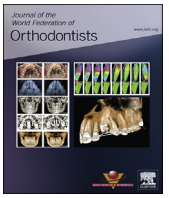
Journal of the World Federation of Orthodontists xxx (2020) 1–5

Contents lists available at ScienceDirect

Journal of the World Federation of Orthodontists

journal homepage: www.jwfo.org



Research

Correlation assessment of cervical vertebrae maturation stage and mid-palatal suture maturation in an Iranian population

Arezoo Mahdian [a], Yaser Safi [b], Kazem Dalaie [c], Shahab Kavoosinejad [d], Mohammad Behnaz [c,*]

[a] Assistant Professor, Orthodontic Research Center, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran
[b] Associate Professor, Oral and Maxillofacial Radiology Department, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[c] Assistant Professor, Department of Orthodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[d] Postgraduate Student, Department of Orthodontics, Tehran University of Medical Sciences, Tehran, Iran

ARTICLE INFO

Article history:
Received 26 February 2020
Received in revised form
12 May 2020
Accepted 13 May 2020
Available online xxx

Keywords:
Cervical vertebrae
Maxillary expansion
Mid-palatal suture
Skeletal age measurement

ABSTRACT

Aim: The aim of the current study was to evaluate the correlation of skeletal age based on cervical vertebrae maturation (CVM) stage and mid-palatal suture (MPS) maturation in an Iranian population.
Material and Methods: This was a cross-sectional analytic study. A total number of 93 samples were included. Samples were taken from patients who were in CS3 to CS6 stages of CVM who had cone-beam computed tomography and lateral cephalometry based on inclusion criteria. The maturation of MPS was assessed based on the cone-beam computed tomography images. In the classification of maturation of MPS, there are five stages (A–E) and the suture fusion occurs in stage D. In stage E, the suture is fused completely. The CVM stage (CS1–6) was also assessed based on the lateral cephalograms. Data were analyzed using Spearman correlation with a significance level of 0.05.
Results: A total of 51 female individuals with a mean age of 14.98 ± 4.806 and 42 male individuals with a mean age of 15.79 ± 5.135 participated in this study. The correlation coefficient between the CVM stage and MPS maturation was 0.691 in female and 0.754 in male individuals ($P < 0.001$). Stage D was correlated with CS4.
Conclusion: The results demonstrated that CVM stages had a significant but moderate positive correlation with the maturation of MPS. Until CS3, the MPS has not been fused and in CS6 the MPS is fused definitely.

1. Introduction

Rapid maxillary expansion is a routine orthopedic procedure to separate the mid-palatal suture (MPS) and is used to treat posterior crossbite and maxillary crowding [1,2]. It is of great importance to determine proper timing for palatal expansion, as its success is related to MPS fusion [3]. For assessing the possibility of orthodontic palatal expansion, most orthodontists use the patient's chronologic age. This indicator might not properly show the true maturational stage of the MPS. So the determination of MPS closure exclusively based on chronologic age is not a proper method [4,5]. Also, some clinicians use occlusal radiography to evaluate MPS maturation, but suture closure in occlusal radiograph does not necessarily indicate histological closure [6].

Recently, an innovative method was presented to categorize MPS maturation based on cone-beam computed tomography (CBCT) assessment. Based on this classification, the clinician can determine the prognosis of palatal expansion in young adults; however, this method costs additional expenses and radiation exposure to the patients [7].

As there are some variations among individuals concerning the timing, duration, and rate of growth, skeletal age is a more appropriate factor in orthodontics compared with chronological age [8]. Several methods have been described for the evaluation of the skeletal age including hand wrist radiography and cervical vertebral maturation (CVM) based on lateral cephalogram [9–11]. CVM provides a reliable clinical approach, as it is possible to assess through conventional lateral cephalograms without extra exposure and costs [11,12]. Based on a systematic review by Santiago et al.

Funding: The authors have not declared a specific grant for this research from any funding agency in the public, commercial, or not-for-profit sectors.
Competing interest: Authors have completed and submitted the ICMJE Form for Disclosure of potential conflicts of interest.
Provenance and peer review: Not commissioned; Externally peer reviewed.
* Corresponding author: Assistant Professor, Department of Orthodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
E-mail address: behnaz1357@yahoo.com (M. Behnaz).

2212-4438/$ – see front matter © 2020 World Federation of Orthodontists.
https://doi.org/10.1016/j.ejwf.2020.05.004

[13], using CVM for assessment of mandibular growth is a reliable and useful method.

