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PREDICTION OF MANDIBULAR GROWTH POTENTIAL BASED ON CERVICAL VERTEBRAL DIMENSION CHANGES: A STUDY IN A PAKISTANI ADOLESCENT POPULATION

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ABSTRACT

Objective

To assess the relationship between mandibular growth potential and changes in cephalometric cervical vertebral dimensions in a sample of Pakistani adolescents.

Materials and Methods

A quasi-experimental study was conducted in the Altamash Institute of Dental Medicine in Karachi, Pakistan, from January to June 2021. Lateral cephalograms were performed on 30 subjects (23 females and 7 males, ages 8–18) at two different times. The geometrical dimensions of the third (CV3) and fourth (CV4) cervical vertebral bodies were measured using cephalometric tracings on 8 x 10-inch acetate matte paper. The association between changes in cervical vertebral dimensions and mandibular growth potential was examined using Pearson correlation analysis. Statistical significance was defined as a p-value of less than 0.05.

Results

The mean age of participants was 12.5 ± 2.7 years. Between the initial and final cephalograms, all cervical vertebral dimensions showed a significant change ($p < 0.001$). There was a weak correlation between mandibular length and cervical vertebral changes in females. Males, on the other hand, showed a moderately positive correlation between the overall height of C4 (H4) and ML, a strong negative correlation between the posterior height of C3 (PH3) and ML, and a strong positive correlation between the anterior height of C4 (AH4) and ML.

Conclusion
A strong correlation between mandibular growth potential and cervical vertebral dimensions was observed among males, suggesting that the Cervical Vertebral Maturation (CVM) method is a valid indicator for determining when and how to plan orthodontic interventions.

Keywords
Mandibular length (ML); Bone maturation; Mandibular growth potential; Cervical vertebrae.

INTRODUCTION

For orthodontic diagnosis, treatment planning, and the timing of interventions required to achieve ideal skeletal and dental relationships, the evaluation of mandibular growth potential is essential. Doctors can improve treatment outcomes and lessen the need for more invasive procedures later in life by accurately identifying the stages of mandibular development and preventing skeletal discrepancies, particularly during the growth phase (1).

Hand-wrist radiographs have historically been used to assess skeletal maturation; however, this technique entails additional radiation exposure and might not be regularly available in all clinical settings. Alternatively, the evaluation of cervical vertebral maturation (CVM) using lateral cephalograms has become more popular because it is non-invasive and makes use of radiographs that have already been taken for orthodontic diagnosis (2). Skeletal maturity and growth potential are estimated by the CVM method by examining the morphological and dimensional changes in the third (CV3) and fourth (CV4) cervical vertebral bodies.

Numerous studies have shown a strong relationship between mandibular growth and cervical vertebral morphology, establishing the CVM method as a reliable indicator of skeletal maturity (3, 4). However, the precision and relevance of these evaluations could be impacted by population-specific differences. Growth patterns vary among populations due to a combination of environmental, genetic, and ethnic factors, which emphasizes the significance of region-specific research (5).

A fundamental connection between skeletal development and craniofacial growth patterns was established by O'Reilly et al., who showed that increases in mandibular length are closely linked to maturational changes in the cervical vertebrae (6,7). The cervical vertebral maturation (CVM) method has been further validated by Franchi et al., who have confirmed that it is a reliable indicator of mandibular skeletal maturity (8).

The anteroposterior length of the third cervical vertebral body (AP3) and the posterior height of the fourth cervical vertebral body (PH4) with mandibular length increment (MLI) were found to be statistically significantly correlated negatively in a study by Moshfeghi et al. The correlation coefficients were $r = -0.601$ and $r = -0.533$, respectively ($p < 0.001$ for both) (9). A rise of 2.46 mm in the anterior height of the third cervical vertebral body (AH3), 2.13 mm in the posterior height of CV3 (PH3), 1.94 mm in AP3, 2.25 mm in the anterior height of CV4 (AH4), 2.29 mm in PH4, and 1.86 mm in the anteroposterior length of CV4 (AP4) were among the mean dimensional changes that were also reported in the study. All changes were statistically significant ($p < 0.001$), and the mean mandibular length increment was 13.92 mm (10).

