Original Article

Predictive accuracy of estimating mandibular growth potential by regression equation using cervical vertebral bone age

ABSTRACT

Introduction: The maturational changes both in size and shape of cervical vertebrae had been widely used not only to assess skeletal maturity but also to predict the same using regression equation. Thus, the aim of this cross-sectional study was to check the predictive accuracy of estimating mandibular growth potential in the North Indian population by regression equation of Mito *et al.*

Materials and Methods: A total of 200 subjects divided into two groups, Group I had 100 adult subjects (18–20 years) and Group II had 100 young subjects (9–14 years) were subdivided according to the gender (50 subjects in each group). Seven linear parameters on cervical vertebral bodies of C3 and C4 were measured to derive cervical vertebral age and applied to the regression equation to estimate the mandibular growth potential in Group II. The mandibular length was measured for both the groups from Co-Gn. The mean value of the actual mandibular length in Group I was statistically evaluated against the corresponding mean value of the predicted mandibular growth potential of Group II.

Results: The actual mandibular length (Group I) and calculated mandibular length obtained by adding mandibular growth potential (from regression equation) to the mandibular length of Group II did not differ significantly for both males and females. Chronological age showed a statistically significant difference and poor correlation with bone age, in Group II.

Conclusion: The regression equation of Mito *et al.* using cervical vertebral bone age has proven to be applicable and accurate in predicting mandibular growth potential in growing young Indian individuals and can be of diagnostic and prognostic value in growth modification procedures in Orthodontics.

Keywords: Cervical vertebral bone age, mandibular growth potential, regression equation

INTRODUCTION

The goal of early orthodontic treatment is to correct the existing or developing skeletal, dentoalveolar, and muscular imbalance to improve the orofacial environment. Assessment of the growth status of the child becomes more important if treatment requires growth modifications by means of myofunctional or orthopedic appliance. Prediction of remaining growth potential and magnitude of craniofacial growth can give valuable information in assisting diagnosis, treatment planning, and evaluation of the outcomes of orthodontic treatment.[1]

Magnitude and timing of human skeletal development has been assessed using physiological parameters including peak growth velocity in standing height, pubertal markers, radiographic assessment of bone maturation, chronological

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age, and staging of dental development. Longitudinal measurements used to calculate peak standing height growth velocity do provide the "gold standard" to assess the validity of growth predictors[2] and is the most valid representation of the rate of overall skeletal growth.

Skeletal maturation staging from the radiographic analysis is a widely used approach to predict the timing of pubertal growth, to estimate growth velocity, and to estimate the proportion of growth remaining.[3] Since a long time, skeletal maturation has been evaluated by the ossification events on the hand–wrist or carpal radiographs which is positively correlated with the stage of growth acceleration of the craniofacial complex. However, hand–wrist radiographs are not a part of routine orthodontic records and require additional exposure to ionizing radiation.

The size and shape of the cervical vertebrae in growing subjects have gained increasing interest as biological indicators of individual skeletal maturity.[2,4] The main reason for the rising popularity of this method is that the analysis of cervical vertebral maturation (CVM) can be performed on the lateral cephalometric radiograph of the patient which is routinely used for orthodontic diagnosis.

Hassel and Farman[4] developed the CVM Index (CVMI) based on the concavities that can be observed in the lower border of the second, third, and fourth cervical vertebrae (C2, C3, and C4) consisting of six of CVM (CVMI 1-6). They also compared it to the hand–wrist skeletal maturation and were highly correlated to skeletal maturation. Mito *et al*.[5] established cervical vertebral bone age as an index for evaluating skeletal maturation and proved that cervical radiographic evaluation was also a reliable method to evaluate skeletal maturation.

The relationship between CVM and mandibular growth changes was studied by O'Reilly *et al*.[6] who suggested that the increment in corpus length, ramus height, and mandibular length was associated with specific maturation stages in the cervical vertebrae. More recently, Baccetti *et al*.[7] confirmed the validity of six CVM stages as biological indicators for both mandibular and somatic skeletal maturity in 24 growing untreated subjects.

According to the result of several clinical studies, the greatest response to the functional appliance occurs during pubertal growth spurts when the mandibular growth is at its peak. Hence, the evaluation of the mandibular skeletal maturation and growth potential of each individual provides information about treatment results in this stage. Further treatment may be required after early orthodontic treatment in class III patients if mandibular growth causes the anterior crossbite relapse. Therefore, predicting the mandibular growth potential for class III malocclusion as early as possible is useful in estimating the severity and deciding the treatment plan of the malocclusion. Another major clinical problem is determining when to apply functional appliance therapy in class II patients. To resolve these problems, the clinicians must be able to accurately predict mandibular growth potential in the growth stage.

The growth potential is defined as the increment from the present length to the final length. Based on the hand–wrist radiographs, five methods are available to predict mandibular growth potential using skeletal maturation as an indicator. Several reports have been published on the prediction of mandibular growth. Mito *et al*.[8] developed a formula to predict mandibular growth potential on the basis of cervical vertebrae bone age in Japanese girls. Chen *et al*.[9] established an equation to predict incremental mandibular length on the basis of cervical vertebrae and compared the corresponding predictive accuracy with the other method.

The purpose of the study is to check the predictive accuracy of the regression equation for estimating mandibular growth potential given by Mito *et al*.[8] on the basis of cervical vertebrae bone age in the North Indian population.