Recently, some studies have used CVM to predict the MPS maturation stage in Brazil [14] and Korea [15]. The results of those studies revealed a strong positive correlation between CVM and MPS maturation stage. The current study was aimed to evaluate correlation of CVM stage and MPS maturation stage in an Iranian population.

2. Materials and methods

2.1. Patients

This prospective cross-sectional study was performed at the Orthodontics Department of Shahid Beheshti University of Medical Sciences from 2018 to 2019. The study protocol was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (Code: IR.sbmu.drc.rec.1397.070). Patients who were referred to the maxillofacial radiology department for taking both lateral cephalogram and CBCT were enrolled in the study. Due to ethical considerations, it was not possible to prescribe x-ray exposure for the patients and only those who needed imaging for diagnostic reasons, such as impacted teeth, asymmetry, or orthognathic surgery, were included. No patient was sent simply to be included in the study sample. The inclusion criteria were healthy patients who were in CS-3 to CS-6 stage of CVM and who had no cleft palate, craniofacial syndrome, or systemic diseases that could influence the growth or bone metabolism. Due to the possible effect on the morphology of suture, those who had a history of maxillary expansion or surgically assisted rapid palatal expansion (SARPE) during previous orthodontic treatment were excluded.

The sample size of 93 was calculated based on the study of Angelieri et al. [14] with $\alpha = 0.05$ and $\beta = 0.9$ and Spearman correlation coefficient of 0.75. Sampling was done sequentially and regardless of age, sex, their malocclusion pattern, and only based on being in the CS-3 to CS-6 of CVM stages. All CBCT images were taken using Planmeca ProMax 3D (Planmeca, Helsinki, Finland). Scans were captured by the following parameters: Kvp: 82, 12 mA, exposure time of 12 to 30 seconds, field of view of 8*8 cm, and 1-mm slice thickness. Reconstruction of images and assessment of CBCT images were done using Planmeca Romexis 2.3.1 software. Lateral cephalometric radiographs were taken using the Proline Planmeca (PM 2002 CC) and the exposure conditions were selected based on the size of the patients. CVM and MPS maturation stage for all patients were assessed by two trained evaluators separately and any disagreement was discussed with an experienced orthodontist.

2.2. Evaluation of CVM stage

CVM stage was determined on lateral cephalograms based on the previously described protocol [12]. This method includes 6 CVM stages (CS1–6) and the morphology of cervical vertebra indicates their maturation stage. At first, lateral cephalograms were skimmed and patients revealing CS3 to CS6 stages of CVM were included. Then, their radiographs were carefully reevaluated and the patient's maturation stage was identified with the utmost care.

In cases in which the examiner was hesitant to differentiate between the CVM stages, such as stages CS-2 and CS-3, three professional orthodontists evaluated the radiograph separately and the CVM stage was determined based on the majority of votes.

2.3. Evaluation of MPS maturation stage

The maturation of MPS was determined on cross-sectional CBCT images. According to Angelieri et al. [7], cross-sectional axial slice that was in the middle of the nasal and palatal surface in the superior-inferior dimension was used. The stage of MPS maturation was determined as described by Angelieri et al. [7] (Fig. 1). In their method, the MPS has five maturation stages (A–E). Although rapid palatal expansion is still possible in stage C, suture fusion in stage D and E obstruct rapid palatal expansion.

2.4. Statistical analysis

Spearman correlation coefficient was calculated to determine the correlation of CVM stage and the MPS maturation stage. Data were analyzed using SPSS v.22 computer software (SPSS, Chicago, IL) with a significance level of 0.05.

3. Results

Among the 93 patients who were enrolled in the study, there were 51 female patients with a mean age of 14.98 ± 4.806 and 42 male patients with a mean age of 15.79 ± 5.135 CVM. The age range for female and male patients was between 9 and 30 and 11 and 28, respectively. The distribution of patients based on CVM stage is demonstrated in Table 1.

Table 2 shows the distribution of the patients based on the MPS maturation stage, age, and gender. No case of suture fusion (stages D and E) was documented before the age of 12 in female patients and before the age of 13 in male patients. However, both stages B and C were observed until 21 years old in male patients.

The distribution of the patients based on MPS maturation and CVM stage is demonstrated in Table 3. Statistical analysis showed the Spearman correlation coefficient between the CVM stage and the MPS maturational stage was positive but moderate ($r = 0.691$ in female patients and $r = 0.754$ in male patients) ($P < 0.001$). Stages D and E, which show suture fusion, were not observed before CVM stage 4 (CS4).