There is limited data available assessing the predictive value of cervical vertebral dimensions for mandibular growth potential in the Pakistani population. This gap highlights the need for a targeted study to ascertain the applicability of the CVM method in Pakistani teenagers and to improve the accuracy of orthodontic growth assessment in this population.

Therefore, the purpose of this study was to use lateral cephalometric radiographs to assess the relationship between changes in cervical vertebral dimensions and mandibular growth potential in a sample of children and adolescents from Pakistan. Based on skeletal maturity indicators, the results are intended to assist clinicians in making well-informed decisions about the type and timing of orthodontic interventions.

MATERIALS AND METHODS

The quasi-experimental study was conducted by the Department of Orthodontics, Altamash Institute of Dental Medicine, Karachi, Pakistan, between January 2020 and January 2021 to assess the correlation between mandibular growth potential and changes in cervical vertebral dimensions. Using a non-probability consecutive sampling technique, 30 orthodontic patients between the ages of 8 and 18 were gathered, consisting of 7 males and 23 females. Using previously published mandibular length values (mean ± SD: 90.87 ± 7.59 mm at baseline and 104.79 ± 4.62 mm at follow-up), the Open-Epi calculator was used to calculate the sample size. This estimated a minimum required size of 4 subjects; however, 30 cases were included to improve reliability. Patients who had been receiving orthodontic treatment for at least two years, had standardized, high-quality lateral cephalometric radiographs available at two time points separated by 12 to 24 months, and had no significant medical conditions or craniofacial trauma were all eligible to participate. Participants had to be in cervical vertebral maturation (CVM) stages I or II at baseline and advance past CVM stage III at follow-up. Individuals with a history of orthodontic treatment or known developmental abnormalities were not included. On acetate matte paper (8 x 10 inches), all lateral cephalograms were traced. Anteroposterior length (AP), anterior height (AH), posterior height (PH), and overall height (H) were among the parameters measured geometrically of the third (CV3) and fourth (CV4) cervical vertebral bodies using the procedure outlined by Mito et al. (2002) (11). The linear distance between the articulare (Ar) and pogonion (Pog) on both radiographs was used to measure mandibular length. The difference between these two time points was used to compute the mandibular length increment (MLI) ($MLI = Ar\text{-}Pog_2 - Ar\text{-}Pog_1$). By subtracting initial values from final measurements, the mean differences in cervical vertebral dimensions were also calculated. Statistical analyses were performed using SPSS version 24. For every cervical vertebral measurement as well as the mandibular growth potential, the mean and standard deviation were determined. Mandibular length and cervical vertebral dimensions baseline and follow-up values were compared using paired t-tests. The relationship between changes in cervical vertebral dimensions and mandibular growth potential was investigated using Pearson correlation analysis. Age, cervical vertebral measurements, and mandibular length increment were quantitative factors; gender and skeletal classification were qualitative factors. Following stratification, Pearson correlation tests were used to evaluate the association between changes in mandibular length and variations in cervical vertebral dimensions, with a p-value < 0.05 being deemed statistically significant. The institutional review board granted ethical approval, and all participants or their legal guardians provided their informed consent. Throughout the study, strict adherence to patient confidentiality was maintained.

RESULTS

The study, which involved 30 patients enrolled at the Altamash Institute of Dental Medicine, aimed to determine the average changes in cervical vertebral dimensions and increments in mandibular length, as well as the relationship between these changes and the potential for mandibular growth. Every single construct showed respectable reliability, with Cronbach's Alpha values higher than 0.5, as shown in Table 1.

