

Relationship between Dental Development and Cervical Vertebrae Development Assessed Using Radiography in an Iranian Population

Original Article

Zahra Tafakhori¹, Mahboubeh Shokrizadeh²,
Mahmood Sheikh Fathollahi³

¹ Assistant Professor, Department of Oral and Maxillofacial Radiology, School of Dentistry and Dental Research Centre, Rafsanjan University of Medical Sciences, Rafsanjan, Iran.

² Dentist, School of Dentistry and Dental Research Centre, Rafsanjan University of medical sciences, Rafsanjan, Iran.

³ Assistant Professor, Department of Epidemiology and Biostatistics and Occupational Environment Research Center, Medical School, Rafsanjan University of Medical Sciences, Rafsanjan, Iran.

Received: Mar 16, 2016
Accepted: Aug 21, 2016

Corresponding Author:

Zahra Tafakhori

Address:

Department of Oral and Maxillofacial Radiology,
School of Dentistry and Dental Research Centre,
Rafsanjan University of Medical Sciences, Aliebneab-
italeb Square, Rafsanjan, P.O.Box:7717931136, Iran.

Email: ztafakhori@yahoo.com

Telephone:+98-34-34280031

Fax: +98-34-34280008

Abstract

Introduction:

Determining the skeletal age and remaining growth potential of patients are important factors in orthodontic treatment. Evaluating cervical vertebrae development is a reliable method for determining skeletal age. This study aimed to evaluate the correlation between dental calcification and stages of skeletal maturation.

Materials and methods:

This descriptive cross-sectional study was conducted on 84 panoramic radiographs and lateral cephalometrics related to 10–15-year-old patients without systematic diseases affecting dental calcification and development. Patient's skeletal age was determined by the stage of cervical vertebrae development and by using Lamparski's method. Dental age of samples was determined by Demirjian's method. Findings were analyzed by SPSS 18 software using Spearman's correlation test to determine the correlation between the cervical vertebrae development and the dental development stages. $P < 0.05$ was considered significant.

Results: Spearman's correlation test showed a significant direct correlation between dental age and skeletal age ($r_2 = 42.5\%$). The linear relationship between dental age and skeletal age was significant ($p < 0.05$). The highest correlation coefficient was between the cervical vertebrae development and the stages of mandibular second premolar calcification in girls ($r_s = 0.609$) and in the second molar in boys ($r_s = 0.471$). In Demirjian's method, stage G of the mandibular second premolar teeth in girls and stage F of the mandibular second molar teeth in boys nearly coincided with the pubertal growth spurt.

Conclusion: The findings of this study showed that, in Demirjian's method, stage G of the mandibular second premolar teeth in girls and stage F of the mandibular second molar teeth in boys was most frequent between developmental stages. According to the relatively high correlation coefficient between the dental age and the skeletal age, using dental calcification stages by panoramic radiography may become a simple first-level diagnostic test to determine skeletal maturity, which requires more studies in different ethnicities and places all around the world.

Key words:

•Tooth Calcification •Panoramic Radiography
•Cervical Vertebrae •Age Determination by Skeleton.

Introduction

Dental/facial anomalies are common reasons for seeking orthodontic treatment. The best response to functional treatments and developmental changes to correct these abnormalities is achieved before the pubertal growth spurt. In general, skeletal maturation is influenced by genetic and environmental factors. Almost all patients show similar growth patterns, but the beginning and rate of growth vary considerably among individuals.^(1, 2) Because the age of onset of puberty differs among people, the rate of skeletal maturation and amount of time remaining for growth should be determined to develop an appropriate treatment plan for patients. Chronological age is not a reliable indicator of skeletal maturation.⁽³⁾ Other indicators, for example, menstruation and breast growth in girls and voice change in boys, are impractical and unreliable estimators of the pubertal growth spurt, since these are affected by environmental factors.⁽⁴⁻⁵⁾ A reliable biological indicator is required in order to determine the time of skeletal maturation.

