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ORIGINAL ARTICLE

Correlation between spheno-occipital synchondrosis, dental age, chronological age and cervical vertebrae maturation in Turkish population: is there a link?

Husniye Demirturk Kocasarac[a], Ayse Burcu Altan[b], Canan Yerlikaya[c], Alper Sinanoglu[d] and Marcel Noujeim[a]

[a]Department of Comprehensive Dentistry, The University of Texas Health Science Center San Antonio, TX, USA; [b]Department of Orthodontics, Faculty of Dentistry, Kocaeli University, Kocaeli, Turkey; [c]Department of Orthodontics, Faculty of Dentistry, Ondokuz Mayis University, Samsun, Turkey; [d]Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Kocaeli University, Kocaeli, Turkey

ABSTRACT

Objective: To assess the correlation between third molar mineralization (TMM), spheno-occipital synchondrosis (SOS) fusion, chronologic age and cervical vertebrae maturation (CVM) for skeletal maturation.

Materials and methods: Radiographs for 116 patients between 8 and 28 years were evaluated for age determination using mandibular TMM, SOS fusion and CVM. Spearman Correlation and Kappa test analyses were used to assess the relationship between variables and for intraobserver reliability.

Results: Strong correlation was found between chronological age and TMM for males ($r = .802$) and females ($r = .842$), very strong correlation was found between age and CVM for males ($r = .812$) and moderate for females ($r = .449$), it was strong between age and SOS fusion for males ($r = .810$) and females ($r = .643$). Correlation between TMM and SOS was found to be strong for males ($r = .759$) and moderate for females ($r = .534$), it was strong between TMM and CVM for males ($r = .723$) and weak for females ($r = .371$). Very strong correlation was found between CVM and SOS fusion for males ($r = .851$) and strong correlation for females ($r = .618$).

Conclusion: Good correlation was found between the degrees of TMM, fusion of SOS and CVM in young Turkish population.

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Spheno-occipital synchondrosis; third molar mineralization; orthodontic treatment; skeletal age

Introduction

Proper timing is an essential part of treatment planning in orthodontics, with special regard to dentofacial orthopedics.[1] Optimal timing is linked intimately to the determination of maturation and subsequent evaluation of growth potential that can contribute considerably to the correction of skeletal imbalances.[2–4] Estimating total remaining growth after orthodontic treatment might be important in predicting posttreatment rebound too. Almost all individuals show same skeletal growth patterns, but timing, duration, speed and amount of growth vary considerably.[4,5]

Because of wide individual variation in the timing of the pubertal growth spurt(s), chronological age is not a reliable indicator of skeletal maturation.[2,6] Some other parameters such as hand and wrist maturation,[2,7] cervical vertebral maturation (CVM) [2,3,8] and dental maturation [1,4] have been proposed to determine skeletal maturation stage and rate. Hand-wrist radiography has been used as the method of choice for the assessment of skeletal maturation for a long time but recently, the routine use of hand-wrist radiography has been questioned from an extra-radiation exposure point of view.[2]

The current interest in orthodontic treatment with no extraction including modification of skeletal growth appears to require as much information as possible about a patient's growth potential.[3] To eliminate extra radiation exposure, CVM in the lateral cephalometric radiographs was evaluated for its correlation to the skeletal maturity and found to be a reliable alternative to the hand-wrist radiograph.[2,3,8] Since the lateral cephalometric radiograph is routinely required for orthodontic diagnosis and treatment planning, no extra radiograph is required to assess CVM.[8] But sometimes it may not be possible to determine the exact maturity stage in borderline cases. Thus using some other parameters, like third molar mineralization stage or spheno-occipital synchondrosis fusion degree, when the images are available, will facilitate the clinician's task.

Dental maturity, often expressed as dental age, is also an indicator of the skeletal maturity.[4] Dental age can be assessed by dental development or tooth mineralization observed in radiographs. Başaran et al. [4] showed the applicability of dental maturation stages as a reliable indicator of facial growth. Similarly, Uysal et al. [3] conducted a study in a Turkish population and found a high correlation between chronologic age and skeletal maturation assessed by the cervical vertebrae and the hand-wrist methods, with correlation coefficients ranging from 0.72 to 0.79, $p < .001$, respectively. But when the individual reaches the age of 15, dental development is almost completed, except third molars. Therefore,

CONTACT Husniye Demirturk Kocasarac, DDS, PhD husniyedemirturk@gmail.com UTHSCSA, Oral and Maxillofacial Radiology, Department of Comprehensive Dentistry, 7703 Floyd Curl Dr., San Antonio, TX 78229, USA

the skeletal maturation estimation based on dental development is, in fact, based on assessment of third molars formation.