Table 1: Reliability Analysis of Cephalometric Measurements (n = 30)

Measurement Parameter	**Cronbach's Alpha**	**95% Confidence Interval**
Overall	0.92	0.76 – 0.919
AH3	0.83	0.606 – 0.911
PH3	0.92	0.744 – 0.942
H3	0.91	0.768 – 0.947
AH4	0.81	0.525 – 0.892
PH4	0.93	0.876 – 0.972
H4	0.86	0.636 – 0.918
ML	0.91	*0.942 – 0.987*

Thirty children undergoing orthodontic evaluation made up the study sample. With a standard deviation of 2.7 years and a mean age of 12.5 years, the participants' ages showed moderate age variability. The oldest participant was eighteen years old, and the youngest was nine. A fairly balanced age distribution around early adolescence was reflected in the median age, which was determined to be 12 years, as shown in Table 2.

Table 2-Descriptive Statistics of participants (n = 30)

Descriptive Measures	Value
Mean	12.5
Standard Deviation	2.7
Minimum	9
Maximum	18
Median	12

The gender distribution of the participants was as follows: 76.7% were female (n = 23), and 23.3% were male (n = 7), resulting in a female-to-male ratio of roughly 4.28:1 as shown in Figure 1.

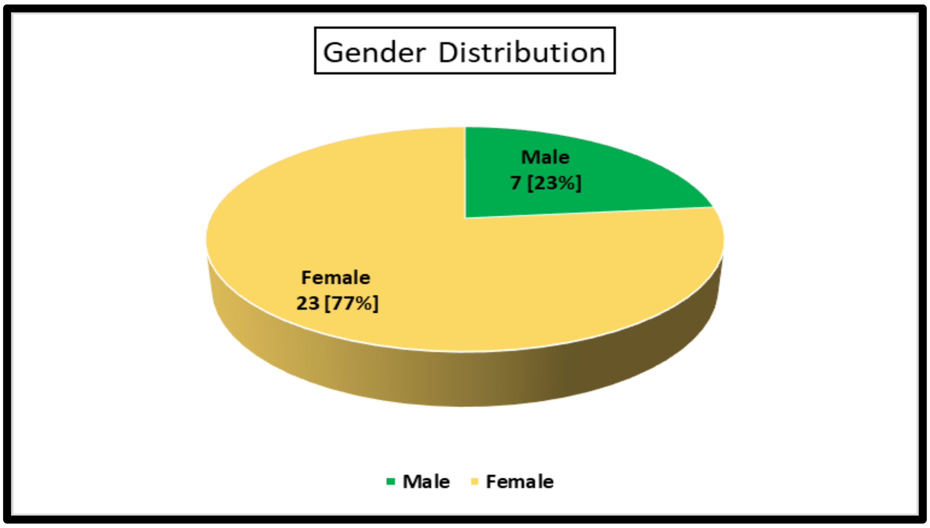

Figure-1 Gender Distribution

According to skeletal classification, 13 participants (43%) had Skeletal Class II malocclusion, while the majority of the children (n = 17; 57%) had Skeletal Class I malocclusion, as shown in Figure 2.