For many years, wrist radiography has been used to determine skeletal maturation.⁽⁶⁻⁹⁾ However, today researchers have concluded that radiography of cervical vertebrae is a good alternative to wrist radiography. Thus, cervical vertebrae maturation is a good diagnostic tool for estimating the pubertal growth spurt.^(10, 12) Dental age is another indicator of physiological age.⁽¹³⁾ Today, evaluating the stages of dental calcification is used to determine dental age. Despite the fact that tooth growth is a rapid process, stages of development and dental calcifications are long term and are not influenced by factors such as early loss of deciduous tooth, ankylosis, and insufficient dental arch length.⁽¹³⁻¹⁴⁾ Lateral cephalometric radiography is less available than panoramic radiography. If the child is not positioned properly, cervical vertebrae might not be clearly identified. Furthermore, calcification stages are easily detected by panoramic radiography. Therefore, if a relationship is established between skeletal maturation stage and dental age that is estimated by dental calcification stages, dental age can be used as the first-line diagnostic tool to determine skeletal growth spurt. Considering the racial and ethnic differences in

dental and skeletal development and the limited studies in Iranian people, we aimed to examine

Materials and Methods

This descriptive-analytical cross-sectional study was conducted on 84 patients (57 girls and 27 boys) attending a private Oral and Maxillofacial Radiology Clinic (age range, 10–15 years) in order to perform panoramic radiography and lateral cephalogram in their dental treatment plan. Sample size was determined according to Heravi)⁽¹⁵⁾ study and using the sample size formula for correlation investigation as.

$$n = \left(\frac{Z_{1-\frac{\alpha}{2}} + Z_{1-\beta} \times \sqrt{1-r^2}}{r} \right)^2 + 2$$

Samples were derived randomly, without allotting an equal number of girls and boys in choosing samples, as this study was cross-sectional. The study was conducted in accordance with the Helsinki Declaration and was approved by the ethics committee of Rafsanjan university of medical sciences (ethical number: ir.rums.rec.1395.23). Informed consent was completed by all patients.

The inclusion criteria for the study included living in Rafsanjan and having been born in Rafsanjan city, the possibility of affording radiography with sufficient quality, an absence of systemic diseases disrupting skeletal development or systemic diseases affecting calcification and dental development (hypophosphatemia, hypophosphatasia, or Ehlers-Danlos syndrome), and an absence of medical or surgical factors affecting the development of permanent mandibular teeth.

Subjects' age was recorded according to their birth date on their birth certificate. Their chronological age was obtained by subtracting the date of birth and date of radiography (age was recorded based on month; if it was under 15 days it was rounded down and if it was over 15 days it was rounded up). Then, panoramic radiographs and lateral cephalograms were prepared by Planmeca (Proline-xc, Helsinki, Finland) digital panoramic

the calcification stages of each tooth. In this method, the developmental stage of seven left mandibular permanent teeth was estimated based on Figure 1. (If there was a missing tooth or a lesion in the area from 31 to 37 teeth, similar tooth on the right side was used. Also, if there were bilateral missing teeth, the patient was not included.)

