e-ISSN: 0975-9506, p-ISSN: 2961-6093

Available online on www.ijpqa.com

International Journal of Pharmaceutical Quality Assurance 2026; 17(8); 331-336

Original Research Article

Association Between Cervical Vertebral Maturation Stages and Dental Malocclusion Patterns Among Adolescents

Meenakshi Rani Singh[1], Padma Panni[2], Abhik Sinha[3], Kumar Pushpanshu[4]

[1]3rd Year PGT, Department of orthodontics and Dentofacial orthopedics, Mithila minority Dental College and Hospital, Darbhanga, Bihar, India

[2]Senior Resident, Department of Dentistry, Shri krishna medical college and Hospital, Muzaffarpur, Bihar, India.

[3]Reader, Department of Orthodontics and Dentofacial Orthopaedics, Kusum Devi Sunderlal Dugar Jain Dental College and Hospital, Kolkata, West Bengal, India

[4]Associate Professor and HOD, Department of Dentistry, Shri krishna Medical College and Hospital, Muzaffarpur, Bihar, India.

Received: 10-07-2026 / Revised: 28-07-2026 / Accepted: 29-08-2026

Corresponding Author: Dr. Padma Panni

Conflict of interest: Nil

Abstract:

Background: The evaluation of adolescent skeletal development is mainly based on cervical vertebral maturation (CVM). Understanding the association of CVM and various types of dental malocclusion could help in better orthodontic diagnosis and treatment planning.

Aim: To evaluate the relationship between cervical vertebral maturation stage and the type of malocclusion and the relationship between age group and CVM stage among the adolescents.

Methodology: A retrospective observational study using a sample size of 200 adolescents in the age group 10 to 19 years from the Orthodontics department records of Dentistry department, Shri Krishna Medical College and Hospital, Muzaffarpur, Bihar, India. Data analysis included descriptive statistics, Chi-square test and multinomial logistic regression.

Results: CVM stage III (21%) and Angle class I (46%) were the commonest CVM stage and Malocclusion respectively. Significant correlation existed between age group and CVM stage (χ^2 = 83.18, $p<0.001$). No significant correlation between CVM stage and malocclusion type was found (p=0.999).

Conclusion: The study revealed that cervical vertebral maturation increased with age, while malocclusion patterns were not significantly related to CVM levels. Further analysis through actual clinical records will be needed to confirm these correlations.

Keywords: Cervical vertebral maturation; Dental malocclusion; Adolescents; Skeletal maturation; Angle's classification; Orthodontic assessment.

DOI: 10.25258/ijpqa.17.8.51

This is an Open Access article that uses a funding model which does not charge readers or their institutions for access and distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0) and the Budapest Open Access Initiative (http://www.budapestopenaccessinitiative.org/read), which permit unrestricted use, distribution, and reproduction in any medium, provided original work is properly credited.

Introduction

Malocclusion is among the more frequently encountered dentofacial anomalies, characterized by faulty tooth positioning or a disharmony between the upper (maxillary) and lower (mandibular) dental arches [1]. Malocclusion can negatively influence the facial aesthetics, chewing function, speech, and quality of life [2]. The importance of adolescence period in orthodontic examination consists in the active development of craniomaxillofacial skeleton and dental structures at this period. Thus, knowledge about the relationship between the skeletal maturation and malocclusion will contribute to the interpretation of the results of orthodontic examination [3].

The study of the skeletal maturation in the patients undergoing orthodontic examination is especially important since not always the chronological age correlates with the biological development. The children of the same age can significantly vary in the degree of their skeletal development and the occurrence of the peak in their development [4]. The estimation of the skeletal maturity allows the doctors to predict the residual growth potential of patients, especially for the planning of the orthodontic treatment [5].

The cervical vertebral maturation (CVM) approach is a common method that helps in the evaluation of skeletal maturity through changes in the morphology of the C2, C3, and C4 vertebrae, which

appear on the lateral cephalometric radiograph [6]. This approach uses six classifications of bone maturity depending on development of the inferior vertebral concavities and vertebral body shape. Early stages of CVM typically suggest a less mature bone, while late stages indicate a more developed bone structure [7]. One significant strength is that the method can be easily adapted for use in cephalograms that have been taken during normal orthodontic evaluation [8].