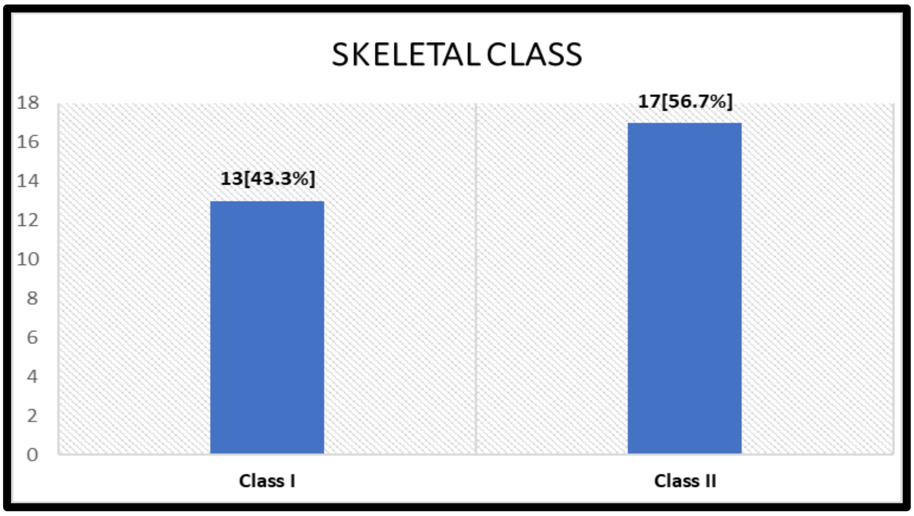

Figure 2-Classification of Skeletal Class

The paired mean differences in mandibular length and cervical vertebral dimensions among orthodontic treatment patients (n = 30) are shown in Table 3. Strong skeletal changes over time were indicated by the analysis, which showed statistically significant increases across all measured parameters with p-values less than 0.001. In particular, the third cervical vertebrae (AH3, PH3, and H3) grew in size by 3.13 mm, 2.36 mm, and 1.49 mm, respectively. Likewise, mean increases of 2.80 mm, 1.65 mm, and 1.68 mm were observed in the fourth cervical vertebra (AH4, PH4, and H4). Significant mandibular growth was indicated by the notable increase of 7.13 mm in the mandibular length (ML).

Table 3- Changes in Cervical Vertebral Dimensions and Mandibular Length (n = 30)

Parameter	Final (Mean ± SD)	Initial (Mean ± SD)	Mean Difference	p-value
AH3	10.72 ± 2.13	7.58 ± 1.59	3.13	< 0.001*
PH3	11.35 ± 1.90	9.00 ± 1.63	2.36	< 0.001*
H3	9.31 ± 1.77	7.82 ± 1.39	1.49	< 0.001*
AH4	9.48 ± 2.11	6.67 ± 1.83	2.80	< 0.001*
PH4	10.87 ± 2.00	9.22 ± 1.81	1.65	< 0.001*
H4	9.41 ± 1.50	7.73 ± 1.48	1.68	< 0.001*
Mandibular Length	82.72 ± 10.43	75.59 ± 9.49	7.13	< 0.001*

*Statistically significant at p < 0.05

There was relatively little association between mandibular growth and vertebral changes, as shown by Table 4, which shows weak and non-significant correlations between mandibular length and individual cervical vertebral dimensions. Nonetheless, a number of cervical vertebral measurements showed strong and statistically significant positive correlations, indicating good internal consistency in indicators of vertebral maturation. Overall, there seems to be little correlation between cervical parameters and mandibular growth potential in this sample, despite their interdependence.

Table 4-Pearson Correlation Between Changes in Cervical Vertebral Dimensions and Mandibular Length (n = 30)

Variables	Mandibular Length	AH3	PH3	H3	AH4	PH4	H4
Mandibular Length	1.000	0.297	-0.080	-0.004	0.170	0.045	0.142
Cervical AH3		1.000	0.519**	0.525**	0.323	0.324	0.442*
Cervical PH3			1.000	0.441*	0.406*	0.057	0.134
Cervical H3				1.000	0.558**	0.123	0.237
Cervical AH4					1.000	-0.048	0.428*
Cervical PH4						1.000	0.000
Cervical H4							1.000

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

In Table 5, males' mandibular length and the AH4 cervical vertebral measurement had a significant positive correlation, according to the gender-based correlation analysis, which may indicate a connection between mandibular growth and vertebral maturation in this population. In contrast, there was no discernible relationship between cervical vertebral changes and mandibular length in females. On the other hand, females showed strong intercorrelations among cervical dimensions, suggesting regular patterns of vertebral maturation. In general, male mandibular growth potential might be more closely associated with certain cervical changes, whereas in females, cervical development seems to be unaffected by mandibular length.

