ORIGINAL RESEARCH

# Morphometric Assessment of Third and Fourth Cervical Vertebra Based on Hassel and Farman Method: A Radiographic Study

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## Abstract

**Aim:** To assess third and fourth cervical vertebra morphologic dimensions as per the cervical vertebral maturation stage proposed by Hassel and Farman from 7 to 18 years.

**Materials and methods:** A cross-sectional radiographic study was conducted on 264 participants within an age-group of 7–18 years who were further categorized into six subgroups having an interval of 1 year and 11 months chronologic age. The maturation stage and morphometric evaluation of the cervical vertebra were assessed for the same patient. The maturation stage was assessed as per the morphologic classification given by Hassel and Farman. The morphometric evaluation was assessed by measuring the anterior (AH3 and AH4), vertebral body (H3 and H4), posterior heights, and anteroposterior width (APW3 and APW4) of third and fourth cervical vertebra in millimeters which was carried out with the help of "IC measure software." One-way analysis of variance (ANOVA), Tukey's multiple comparison, and Spearman's correlation coefficient were utilized to determine the significance and correlation between the vertebral maturation and millimetric measurement between age-groups. The multiple comparison levels were set at 0.05 level of significance.

**Results:** A high significant correlation was observed between PH3 and APW3 ($r$, 0.737$^{**}$). Moderate significant correlation was observed with H3 and PH3 ($r$, 0.605$^{**}$, 0.640$^{*}$), and APW3, APW4 ($r$, 0.534$^{**}$, 0.614$^{*}$) in the initiation stage in both the vertebrae; AH3, H3 ($r$, 0.498$^{**}$) and H3, APW3 ($r$, 0.576$^{**}$) in deceleration stage. A negative moderate significant correlation between AH4, PH4 ($r$, –0.691$^{**}$) was observed in the deceleration stage. The transition, maturation, and completion stages did not reveal any significant correlation.

**Conclusion:** Significant morphologic difference was observed among all the stages of vertebral maturation. Higher dimensions were observed among males. Anteroposterior width had the highest dimension. Significant morphometric changes were observed in stages of maturation and transition stages.

**Clinical significance:** The dimensions of anterior, vertebral, and posterior height of the third and fourth cervical vertebra can supplement in identifying the precise morphologic classification whenever there is an overlap in the opinion of staging cervical vertebral maturation based on Hassel and Farman.


**Keywords:** Cervical vertebra, Hassel and Farman method, Morphometric.

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## Introduction

Carnal maturation traits, stature, weight, and skeletal maturation are routinely used to recognize and scrutinize the stages of growth of an individual. Skeletal development is totally dependent on the form and shape of cervical vertebrae. Assessment of skeletal age is done by analyzing cephalogram rather than hand wrist radiograph in a routine clinical procedure to avoid excess radiation exposure.[1–6]

The shape and dimensions of cervical vertebrae of a subject are the two major parameters that appraise the cervical vertebral maturity.

Excluding the Atlas, the first five cervical vertebrae differentiation is categorized into five or six maturational stages.[3–5] Shape, height-width ratio, and the depth of the inferior concavity are the morphologic traits that indicate the transformation and assist in the assessment of the cervical vertebral maturation. These features during ontogeny progressed in caudal direction, from C2 to C6. These methods are very easy to apply; however, these methods come with certain limitations.[5] Still, the most commonly used vertebrae are the second, third, and fourth cervical vertebra to determine skeletal maturation. There are many methods of cervical vertebral maturation assessment like Baccetti et al., Hassel-Farman, Seedat-Forsberg, Lamparski,[7] etc.

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McNamara and Franchi pooled their understanding after staging many lateral cephalograms, a more detailed narration of portraying individual six stages of cervical vertebral maturation is required.[8]

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The literature portrayed that newer quantitative equations were derived for calculating the cervical vertebral bone age. Mito et al.[9] derived a formula for cervical vertebral bone age.[10,11] Formulas have been developed in Brazilian subjects to assess reliability. They derived the formula using dimensions like the anteroposterior width, anterior, vertebral body, and posterior height.

The change in shape of the vertebra has an impact on the dimensions of the vertebra. The dimension of the vertebra can be appraised in terms of anterior (AH), vertebral (H), posterior height (PH), and anteroposterior width (APW). We could not find any literature that appraised the morphology of the cervical vertebra in terms of dimensions as per the morphologic classification of cervical vertebral maturation stage. It is observed that morphologic classification is as per the opinion of the specialist. A routine encounter of overlap in the process of identification of the maturation stage as per the morphologic stage is observed which advocates regular training for precise diagnosis.

