Original Article

Morphological comparison of cervical vertebrae in adult females with different sagittal craniofacial patterns: A cross-sectional study

ABSTRACT

Introduction: Cervical vertebral maturation (CVM) methods have gained popularity to assess growth and development status for orthodontic patients. Although craniofacial and craniocervical structures are known to be associated, there is no evidence in the literature if this relation might negatively affect the accuracy of CVM assessments. Therefore, this study aimed to comparatively investigate the sizes of the 2nd, 3rd, and 4th cervical vertebrae in adult females (radius union stage of skeletal maturity) who have different sagittal skeletal patterns.

Materials and Methods: A cross-sectional study was conducted, and 151 lateral cephalometric radiographs of adult female patients were assessed in the study. Patients were assigned to three groups according to ANB angle. Parameters including concavity depth at the lower border of the 2nd, 3rd, and 4th cervical vertebrae and base length, upper border length, body length, posterior height, anterior height, and body height of the 3rd and 4th cervical vertebrae bodies were measured. One-way analysis of variance was used for between-group comparisons.

Results: No statistically significant differences were found between groups in terms of concavity depth at the lower borders of the 2nd, 3rd, and 4th cervical vertebrae ($P > 0.05$). Base length, upper border length, body length, posterior height, anterior height, and body height of the 3rd and 4th cervical vertebrae were also similar between groups ($P > 0.05$).

Conclusions: The results of this study supports that sagittal craniofacial pattern has no effect on the accuracy of using the methods assessing CVM and calculating cervical vertebral age.

Key words: Cephalometrics; cervical vertebrae; growth and development; sagittal growth.

Introduction

Evaluation of dentofacial growth is critical for the treatment planning in individuals with skeletal orthodontic anomalies. Maturity status of the patient needs to be accurately evaluated to predict future growth potential, which may help or complicate to achieve goals in orthodontic and/or orthopedic treatment. Since considerable chronological variation is known to occur among individuals in the timing of certain growth periods, biological age assessments have become necessary to assess growth. Even though the most accurate method to assess the growth status of an individual patient is to monitor the amount of his/her increase in body height at certain time intervals,[1] this approach is not that useful in clinical environment as it does not provide information about the pace or amount of future growth.[2] Some other indicators that have been proposed to assess growth and development status include sexual development

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indicators such as voice changes or menarche[3] and dental development indicators.[4] These approaches also proved to be useless in the orthodontic clinic since sexual development signs often appear during the cessation of the pubertal growth spurt and dental age is not reliable at all because of the large inter individual variation among patients.[5]

Skeletal age assessment has been proved to be the most convenient way to predict individual growth status.[6] Skeletal maturation methods are based on the radiographic features of some part of the body, and in orthodontics, this has been the hand and wrist for the most part. Hand-wrist radiographs were extensively studied and several methods were introduced by different researchers to assess growth.[5,7,8] Skeletal age assessment using hand-wrist radiographs was clearly the gold standard until Lamparski's (1972) study which have demonstrated that morphological changes in cervical vertebrae correlates to the stages derived from hand-wrist radiographs, thus can be used in determining skeletal maturity.[9]

Several modifications for different cervical vertebral maturation (CVM) methods have been developed until today. Two main approaches to examine maturity from cervical vertebrae can be defined as: (1) Visual examinations as suggested by Hassel and Farman and Baccetti *et al*. and (2) regression formulas as suggested by Mito *et al*. and Chen *et al*.[10-13] CVM have some advantages over hand-wrist radiographs since vertebrae commonly appear on lateral cephalometric radiographs so a separate diagnostic record with radiation dose to the patient can be avoided.[14] However, hand-wrist radiographs are still being used in some practices because there are questions about the accuracy of CVM methods.[15,16]

Another potential problem when assessing growth status from cervical vertebrae appears when one looks into the literature. It has been repeatedly reported that an association exists between craniocervical and craniofacial morphology.[17-19] Indeed, recent studies about the vertebral morphology among different skeletal craniofacial patterns revealed some differences,[20,21] which in turn may affect the accuracy of CVM methods. Along with this, there is evidence that patients with different sagittal patterns also have different maturation patterns both in timing and in intensity as well.[22] Therefore, those studies showing differences in vertebral morphology between skeletal patterns might be misleading in terms of CVM assessment since the inclusion of subjects were performed based on chronological age. There is a need to better understand vertebral morphology between different sagittal craniofacial patterns without the interfering effects of growth. The present study aimed to investigate the morphologies of 2nd, 3rd, and 4th cervical vertebrae in female adults at radius union (Ru) stage of skeletal maturity with different sagittal skeletal growth patterns. The null hypothesis is defined as "there are no differences in certain vertebral measurements among adult females with different sagittal craniofacial patterns."