Table 5- Gender-Wise Correlation Between Cervical Vertebral Dimensions and Mandibular Length

Variable	Male (n = 7)	Female (n = 23)
AH3 – ML	0.173	0.306
PH3 – ML	–0.706	0.053
H3 – ML	0.126	0.000
AH4 – ML	0.837*	–0.079
PH4 – ML	–0.006	0.132
H4 – ML	0.499	–0.039

*Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

This study used cephalometric analysis to evaluate the association between changes in cervical vertebral dimensions and mandibular growth potential in a population of adolescents from Pakistan. Mandibular length and cervical vertebral measurements significantly increased over time in the 30 patients who were enrolled. Especially for growing patients in need of orthodontic treatment, the application of the CVM method yielded important insights, particularly in growing patients regarding skeletal maturity and its relationship to craniofacial growth. An essential part of orthodontic diagnosis and treatment planning is skeletal maturity evaluation. Since skeletal growth cannot be accurately predicted by chronological age alone, alternative techniques such as the cervical vertebral maturation (CVM) approach have become more and more popular. Advantages include convenience and reduced radiation exposure of evaluating CVM using pre-existing lateral cephalograms as opposed to hand-wrist radiographs. Previous research has shown that the CVM method is a reliable and useful technique for determining peak mandibular growth periods and evaluating skeletal growth stages (12,13). After reviewing the patient's diagnostic records, the orthodontist decides on the best course of treatment. While many factors are taken into consideration when deciding on a treatment plan, one that the orthodontist rarely has "modifiable" control over is the patient's maturity. The timing of orthodontic treatment is typically determined by the parents' decision to have their child treated, rather than by the best time for treatment in terms of physiology (14). Therefore, the orthodontist can determine the patient's maturity level and modify the treatment plan to provide the best possible outcome for the patient at that level.

In this study, all measured cervical vertebral dimensions (AH3, PH3, H3, AH4, PH4, H4) and mandibular length (ML) increased significantly; all differences were statistically significant ($p < 0.001$). These results align with earlier research that emphasizes how skeletal growth changes as a person enters puberty (15,16). Only weak, non-significant relationships were found when comparing changes in mandibular length to changes in cervical vertebral dimensions overall. This suggests that although both structures expand over the same time frame, there isn't always a direct correlation between their changes. The results showed an interesting pattern when categorized by gender. A statistically significant positive correlation between mandibular length and AH4 was observed in males, indicating that changes in anterior height in the fourth cervical vertebra could be used to predict mandibular growth potential (17). Our results align with previous studies that demonstrated population and gender specific differences in growth patterns. For instance, research by Moshfeghi et al. reported significant associations between mandibular length increment and cervical vertebral dimensions such as AP3 and PH4 (18). Similarly, studies by Chen et al. and Baccetti et al. emphasized the predictive power of AH3, AH4, and AP3 in assessing mandibular growth velocity. These findings reinforce the potential utility of CVM-based indicators in longitudinal orthodontic assessment, particularly when used in conjunction with other growth predictors (19,20).

The results of this study show that the average age of the Patients was 12.5±2.7 years (Min to Max: 09 to 18) with a median age of 12. These results were consistent with the study conducted in Saudi Arabia, where the mean age was 12.31 ± 2.9 years (12.82 ± 3.01 years for males, 11.83 ± 2.73 years for females), respectively (21). The main limitation of the study was the sample size, particularly for gender-specific subgroup analysis, which was relatively small. Larger, multicenter studies with balanced gender distribution could provide more generalizable data. Additionally, the retrospective nature and limited follow-up duration may have affected the accuracy of growth prediction. To improve the validity and generalizability of the results across Pakistan's diverse adolescent populations, future studies should be conducted with a larger and more balanced sample size, especially including equal representation of both genders.

CONCLUSION

The results of this study show a strong relationship between cervical vertebral skeletal maturation and chronological age, especially for male participants. This demonstrates the validity of the Cervical Vertebral Maturation (CVM) method as a reliable technique for determining skeletal maturity and forecasting the potential for mandibular growth, particularly in males. Furthermore, the findings show that Females tend to reach cervical vertebral maturity earlier than males of the same age group. These findings highlight the CVM method's clinical utility in identifying the best time and strategy for orthodontic treatment planning that takes into account each patient's unique growth patterns as well as gender.

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