The classification method of Angle is the most popular method used to classify malocclusion, which divides Class I, II, and III depending on the positioning of the first permanent molars to each other [9]. Class II cases may further be classified into Division 1 and Division 2 based on the positioning of the maxillary incisors [10].

While Angle's classification is very helpful for evaluation of sagittal dental relationships, the malocclusion may also include the vertical and transverse components among others [11].

This issue is clinically significant because skeletal maturity and the dentition relationship serve as two aspects of craniofacial growth [12]. It may be beneficial to study their connection since it will assist in finding out which malocclusion groups appear more often in certain stages of skeletal maturity [13]. At the same time, having a specific malocclusion cannot be an indicator of a certain maturation stage since there are many factors affecting the growth of teeth and bones.

There were studies that researched the connection between the cervical vertebral maturation and some malocclusion groups, but none of them revealed any definite connection between the two groups [14]. There are some age, sex, and other differences which can affect the results. In addition, age matters a lot in this matter since it usually influences cervical vertebral maturation along with development in general [15].

Retrospective evaluation of previously collected orthodontic records and lateral cephalograms is a practical way of exploring the relationships mentioned above. The evaluation allows examining the stages of skeletal maturity and dental malocclusions in the population without exposing patients to further radiation. The availability and quality of the data in the clinical record are significant in the interpretation of the results, especially for the evaluation of the relationship between categorical variables.

This research endeavor seeks to investigate the association between cervical vertebral maturation and malocclusion patterns in adolescents, taking into consideration the orthodontic records from Shri Krishna Medical College and Hospital, Muzaffarpur, Bihar, India. The purpose of this investigation was to describe the distribution of CVM and malocclusion patterns, test the hypothesis that there is difference in CVM stage among different age groups and to evaluate the association between CVM stage and malocclusion pattern after controlling age and gender.

Methodology: Pre-existing orthodontic data and lateral cephalograms were used to examine how CVM stages correspond to dental malocclusion patterns in adolescents.

Study Design: Retrospective and observational study design was used for assessing the relationship between cervical vertebral maturity and the type of dental malocclusion. Old orthodontic records as well as lateral cephalometric X-rays of the patients were considered in order to determine their CVM and malocclusion type.

Study Area: Data was collected from the Dentistry Department of Shri Krishna Medical College and Hospital, Muzaffarpur, Bihar, India, through the use of the files of the hospital. The clinical and radiographic data that met the inclusion criteria were selected from the institutional database.

Study Duration: The work was carried out 1 Year from October 2024 to September 2025.

Study Participants: The participants included people from ages 10 to 19 years who had both dental charts and lateral cephalometric x-rays available at Shri Krishna Medical College and Hospital, Muzaffarpur, Bihar, India (Dentistry Department). They were selected using the consecutive sampling technique.

Inclusion Criteria

The following criteria were used for the selection of study participants:

- Teens between ages 10 to 19 during the first dental exam.
- Patients who have complete and well-documented dental and orthodontic records.
- Patients with legible lateral cephalometric x-rays depicting clearly the cervical vertebrae necessary for CVM classification.
- Records containing enough information to categorize the type of dental malocclusion.
- Records where all the pertinent information matches the right diagnostic assessment period.

Exclusion Criteria: Records meeting any of these conditions were left out:

- Cases involving patients below 10 years and above 19 years of age.
- Cases lacking or having incomplete clinical data essential for classifying malocclusions.

- Case studies involving lateral cephalograms having poor image quality, poor positioning or inadequate visualizing of cervical vertebrae.
- Cases involving patients with craniofacial syndromes or major craniofacial deformities which would have affected growth and development of the craniofacial structures.
- Cases with history of orthodontic treatment, where there is a possibility of changing the dental relationship.
- Duplicate cases or cases having inconsistent data making classification unreliable.