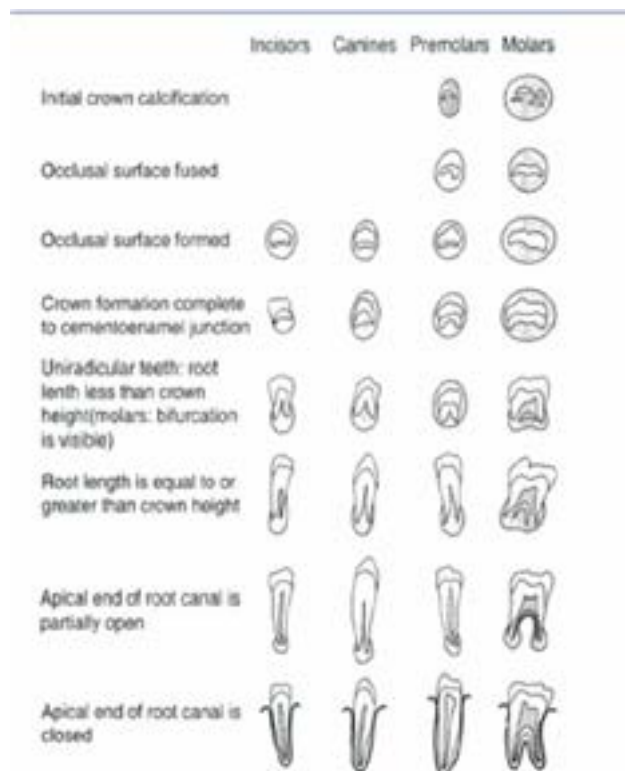


Figure 1. The stages of root development in single- and multiple-rooted teeth

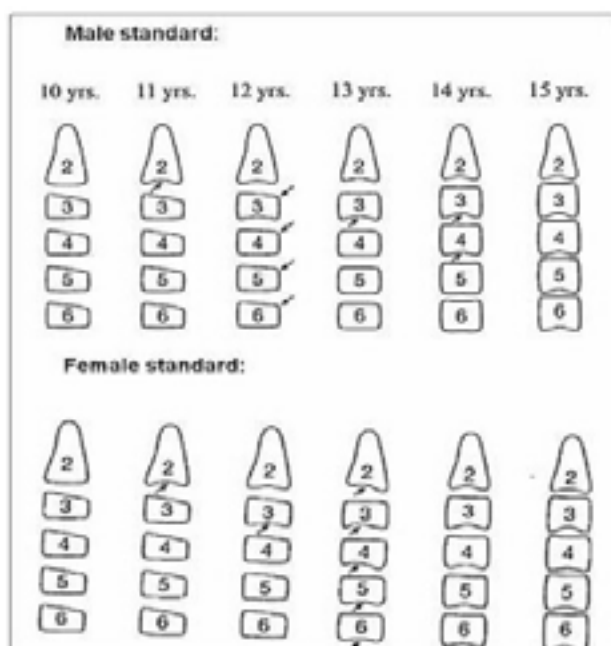


Figure 2. Six stages in evolution of cervical vertebrae maturation according to method of Lamparski

Patients' skeletal age was estimated using Lamparski's⁽¹⁶⁾ method, which includes six stages (Figures 2 and Table 1), based on lateral cephalometrics radiography. This method depends on six cervical vertebrae morphologies (C2–C6). Then, chronological, dental, and skeletal ages were compared with each other. In terms of the reproducibility of this study, the same researcher re-examined 30 panoramic radiographs randomly four weeks later and differences between the two observations were recorded.

Table 1: Six Stages in Evolution of Cervical Vertebrae Maturation According to the Method of Lamparski⁷¹⁵

	Male standard	Female standard
Stage 1 (10 years)	All inferior borders are flat. Superior vertebral borders are tapered from posterior to anterior (wedge-shaped).	All inferior borders are flat. Superior vertebral borders are tapered from posterior to anterior (wedge-shaped).
Stage 2 (11 years)	A concavity has developed in lower borders of C-2.	A concavity has developed in lower borders of C-2, the anterior height of the bodies have increased.
Stage 3 (12 years)	The concavity in C2 has deepened, the anterior vertical height have increased.	A concavity has developed in the inferior border of the third vertebrae; the remaining borders are still flat.
Stage 4 (13 years)	A concavity has developed in the inferior border of the third vertebrae.	The concavity of the third vertebrae has increased and a definite concavity has formed in C4, concavities in C5 and C6 has just beginning to form, all bodies are now rectangular in shape.
Stage 5 (14 years)	The concavity of the third vertebrae has increased.; All bodies are now rectangular in shape.	The spaces between the bodies are smaller, the concavities are all well-defined in all six bodies, and all bodies are now square in shape.
Stage 6 (15 years)	The spaces between the bodies are smaller, the concavity of the C4 has deepened and the concavities are developing in C5 and C6, all bodies are square in shape.	All bodies are increased in vertical height and are higher than their wide, all concavities have deepened.

All information was recorded using a checklist provided for each patient. Information was encoded and entered into SPSS 18.0 software (SPSS Inc., Chicago, IL, USA). To investigate the relationship between stages of cervical vertebrae development and stages of dental calcification, the non-parametric test of Spearman's correlation coefficient (rs) was used. In order to compare mean quantitative variables in girls and boys, an independent two-sample t-test was used. To investigate the relationship between skeletal age and dental age, multiple linear regressions were used. For intra-observer variability, the coefficient Kappa (κ) test and Pearson's correlation coefficient (r) were used. Significance level was considered 0.05.

Results

In this study, 84 patients, including 57 girls (67.9%) and 27 boys (32.1%) aged 10–15 years were evaluated.

After comparing the mean chronological age, dental age, and cervical vertebrae age in girls and boys, we found that the mean of all three ages was higher in girls than in boys (Table 2). Comparing the chronological and cervical vertebrae age according to the tooth number revealed no significant difference (Table 3). Correlation coefficient between skeletal age and dental calcification stages showed that the highest correlation coefficients in girls was seen in the second premolar, followed by the first premolar, canine, the second molar, lateral, central, and the first molar.