MATERIALS AND METHODS

The sample for the study included a lateral cephalogram of 200 subjects having class I molar relationship in permanent dentition or end-on or mesial step molar relationship in mixed dentition stage (age range of 9–20 years). Patients having any history of bone disease or bone deformities, traumatic lesion, or malformation of cervical vertebrae or jaw bone were excluded. The approval was taken from the Ethical and Research Committee of Babu Banarasi Das College of Dental Sciences, BBDU, Lucknow. A signed informed consent was obtained from each subject as per the guidelines of the University.

Sample distribution

The sample was divided into two groups (Group I and Group II) based on chronological age. Each group was further divided into two subgroups on the basis of gender [Table 1].

Planmeca Proline XC cephalostat (Finland) machine was used to take digital lateral cephalograms of selected subjects. The position of the head of the subject was retained with respect to Frankfort horizontal plane, which was parallel to the floor with the subject in standing position by means of functional head positioner. The subjects were asked to occlude their teeth in maximum intercuspation, i.e., centric occlusion with the relaxed lip position.

Tracing of lateral cephalogram was conducted in a dark room to appreciate the cephalometric landmarks more clearly. Landmarks on the mandible and the cervical bodies were identified and traced.

Following landmarks were located on lateral cephalogram which were previously used in a study conducted in Japan by Mito *et al*.[5]

Landmarks on the mandible: Following landmarks were located on the mandible [Figure 1]

1. Condylon (Co): A point on the condylar head in contact with and tangent to the ramus plane
2. Gnathion (Gn): A point located by taking the midpoint between the anterior (pogonion) and inferior (menton) points of the bony chin.

Landmarks on the cervical vertebral bodies C3 and C4 :Following landmarks were located on cervical vertebral bodies C3 and C4 [Figure 2]

1. C3up (cervical 3 upper posterior): The most superior point on the upper posterior border of the body of C3
2. C3ua (cervical 3 upper anterior): The most superior point on the upper anterior border of the body of C3
3. C3la (cervical 3 lower anterior): The most anterior point on the lower border of the body of C3
4. C3lp (cervical 3 lower posterior): The most posterior point on the lower borders of the body of C3
5. C4up (cervical 4 upper posterior): The most superior point on the upper posterior border of the body of C4
6. C4ua (cervical 4 upper anterior): The most superior point of the upper anterior border of the body of C4
7. C4la (cervical 4 lower anterior): The most anterior point on the lower border of the body of C4
8. C4lp (cervical 4 lower posterior): The most posterior point on the lower border of the body of C4.

Reference lines used in the study :Following reference lines were used [Figure 3]

1. Tangent on the lower border of C3: Tangent drawn at the lower border of C3 passing through points C3la and C3lp named as reference line

Table 1: Distribution of the sample

Groups (*n*=200)	Subgroups	Number of sample (*n*)	Mean age±SD (years)
Group I (control) (*n*=100)	Group I-A (males)	50	18.94±0.84
	Group I-B (females)	50	18.98±0.89
Group II (study group) (*n*=100)	Group II-A (males)	50	11.84±0.79
	Group II-B (females)	50	11.52±1.07

2. Tangent on the lower border of C4: Tangent drawn at the lower border of C4 passing through C4la and C4lp named as reference line.