The Spearman correlation coefficient between age and MPS maturational stage was positive but relatively week ($r = 0.543$ in female and $r = 0.594$ in male patients) ($P < 0.001$).

The weighted kappa coefficients for the evaluation of the intra- and inter-examiner reproducibility for the MPS maturation stage were 0.89 and 0.90, and for CVM evaluation were 0.93 and 0.88, respectively, demonstrating almost perfect agreement according to the scale of Landis and Koch [16].

4. Discussion

This study was performed to evaluate the correlation between MPS maturation and CVM stage in an Iranian population. The results demonstrated a positive moderate correlation.

Maxillary constriction can be treated with slow orthodontic expansion and rapid maxillary expansion, which can be performed until the MPS is open. SARPE or two-segmented LeFort I-type osteotomies are indicated in patients with mature MPS [17]. Some authors recommended that orthopedic expansion is not effective for patients older than 14 years [7] or 15 years [18], and surgical treatment should be considered for them. However, SARPE was recommended only for male patients older than 25 years and female patients older than 20 years in another study [19]. So there is currently no clinical guideline for timing of palatal expansion [15].

A precise method for evaluation of MPS could prevent the wrong diagnosis regarding treatment plan for maxillary expansion. Evaluation of MPS presented by Angelieri et al. [7,20] is a valuable method. It has been shown that this method has good reliability [14,21]; however, to improve clinician skills in the proper use of this method, a relatively long training time is necessary [21].

Please cite this article in press as: Mahdian A, et al., Correlation assessment of cervical vertebrae maturation stage and mid-palatal suture maturation in an Iranian population, Journal of the World Federation of Orthodontists (2020), https://doi.org/10.1016/j.ejwf.2020.05.004