Table 2: Comparing the mean of chronological age, dental age and cervical vertebrae age in girls and boys

	Girl Number	mean ± SD	Boy Number	mean ± SD	P-value
Chronological Age (Year)	57	12.79 ± 1.57	27	11.93 ± 1.67	0.024
Dental Age (Year)	57	12.68 ± 1.84	27	11.63 ± 1.90	0.018
Cervical Vertebrae Age (Year)	57	12.81 ± 1.72	27	11.07 ± 1.36	<0.001

Table 3: Comparing the mean of chronological and cervical vertebrae age (year) according to the tooth number

Tooth number	Chronological age (n = 84)	Cervical vertebrae age (n = 84)	P-value
Central	12.56 ± 1.62	12.49 ± 1.58	0.939
Lateral	12.63 ± 1.39	12.57 ± 1.33	0.893
Canine	12.49 ± 1.73	12.47 ± 1.67	0.984
First premolar	12.50 ± 1.55	12.55 ± 1.43	0.971
Second premolar	12.58 ± 1.67	12.50 ± 1.65	0.926
First molar	12.61 ± 1.46	12.54 ± 1.53	0.880
Second molar	12.69 ± 1.71	12.59 ± 1.68	0.805

Data are presented as mean ± SD (standard deviation). Data are compared using paired t-test

The highest correlations for boys were observed in the second molar, followed by canine, the first premolar, and the second premolar, lateral, the first molar, and central. According to the results obtained, the highest correlation coefficient in girls was between the stages of cervical vertebrae development, the second premolar tooth calcification stages, and the highest correlation coefficient in boys was between stages of cervical vertebrae development and the second molar tooth calcification stages (Table 4). Also, in

Demirjian's method, stage G of the mandibular second premolar teeth in girls [24 person (42.1%)] and stage F of the mandibular second molar teeth in boys [10 person (37.0%)] had the highest frequency between developmental stages. Multiple linear regressions showed that skeletal age is calculated using two variables of dental age and gender from the following linear equation:

$$\text{Skeletal age} = 7.019 + (0.457 \times \text{dental age}) - (1.254 \times \text{gender})$$

In the above formula, if a child's gender is male, 1 is replaced for gender and if child's gender is female zero is replaced. In the above linear relation, the value of $R^2 = 42.5\%$ was calculated. In other words, the changes of skeletal age can be explained 42.5% by two variables of the child's dental age and gender.

For intraobserver variability, coefficient Kappa (κ) test and Pearson's correlation coefficient (r) were used.

To assess intraobserver variability, coefficient of agreement $\kappa = 0.851$ in the review stage 31–37 and $\kappa = 0.877$ in the review CVM; showing that stages read by an observer in two stages within four weeks have a reasonable agreement. Pearson's correlation coefficient was calculated to examine the agreement of dental age and the value of $r = 0.918$ was obtained, indicating a strong positive correlation between read dental age in the first and second stage.

Table 4. Spearman's correlation coefficients between skeletal age and dental calcification stages according to gender

Tooth number	Girls (n = 57)	Boys (n = 27)
Central	rs = 0.286 P = 0.031	rs = 0.064 P = 0.750
Lateral	rs = 0.323 P = 0.014	rs = 0.365 P = 0.061
Canine	rs = 0.525 P < 0.001	rs = 0.460 P = 0.016
First premolar	rs = 0.224 P < 0.001	rs = 0.453 P = 0.018
Second premolar	rs = 0.609 P < 0.001	rs = 0.404 P = 0.036
First molar	rs = 0.202 P = 0.133	rs = 0.329 P = 0.093
Second molar	rs = 0.444 P < 0.001	rs = 0.471 P = 0.013

Discussion

Patients with dentofacial deformities and abnormalities need functional treatments or jaw orthopedics during growth. (17) Determining skeletal maturation and evaluation of remaining growth potential of patient are important factors in orthodontic treatments. Different methods have been proposed for assessing skeletal maturity. Cervical vertebrae are reliable indicators of

skeletal maturity. (16, 18-19)

Dental age is another physiological indicator determined by examining tooth calcification stage. The Demirjian (14) method is the most reliable and the most common method for estimating dental age that can be investigated by panoramic radiography.

There is a relatively high correlation coefficient between dental calcification stages (except for central, lateral, and first molar teeth) and cervical vertebrae development stages in girls (0.444–0.609) and boys (0.404–0.471). However, this correlation is less for central, lateral, and first molar teeth in girls (0.202–0.323) and boys (0.064–0.365), which could be due to the age range of our patients (10–15 years old, in which the growth of dental roots is complete). This could also account for the differences between our findings and those of Basaran (20), who reported a high correlation of skeletal age and dental age for all teeth (except third molar teeth), because age range was more extensive in his study (7–18 years old, which could also include roots development period of central, lateral and the first molar teeth). Our findings were similar to the study of Chen et al. (21) which reported correlation coefficients between dental maturity and cervical vertebral maturity ranging from 0.391 to 0.582 for girls and from 0.464 to 0.496 for boys. Furthermore, in the study of Mittal et al., (22) correlations between dental development and skeletal maturity ranged from 0.403 to 0.758 for males and 0.419 to 0.811 for females.