Materials and Methods

A cross-sectional study was planned. Ethical approval was granted from the, Faculty of Medicine, Ethical Committee (Reference No: B.30.2.YYU.001.00.00/33). A total of 151 females at Ru stage, who have applied for the treatment between August 23, 2010 and June 13, 2014, were enrolled in the study. Informed consent forms stating that diagnostic material could be used for research purpose were obtained from all participants.

Individuals who had syndromes such as ectodermal dysplasia, those who had undergone orthodontic treatment in the past, and of whom pretreatment hand-wrist radiographs and lateral cephalometric radiographs were of poor quality, were excluded from the study.

Hand-wrist radiographs were examined according to the Fishman maturation prediction method (FMP). It was accepted that the adolescent growth of the individual is completed in the Ru stage (Skeletal maturity indicators – 11th stage) of skeletal maturity, when fusion is seen in the epiphysis and diaphysis of the radius bone.[5]

On the lateral cephalometric radiographs of females at Ru stage; ANB angle was measured and the individuals were divided into three groups according to the sagittal skeletal pattern: Class I (ANB; 0°–4°), Class II (ANB; >4°), and Class III (ANB; <0°).

The points presented at Figure 1 were marked on the bodies of the 2nd, 3rd, and 4th cervical vertebrae. The distance between these points, which are shown in Table 1 was measured in mm.

All measurements performed on the cephalometric radiographs, which were calibrated using Nemoceph® NX 2005 (Nemotec, Madrid, Spain) software, were done by a single researcher (C.A.).

In order to determine the reliability of the measurements, same measurements were repeated in randomly selected 20 lateral cephalometric radiographs 2 weeks.

Statistical analyses were done using NCSS (Number Cruncher Statistical System) 2007 and PASS (Power Analysis and Sample Size) 2008 Statistical Software (UT, USA) package program.

Intraclass correlation coefficients were calculated on retraced cephalograms to assess the reliability of the measurements. Kolmogorov–Smirnov tests were used to assess the normality of the data. In addition to descriptive statistical methods (mean, standard deviation), one-way analysis of variance was used for between-group comparisons. The level of significance was set to be $P < 0.05$ for all statistical analyses.

Results

Intraclass correlation coefficients of the measurements performed on 20 lateral cephalometric radiographs, which were reevaluated to assess the reliability of measurements, are demonstrated in Table 2. The reliability coefficients of the measurements was higher than 0.92 (0.924–0.977) in all parameters excluding the length of the upper border of the 3rd cervical vertebra (0.896).

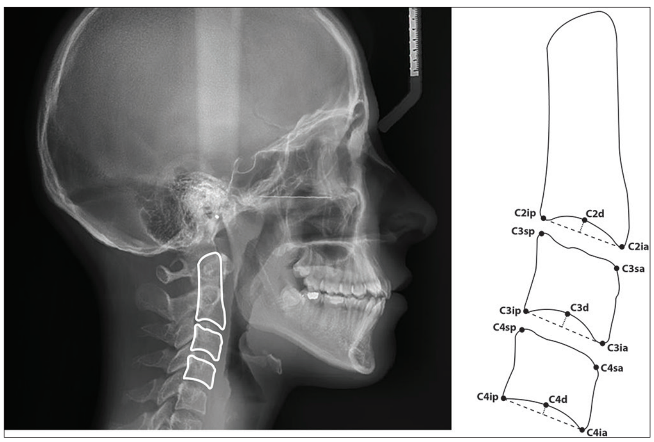

Figure 1: The points marked on the bodies of the 2nd, 3rd and 4th cervical vertebrae