The spheno-occipital synchondrosis (SOS) is described as the development of a union between two immovable bones by the formation of either hyaline cartilage or fibro-cartilage.[9] The maturation of SOS is important due to its late ossification [10] and significant role for expansion of the ossification centres and to the growth of the cranial base.[9]

Growth of the SOS translates the upper face and the maxillary complex forward to increase the depth of the upper face with little change in height or may be expressed vertically to contribute primarily to upper facial height and influences the spatial position of the upper teeth during orthodontic treatment.[11] The issue that has masked the role of the SOS has been the method of superimposing cephalometric tracings on the anterior cranial base to show the direction of growth of the whole face.[11]

As the result of recent advances in radiology, cone-beam computed tomography (CBCT) is becoming more popular and is recommended in orthodontics for several purposes, such as rapid maxillary expansion (RME) effects on naso-maxillary structures and evaluating the positions of impacted teeth and bone grafts in cleft regions.[12] The images of head and neck are examined in all three planes, one CBCT volume can exhibit the cervical vertebrae, teeth and spheno-occipital synchondrosis.[2,12] Demirturk Kocasarac et al.,[10] in an age estimation study in a Turkish population, used spheno-occipital synchondrosis fusion degree from CBCT and third molar mineralization stages from panoramic radiography and showed a significant correlation between dental and skeletal maturation for both sexes ($r = .586$ for males, $r = .774$ for females, $p < .001$). The authors stated that the earliest age at which third molar totally developed (Stage H) is 19 years in males (mean 23.1 years) and 18 years in females (mean 22.68 years). The earliest age at which spheno-occipital synchondrosis is fused (Stage 3) is 14 years (mean 20.56) in females and 11 years (mean 18.5) in males. This result indicates the applicability of these parameters for estimating the skeletal maturity and age estimation.

Assessment of maxillofacial growth is a crucial step in establishing an adequate treatment plan for orthodontics, orthognathic surgery or implant dentistry

Establishing a correlation between CVM and SOS will aid the practitioner to estimate the degree of SOS fusion and maxillo-facial growth from a cephalometric image without the need of a CBCT examination necessary for an accurate assessment of SOS but providing a high radiation dose to the patient. This may also replace a hand-wrist projection further reducing the dose to young and young adult patients.

Relationship between chronologic age and skeletal growth indicators will also offer a great help in forensic dentistry field for age estimation in young individuals.

The aim of the current study is to assess the correlation between 3rd molar mineralization, SOS fusion degree, chronologic age and CVM. To our knowledge, no study has described the relationship between these four indicators, all together, in assessing skeletal maturity.

Material and methods

Case selection

A retrospective cross-sectional study was designed. The population consisted of 116 subjects (43 male age ranges 8–27, mean 15.13 and 73 female age ranges 8–28, mean 16.39) who had panoramic radiographs, lateral cephalometric radiographs and CBCT scans. Images were acquired with a maximum of 3 months interval, they were taken for multiple reasons, such as, but not limited to, orthodontic treatment, trauma and pathology purposes. The study population was randomly selected from the modern multicultural Turkish society. CBCT scans showing modifications of the cranium, congenital and/or developmental disorders, abnormal morphology resulting from trauma and pathologic conditions which potentially affected the area of interest were excluded. Panoramic radiographs with image deformity and displaying obvious dental pathology affecting third molars and lateral cephalometric radiographs with image deformity and any obvious pathology affecting the area of interest were also excluded. Five patients with agenesis of mandibular third molars, four with suspicion of a craniofacial syndrome and five with history of maxillofacial trauma causing fracture in the area of mandibular angle were excluded.

Radiological assessment

Data acquisition

CBCT volumes for all patients were retrieved from the dental school archives. All the images were acquired using Planmeca® CBCT machine (Planmeca, Promax 3D max, Helsinki, Finland). Images were reconstructed with Romexis®, the proprietary software of Planmeca®. Depending on the voxel size of the volumetric data, sub-millimeter slice thickness were preferred (0.2–0.4 mm) for assessment of each plane. As the view of choice, the mid-sagittal image of each spheno-occipital synchondrosis was used. Panoramic images and lateral cephalometric images were acquired using Morita Veraviewepocs (J. Morita Mfg. Corp., Kyoto, Japan) which was operated at 70 kVp and 10 mA.