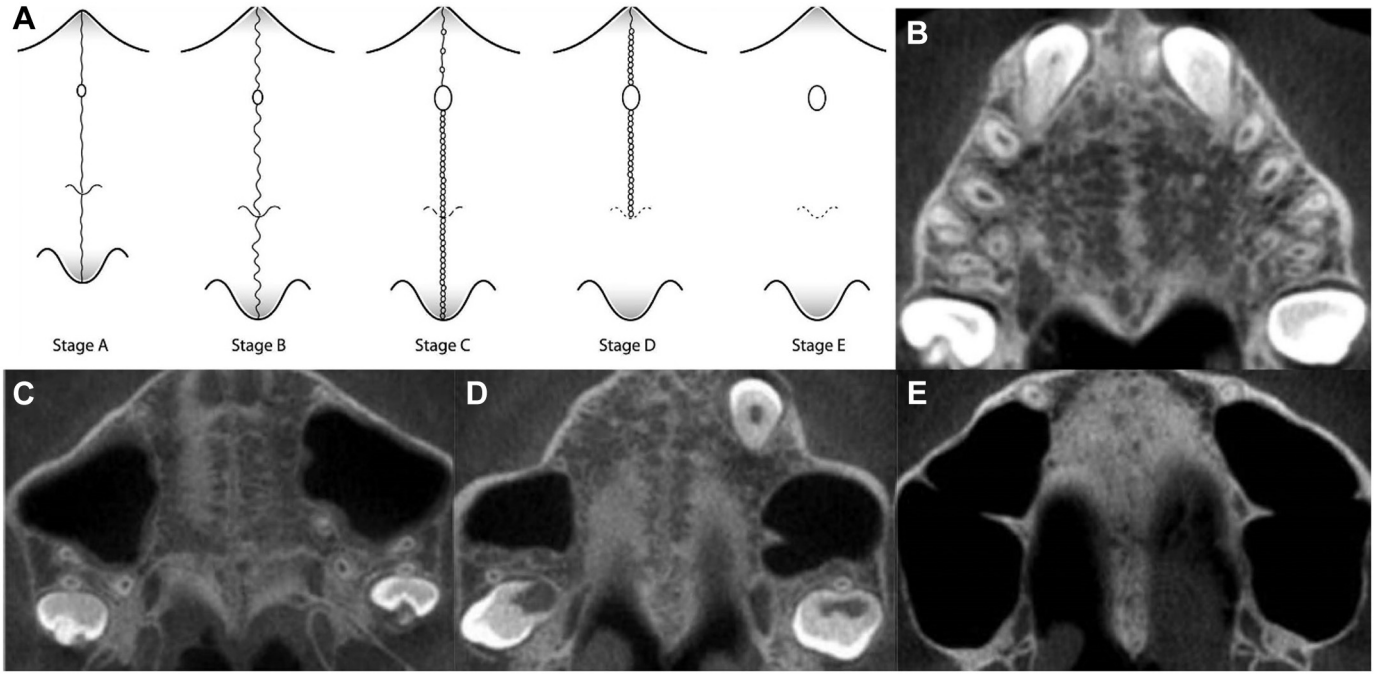


Fig. 1. A - Stage (A) Schematic image of the maturational stages of mid-palatal suture (7). B- Stage (B) one scalloped, high-density line at the midline. C- Stage (C) Two parallel, scalloped, high-density lines. D- Stage (D) The suture is fused in palatine bone. E- Stage (E) The suture is completely fused. (Figure 1A - reprinted with permission from Elsevier.)

It seems that the fusion of MPS is related to skeletal age [22]. In the current study, the correlation between CVM and MPS maturation stage was positive but moderate (r = 0.691 in female and r = 0.754 in male patients). However, in previous studies by Angelieri et al. in Brazil [14] and by Jang et al. in Korea [15] there was a strong correlation between two staging methods (r = 0.908 and 0.874, respectively). The difference might be not only due to the racial difference but also due to the sample size; however, these two reasons alone cannot justify this large difference. The more important reason could be the differences in the inclusion criteria. In previous studies, all patients in CS1 to CS6 stages of CVM were included, whereas we excluded the CS1 and CS2 stages. Because most patients who were in these two CVM stages showed the A and B stages of MPS maturation, which might have resulted in the higher correlation coefficient observed in previous studies.

A noteworthy finding was that in our study no case of suture fusion (stage D and E) was found before CS4. Similarly, previous studies reported that suture fusion starts from CS4 [14,15]. Therefore, nonsurgical palatal expansion could be done before this stage. In addition, the study of Kwak et al. [21] in Korea on adult patients with CS5 and CS6 showed that suture fusion did not occur in all cases. The MPS was not fused in 61.9% and 38.2% of samples in CS5 and CS6, respectively [21]. In our study also, the fusion of MPS was not complete in 27% of male patients in CS5. However, all female

Table 1
Distribution of samples based on cervical vertebrae maturation (CVM) stage

CVM stage	Female		Male	
	Frequency	Percent	Frequency	Percent
3	12	23.52	15	35.71
4	16	31.37	9	21.42
5	12	23.52	11	26.19
6	11	21.56	7	16.66
Total	51	100	42	100.0

Table 2
Distribution of the samples based on MPS maturation, age, and gender

Gender	MPS maturation				Total
	B	C	D	E	
Female					
Age					
10	0	2	0	0	2
11	0	8	0	0	8
12	0	5	3	2	10
13	1	3	4	3	11
14	0	0	2	2	4
16	0	0	1	2	3
18	0	0	1	2	3
19	0	0	1	0	1
20	0	0	0	1	1
21	0	0	0	1	1
23	0	0	1	0	1
24	0	0	1	2	3
25	0	0	1	1	2
30	0	0	0	1	1
Total	1	18	15	17	51
Percent	1.90	35.29	29.41	33.33	100
Male					
Age					
9	2	0	0	0	2
11	2	2	0	0	4
12	0	4	0	0	4
13	0	4	3	0	7
14	0	2	2	0	4
15	0	2	3	4	9
17	0	2	0	1	3
19	0	1	0	0	1
21	0	1	0	0	1
23	0	0	2	0	2
24	0	0	0	1	1
26	0	0	0	1	1
27	0	0	0	1	1
28	0	0	1	0	1
29	0	0	0	1	1
Total	4	18	11	9	42
Percent	9.52	42.85	26.19	21.42	100

Please cite this article in press as: Mahdian A, et al., Correlation assessment of cervical vertebrae maturation stage and mid-palatal suture maturation in an Iranian population, Journal of the World Federation of Orthodontists (2020), https://doi.org/10.1016/j.ejwf.2020.05.004

Table 3
Correlation of cervical vertebrae maturation (CVM) stage and mid-palatal suture maturation stage