Therefore, the aim of this study was to determine the interrelationship of the anterior, vertebral, posterior height, and anteroposterior width of the third and fourth cervical vertebra to the maturational stages of the cervical vertebra as per Hassel and Farman among 7–18 years individuals.

## Materials and Methods

A total of 264 patients having an age range of 7–18 years were selected with their consent. Patient with no medical history or any other surgical disease had been included in the study. All the cephalograms of participants undertaken for assessment included in the study were captured by the same machine under a standardized protocol in the Department of Oral Medicine and Radiology.[12] Any history of bone disease or deformities, trauma or disease to face, and/or neck, etc., was excluded. Since the age range of the participants was large, the patients' lateral cephalograms were divided into six groups having 44 (22 male and 22 female) cephalograms in each group, having an age interval of 1 year and 11 months (7 years 1 month to 8 years 11 months, 9 years 1 month to 10 years 11 months, 11 years 1 month to 12 years 11 months, 13 years 1 month to 14 years 11 months, 15 years to 16 years 11 months, 17 years to 18 years 11 months). The participants' age ranged from 7 to 18 years which provided the advantage of inclusion of all the stages of vertebral maturation.

The guidelines of Hassel Farman's method were carried out for assessing the maturational stage. Both the third and fourth cervical vertebra of all the patients were traced and matched to the most nearing stage of maturation (Fig. 1) for 30 lateral cephalograms, selected randomly. The millimetric measurement of both the vertebrae was measured using the digital software ("IC measure," "Germany") (Fig. 2). Before subjecting it to the maturational staging as per the Hassel and Farman's method, Cohen's kappa statistical test was carried out to assess the interobserver agreement between two judges. A value of 0.81–1.00 suggested an almost perfect agreement according to Cohen. A value of 0.85 was obtained.

Mean and standard deviation were calculated for the third and fourth cervical vertebra in terms of the anteroposterior width (APW3, 4), anterior (AH3, 4), middle (H3, 4), and posterior height (PH3, 4), respectively. One-way ANOVA and Tukey's *post-hoc* test were used to determine the significance. Mean plot was utilized to determine the variations of the sizes of the third and fourth cervical vertebra.