CBCT images of spheno-occipital synchondrosis, panoramic images and lateral cephalometric images were adjusted and exported as tagged image file format (*tiff) and gathered a separate folder for observer evaluation. The file set did not contain any demographic data and images were displayed in a random order.

Assessment of dental age, cervical vertebral maturation and spheno-occipital synchondrosis fusion degree

For determining cervical vertebrae maturation, the criteria proposed by Lamparski [13] and detailed by Hassel and Farman [14] was used (Table 1). Dental age was calculated from third molar tooth which was scored from A to H according to method of Demirjian et al. [15] on panoramic radiographs (Table 2). A four-stage system of Franklin and Flavel [16] was used to assess the fusion degree of the spheno-occipital synchondrosis (Table 3 and Figure 1).

A total of 116 images for both third molar tooth and spheno-occipital synchondrosis assessed by one maxillofacial radiologist and cervical vertebrae was evaluated by one orthodontist independently and unaware of one another's results.

Table 1. Cervical vertebrae maturation indicators suggested by Hassel and Farman[14] CVS, cervical vertebrae stage.

CVS- 1: Initiation stage
- It coincides with 1st and 2nd skeletal maturity stages of Fishman's hand-wrist method.
- Adolescent growth just begins.
- Adolescent growth rate up to 80–100% is expected.
- C2, C3 and C4 cervical vertebrae are wedge-shaped and superior vertebral borders tend to taper from posterior to anterior.

CVS- 2: Acceleration stage
- It coincides with 3rd and 4th skeletal maturity stages of Fishman's hand-wrist method.
- Adolescent growth accelerates.
- Adolescent growth rate of 65–85% is expected.
- The bodies of C3 and C4 are nearly rectangular in shape.
- The inferior border of C4 is flat

CVS- 3: Transition stage
- It coincides with 5th and 6th skeletal maturity stages of Fishman's hand-wrist method.
- Adolescent growth increases rapidly toward its peak.
- Adolescent growth rate of 25–65% is expected.
- Cervical spine becomes apparent in the inferior borders of C2 and C3.
- The inferior border of C4 is flat.
- The bodies of C3 and C4 are nearly rectangular in shape.

CVS- 4: Deceleration stage
- It coincides with 7th and 8th skeletal maturity stages of Fishman's hand-wrist method.
- Adolescent growth decelerates thoroughly.
- Adolescent growth of 10–25% is expected.
- Concavity becomes apparent in the inferior borders of C2, C3, and C4.
- The vertebral bodies of C3 and C4 are becoming square in shape.

CVS- 5: Maturation stage
- It coincides with 9th and 10th skeletal maturity stages of Fishman's hand-wrist method.
- Adolescent growth is not significant.
- Adolescent growth of 5–10% is expected.
- More accentuated concavities are seen in the inferior borders of C2, C3, and C4.
-.The bodies of C3 and C4 are nearly square in shape.

CVS- 6: Completion stage
- It coincides with 11th skeletal maturity stages of Fishman's hand-wrist method.
-Adolescent growth is considered to be complete at this stage, no growth is expected.
-Deep concavities are seen in the inferior borders of C2, C3, and C4.
-C-3 and C-4 are greater in height than in width

Statistical analysis

Statistical analyses were performed with IBM SPSS for Windows version 20.0 (SPSS, Chicago, IL, USA). Spearman Correlation Analysis was used to assess the relationship between variables. Intra-observer reliability was calculated using Kappa test (κ) based on the re-assessment of 40 images, with a month interval left between scoring sessions.

Results

Table 4A–C show descriptive statistics of cervical vertebrae maturation, third molar mineralization process, and spheno-occipital synchondrosis fusion degree for both the sexes. The oldest age at cervical vertebral stage (CVS) 1 is 10 years in females and 14 years in males. The youngest age at CVS 6 is 13 years in females and 16 years in males. The earliest age at which third molar totally developed (Stage H) is 24 years in males (mean 25.25 years) and 19 years in females (mean 23.42 years). The latest age at which spheno-occipital synchondrosis remained open (Stage 0) is 12 years in females and 14 years in males. The earliest age at which spheno-occipital synchondrosis is fused (Stage 3) is 13 years in females and 14 years in males.