In the current study, the highest correlation was observed between skeletal age and calcification stages in the mandibular second premolar in girls (0.609), consistent with the results of Kalinowski et al. (23) study that showed the highest correlation with the second premolar in both genders. In boys, the strongest correlation was also observed between skeletal age and the second molar calcification stages, consistent with the results of Rai (24) and Kumar et al. (25), which showed the strongest relationship with the second molar in both genders and the study of Basaran et al. (20), which showed the strongest relationship in the second molar in boys. On the other hand, Chen et al. (21) reported the highest correlation for the mandibular second molar and the lowest correlation for the canine in girls, and the canine and the first premolar as the highest and the lowest

correlations in boys. Valizade et al.⁽²⁶⁾ reported greater correlations between the two stages in the first and second premolar, canine, and central incisor. However, Mittal et al.⁽²²⁾ showed the highest correlation for the second molar and the lowest correlation for the third molar in male and female subjects.

Heravi et al.⁽¹⁵⁾, similar to Chertkow et al.⁽²⁷⁾, found the highest relationship between various skeletal indicators of the pubertal growth spurt with mandibular canine calcification stage G; however, Valizadeh et al.⁽²⁶⁾ found the strongest relationship with the first and second molars (stage E) in both genders.

This difference can be attributed to the difference in the method of determining of skeletal age, that is, the Baccetti method in their study and the Lamparski method in our study, as well as racial and ethnic differences in dental and skeletal development, as reported in two studies.

According to the results of the present study, stage G of the mandibular second premolar in girls and F stage of the mandibular second molar in boys have the highest frequency in Demirjian's method, which could indicate that these stages are synchronized with the pubertal growth spurt.

According to the results of the study of Baccetti et al.⁽¹¹⁾ and Al khal et al.⁽²⁸⁾ and by comparing the cervical vertebrae development using the Baccetti⁽¹¹⁾ and Lamparski⁽¹⁶⁾ methods, we can conclude that stage of 12 years old in girls in Lamparski's method coincides with the pubertal growth spurt. This confirms our finding that the highest percentage of observing stage G in the second premolar was in 12-year olds.

Furthermore, we obtained a relatively high

correlation coefficient ($R^2 = 42.5\%$) between dental age obtained by Demirjian⁽¹⁴⁾ method and skeletal age obtained from the cervical vertebrae by the Lamparski⁽¹⁶⁾ method, and developed a linear model for estimating skeletal age using dental age.

$$\text{Skeletal age} = 7.019 + (0.457 \times \text{dental age}) - (1.254 \times \text{gender})$$

Thus, this model can be used to estimate the individual's skeletal age based on dental age in up to approximately 42% of cases, when only panoramic radiographic data is available.

Conclusion

The findings of this study showed that, in Demirjian's method, stage G of the mandibular second premolar teeth in girls and stage F of the mandibular second molar teeth in boys were most frequent between developmental stages. According to the relatively high correlation coefficient between dental age and skeletal age, using dental calcification stages by panoramic radiography may become a simple first-level diagnostic test to determine skeletal maturity, which requires more studies in different ethnicities and places worldwide.

Acknowledgments

The Authors would like to thank the Clinical Research Development Center for its support and collaboration in Ali Ebne Abitaleb Hospital, Rafsanjan University of Medical Science, Rafsanjan, Iran.

References

1. Fishman L. Maturation development and facial from relative to treatment timing. In: Subtenly J, editor. Early orthodontic treatment. Chicago: Quintessence. 2000; 41(4): 265-85.
2. Moore RN, Moyer BA, Dubois LM. Skeletal maturation and craniofacial growth. Am J Orthod Dentofacial Orthop. 1990; 98(1): 33-40.
3. Fishman LS. Chronological versus skeletal age, an evaluation of craniofacial growth. Angle Orthod. 1979; 49(3): 181-9.
4. Marshall WA, Tanner JM. Variations in the pattern of pubertal changes in girls. Arc Dis Child. 1969; 44(4): 291-303.
5. Marshall WA, Tanner JM. Variations in the pattern of pubertal changes in boys. Arc Dis Child. 1970; 45(1): 13-23.
6. Fishman LS. Radiographic evaluation of skeletal maturation, a clinically oriented method based on hand-wrist films. Angle Orthod. 1982; 52(1): 88-112.
7. Hagg U, Taranger J. Maturation indicators and pubertal growth spurt. Am J Orthod. 1982; 82(3): 299-309.
8. Chapman SM. Ossification of the adductor sesamoid and the adolescent growth spurt. Angle Orthod. 1972; 42(2): 236-45.
9. Houston WJ, Miller JM. Prediction of the timing of the adolescence growth spurt from ossification events in hand-wrist

films. *Br J Orthod.* 1979; 6(1): 142-52.