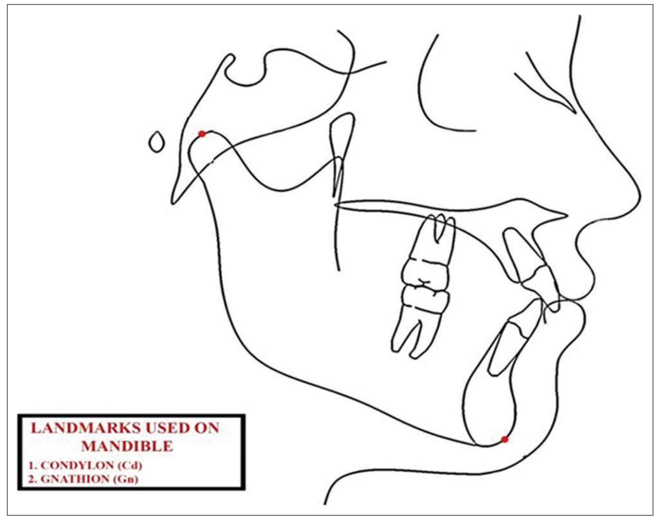


Figure 1: Landmarks used in the study on the mandible

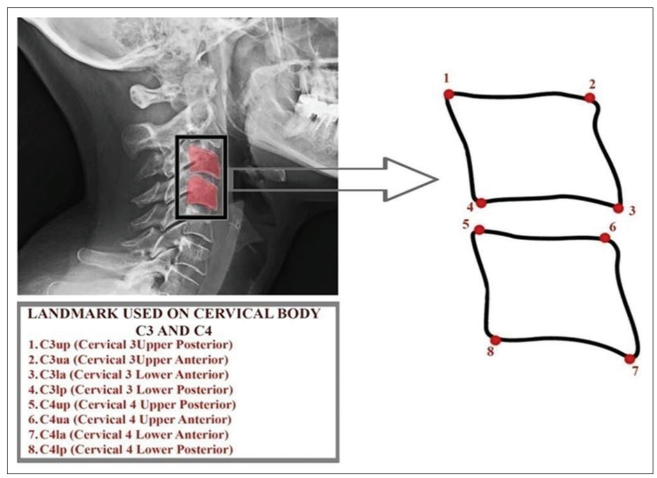


Figure 2: Landmarks used in the study on cervical body of C3 and C4

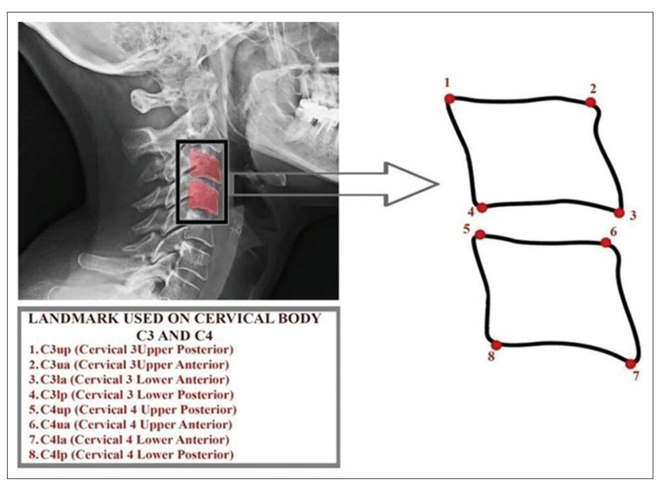


Figure 3: Reference lines used and parameters of cervical vertebral bodies measured on cephalometric radiographs

Parameters measured for the study

Measurement on the cervical vertebrae: Measurements taken on cervical vertebrae are shown in Figure 3

1. AH3 (anterior vertebral body height of the C3): Distance between the point C3ua and the point drawn perpendicular from C3ua to tangent on the lower border C3
2. AP3 (anteroposterior vertebral body length of C3): Anteroposterior distance at the middle of the cervical vertebral body (C3) measured parallel to the tangent on the lower border of C3
3. PH 3 (posterior vertebral body length of the C3): Distance between the point C3up and the point drawn perpendicular from C3up to the tangent on the lower border of C3
4. AH4 (anterior vertebral body height of C4): Distance between the point C4ua and the point drawn perpendicular from C4ua to tangent on the lower border C4
5. AP4 (anteroposterior vertebral body length of C4): Anteroposterior distance at the middle of the cervical vertebral body (C4) measured parallel to the tangent on the lower border of C4
6. PH 4 (posterior vertebral body length of the C4): Distance between the point C4up and the point drawn perpendicular from C4up to the tangent on the lower border of C4.

Measurement on the mandible: Measurement taken on the mandible are shown in Figure 4

1. Mandibular length (mm): Linear distance from Condylon (Co) to Gnathion (Gn).

- Estimation of actual growth potential – Actual growth potential was calculated by subtracting the mean mandibular length (Cd-Gn) of the study group from the mean mandibular length (Cd-Gn) of control group
  - Actual growth potential (mm) = mean mandibular length (mm) of Group I-mean mandibular length (mm) of Group II

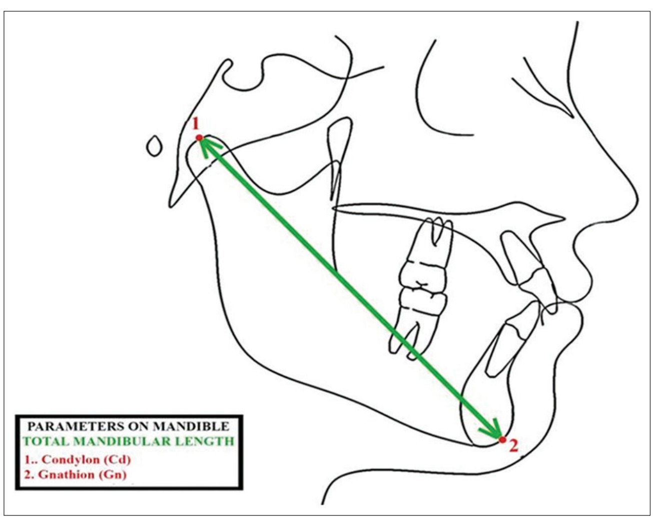


Figure 4: Parameter measured on the mandible

- Calculation of cervical bone age – The cervical vertebral bone age was established for each young subject by measuring the geometrical dimensions of the third and fourth cervical vertebral bodies (CV3 and CV4) and the regression equation given by Mito *et al*.[5]
  - Cervical vertebral bone age (years) = $-0.20 + 6.20 \times AH_3/AP_3 + 5.90 \times AH_4/AP_4 + 4.74 \times AH_4/PH_4$
- Estimation of calculated growth potential – The mandibular growth potential was estimated from the cervical bone age for each young subject by applying the following formula:[5]
  - Mandibular growth potential (in mm) = $-2.76 \times$ cervical vertebral bone age $+ 38.68$.

The mean value of the actual growth potential in the adult groups was statistically evaluated against the corresponding mean value of the predicted mandibular growth potential (calculated by the cervical vertebral bone age) to detect any significant difference between the means to predict the accuracy of regression equation to find the remaining mandibular growth potential.

Pearson correlation coefficients were used to determine the relationship of subjects groups while the correlation was defined as a measure of the strength of a linear relationship between two group variables.