Based on the re-assessment of 40 images separated by 1 month interval, Kappa test showed perfect intra-observer agreement; $\kappa_1 = .841$ (5 total disagreements with 1 stage difference), $\kappa_2 = .878$ (4 total disagreements with 1 stage difference) and $\kappa_3 = .889$ (3 total disagreements with 1 stage difference); for CVM, third molar tooth mineralization and SOS fusion respectively ($p < .001$).

Table 5(A) shows the distribution of calcification stages of third molar at CVS 1-CVS 6. Although closing of the roots (Stage H) of the third molar was completed in some of the cases in CVS 6 for both sexes, there were cases with uncompleted apical formation. Table 5(B) shows the distribution of fusion stages of SOS at CVS 1-CVS 6. Stage 0 and Stage 1 were not seen after CVS 4 and Stage 2 after CVS 5. The closing of the synchondrosis (Stage 2) was finished in the CVS 5. In CVS 6, spheno-occipital synchondrosis was closed (Stage 3).

Table 2. Definition of the staging system used to score third molar tooth calcification proposed by Demirjian et al.[15]

Stage A: Calcification of some occlusal points with no fusion
Stage B: Fusion of calcified points creating a visible occlusal surface outline
Stage C: Completely formed surface enamel with early dentin formation. The outline of the pulp chamber begins to form but horns not visible
Stage D: Completely formed crown done to the CEJ level, the root starts to form, beginning of pulp horn shaping up but the pulp chamber is still rounded.
Stage E: The crown is longer than the forming root, the pulp horns are more individualized but the pulp chamber walls are still straight. Beginning of furcation calcification.
Stage F: The walls of the pulp are triangular and the root is equal or slightly longer than the crown. The bifurcation began to develop giving the roots their early shape
Stage G: The borders of the root are parallel but the apex is still open, evaluation is done on the distal root only
Stage H: The apex is completely formed, the PDL space is visible and uniform along all the root surfaces

CEJ, cemento-enamel junction; PDL, periodontal ligament.

Table 3. Definition of the staging system used for scoring spheno-occipital synchondrosis fusion degree.[16]

Stage	Status	Description
0	Unfused	Completely open with no evidence of fusion between the basilar portion of the occipital and the sphenoid – no bone present in the gap.
1	Fusing endocranially	No more than half the length of the synchondrosis is fused proceeding endo- to ectocranially.
2	Fusing ectocranially	Greater than half the length of the synchondrosis is fused- the ectocranial (inferior) border remains unfused.
3	Complete fusion	Completely fused with the appearance of normal bone throughout- a fusion scar may be present.