Table 1: Measurements performed on cephalometric radiographs

Measurements	Explanations
Length of upper border	Distance between the Points sp and sa
Length of vertebral base	Distance between ip and ia Points
Vertebral body width	Width of the vertebral body measured from the middle
Anterior height	Distance between the Points sa and ia
Posterior height	Distance between the Points sp and ip
Height of the vertebral body	Height of the vertebral body measured from the middle
Concavity depth at the lower border	Perpendicular distance of Point D to the Points ip and ia

sp - Superior posterior; sa - Superior anterior; ip - Inferior posterior; ia - Inferior anterior

Mean chronological ages of the individuals that form the study groups are demonstrated in Table 3. It was found that there was no statistically significant difference between the mean chronological ages of the individuals among study groups ($P > 0.05$).

Between-group comparisons of morphological parameters of the 2nd, 3rd, and 4th cervical vertebrae are demonstrated in Table 4. No statistically significant difference was found between the groups in terms of concavity depth at the lower border of the 2nd cervical vertebra ($P > 0.05$).

It was determined that there was no statistically significant difference in the body height, body width, upper border length, vertebral base length, anterior height, posterior height, and concavity depth at the lower border of the 3rd cervical vertebrae between groups ($P > 0.05$).

There was also no statistically significant difference in the body height, body width, upper border length, vertebral base length, anterior height, posterior height, and concavity depth at the lower border of the 4th cervical vertebrae between groups ($P > 0.05$). *Post hoc* power of the tests varied between 0.702 and 0.823.

Discussion

Increases occur in vertical height,[6,12,23,24] horizontal length,[6,12,23,24] and concavity depth at the lower border[6,23] of cervical vertebral body during skeletal maturation under the influence of environmental and genetic factors.[24] It has been demonstrated in the literature that there are significant differences between head and cervical posture among different craniofacial configurations.[25] At this point, investigation of the possible effects of skeletal pattern on cervical vertebrae-related parameters, without the influence of growth, was considered necessary, as it would eliminate the question marks in accepting cervical vertebral age as an indicator of overall maturation, and accordingly, this study was planned.

Females at Ru stage of skeletal maturation who have completed adolescent growth according to FMP were included in the study to clear the effects of growth- and gender-related error on the study outcomes. FMP was preferred to assess hand-wrist radiographs because of its easy application and proven validity.[2,13,26] Morphological measurements in cervical

Table 2: Intraclass correlation coefficients

	Length of upper border	Length of vertebral base	Posterior height	Concavity depth at the lower border	Height of posterior margin
C3	0.896 (0.812-0.921)	0.925 (0.888-0.965)	0.933 (0.899-0.983)	0.955 (0.858-0.959)	0.926 (0.876-0.979)
C4	0.924 (0.892-0.954)	0.937 (0.911-0.989)	0.958 (0.932-0.977)	0.977 (0.926-0.993)	0.935 (0.911-0.979)

vertebrae were performed using parameters related to the 2nd, 3rd, and 4th cervical vertebral bodies as recommended by Baccetti *et al*.[6,11] and Mito *et al*.[12] First and fifth vertebrae were excluded for the same reasons with the CVM methods; examination of the 1st cervical vertebral body is difficult, and the 5th cervical vertebral body is not always wholly contained within imaging borders.[12]

The length of upper border and vertebral base, and posterior and anterior height of the 3rd and 4th cervical vertebrae bodies are some of the determinants of CVM method, developed by Baccetti *et al*.[11] There were no statistically significant differences between the groups in any of these parameters. The other determinant of this method is the concavity depths at the lower border of the 2nd, 3rd, and 4th cervical vertebrae. No statistically significant differences were observed between the groups at these parameters as well. These results supports the reliability of visual examination-based CVM methods among patients with different sagittal skeletal patterns.

The results of this study also supports the reliability of using regression formulas to assess the skeletal age more precisely even though these methods could be more vulnerable against slight differences between groups which may not even become significant for visual examination. In the regression formula developed by Mito *et al*., it was reported that bone age can be calculated more objectively using the parameters related to vertebral bodies. The method was developed by utilizing a cross-sectional study and validated on the records of 66 female patients without considering their skeletal patterns.[12] Chen *et al*. also published a method which they called quantitative CVM method. Although this approach seems more robust as it was developed utilizing longitudinal data, craniofacial patterns were not considered in the development process as well.[13] However, the results of the present study showed that there were no statistically significant differences between sagittal patterns in terms of width, anterior height and posterior height of the third cervical vertebral body and width, body height, and anterior or posterior height of the fourth cervical vertebral body, which are among the parameters used in these regression formulas.