Reliability analysis

The reading of ten randomly selected samples was repeated twice with an interval of 1 week by the single investigator. All the measurements were recorded on Microsoft excel (2007) spreadsheet. The student's *t*-test was used to determine whether there were any significant differences between the two readings. It was observed that there was no statistically significant difference between the two readings.

The cephalograms were traced and parameters selected for the study were measured. Data were tabulated and analyzed in the following manner:

1. Evaluation of bone age from cervical vertebrae measurements of growing subjects
2. Evaluation of mandibular growth potential of growing subjects
3. Calculation of mandibular length of adult subjects
4. Comparison of actual mandibular length and calculated mandibular length.

RESULTS

Table 2 shows descriptive statistics of chronological age and bone age in different groups. Table 3 shows the measured

Table 2: Descriptive statistics of chronological age and bone age in different groups

Groups	Subgroups	Chronological age (years)			Bone age (years)		
		Mean±SD	95% CI for mean		Mean±SD	95% CI for mean	
			Lower limit	Upper limit		Lower limit	Upper limit
Group I	Group I-A (*n*=50)	18.98±0.0843	18.70	19.18	NA	A	NA
	Group I-B (*n*=50)	18.98±0.892	18.73	19.23			
Group II	Group II-A (*n*=50)	11.84±0.792	11.61	12.07	10.88±1.200	10.54	11.22
	Group II-B (*n*=50)	11.52±1.074	11.21	11.83	11.89±0.937	11.63	12.16

CI: Confidence interval, SD: Standard deviation, NA: Not available

Table 3: Descriptive statistics of mandibular length and mandibular growth potential in different groups

Groups	Subgroups	Mandibular length (Cd-Gn) (mm)			Mandibular growth potential (mm)		
		Mean±SD	95% CI for mean		Mean±SD	95% CI for mean	
			Lower limit	Upper limit		Lower limit	Upper limit
Group I	Group I-A (*n*=50)	113.54±6.380	111.73	115.35	NA	NA	NA
	Group I-B (*n*=50)	106.90±5.281	105.40	108.40			
Group II	Group II-A (*n*=50)	103.42±3.239	102.50	104.34	8.52±3.118	7.63	9.41
	Group II-B (*n*=50)	99.18±3.821	98.09	100.27	5.72±2.641	4.97	6.48

CI: Confidence interval, SD: Standard deviation, NA: Not available

Table 4: Statistical comparison of mandibular growth potential in males (Group I-A vs. Group II-A)

Groups	Mandibular growth potential (mm), mean±SD		Level of significance (*P*)
Group I-A (actual)	10.12	6.37	0.149
Group II-A (calculated)	8.53	3.12	

P>0.05: Not significant. SD: Standard deviation

mandibular length of the four groups and the mandibular growth potential of the two study groups, i.e., II-A and II-B. Table 4 shows a statistical comparison between Group I-A and II-B. Group I-A has a mean mandibular growth potential of 10.12 ± 6.37 mm and Group II-A shows mean mandibular growth potential of 8.53 ± 3.12 mm. On application of unpaired *t*-test, a statistically nonsignificant difference was found between the two groups ($P > 0.05$).

Table 5 shows the comparison between the mandibular growth potential of Group I-B and II-B where Group I-B has a mean of 7.72 ± 5.28 mm, whereas Group II-B has a mean of 5.73 ± 2.64 mm. On applying unpaired *t*-test, a statistically nonsignificant difference was found between the two groups ($P > 0.05$).

Table 6 shows correlating chronological age with the bone age, mandibular length, and mandibular growth potential in Group IA. The "*r*" value was found to be 0.283, 0.340, and −0.286, respectively, showing that both the bone age and mandibular length were positively correlated with chronological age, whereas mandibular growth potential was negatively correlated with chronological age. All the parameters were statistically just significant ($P < 0.05$).

Table 7 shows correlating chronological age with the bone age, mandibular length, and mandibular growth potential in Group II-B. The "*r*" value was found to be 0.304*, 0.265, and −0.303, respectively, showing that both the bone age and mandibular length were positively correlated with chronological age, whereas mandibular growth potential was negatively correlated with chronological age. All the parameters were statistically just significant ($P < 0.05$).

DISCUSSION

The growth and development of the human face provides a fascinating interplay between the form and function. The repositioning of the apical bases for the correction of skeletal discrepancies requires the knowledge of craniofacial growth and development. The growth status of the child becomes more important while planning the orthodontic treatment, especially when the treatment requires growth modification by the means of myofunctional or orthopedic appliance. Optimal effectiveness in the use of orthodontic or orthopedic appliances is best attained during the pubertal growth spurt.[5]