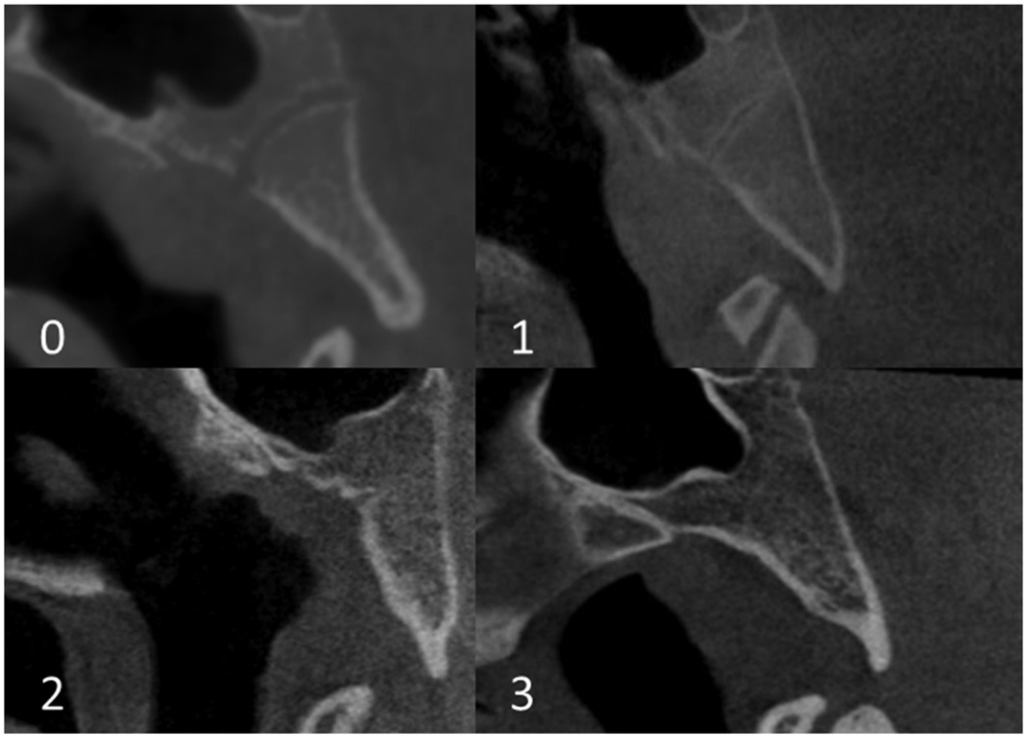

Figure 1. Mid-sagittal CBCT images demonstrating spheno-occipital synchondrosis fusion stages. Stage 0, unfused; Stage 1, fusing endocranially; Stage 2, fusing ectocranially. Stage 3, complete fusion.

Table 4A. Descriptive characteristics for CVS of the study population.

Stages	Gender	Number	Mean age (years)	Minimum age	Maximum age	95% CI mean age	SD
CVS 1	Male	8	10.12	8	14	8.77–11.47	1.95
	Female	1	10.0	10.0	10.0	–	–
CVS 2	Male	12	12.33	9.0	15	11.17–13.49	2.05
	Female	2	8.5	8	9	7.53–9.47	0.7
CVS 3	Male	5	14.8	13	17	13.5–16.1	1.48
	Female	8	13.0	12	15	12.24–13.76	1.06
CVS 4	Male	7	20.85	16	27	17.45–24.25	4.59
	Female	22	16.31	11	25	14.67–17.95	3.93
CVS 5	Male	8	17.75	14	25	15.24–20.26	3.61
	Female	31	17.58	13	24	16.39–18.77	3.38
CVS 6	Male	3	20.0	16	24	15.5–24.5	4.0
	Female	9	18.0	13	28	14.84–21.16	4.84

CVS: cervical vertebra stages; CI: confidence interval; SD: standard deviation.
CI = Mean ±1.96 SEM.

Table 4B. Descriptive characteristics for third molar mineralisation stages of the study population.

Stages	Gender	Number	Mean age (years)	Minimum age	Maximum age	95% CI mean age	SD
Stage 1	Male	5	9.20	8	10	8.00–10.40	1.09
	Female	4	12.50	10	15	10.47–14.53	2.08
Stage 2	Male	2	11.00	11	11	–	0
	Female	5	11.20	8	13	9.08–13.32	1.92
Stage 3	Male	11	13.54	11	16	12.38–14.70	1.69
	Female	15	13.86	12	16	13.23–13.03	1.24
Stage 4	Male	8	13.37	9	15	11.67–15.07	2.44
	Female	19	14.73	9	18	13.69–15.77	2.32
Stage 5	Male	2	12.50	9	16	5.64–19.36	4.94
	Female	2	19.50	19	20	18.53–20.47	0.70
Stage 6	Male	4	17.75	15	20	15.59–19.91	2.21
	Female	10	17.70	14	22	16.18–19.22	2.45
Stage 7	Male	7	18.57	14	24	15.63–21.06	3.35
	Female	11	20.27	18	23	19.01–21.53	2.14
Stage 8	Male	4	25.25	24	27	24.03–26.47	1.25
	Female	7	23.42	19	28	21.29–24.55	2.87

CI: confidence interval; SD: standard deviation.
CI = Mean ±1.96 SEM.

Table 4C. Descriptive characteristics for SOS fusion stages of the study population.

Stages	Gender	Number	Mean age (years)	Minimum age	Maximum age	95% CI mean age	SD
Stage 0	Male	9	10.55	8	14	9.17–11.93	2.12
	Female	4	9.75	8	12	8.08–11.42	1.70
Stage 1	Male	13	12.38	9	15	11.26–13.50	2.06
	Female	8	12.62	12	14	12.11–13.13	0.74
Stage 2	Male	8	18.62	15	27	15.50–21.74	4.50
	Female	14	15.00	11	23	13.38–16.62	3.11
Stage 3	Male	13	18.92	14	25	16.80–21.04	3.90
	Female	47	18.02	13	28	16.99–19.05	3.63

SOS: spheno-occipital synchondrosis; CI: confidence interval; SD: standard deviation.
CI = Mean ±1.96 SEM.