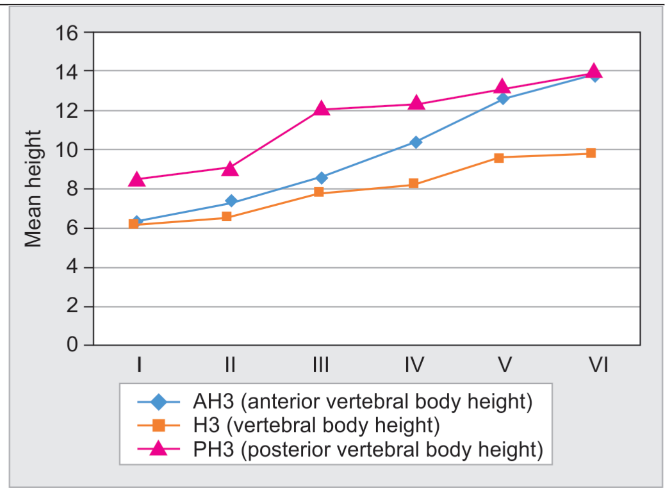


**Fig. 1:** Illustration of tracing of second, third, and fourth cervical vertebrae

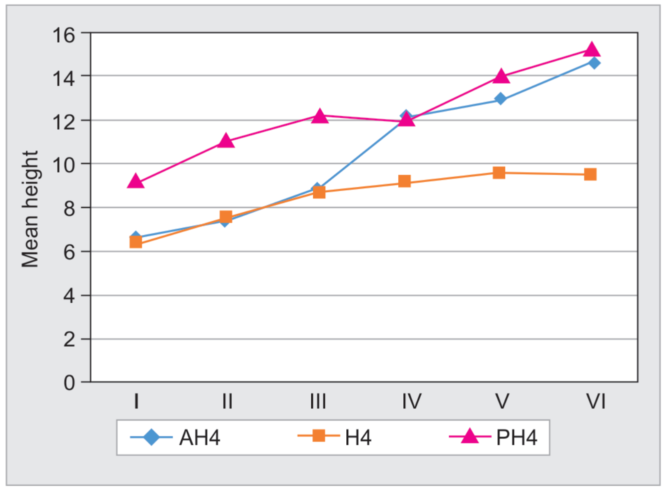


**Fig. 2:** Illustration of measurements used to determine cervical bone age

**Table 1:** Frequency distribution of cervical vertebral maturation

| | *Gender* | | |
|---|---|---|---|
| *CVMI stage* | *Male* | *Female* | *Total* |
| I | 20 | 10 | 30 |
| II | 27 | 24 | 51 |
| III | 30 | 22 | 52 |
| IV | 10 | 17 | 27 |
| V | 21 | 20 | 41 |
| VI | 24 | 39 | 63 |
| Total | 132 | 132 | 264 |

## Observations and Results

On appraisal of the cervical vertebral maturation distribution, the majority of samples included in the study revealed that the transition stage was followed by the acceleration, completion, maturation, initiation, and deceleration stages among males. Among females, the majority of the samples revealed that the completion stage was followed by the acceleration, transition, maturation, deceleration, and initiation stages (Table 1). When the

**Table 2:** Mean values of dimensions of third and fourth cervical vertebra

| *Stage of cervical vertebral maturation* | *Gender* | *AH3 (anterior vertebral body height in mm)* | *H3 (vertebral body height in mm)* | *PH3 (posterior vertebral body height in mm)* | *APW3 (antero-posterior-vertebral body length in mm)* | *AH4 (anterior vertebral body height in mm)* | *H4 (vertebral body height in mm)* | *PH4 (posterior vertebral body height in mm)* | *APW4 (antero-posterior-vertebral body length in mm)* |
|---|---|---|---|---|---|---|---|---|---|
| Stage 1 | Female | 5.06 ± 0.87 | 5.50 ± 0.76 | 7.0604 ± 0.67 | 9.4316 ± 0.84 | 5.8974 ± 0.57 | 5.4869 ± 0.50 | 8.0354 ± 0.64 | 10.563 ± 0.72 |
| | Male | 6.19 ± 0.70 | 6.59 ± 0.22 | 9.09 ± 0.52 | 11.56 ± 0.80 | 6.82 ± 0.71 | 6.61 ± 0.51 | 9.66 ± 0.68 | 12.23 ± 0.43 |
| Stage 2 | Female | 7.09 ± 0.93 | 6.31 ± 0.74 | 9.30 ± 1.56 | 11.78 ± 0.76 | 7.48 ± 0.90 | 7.07 ± 0.67 | 10.93 ± 0.82 | 12.46 ± 1.10 |
| | Male | 7.68 ± 0.94 | 7.19 ± 0.70 | 9.50 ± 1.26 | 11.87 ± 0.84 | 8.10 ± 1.01 | 7.94 ± 0.83 | 11.01 ± 2.85 | 13.16 ± 1.07 |
| Stage 3 | Female | 8.25 ± 1.06 | 7.58 ± 0.78 | 12.30 ± 0.97 | 13.44 ± 1.54 | 8.92 ± 1.01 | 8.36 ± 0.80 | 12.62 ± 1.28 | 14.66 ± 1.72 |
| | Male | 8.98 ± 0.90 | 7.85 ± 1.11 | 12.37 ± 1.24 | 12.72 ± 0.95 | 8.76 ± 1.24 | 8.57 ± 1.36 | 11.80 ± 1.89 | 13.74 ± 1.10 |
| Stage 4 | Female | 10.26 ± 0.84 | 7.98 ± 0.92 | 12.01 ± 0.66 | 12.45 ± 1.41 | 11.22 ± 0.90 | 9.23 ± 1.00 | 12.76 ± 0.83 | 13.79 ± 1.35 |
| | Male | 10.99 ± 0.66 | 8.90 ± 0.84 | 12.97 ± 0.64 | 13.19 ± 0.88 | 13.89 ± 0.55 | 8.81 ± 0.90 | 10.53 ± 0.81 | 14.42 ± 0.72 |
| Stage 5 | Female | 12.213 ± 0.920 | 9.058 ± 0.740 | 12.651 ± 1.154 | 12.756 ± 1.274 | 12.36 ± 80.943 | 10.204 ± 1.046 | 13.730 ± 1.424 | 14.265 ± 1.442 |
| | Male | 12.15 ± 1.53 | 9.36 ± 1.07 | 13.36 ± 1.07 | 15.05 ± 0.99 | 13.36 ± 1.08 | 8.96 ± 1.06 | 14.21 ± 1.17 | 14.16 ± 1.33 |
| Stage 6 | Female | 13.62 ± 0.75 | 9.63 ± 0.94 | 13.61 ± 0.87 | 14.48 ± 1.46 | 14.36 ± 1.25 | 9.13 ± 1.05 | 14.62 ± 0.95 | 15.46 ± 1.16 |
| | Male | 14.60 ± 0.75 | 10.22 ± 1.14 | 14.67 ± 1.17 | 15.03 ± 1.27 | 14.93 ± 0.84 | 9.74 ± 1.17 | 15.76 ± 1.13 | 15.74 ± 1.40 |