To determine the stages of growth, various physiological parameters including chronological age, peak growth velocity in standing height, weight, sexual maturation characteristics, and dental development had been used but are inadequate. Several biological indicators such as hand–wrist radiograph, the morphology of cervical vertebrae, and changes in the middle phalanx of the third finger have been evaluated as potential markers for assessment of an individual's peak growth.[3] Certain bones such as hand, foot, elbow, shoulder, and cervical vertebrae in the body demonstrate an organized event of ossification that can be seen radiologically for determining skeletal maturation by predicting the timing of pubertal growth, by estimating growth velocity, and proportion of remaining growth.[2-4] The classical and most widely used method for skeletal age estimation is the analysis of hand–wrist radiograph, whose validity and reliability have been confirmed in many studies.[3,6,8] Based on the hand–wrist radiographs, five methods are available to predict mandibular growth potential using skeletal maturation as an indicator, i.e., the ossification events method, the growth potential method, the growth percentages method, the growth chart method, and the multiple regression method. However, these methods require expert knowledge and expenditure of time by the operator and their accuracy is not established. Recently, many studies have focused on the evaluation of skeletal maturational changes in both size and shape of cervical vertebrae in growing subjects.[2,4,5] The main reason for increasing popularity of using cervical vertebrae to determine skeletal maturity was that the analysis can be performed on lateral cephalogram that is used routinely in orthodontic diagnosis, with no need of extraradiation exposure as needed for hand–wrist radiographs. Lamparski[2] suggested the morphological changes of the cervical vertebrae to evaluate the skeletal maturation are readily visible on the lateral cephalometric radiograph. Hassel and Farman[4] developed CVMI based on the concavities that can be observed in the lower border of the second, third, and fourth cervical vertebrae. They also compared it to the hand–wrist skeletal maturation and found high correlation between the two methods. The relationship between CVMI and mandibular growth changes was studied by O'Reilly and Yanniello[6] who suggested that the increment in corpus length, ramus height, and mandibular length was associated with specific maturation stages of the cervical vertebrae. Franchi *et al*. confirmed the validity of CVMI stages as biological indicators for both mandibular and somatic skeletal maturity in their consecutive studies.[9-11]

The prediction of mandibular growth potential provides valuable information for treatment planning and evaluating occlusal stability after treatment. According to the results of several clinical studies, the greatest response to the functional appliance occurs during pubertal growth spurt when the mandibular growth is at its peak and this would be the ideal time to use the functional appliance in Class II patients. The early treatment of Class III patients, without predicting the mandibular growth potential can result in relapse with the development of anterior crossbite, later demanding for its correction.[5,8,12] Therefore, predicting the mandibular growth potential for class III malocclusion as early as possible is useful in estimating the severity and deciding the treatment plan of this malocclusion.

Among the various methods available to predict mandibular growth potential, the multiple regression method had been widely used in previous studies. Mitani and Sato attempted to predict mandibular growth potential with bone age, which is determined with hand–wrist radiographs, using Tanner and Whitehouse method.[6,13] They found that the growth potential method was the most accurate means of predicting mandibular growth. Mito *et al*.[8] developed a formula to predict mandibular growth potential on the basis of cervical vertebrae bone age in Japanese girls.

Cervical vertebral bone age is an objective method of evaluating skeletal maturation by measuring the natural maturational changes in the vertebral body of the third and fourth cervical vertebrae. Mito *et al*. in 2002[5] derived a mathematical formula to calculate the individual bone age by a stepwise multiple regression analysis with the chronological age as a dependent variable and the dimensional changes in

Table 5: Statistical comparison of mandibular growth potential in females (Group I-B vs. Group II-B)

Groups	Mandibular growth potential (mm), mean±SD		Level of significance (*P*)
Group I-B (actual)	7.72	5.28	0.056
Group II-B (calculated)	5.73	2.64	

P>0.05: Not significant, SD: Standard deviation

Table 6: Correlation of chronological age with bone age, mandibular length, and mandibular growth potential in Group II A (males)

Correlations	Chronological age (years) (*n*=50)	Bone age (*n*=50)	Mandibular length (*n*=50)	Mandibular growth potential (*n*=50)
Pearson correlation (*r*)	1	0.283	0.340*	−0.286
Significance (two-tailed) (*P*)	-	0.046*	0.016*	0.044*

P>0.05: Not significant, **P*<0.05: Just significant

Table 7: Correlation of chronological age between bone age, mandibular length, and mandibular growth potential in Group II-B (females)

Correlations	Age (*n*=50)	Bone age (*n*=50)	Mandibular length (*n*=50)	Mandibular growth potential (*n*=50)
Pearson correlation (*r*)	1	0.304*	0.265	−0.303*
Significance (two-tailed) (*P*)	-	0.032	0.062	0.032

P>0.05: Not significant, **P*<0.05: Just significant the cervical vertebral bodies as an independent variable. In another study by Mito *et al*., in 2003,[8] this cervical vertebral bone age was used to estimate the mandibular growth potential in Japanese girls. Similarly, cervical vertebral bone age was used in many studies to derive regression equation to predict mandibular growth potential.[11,14] As racial and ethnic differences are seen among various population groups, hence equation derived for one might not be applicable for other population groups. Considering this, the purpose of the present study was to check the predictive accuracy of the regression equation given by Mito *et al*.[5] for estimating mandibular growth potential in the North Indian population.

The sample for this study included lateral cephalogram of 200 subjects with the age range of 9–20 years and was divided into two groups based on chronological age: Group I had 100 adult subjects (18–20 years) with equal number of males (Group I-A) and females (Group I-B), Group II had 100 young subjects (9–14 years) with equal number of males (Group II-A) and females (Group II-B). The groups were divided on the basis of gender because sex-dependent differences are seen for skeletal maturation.

Some reports have shown that Articulare "Ar" is a good substitute for "Co" as it cannot be accurately and consistently located on the closed-mouth lateral cephalogram.[15-17] However, articulare is a constructed cephalometric point that depends on the relation of the ramus of the mandible with the cranial base while condylion is an independent fixed anatomical landmark. Hence in the present study, we used Co as a reference point for measurement of mandibular length from gnathion.