Gender	Mid-palatal suture maturation			
	B	C	D	E
Female				
CVM stage				
CS3				
Frequency	1	11	0	0
% within CVM	8.33	91.66	00.0	00.0
CS4				
Frequency	0	7	4	5
% within CVM	0.0	43.75	25.0	31.25
CS5				
Frequency	0	0	6	6
% within CVM	0.0	0.0	50.0	50.0
CS6				
Frequency	0	0	5	6
% within CVM	0.0	0.0	45.45	54.54
Total				
Frequency	1	18	15	17
% within CVM	1.96%	35.29	29.41	33.33
Male				
CVM stage				
CS3				
Frequency	4	11	0	0
% within CVM	26.66	73.33	0.0	0.0
CS4				
Frequency	0	4	3	2
% within CVM	0.0	44.44	33.33	22.22
CS5				
Frequency	0	3	5	3
% within CVM	0.0	27.27	45.45	27.27
CS6				
Frequency	0	0	3	4
% within CVM	0.0	0.0	42.85	57.15
Total				
Frequency	4	18	11	9
% within CVM	9.52	42.85	26.19	21.42

patients in CS5 and all patients in CS6 showed suture fusion. So, nearly a quarter of men in CS5 have the opportunity to receive orthopedic treatment and avoid surgery, whereas at this point none of the women have this chance. CBCT images should be assessed to find these men. All men and women in the CS6 will probably have to undergo surgical treatment.

Regarding patients' age, the results of our study showed that suture fusion starts from the age of 12 in female individuals and 13 in male individuals. Similarly, Jang et al. [15], reported that the suture fusion started from the age of 11. However, in the study by Angelieri et al. [14], suture fusion was observed in patients of 14 to 18 years old. Stage B was observed in female and male individuals until the age of 13 and 11 respectively, while 4.3 % of patients between the ages of 21 and 25 also exhibited the same [23]. Stage E was detected in girls at age 12 and in boys at age 15 in the present study. Similarly, in Jimenez-Valdivia et al. [23], reported that this stage was found in 9.7% of girls and 5.9% of boys between the ages of 10 to 15. Nevertheless, none of the patients in the 10 to 19 and 20 to 29 age group revealed this stage in another study [24].

Considering the results of our study, there is a moderate correlation between CVM and MPS maturation stages. This indicates that the MPS maturation stages could not be determined entirely and reliably on the basis of the CVM stages. However, it was demonstrated that before CS4, the suture has not been fused and palatal expansion could be done without surgery. In addition, the clinicians should consider that the MPS is not the only determinant for the possibility of nonsurgical expansion, and other sutures, such as the zygomaticotemporal, zygomaticofrontal, and zygomaticomaxillary, might also play a role in the treatment effects[25,26].

5. Conclusion

The results of the present study in an Iranian population, aimed at correlating CVM and MPS maturation stages could observe that:

1. The correlation between the CVM stage and the MPS maturation stage was positive but moderate ($r = 0.691$ in female and $r = 0.754$ in male individuals).
2. MPS fusion does not occur in girls younger than 12 years and boys younger than 13 years.
3. MPS fusion can be expected to occur from CS4. Fusion would be expected to be complete by CVM stage 5 in female individuals, but may not actually commence until CVM stage 5 in some male individuals.

Acknowledgments

The present study was based on a research plan in the form of a thesis for the postgraduate degree in orthodontics in the School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Author contributions: All authors contributed to this project and article equally. All authors read and approved the final manuscript.

