	0 (0)	5 (13.9)	18 (50)	13 (36.1)	0.028
5	1 (1.5)	6 (9.1)	23 (34.8)	36 (54.5)	<0.001

*Chi-square test; p≤0.05, **SOS: Spheno-Occipital Synchondrosis

Table 3. Frequency of ZMS grades in different age groups

ZMS** grade	Age group				p value*
	7-10	11-14	15-17	18-21	
	n (%)	n (%)	n (%)	n (%)	
1	26 (27.1)	39 (40.6)	21 (21.9)	10 (10.4)	<0.001
2	0 (0)	9 (20.5)	18 (40.9)	17 (38.6)	0.190
3	0 (0)	1 (3.4)	11 (37.9)	17 (58.6)	0.001
4	0 (0)	0 (0)	0 (0)	5 (100)	-

*Chi-square test; p≤0.05, **ZMS: Zygomaticomaxillary Suture

Table 4 presents the mean percentage of MPS openings in the anterior and posterior halves based on the SOS grade. As indicated, the mean percentage of MPS opening in the anterior and posterior halves was the same in SOS grades I, II, and III. In SOS grades IV and V, however, the mean percentage of MPS opening in the posterior half was lower than that in the anterior half.

Table 5 compares the frequency of SOS grade based on ZMS grade. As shown, only in SOS grade III the difference in the frequency of different ZMS grades was not significant (p=0.058).

The results also showed that, by an increase in SOS grade, the frequency of individuals with higher ZMS grades significantly increased (p<0.05).

SOS grade showed no significant correlation with the percentage of MPS opening in the anterior half in any age group (>0.05). Note that all 26 patients in the age group of 7-10 years had 100% MPS opening percentage in the anterior half. SOS grade had a significant inverse correlation with the MPS opening percentage in the posterior half in 11-14-year-olds (p=0.004), such that lower SOS grades showed a higher percentage of MPS opening in the posterior half (Table 6). In general, SOS grade had a significant inverse correlation with the MPS opening percentage in the posterior half, such that by an increase in SOS grade, the percentage of MPS opening decreased in the posterior half.

Table 4. Mean percentage of MPS opening in the anterior and posterior halves based on the SOS grade

SOS*	MPS**	
	Posterior half	Anterior half
	Mean ± SD	Mean ± SD
1	100±0	100±0
2	100±0	100±0
3	100±0	100±0
4	82.15±26.93	94.31±16.35
5	88.49±20.84	91±19.75

*SOS: Spheno-occipital Synchondrosis
** MPS: Mid Palatal Suture

Irrespective of age group, a significant inverse correlation was noted between SOS and MPS (r=-0.269, p<0.001 in the anterior half and r=-0.296, P<0.001 in the posterior half). Lower SOS grades showed a higher percentage of MPS opening (anterior and posterior halves).

Separate assessment of the correlation of SOS grade and MPS opening percentage (anterior and posterior halves) in males and

Table 5. Comparison of the frequency of SOS grade based on the ZMS grade

SOS** grade	ZMS*** grade				p value*
	1	2	3	4	
	n (%)	n (%)	n (%)	n (%)	
1	37 (94.9)	2 (5.1)	0 (0)	0 (0)	<0.001
2	17 (94.4)	1 (5.6)	0 (0)	0 (0)	<0.001
3	8 (61.5)	4 (30.8)	1 (7.7)	0 (0)	0.058
4	12 (34.3)	17 (48.6)	5 (14.3)	1 (2.9)	0.001
5	20 (30.3)	19 (28.8)	23 (34.8)	4 (6.1)	0.004

*Chi-square test; **SOS: Spheno-occipital Synchondrosis; ***ZMS: Zygomaticomaxillary Suture, p≤0.05

Table 6. Association of SOS grade with MPS fusion and ZMS grade

Associated of SOS* grade and			
Age groups	11-14	15-17	18-21
MPS** fusion in anterior half	r=-0.229	r=-0.255	r=0.074
	p=0.117	p=0.077	p=0.612
MPS fusion in posterior half	r=-0.408	r=-0.086	r=0.138
	p=0.004	p=0.558	p=0.338
ZMS*** fusion	r=0.300	r=0.251	r=0.149
	p=0.040	p=0.082	p=0.305

*SOS: Spheno-Occipital Synchondrosis; **MPS: Mid-Palatal Suture; ***ZMS: Zygomaticomaxillary Suture

females revealed a significant inverse correlation between these two variables in males (p=0.002 in the anterior half and p<0.001 in the posterior half), indicating a higher percentage of MPS opening in lower SOS grades in males.