As the cervical vertebra, lower than C4, could not be observed, when a thyroid protective collar was worn for radiation protection hence were not considered in the present study. Baccetti *et al*.[18] showed that only the shape change of C2, C3, and C4 was enough to show skeletal maturation but C2 shows very little morphological change and is difficult to measure hence was neither used by Mito *et al*.[5] and nor in the present study.

The cephalometric tracings were done for cervical vertebrae and for the points required for measuring mandibular length for Group II whereas the points required for measuring mandibular length were only traced for Group I. For both the groups, the mandibular length was measured as the linear distance between the Condylion "Co" (the most superior point on the head of the condyle) and the Gnathion "Gn" (the anteroinferior point on the mandibular symphysis).

The cervical vertebral bone age was established for each young subject by measuring the geometrical dimensions of the third and fourth cervical vertebral bodies (CV3 and CV4) and substituting it in the formula. This cervical vertebral age of Group II-A and Group II-B was substituted in the regression equation given by Mito *et al*.[5] to obtain predicted mandibular growth potential. The calculated total mandibular length for each subject for Group II was established by adding the predicted mandibular growth potential value to the actual mandibular length (Co-Gn) of each subject of the same group. The mean value of this resultant calculated mandibular length for Group II was compared with the mean value of actual mandibular length (Co-Gn) of Group I.

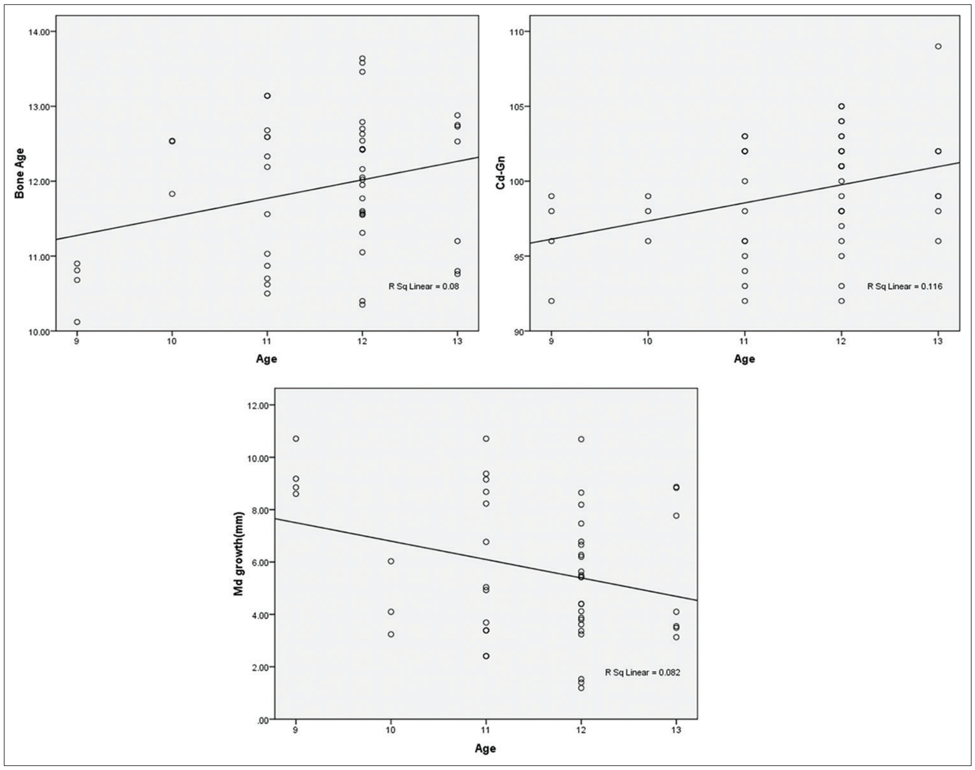
The results of the present study showed that actual mandibular growth potential (Group I) and calculated mandibular growth potential obtained from regression equation (Group II) did not differ significantly for both males ($P > 0.05$) and females ($P > 0.05$).

It has long been recognized that an individual's chronologic age does not necessarily correlate well with his maturation age. Skeletally, one may be retarded or advanced in various degrees of deviation from the actual chronological age.[19] Hence, the chronological age was not taken in to account for the calculation of mandibular growth potential in the present study.