References

[1] McNamara JA. Long-term adaptations to changes in the transverse dimension in children and adolescents: an overview. Am J Orthod Dentofacial Orthop 2006;129:S71–4.
[2] McNamaraa JA. Maxillary transverse deficiency. Am J Orthod Dentofacial Orthop 2000;117:567–70.
[3] Dhiman S, Maheshwari S, Verma SK. Assessment of maturity in orthodontics: a review. J Adv Clin Res Insights 2015;2:101–10.
[4] Melsen B. Palatal growth studied on human autopsy material. A histologic microradiographic study. Am J Orthod 1975;68:42–54.
[5] Wong RW, Alkhal HA, Rabie AB. Use of cervical vertebral maturation to determine skeletal age. Am J Orthod Dentofacial Orthop 2009;136:484.e1–6. discussion 5.
[6] Wehrbein H, Yildizhan F. The mid-palatal suture in young adults. A radiological-histological investigation. Eur J Orthod 2001;23:105–14.
[7] Angelieri F, Cevidanes LH, Franchi L, Goncalves JR, Benavides E, McNamara Jr JA. Midpalatal suture maturation: classification method for individual assessment before rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2013;144:759–69.
[8] Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dentofacial Orthop 1995;107:58–66.
[9] Franchi L, Baccetti T, McNamara Jr JA. Mandibular growth as related to cervical vertebral maturation and body height. Am J Orthod Dentofacial Orthop 2000;118:335–40.
[10] Baccetti T, Franchi L, McNamara Jr JA. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. Angle Orthod 2002;72:316–23.
[11] Lione R, Franchi L, Fanucci E, Lagana G, Cozza P. Three-dimensional densitometric analysis of maxillary sutural changes induced by rapid maxillary expansion. Dentomaxillofac Radiol 2013;42:71798010.
[12] Baccetti T, Franchi L, McNamara JA. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Semin Orthod 2005;11:119–29.
[13] Santiago RC, de Miranda Costa LF, Vitral RW, Fraga MR, Bolognese AM, Maia LC. Cervical vertebral maturation as a biologic indicator of skeletal maturity. Angle Orthod 2012;82:1123–31.
[14] Angelieri F, Franchi L, Cevidanes LH, McNamara Jr JA. Diagnostic performance of skeletal maturity for the assessment of midpalatal suture maturation. Am J Orthod Dentofacial Orthop 2015;148:1010–6.
[15] Jang HI, Kim SC, Chae JM, et al. Relationship between maturation indices and morphology of the midpalatal suture obtained using cone-beam computed tomography images. Korean J Orthod 2016;46:345–55.
[16] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
[17] Agostino P, Ugolini A, Signori A, Silvestrini-Biavati A, Harrison JE, Riley P. Orthodontic treatment for posterior crossbites. Cochrane Database Syst Rev 2014;8:CD000979.
[18] Bjork A, Skieller V. Growth of the maxilla in three dimensions as revealed radiographically by the implant method. Br J Orthod 1977;4:53–64.
[19] Capelozza Filho L, Cardoso Neto J, da Silva Filho OG, Ursi WJ. Non-surgically assisted rapid maxillary expansion in adults. Int J Adult Orthodon Orthognath Surg 1996;11:57–66.

Please cite this article in press as: Mahdian A, et al., Correlation assessment of cervical vertebrae maturation stage and mid-palatal suture maturation in an Iranian population, Journal of the World Federation of Orthodontists (2020), https://doi.org/10.1016/j.ejwf.2020.05.004

[20] Angelieri F, Franchi L, Cevidanes LH, Bueno-Silva B, McNamara Jr JA. Prediction of rapid maxillary expansion by assessing the maturation of the midpalatal suture on cone beam CT. Dental Press J Orthod 2016;21:115–25.
[21] Kwak KH, Kim SS, Kim YI, Kim YD. Quantitative evaluation of mid-palatal suture maturation via fractal analysis. Korean J Orthod 2016;46:323–30.
[22] Korbmacher H, Schilling A, Puschel K, Amling M, Kahl-Nieke B. Age-dependent three-dimensional microcomputed tomography analysis of the human mid-palatal suture. J Orofac Orthop 2007;68:364–76.
[23] Jimenez-Valdivia LM, Malpartida-Carrillo V, Rodríguez-Cárdenas YA, Dias-Da Silveira HL, Arriola-Guillén LE. Midpalatal suture maturation stage assessment in adolescents and young adults using cone-beam computed tomography. Prog Orthod 2019;20:38.
[24] Haghanifar S, Mahmoudi S, Foroughi R, Mir APB, Mesgarani A, Bijani A. Assessment of midpalatal suture ossification using cone-beam computed tomography. Electron Physician 2017;9:4035.
[25] Ghoneima A, Abdel-Fattah E, Hartsfield J, El-Bedwehi A, Kamel A, Kula K. Effects of rapid maxillary expansion on the cranial and circummaxillary sutures. Am J Orthod Dentofacial Orthop 2011;140:510–9.
[26] Magnusson A, Bjerklin K, Nilsson P, Jönsson F, Marcusson A. Nasal cavity size, airway resistance, and subjective sensation after surgically assisted rapid maxillary expansion: a prospective longitudinal study. Am J Orthod Dentofacial Orthop 2011;140:641–51.

Please cite this article in press as: Mahdian A, et al., Correlation assessment of cervical vertebrae maturation stage and mid-palatal suture maturation in an Iranian population, Journal of the World Federation of Orthodontists (2020), https://doi.org/10.1016/j.ejwf.2020.05.004