Table 5A. Distribution of stages of third molar tooth mineralization at each cervical vertebral maturation stages of study population.

	CVS 1		CVS 2		CVS 3		CVS 4		CVS 5		CVS 6	
3rd molar stages	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)
A	3 (37.5)	1 (100)	2 (16.7)			2 (25)				1 (3.2)		
B	2 (25)			1 (50)		2 (25)		2 (9.1)				
C			7 (58.3)		2 (40)	3 (37.5)	2 (28.6)	5 (22.7)		5 (16.1)		2 (22.2)
D	2 (25)		3 (25)	1 (50)	2 (40)	1 (12.5)		5 (22.7)	1 (12.5)	9 (29)		3 (33.3)
E	1 (12.5)							1 (4.5)		1 (3.2)	1 (33.3)	
F							1 (14.3)	4 (18.2)	3 (37.5)	5 (16.1)		1 (11.1)
G					1 (20)		2 (28.6)	2 (9.1)	3 (37.5)	7 (22.6)	1 (33.3)	2 (22.2)
H							2 (28.6)	3 (13.6)	1 (12.5)	3 (9.7)	1 (33.3)	1 (11.1)

CVS: cervical vertebral stage.

Table 5B. Distribution of stages of SOS fusion at each cervical vertebral maturation stages of study population.

CVS	CVS 1		CVS 2		CVS 3		CVS 4		CVS 5		CVS 6	
SOS stages	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)
0	6 (75)	1 (100)	2 (16.7)	2 (100)	1 (20)	1 (12.5)						
1	2 (25)		9 (75)		2 (40)	5 (62.5)		3 (13.6)				
2			1 (8.3)			1 (12.5)	5 (71.4)	7 (31.8)	2 (25)	6 (19.4)		
3					2 (40)	1 (12.5)	2 (28.6)	12 (54.5)	6 (75)	25 (80.6)	3 (100)	9 (100)

SOS: spheno-occipital synchondrosis; CVS: cervical vertabral stages.

Table 6. Correlation coefficients between CVM, age, third molar tooth and SOS.

	CVM (r_s)		AGE (r_s)		3rd Molar (r_s)		SOS (r_s)	
Parameters	Male	Female	Male	Female	Male	Female	Male	Female
CVM (r_s)			0.812[a]	0.449[a]	0.723[a]	0.371[a]	0.851[a]	0.618[a]
AGE (r_s)					0.802[a]	0.842[a]	0.810[a]	0.643[a]
3rd Molar (r_s)							0.759[a]	0.534[a]
SOS (r_s)								

CVM, cervical vertebra maturation; SOS, spheno-occipital synchondrosis; rs, spearman correlation coefficient; [a]$p < .01$.

Table 6 shows correlation coefficients between CVM, third molar tooth, SOS and chronologic age.

Relation of chronologic age with dental age and skeletal age

The Spearman Correlation indicates a very strong relationship between age and CVM for males ($r = .812$) and a moderate relationship for females ($r = .449$) $p < .001$. A very strong correlation between age and third molar calcification were seen for both sexes ($r = .802$ for males; $r = .842$ for females, $p < .001$), showing dental age is compatible with chronologic age ($p < .001$). The relation between age and spheno-occipital synchondrosis fusion was found very strong for males ($r = .810$) and strong for females ($r = .643$) $p < .001$.

Relation between dental age and skeletal age

When we evaluated the correlation coefficient (r) between third molar mineralization and CVM, a strong correlation ($r = .723$) was seen for males, and a weak correlation ($r = .371$) for females, demonstrating dental age is relatively compatible with skeletal age ($p < .001$). The relation between third molar mineralization and SOS fusion was found strong for males ($r = .759$) and moderate for females ($r = .534$) $p < .001$.

A very strong correlation ($r = .851$) was seen between CVM and SOS fusion for males and a strong correlation ($r = .618$) for females ($p < .001$), indicating SOS fusion stages might be an alternative parameter for orthodontists to evaluate skeletal maturation.

Discussion

Changes in the rate of growth in adolescence may lead to some changes in orthodontic treatment. Therefore, it is important for orthodontists to pay attention to the periods of growth and development in the objective of providing appropriate treatment alternative to the individuals during their development periods and achieve a favourable stability along with maximum success. Being aware of the density of the growth period as well as spurt and arrest is also important in terms of the permanence of the treatment outcomes. According to Ricketts, [17] to benefit from growth, we should first know the growth rate, growth direction and the time when the peak of growth spurt will be.