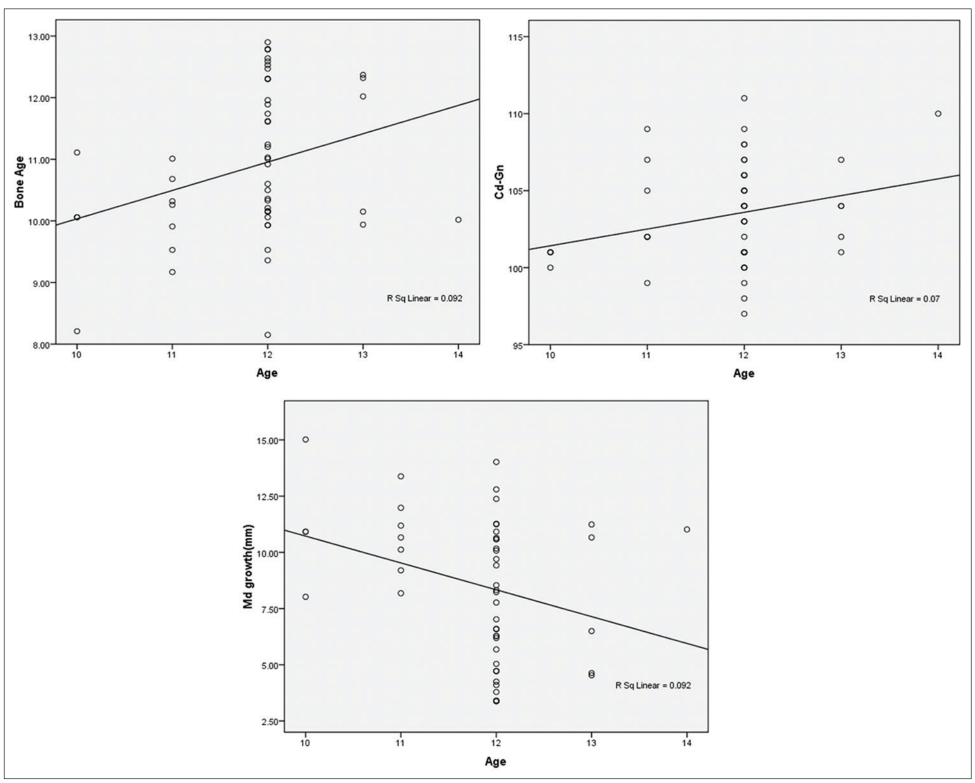
The mean chronological age of the control group (adult males and females) Group I-A was found to be 18.98 ±0.0843 years and 18.98 ± 0.892 years for Group I-B. Among the study group (young males and females), Group II-A had the mean chronological age of 11.84 ± 0.792 years and Group II-B had a mean age of 11.52 ± 1.074 years [Table 2].

The bone age was not calculated for Group I-A and Group I-B as they were adults and had completed their growth with no remaining mandibular growth potential. The bone age calculated on the basis of the formula given by Mito *et al*.[5] showed a mean value of 10.88 ± 1.200 years for Group II-A and 11.89 ± 0.937 years for Group II-B [Table 2]. The correlation between the chronological age and bone age of Group II-A and Group II-B was on the lower side for both males ($r = 0.283$) and females ($r = 0.304$) and the difference was statistically significant ($P < 0.05$) [Tables 6, 7 and Graphs 1, 2].

This finding of our study is in accordance with the common conceptual belief that chronological age is a poor measure of skeletal growth and maturation. Thus chronological age did not show a significant correlation with mandibular length or mandibular growth potential. Similarly, a significant



Graph 1: Scatterogram correlating chronological age with bone age, mandibular length (Co-Gn), and mandibular growth potential in Group II-A



Graph 2: Scatterogram correlating chronological age with bone age, mandibular length (Co-Gn), and mandibular growth potential in Group II-B

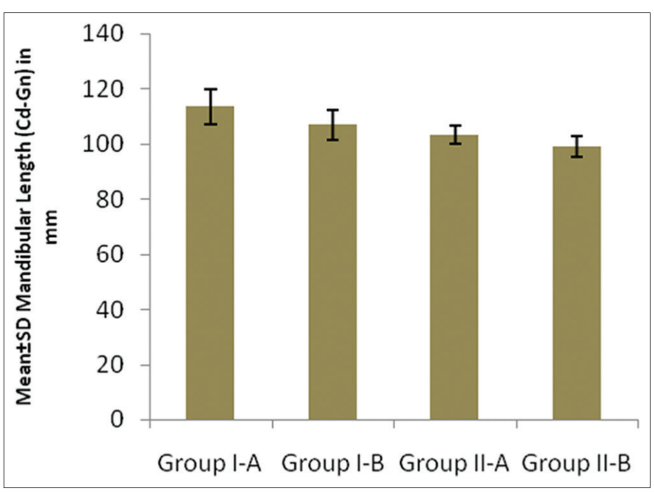
difference between the two ages has been reported by Mito *et al*.[8] for Japanese girls and Tiro *et al*.[15] for the Bosnian population. Our findings were in contrast to previous reports where the close association between chronological age and skeletal maturation assessed by the hand–wrist method was found in Saudi male subjects.[20] In contrast to our study, Alhadlaq *et al*.[14] did not find a significant difference between the cervical vertebral bone age and the chronological age in the Saudi young males and females group. This discrepancy between the studies, however, could possibly be explained by the differences in sample size and ethnic background. Similar to our study, Caldas Mde *et al*.[21] found that chronological age differed significantly with cervical vertebral and bone age for both Brazillian males and females. Cervical vertebral age and bone age did not show a significant difference and either could be used to assess skeletal maturation. In another study by Caldas Mde *et al*.,[22] no significant difference was found between cervical vertebral bone age and chronological age using cervical vertebral computerized analysis. This is contrary to our study because their sample had a wider range distribution, i.e., between 7 and 16 years for both males and females, whereas we had taken the age range to be between 9 and 14 years A wide age range of the sample may affect the correlation result because of the inability of skeletal maturity methods to detect changes in skeletal maturity precisely when the subjects are either too far ahead of or too far past the pubertal growth spurt.

The mandibular length for Group I-A was 113.54 ± 6.38 mm and 106.90 ± 5.28 mm for Group I-B in the present study. The mandibular length (Co-Gn) for Group II was 103.42 ± 3.23 mm for Group II-A and 99.18 ± 3.82 mm for Group II-B [Table 3 and Graph 3].