**Table 3:** Comparison of dimensions of third and fourth cervical vertebra

| *ANOVA* | *Sig.* |
|---|---|
| AH3 (anterior vertebral body height) | 0.000 |
| Between groups | |
| Within groups | |
| H3 (vertebral body height) | 0.660 |
| Between groups | |
| Within groups | |
| PH3 (posterior vertebral body height) | 0.000 |
| Between groups | |
| Within groups | |
| APW3 (antero-posterior-vertebral body length) | 0.000 |
| Between groups | |
| Within groups | |
| AH4 (anterior vertebral body height) | 0.000 |
| Between groups | |
| Within groups | |
| H4 (vertebral body height) | 0.000 |
| Between groups | |
| Within groups | |
| PH4 (posterior vertebral body height) | 0.000 |
| Between groups | |
| Within groups | |
| APW4 (antero-posterior-vertebral body length) | 0.000 |
| Between groups | |
| Within groups | |

dimensions of both cervical vertebrae were analyzed according to cervical vertebral maturation stages, it was observed that as the stage of maturation increased, the dimensions of the vertebra also increased in height and width. Males depicted a larger dimension in both cervical vertebrae (Table 2). The dimensions of both the cervical vertebra were evaluated both within and between the groups among all the stages of cervical vertebral maturation. Except H3, all the parameters divulge statistical significance (Table 3).

When AH3 was compared among all the stages of cervical vertebral maturation, a significant difference was observed among all the stages of maturation. The height of the vertebral body H3 was also analyzed and a significant difference was observed among all the stages except in stages between initiation, acceleration and transition, and deceleration stages. The PH3 had a nonsignificant difference in the maturation stages of transition, deceleration, and maturation. APW3 also revealed a nonsignificant difference in stages of deceleration, maturation, and completion.

Similarly, the fourth cervical vertebra was analyzed. The AH4 revealed a significant difference among all stages of maturation except stages of deceleration and maturation. Among stages of transition, deceleration, maturation, and completion, the H4 had a nonsignificant difference. A nonsignificant difference among stages of transition, deceleration, maturation, and completion is shown by PH4. APW4 divulges a nonsignificant relation in stages of transition, deceleration, and maturation.

Throughout the stages of maturation, dimensions of both the cervical vertebrae were correlated. In the initiation stage, a moderately significant correlation between the H3, PH3 ($r$, $0.605^{**}$), and APW3 ($r$, $0.534^{**}$), and H4, PH4, and APW4 ($r$, $0.640^{*}$, $0.614^{*}$) was

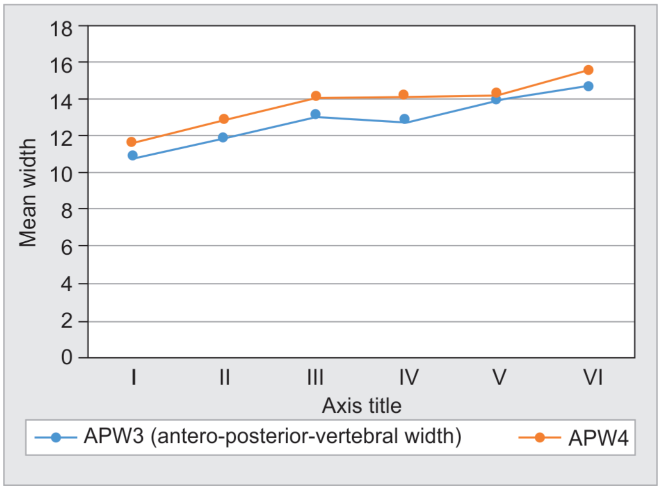


**Fig. 3:** Mean plot of anterior, vertebral, and posterior height of third cervical vertebrae

**Fig. 4:** Mean plot of anterior, vertebral, and posterior height of fourth cervical vertebrae

observed. A highly significant correlation was observed between PH3 and the APW3 (*r*, 0.737**).