The aim of the present study was to evaluate the skeletal maturity of an individual by assessment of 3rd molar mineralization and spheno-occipital synchondrosis fusion and to correlate the changes in the morphologic characteristics of cervical vertebrae maturation in order to avoid unnecessary radiation exposure.

Racial variations in skeletal maturity evaluated with hand-wrist bone maturation, CVM and SOS fusion degree were previously reported.[3,8,10,13,16] For this reason, the result of our study might be different from previously published studies from other populations.

In the modern world, contemporary population-specific standards must be used for skeletal maturation assessment, such task is ruled, and affected, by multiple factors including, size of the population, distribution of the study sample as well as the ethnicity and socioeconomic level.

In a CT-based study, Can et al. [18] reported that, in a western Turkish population, the SOS fusion started approximately 2 years earlier in females who were joined by males later on, and the fusion was completed by the age of 17 years in both genders. They also observed that the synchondrosis was open at mean ages of 11.5 and 10.7 for males and females, respectively, in a study population from 10 to 25 years old.

In a recent CBCT study, Sinanoglu et al. [19] in a study done in a Turkish population evaluated 238 images for 90 males (between 7 and 25) and 148 females (between 8 and 25), they found that Spheno-occipital synchondrosis was totally open (Stage 0) at a mean age of 10 for both genders. The mean age for complete fusion (Stage 3) in this study was higher than Can et al.'s [18] results, with mean ages of 18 and 20 for females and males, respectively.

Franklin and Flavel [16] evaluated spheno-occipital synchondrosis in Australian population and reported the youngest age for attainment of Stage 3 as 13.42 years in males (mean 19.83 years) and 11.75 years in females (mean 18.62 years). The latest age at which fusion remains incomplete (Stage 2) is 16.83 (mean 16.38) for males and 15.09 (mean 13.53) years for females.

Başaran et al. [4] reported a strong relationship between cervical vertebral maturity and dental calcification stages of the teeth, except the third molars, with the correlation coefficients ranging from .601 to .911 for males and from .684 to .843 for females, $p < .001$. Similarly, Bhat and Kamath [7] in a study with Indian population, found a strong correlation between mandibular third molar tooth and skeletal age (hand-wrist) ($r = .85$, $p < .001$). The present study findings are in concordance with these studies, between third molar mineralization and CVM, we found a strong correlation ($r = .723$) for males, and a weak correlation ($r = .371$) for females, ($p < .001$). A strong relationship ($r = .759$) for males and a moderate relationship ($r = .534$) for females were seen between SOS fusion and third molar mineralization.

Demirturk Kocasarac et al. [10] stated a moderate relationship between age and spheno-occipital synchondrosis fusion for males ($r = .599$) and a strong relationship for females ($r = .814$), $p < .001$. The authors reported a strong relationship between age and third molar calcification for both sexes ($r = .839$ for males; $r = .850$ for females, $p < .001$).

In the present study, the correlation between chronologic age and skeletal maturation assessed by the cervical vertebral maturation method was strong ($r = .812$) for males and moderate ($r = .449$) for females and for SOS fusion method the correlation was strong ($r = .810$) both for males ($r = .810$) and females ($r = .643$) $p < .001$. A very strong correlation between age and third molar calcification were seen for both sexes ($r = .802$ for males; $r = .842$ for females, $p < .001$), showing dental age is compatible with chronologic age ($p < .001$). However, Fishman [20] stated that maturational indicators give more reliable results in normally growing children. Therefore, the use of skeletal age would be more accurate and helpful than chronologic age.

When suitable CBCT images are available, skeletal maturity may be evaluated by observing morphologic changes in the spheno-occipital synchondrosis in order to determine the remained growth amount of upper face. Joshi et al. [2] reported that cervical vertebrae maturation from CBCT may provide a reliable assessment of the pubertal growth spurt. Thus hand-wrist radiography can be avoided. This will not only decrease the cost, but also eliminate the extra radiation to the patient. But it should be kept in mind that CBCT should not be performed only for skeletal maturity assessment purpose.