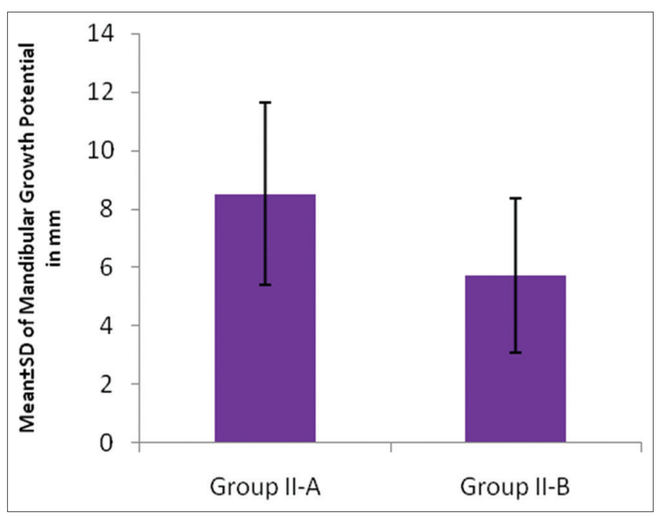
The difference between these measurements was taken to obtain actual growth potential that was 10.12 ± 6.37 mm for males and 7.72 ± 5.28 mm for females [Table 4]; the mandibular growth potential obtained from regression equation for Group II was 8.52 ± 3.11 mm for males and 5.72±+ 2.4 mm for females [Table 3 and Graph 4].

The actual and calculated mandibular growth potential did not differ significantly for both males and females [Tables 4 and 5].

These findings reflect the validity and accuracy of the cervical vertebral bone age method in predicting the mandibular growth potential in the growing North Indian population. Mito *et al*.[5] compared predicted growth potential obtained using cervical vertebral age, chronological age, and bone age with actual potential obtained by regression analysis and found that the difference between actual and predicted potential was highest when using chronological age, followed by cervical age and then bone age. Similarly Alhadlaq *et al*.[14] calculated the mandibular growth potential in 84 young Saudi subjects using an established cervical vertebral bone age method. They found no significant difference ($P < 0.05$) between the mandibular length predicted by the cervical vertebral bone age and the actual mandibular length in the adult group for both males and females. Similar findings of accurate prediction of the mandibular growth potential using cervical vertebral bone age have been reported by Mito *et al*.[8] for Japanese girls. Mito *et al*. conducted a study on 20 Japanese girls divided into two groups; one group was used to derive a formula for predicting mandibular growth potential, the other to compare predicted values with actual values. Each group included subjects in the initial stage of the pubertal. They find that the formula derived from their study might be useful for treating orthodontic patients in the growth stage. Moshfeghi *et al*.[23] conducted a longitudinal study in 33 Iranian girls (9–11 years) to establish an equation to predict incremental mandibular length on the basis of the analysis of the cervical vertebrae and to compare the predictive accuracy with the method by Mito *et al*.[5] They concluded that the cervical vertebral measurements were accurate to predict properly the mandibular growth potential.



Graph 3: Mean and standard deviation of mandibular length (mm) in Group I-A, I-B, II-A, and II-B



Graph 4: Mean and standard deviation of mandibular growth potential (mm) in Group II-A and II-B

Chen *et al*.[11] conducted a study on 23 Japanese girls to establish an equation to predict incremental mandibular length on the basis of the analysis of the cervical vertebrae and to compare the predictive accuracy with other methods. Their results suggest that with the use of cervical vertebral measurements, it may be possible to estimate the mandibular growth potential accurately and the predictive accuracy of this method was established with two other methods is growth percentage and growth potential method. They also established an equation specifically for Class III malocclusion to predict the mandibular growth and established its validity.

The limitation of the present study is its cross-sectional design. For reliable and accurate results, a longitudinal study must be done, but obtaining larger sample sizes for longitudinal studies is difficult and is associated with an increase in the number of radiographic exposures. Within these limitations of the study, it can be suggested that the regression equation by Mito *et al*. can be applied for our population in estimating mandibular growth potential. The clinical application of this study for class II subjects will be during the planning of the growth modification procedure. The estimation of mandibular growth potential will help us in predicting the amount of skeletal changes that can be achieved by functional therapy. In Class III malocclusion associated with mandibular prognathism, the estimation of mandibular growth potential can help us in deciding the type of treatment possible, i.e., orthodontics alone or in combination with the surgical approach.

Further studies in this direction should include more representative sample from other regions of North India to prove the predictive accuracy of this method. To be more significant for clinical application, it might be necessary in the future to conduct studies to improve the predictive precision by increasing the number of subjects, adding those with various skeletal patterns, and making a separate formula for each skeletal pattern, if necessary.

CONCLUSION

1. Predicted mandibular growth potential obtained from the regression equation of young group did not differ significantly to actual growth potential in adults for both males and females
2. Regression equation obtained by cervical vertebral bone age has proven to be applicable and accurate in predicting mandibular growth potential in growing young Indian individuals
3. Chronological age showed a statistically significant poor correlation with bone age, mandibular length, and mandibular growth potential in young and adult North Indian males and females.

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Conflicts of interest

There are no conflicts of interest.

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