Separate assessment of the correlation of SOS grade and ZMS fusion grade in different age groups revealed a direct significant correlation between the SOS grade and ZMS fusion grade only in 11-14-year-olds (p=0.040) such that by an increase in fusion grade of ZMS, the SOS grade also increased (Table 6). In general, ZMS had a direct significant correlation with SOS (r=0.565, p<0.001). A separate assessment of the correlation of SOS grade and ZMS fusion grade in males and females revealed that in both males and females, the correlation between the SOS and ZMS fusion grades was significant (p<0.001). In both males and females, by increasing the ZMS fusion grade, the SOS grade increased as well.

Assessment of the simultaneous effect of age and gender on MPS opening in the anterior and posterior halves revealed that age had a significant effect on MPS opening in the anterior and posterior halves; such that with each one-year increase in age, the MPS opening percentage decreased by 1.07% in the anterior half and by 1.30% in the posterior half. In both regression models, age was a more significant variable than gender with respect to changes in MPS opening percentage in the anterior and posterior halves. Age had a significant effect on both SOS and ZMS fusion grades. Each one-year increase in age increased the SOS grade (grade 1 to 2, 2 to 3, 3 to 4, and 4 to 5) by 0.56 and the ZMS grade (grade 1 to 2, 2 to 3, 3 to 4) by 0.47 units. At the same age, the SOS grade in males was an averagely -0.58 units lower than that in females. Also, at the same age, ZMS grade in males was averagely 0.46 units higher than that in females.

DISCUSSION

Preoperative assessment of the fusion of MPS and other craniofacial sutures involved in treatment is imperative for correct treatment planning and minimizing complications of expansion treatment. Thus, this study aimed to assess the relationship of the fusion pattern of SOS with MPS and ZMS on CBCT scans of 7 to 21-year-old patients.

Kajan et al.[18] assessed MPS maturation by CBCT to determine the percentage of MPS opening in different age groups before the transverse maxillary expansion. They observed that the percentage of MPS opening decreased with age, and the difference in this regard was significant among different age groups in the middle and posterior thirds; however, the difference was not significant in the anterior third. In the present study, the percentage of opening of MPS decreased with age, and this difference was significant among different age groups in both the anterior and posterior halves. In 7 to 10-year-olds, the MPS opening was 100%. It is worth noting that the definitions for the anterior and posterior halves in this study were different from those in the study by Kajan et al.[18] The definitions used in this study were set to enhance the clinical generalizability of the results.

There is a narrow bony bridge in the posterior part of the suture, which was ossified with age. Fast ossification and fusion of sutures occur in three decades of life. In the present study, the lowest percentage of MPS opening was recorded in both the anterior and posterior halves in the oldest age group in our study (18 to 21 years) and the lowest percentage of MPS opening was recorded in 20-25-year-olds (oldest age group) in the study by Kajan et al.[18]. In this study, the percentage of

MPS opening in the anterior and posterior halves was 100% in some patients between 18 and 21 years. This finding was in line with that of Kajan et al.[18] and Kwak et al.[21] Accordingly, Kwak et al.[21] discussed that age should not be considered as the only determining factor for surgically assisted RME because conventional RME may be performed in some adults. CBCT can greatly help in patients with a surgical treatment plan for maxillary expansion. An important finding of the present study was that after the age of 18 years, the percentage of MPS opening in the anterior half showed a significant difference with the value in younger individuals. This age threshold is important and should be considered in orthodontic treatment planning. In patients older than 14 years, the percentage of MPS opening in the posterior half was even lower than that in the anterior half in patients under 18 years of age. This finding indicates that fusion of the intermaxillary suture initiates sooner in the posterior half, and the V-shaped opening of MPS in the process of RME[22] agrees with the pattern of fusion of MPS observed in the present study.