To evaluate SOS fusion using computed tomography, Bassed et al. [21] changed the staging system used previously by El-Sheikh and Ramadan [22] to a five grade system with an additional stage for scar formation. The purpose was to acquire more specific information and to focus on the superiority of CT examinations over macroscopy. However, to limit the subjectivity in evaluation, especially in borderline cases, Franklin and Flavel [16] proposed using a system of four stages. Fusion scars might persist for decades after fusion, in our study we also observed fusion scars in the synchondrosis area. Due to these concerns, we adopted a four grade staging system in our study.

A sex distinction must be made in estimating facial growth according to dental and skeletal maturity. This is because of the difference in the onset of the pubertal periods and maturation time between boys and girls. Table 4(A) and (C) show that, in the four stages of cervical vertebral maturity (CVS 2, CVS 3, CVS 4 and CVS 6), and two stages of spheno-occipital synchondrosis fusion process (stage 0 and stage 2) girls were younger, a balance was seen at CVS 1 and CVS 5 for cervical vertebral maturity and stage 1 and stage 3 for SOS. Girls reach the maturation earlier than boys and this finding is compatible with the findings of Başaran et al. [4] However, it was reported that tooth mineralization relative to hand and wrist maturation shows a tendency for early maturation in boys.[7] In the current study, early maturation was seen in the A, C, E and G stages of third molar mineralization in males. Nonetheless, it is noteworthy that, the mean ages in the subgroups in different studies may differ dependent on the inequality of sample distribution.

Our study presents with some limitations such as the lack of interobserver analysis; in order to have more accurate results, one experienced radiologist evaluated SOS and 3rd molars on CBCT and one experienced orthodontist assessed CVM stages on lateral cephalometric radiographs. So only intra-observer analysis was made and inter-observer analysis could not be conducted since the two reviewers did not assess all parameters.

The other limitation is related to the relatively reduced sample size, the population is not large enough to make a reliable regression and/or transition analysis. And also we do not have the sample population to test our regression formula.

Conclusion

These findings indicate that, in Turkish population, there is a good relationship between skeletal maturation assessed by cervical vertebrae maturation method as seen on lateral cephalometric radiograph, third molar mineralization stages as seen on panoramic radiograph and spheno-occipital synchondrosis fusion stages as seen on CBCT. These results might offer a new approach for orthodontists to evaluate skeletal maturity by using spheno-occipital synchondrosis from CBCT or third molar mineralization from panoramic radiography when the images are available for any particular reason.

Disclosure statement

The authors declare that they have no conflict of interest.

Notes on contributors

Husniye Demirturk Kocasarac, got her dental degree in 2008 and her PhD in Oral and Maxillofacial Radiology (OMFR) in 2014 from Ondokuz Mayis University, Faculty of Dentistry, Samsun, Turkey. She was an assistant professor in the Department of Oral and Maxillofacial Radiology in Kocaeli University, Faculty of Dentistry, Kocaeli, Turkey from 2014 to 2016. Currently, she is a resident in OMFR graduate program in the University of Texas, Health Science Center, School of Dentistry, San Antonio, Texas, USA.

Ayse Burcu Altan, took her dental degree from Ege University, Faculty of Dentistry, İzmir, Turkey, in 2003 and her PhD in Orthodontics in 2010 from Cumhuriyet Univesity, Faculty of Dentistry. She is now an associated professor in the Department of Orthodontics in Kocaeli University, Faculty of Dentistry, Kocaeli, Turkey.

Canan Yerlikaya, got her dental degree from Hacettepe University, Faculty of Dentistry, Ankara, Turkey, in 2009 and her PhD in 2016 from Ondokuz Mayis University, Faculty of Dentistry, Samsun, Turkey. She is now practicing in Bursa Dental Hospital, Bursa, Turkey.

Alper Sinanoglu, graduated with a dental degree in 2000 and a PhD in Oral Diagnosis and Radioloy in 2007 from Marmara University, Faculty of Dentistry, İstanbul, Turkey. Currently, he is head of department of OMFR in Kocaeli University Faculty of Dentistry, Kocaeli, Turkey.

Marcel Noujeim, received his dental degree in 1999 and radiology degree in 1996 from the Lebanese University, School of Dentistry. He finished a Master of Science (MS) degree in OMFR in the University of Texas, Health Science Center, School of Dentistry in 2006. He is director of graduate OMFR program, Department of Comprehensive Dentistry, University of Texas Health Science Center San Antonio, School of Dentistry, and a collaborating professor in the University of Campina, School of Dentistry in Piracicaba, Brazil.

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