When the acceleration stage was appraised, a moderately significant correlation was observed between AH3 and H3 (*r*, 0.498**). The appraisal of the deceleration stage revealed a moderately significant correlation between the H3 and APW3 (*r*, 0.576**). A negative moderate significant correlation was observed between AH4 and PH4 (*r*, –0.691**).

The analysis of the transition, maturation, and completion stage revealed that no moderate-to-high significant correlation was observed among all the parameters.

The mean plots were derived based on the observation of heights made on each radiograph. A positive incline was observed with AH3, H3, and AH4 (Figs 3 and 4). A flat incline was observed for PH3 and a negative incline for APW3 and PH4 during the conversion from the transition stage to deceleration stage (Figs 3 to 5). A negative incline was also observed for H4 as the maturation progressed from the maturation stage to completion stage (Fig. 4). A flat curve was observed with APW4 as the maturation progressed from the transition stage to maturation stage (Fig. 5).

**Fig. 5:** Mean plot of anteroposterior width of third and fourth cervical vertebra

## Discussion

The growth of an individual is a consequence of the metamorphosis of a given bone according to his/her own rhythm of growth.[11] Literature suggested that the metamorphosis of the cervical vertebra is subjected to the change in the shape and size from birth till maturity.[2]

As advocated by Baccetti et al., the morphologic changes of second, third, and fourth cervical vertebrae were adequate to assess skeletal maturation.[5] For obtaining high diagnostic accuracy and intrarater repeatability in the visual assignment of the CVMI stages, it is important to get trained regularly.[10]

Due to low reproducibility and being individualistic, current cervical vertebral maturation qualitative methods have been disapproved. To analyze the cervical vertebral maturation quantitatively, mill metric evaluation in terms of height and width is needed.

When the literature was appraised, mill metric evaluation in terms of height and width of the cervical vertebra was done to evaluate the regression equation in order to assess the skeletal maturity in the form of a regression equation.[9] Although the quantitative evaluation of the cervical vertebra based on the stages of maturation of the cervical vertebra was not observed, the manual method of evaluation would be cumbersome and the measurement would be restricted to a single decimal number arbitrarily. Hence, digital software was utilized for determining the height and width of the cervical vertebra.

Baccetti et al. suggested that the third and fourth cervical vertebra were more clearly visible on the lateral cephalogram even when the patient was advised to wear the thyroid collar. Hence third and fourth cervical vertebra were utilized for the millimetric evaluation of the cervical vertebra as per the maturation of morphologic classification.

When the stage of maturation was evaluated based on the chronological age, initiation was not observed among the participants included in the study. For acceleration stage majority of the female participants were observed in 7–8 years 11 months groups and 9–10 years 11 months for males. Similarly for transition stage, 9–10 years 11 months was observed among females and 7–8 years 11 months for males. The chronologic age for deceleration stage was observed to be 11–12 years 11 months for females and

9–10 years 11 months for males. Similarly for maturation stage, maximum females were observed in the age period of 13–14 years 11 months and 11–12 years 11 months for males. Completion stage of maturation was observed among 15–16 years 11 months for females and 17–18 years 11 months for males. The observation made in this study was homogeneous to the observations made by Madhu.[13]

Skeletal maturity assessment plays a significant role in determining the treatment timing for correcting the skeletal relation utilizing the inherent growth potential of an individual. Tanner et al. depicted that the peak height velocity take place, on average, around 12 years in girls and 14 years in boys. Literature suggests that the maximum skeletal changes were observed during the maturation stages of transition and deceleration indicating the maximum amount of growth potential of an individual.[14,15] Observations of this study were in harmony with the above-mentioned results.