Table 3: Mean chronological ages of the individuals that form the study groups

	n	Chronological age
Class I	76	19.79±5.52
Class II	50	20.50±3.96
Class III	25	17.83±3.08
P		0.069

The literature includes two studies, which compare the cervical vertebral morphologies of individuals with different sagittal skeletal growth and development patterns. Comparison of the material and methods of these two studies, which were conducted by Baydas *et al*.[20] and Watanabe *et al*.,[21] revealed some differences. Baydas *et al*. included individuals aged 13–15 years in their study.[20] They stated that gender- and growth-related variations of the individuals influenced the outcomes of the study.[20] Considering these variations, Watanabe *et al*.[21] included females aged between 19 and 41 years in the study and reported that the height of the atlas dorsal arch is affected by the sagittal skeletal pattern. However, morphological evaluations were limited to the 1st cervical vertebra.[21] This present study was designed to compare the morphologies of the 2nd, 3rd, and 4th cervical vertebrae of female individuals in Ru stage of maturity to avoid potential errors that might emerge from growth- or gender-related differences among participants. Results of this study revealed no statistically significant difference between

Table 4: Comparison of the measurements between groups - ANOVA

	Class I (*n*=76)	Class II (*n*=50)	Class III (*n*=25)	*P*
C2 concavity depth at the lower border	1.87±0.46	1.93±0.48	1.90±0.54	0.813
C3 length of upper border	12.75±1.07	12.74±1.15	13.08±1.20	0.386
C3 length of vertebral base	13.22±1.12	13.01±1.07	13.34±1.09	0.654
C3 anterior height	12.13±1.06	12.04±1.06	12.10±0.91	0.887
C3 posterior height	13.46±1.17	13.60±1.08	13.71±1.01	0.572
C3 concavity depth at the lower border	2±0.46	2.07±0.35	2.04±0.43	0.296
C4 length of upper border	12.69±1.27	12.64±1.19	12.88±1.37	0.734
C4 length of vertebral base	13.41±1.07	13.15±1.1	13.65±1.16	0.154
C4 anterior height	11.96±0.93	11.99±1.16	11.90±1.02	0.935
C4 posterior height	13.47±1.00	13.47±1.10	13.37±1.06	0.908
C4 concavity depth at the lower border	1.89±0.43	1.89±0.37	1.92±0.48	0.951
C3 height of the vertebral body	12.90±0.93	12.98±0.94	12.90±0.84	0.884
C3 width of the vertebral body	13.06±1	12.94±0.87	13.34±0.94	0.230
C4 height of the vertebral body	12.64±0.93	12.77±0.93	12.73±0.81	0.729
C4 width of the vertebral body	13.18±1.09	13.02±0.97	13.32±1.03	0.48

the groups in terms of the morphology of cervical vertebrae. This was not consistent with the findings of Baydas *et al*.[20] who reported differences at the lower border concavity depth of the 2nd and 4th cervical vertebra, and anterior and posterior height of the 4th cervical vertebra. This inconsistency was considered to result from growth-related variations of the individuals that formed the study groups.

The results of this study should be interpreted with caution. The limitations of this study mostly arose from its cross-sectional design. More robust evidence can be gained from longitudinal diagnostic material from both genders and different hand-wrist skeletal maturation stages. Another limitation of this study is the ANB angle that was used to assign patients into sagittal patterns. Although ANB angle is a practical and commonly used cephalometric measurement, it has certain limitations. Assessment of this same hypothesis using shape analysis methods to group patients into craniofacial patterns could be a beneficial approach to overcome this particular limitation.

Conclusions

No statistically significant difference was determined in the parameters related to the bodies of 2nd, 3rd, and 4th cervical vertebrae among females in Ru stage of skeletal maturity with different sagittal skeletal growth and development patterns. The results of this study support that sagittal skeletal pattern has no effect on the accuracy of CVM assessments and cervical vertebral age calculations.

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Conflicts of interest
There are no conflicts of interest.

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