10. Chang HP, Liao CH, Yang YH, Chang HF, Chen KC.. Correlation of cervical vertebral maturation with hand-wrist maturation in children. *Kaohsiung J Med Sci* 2001; 17(2): 29-35.
11. Baccetti T, Franchi L, McNamara JA Jr. An improved version of the cervical vertebral maturation (CVM) method for the assessment of mandibular growth. *Angle Orthod.* 2002; 72(1): 316-23.
12. Kucukkeles N, Acar A, Biren S, Arun T. Comparisons between cervical vertebrae and hand-wrist maturation for the assessment of skeletal maturity. *J Clin Pediatr Dent.* 1999; 24(1): 47-52.
13. Willems G, Moulin Romsee C, Soheim T. Non-destructive dental age calculation methods in adults: intra-and-inter-observer effects. *Forensic Sci Int.* 2002; 126(3): 221-6.
14. Demirjian A, Goldstein H, Tanner JM. A new system for dental age assessment. *Hum Biol.* 1973; 45(2): 211-27.
15. Heravi F, Imanimoghaddam M, Rahimi H. Correlation between cervical vertebral and dental maturity in Iranian subjects. *J Calif Dent Assoc.* 2011; 39(12): 891-6.
16. Lamparski DG. Skeletal age assessment utilizing cervical vertebrae [MSC thesis]. USA: University of Pittsburg; 1972.
17. Imanimoghaddam M, Heravi F, Khalaji M, Esmaily H. Evaluation of the correlation of different method in determining skeletal maturation utilizing cervical vertebrae in lateral cephalogram. *J Mash dent sch.* 2008; 32(2): 95-102. Persian.
18. Hassel B, Furman AG. Skeletal maturity evaluation using cervical vertebrae. *Am J Orthod Dentofacial Orthop.* 1995; 107(1): 58-66.
19. O'Reilly MT, Yanniello GJ. Mandibular growth changes and maturation of cervical vertebrae: a longitudinal cephalometric study. *Angle Orthod.* 1988; 58(2): 179-84.
20. Basaran G, Ozer T, Harnamcia N. Cervical vertebral and dental maturity in Turkish subjects. *Am J Orthod Detofacial Orthop.* 2007; 131(1): 447.e13-447.e20.
21. Chen J, Hu H, Guo J, Liu Z, Liu R, Li F, Zou S. Correlation between dental maturity and cervical vertebral maturity. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2010;110(6):777-83.
22. Mittal S, Singla A, Virdi M, Mittal B. Co-Relation Between Determination of Skeletal Maturation Using Cervical Vertebrae and Dental Calcification Stages. *int j of forensic science.* 2009; 4(2).
23. Kalinowska I, Kolasa Raczka A, Kalinowski P. Relationship between dental age according to Demirjian and cervical vertebra maturity in Polish children. *Eur J Orthod.* 2011; 33(1): 75-83.
24. Rai B. Relationship of dental and skeletal radiograph: maturity indicator. *Internet J Biol Anthropol.* 2008; 2 (1) DOI: 10.5580/1aa0.
25. Kumar S, Singla A, Sharma R, Virdi MS, Anupam A, Mittal B.. Skeletal maturation evaluation using mandibular second molar calcification stages. *Angle Orthod.* 2012; 82(3):501-6.
26. Valizadeh S, Eil N, Ehsani S, Bakhshandeh H. Correlation between dental and cervical vertebral maturation in Iranian females. *Iran J Radiol.* 2013; 10(1): 1-7.
27. Chertkow S, Fatti P. The relationship between tooth mineralization and early evidence of the ulnar sesamoid. *Angle Orthod.* 1979; 49:282-288.
28. Al khal HA, Wong RW, Rabie AB. Elimination of hand-wrist radiographs for maturity assessment in children needing orthodontic therapy. *Skeletal Radiol.* 2008; 37(3): 195-200.