The majority of the parameters revealed a positive moderately significant correlation in the stages of initiation, acceleration, and deceleration. In the initiation stage, a highly significant correlation was observed between posterior height and the anteroposterior width of the third cervical vertebra. Although a negative moderately significant correlation was seen between the anterior and posterior height for the fourth cervical vertebra in the deceleration stage, we could not find any literature to appraise the observations made in this study. A probable reason attributed for such an observation could be differential growth occurring in the vertebra as per the morphologic stages of maturation.[3]

An increase in dimension was observed with AH3, H3, and AH4 as the vertebrae maturation progressed from initiation to completion (Figs 3 and 4). The dimensions PH3 during the transition to deceleration stages and APW4 from the transition to maturation stages were observed to be relatively stable (Figs 3 and 5). The dimensions APW3 and PH4 decreased in the transition to deceleration stages (Figs 4 and 5); H4 in the maturation to completion stage (Fig. 4). We could not find any literature on this pretext to compare and correlate. Based on the observation of this study, it can be inferred that AH3, AH4, and H3 denoted a harmonious relation to morphologic classification as given by Hassel and Farman. Hence when any overlap of opinion exists while assessing the morphologic vertebral maturation, additional weightage should be given to the anterior dimensions of the third and fourth cervical vertebra.

The results of the present study should be interpreted cautiously as the design of the study involved analyzes of the data collected at a given point of time across a sample population or a predefined subset that limits investigating the growth of an individual. Further studies are required to determine the role of individual dimension in the individual maturational stages of morphologic classification employed for cervical vertebra.

## Conclusion

On morphometric evaluation, it was observed that higher dimensions of vertebra were observed among males. As the maturation stage of the vertebra increased, the morphologic dimensions were also increased. Of all the stages of cervical vertebral maturation, only anteroposterior width had the largest dimension among both the cervical vertebra. However, only in initiation both the third and fourth cervical vertebra revealed a concordance in dimensions. The dimensions of the fourth cervical vertebra had a higher inter-relation to the deceleration stage. The synchronicity of increase in dimensions was observed from initiation to deceleration stages.

## References


1. Lampalski D. Skeletal age assessment utilizing cervical vertebrae [Master of Science Thesis]. University of Pittsburgh; 1972.
2. O'Reilly MT, Yanniello GJ. Mandibular growth changes and maturation of cervical vertebrae: a longitudinal cephalometric study. Angle Orthod 1988;58(2):179–184. DOI: 10.1043/0003-3219(1988)058<0179:MGCAMO>2.0.CO;2.
3. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dentofacial Orthop 1995;107(1):58–66. DOI: 10.1016/s0889-5406(95)70157-5.
4. Franchi L, Baccetti T, McNamara Jr JA. Mandibular growth as related to cervical vertebral maturation and body height. Am J Orthod Dentofacial Orthoped 2000;118(3):335–340. DOI: 10.1067/mod.2000.107009.
5. 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(4):316–323. DOI: 10.1043/0003-3219(2002)072<0316:AIVOTC>2.0.CO;2.
6. Baccetti T, Franchi L, McNamara JA Jr. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Semin Orthod 2005;11(3):119–129. DOI: 10.1053/j.sodo.2005.04.005.
7. Lamparski DG, Nanda SK. Skeletal age assessment utilizing cervical vertebrae. Craniofacial Growth Ser 2002;39:171–184.
8. McNamara Jr JA, Franchi L. The cervical vertebral maturation method: a user's guide. Angle Orthod 2018;88(2):133–143. DOI: 10.2319/111517-787.1.
9. Mito T, Sato K, Mitani H. Cervical vertebral bone age in girls. Am J Orthod Dentofacial Orthop 2002;122:380–385. DOI: 10.1067/mod.2002.126896.
10. Perinetti G, Caprioglio A, Contardo L. Visual assessment of the cervical vertebral maturation stages: a study of diagnostic accuracy and repeatability. Angle Orthod 2014;84(6):951–956. DOI: 10.2319/120913-906.1.
11. Shamsher RM, Ijaz AB, Orth MC. Age of high growth rate in adolescent period of development. Pak Oral Dent J 2005;25:53–58.
12. Kulkarni N, Dave B. Correlation of cervical vertebral bone age and Demirjian's stages of dental maturation for lower left permanent canine and second molar. J Contemp Dent Pract 2019;20(4):471–475. DOI: 10.5005/jp-journals-10024-2541.
13. Madhu S. Correlation between cervical vertebrae maturation and chronological age: a radiographic study. World J Dent 2017;8(5):382–385. DOI: 10.5005/jp-journals-10015-1470.
14. Tanner JM, Whitehouse RH, Marubini E, et al. The adolescent growth spurt of boys and girls of the Harpenden growth study. Ann Hum Biol 1976;3(2):109–126. DOI: 10.1080/03014467600001231.
15. Singh S, Singh M, Saini A, et al. Timing of myofunctional appliance therapy. J Clin Pediatr Dent 2010;35(2):233–240. DOI: 10.17796/jcpd.35.2.9572h13218806871.