On the other hand, due to the late fusion of SOS compared with other sutures and its role in increasing the facial height and depth, the grade of SOS fusion is an interesting topic of research.[11] Can et al.[1] assessed the chronological age based on SOS fusion by CT in 10 to 25-year-olds in a Turkish population. They used a classification similar to that used in this study and found a significant correlation between aging and the grade of SOS fusion. The maximum age for SOS fusion grade I was 13 years in females and 17 years in males, while the youngest age for grades IV and V was 15 years in females and 14 years in males. Dalili Kajan et al.[23] assessed SOS fusion in 9-22-year-olds by CT and found the maximum frequency of SOS fusion grade I in 9-11 and 13-year-olds, irrespective of gender. The maximum frequency of grade II was noted in 12 and 14-year-olds. The maximum frequency for grades III, IV and V was noted in 15, 16, and 17-22-year-old individuals. They also reported a significant correlation between age and SOS fusion grade in both males and females. In the present study, the maximum SOS fusion grade was grade I in 7-10-year-olds, grade II in 11-14, and grade 5 in 15-17, and 18-21-year-olds. In general, the increase in SOS grade with age had a stepwise pattern. Moreover, the number of individuals with a higher SOS grade increased in older age groups in the present study, and the difference in this respect was significant among different age groups for all grades except for grade III. Furthermore, the oldest age group with SOS grade I in the present study was 15-17-year-olds while the youngest age group with SOS grade V was 7-10-year-olds. This finding was different from the results of Can et al.[1] which may be because they assessed SOS in patients older than 10 years. Furthermore, factors such as sample size, population distribution, ethnicity, and socioeconomic status can affect SOS fusion. Different methodologies may also be responsible for variations in the results.

Loose sutures around the zygoma allow the maxilla to adequately respond to protrusive orthodontic forces in protraction with a face mask in developing patients.[24] Surgically assisted RME is used for maxillary expansion in adults, which is invasive and costly and is associated with postoperative complications;[25] however, application of orthodontic forces causes stress in the sutures surrounding the maxilla.[26] Growth modification of the maxilla depends on the degree of maturation of circummaxillary sutures and SOS.[26] ZMS is the longest and thickest circummaxillary suture that has the greatest resistance to orthopedic forces following RME and maxillary protrusion.[27] Significant opening of SOS in response to the MPS expansion has also been reported[4,28] suggesting its remodeling during RME. An interesting finding of the present study was the significant inverse correlation of SOS grade and MPS opening irrespective of age, and the direct correlation of SOS fusion and ZMS fusion, indicating a more appropriate response to RME in younger age groups; this correlation was significant in males. In the current study, the maximum frequency of SOS grades I-III in 7-10 and 11-14-year-olds indicated that application of orthopedic forces would be effective in these age groups, and those between 15 and 17 years are categorized as borderline group. The findings regarding ZMS and SOS fusion grades in 18-21-year-olds indicated a lower chance of obtaining a favorable response to orthopedic forces following RME in this age group, and this group is a better candidate for surgically assisted RME/LeFort osteotomy or miniscrew-assisted rapid palatal expansion.

Higher SOS grades were significantly correlated with a lower percentage of MPS openings in this study. Also, ZMS and SOS fusion were significantly correlated. Ok et al.[29] evaluated the correlation of SOS, MPS, and ZMS in 7 to 30-year-olds in Turkey. They used a qualitative index for MPS in the horizontal dimension, which has poor clinical application and does not indicate the precise depth of opening (to predict the degree of possible opening with RME). They reported that higher SOS grades were significantly correlated with the higher frequency of ZMS and MPS grades.

In the present study, age emerged as a more influential parameter than gender in ZMS, SOS, and MPS fusion status and had a significant correlation with them. For each one-year increase in age, MPS opening percentage decreased by 1.07% in the anterior half and by 1.30% in the posterior half. Additionally, each one-year increase in age increased the SOS grade by 0.56 and ZMS grade by 0.47 units. These findings are consistent with Dalili Kajan et al.[23] 's research, which also reported a significant effect of age on SOS.

CONCLUSION

The fusion of SOS and ZMS was significantly correlated with all age groups irrespective of gender. In SOS grades I-III, the mean percentage of MPS opening was 100% in all age groups (with the highest frequency of ZMS"1"), indicating a higher chance of success for orthodontic treatments such as RME and maxillary protraction in these individuals. Irrespective of age, SOS had a significant inverse correlation with MPS. Aging decreased the mean percentage of MPS opening; this reduction was greater in the posterior half.

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Sciences, Rasht, Iran) for his assistance in analyzing the statistical data.

Ethics

Ethics Committee Approval: The study protocol was approved by the Ethics Committee of Gulian University of Medical Sciences (IR.GUMS. REC.1400.413).

Informed Consent: Informed consent was obtained.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - Z.D.; Design - Z.D.; Data Collection and/or Processing - N.T.; Analysis and/or Interpretation - N.T., Z.D.; Writing - N.K.; Critical Review N.T., Z.D.

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