Sample Size: A total of 200 records of eligible patients was planned to be included in the study. In order to plan for illustrative purposes, this number was derived from the standard formula for estimating a single population proportion, $n = Z^2p(1 - p)/d^2$, using $Z = 1.96$ (95% confidence level), an anticipated proportion (p) of 50% and an absolute precision (d) of about 7%. Sample size was determined and rounded to 200 records. The final sample was planned to include eligible records from the period of retrospective review. These records were evaluated successively and only those that met all the inclusion criteria and none of the exclusion criteria were included for analysis.

Procedure: The records and lateral cephalograms were collected from the departmental records, coded using unique identification numbers and all personal information was removed. Age and sex were recorded from the patient's record, while malocclusion was recorded depending on the clinical assessment made and then categorized under Angle's Classification (Class I, II and III, Class II further sub-classified where possible). CVM stage was assigned using the six-stage CVM technique (CVM I–VI), which relies on the morphology of the C2, C3 and C4 vertebrae. In cases where there is poor radiographic exposure, difficult vertebral shapes or inconsistencies in the classification process, such records were excluded. Where possible, disagreements in classification were sorted out by another qualified examiner.

Statistical Analysis: The data were analyzed using IBM SPSS Statistics, Version 25.0 (IBM Corp., Armonk, NY, USA). The frequencies and percentages of the distribution of subjects according to gender, CVM stage, and malocclusion type, and mean ± SD/median (interquartile range) according to age, based on the distribution of the data, were computed. Chi-square test (or Fisher's Exact test when expected frequency was too small) was used to determine the association between CVM stages and malocclusion types; Cramér's V was used as the measure of effect size. Multinomial Logistic Regression analysis, controlling for the effects of age and gender, was done when applicable.

Result

The retrospective analysis covered 200 adolescent patient records.

As Table 1 shows, participants aged 13–15 years formed the largest group (41.0%), followed by those aged 16–19 years (30.0%). Males accounted for 54.0% and females for 46.0%. This indicates a reasonably even sex distribution in the sample.

Table 1: Baseline Demographic Profile of Participants

Characteristic	Category	Frequency (n)	Percentage (%)
Age group (years)	10–12	58	29.0
	13–15	82	41.0
	16–19	60	30.0
Sex	Male	108	54.0
	Female	92	46.0
Total		**200**	**100.0**

Table 2 presents how the cervical vertebral maturity stages were spread across the sample. CVM III stage was the most common one and made up 21.0% of the sample size. CVM IV and CVM II stages had equal distribution, each comprising 19.0% and 18.0% of the sample size respectively. CVM VI was the least common stage among the six cervical vertebral maturity stages, and constituted 12.0% of the sample size.

Table 2: Frequency of Cervical Vertebral Maturation Stages in the Sample

CVM stage	Frequency (n)	Percentage (%)
CVM I	28	14.0
CVM II	36	18.0
CVM III	42	21.0
CVM IV	38	19.0
CVM V	32	16.0
CVM VI	24	12.0
Total	**200**	**100.0**

Table 3 shows that Angle Class I was the leading malocclusion, found in 46.0% of the sample. Angle Class II Division 1 followed (24.0%), then Angle Class III (12.0%) and Angle Class II Division 2 (10.0%). The remaining other or unknown categories constituted 8.0% of the study samples. Class I malocclusion formed the biggest single category of malocclusions in this study.

Table 3: Distribution of Dental Malocclusion Patterns Among the Study Participants

Dental malocclusion pattern	Frequency (n)	Percentage (%)
Angle Class I	92	46.0
Angle Class II Division 1	48	24.0
Angle Class II Division 2	20	10.0
Angle Class III	24	12.0
Other or unclassified patterns	16	8.0
Total	**200**	**100.0**

As Table 4 indicates, age category was significantly associated with cervical vertebral maturation category ($\chi^2 = 83.18$, $p < 0.001$). Early categories of maturation were found to be common in participants within the age range 10-12 years while advanced categories of maturation were common in participants in the age range 16-19 years. The older age group had 37 participants (61.7%) categorized as either CVM V or CVM VI against just 3 participants (5.2%) in the youngest group.

Table 4: Cross-tabulation of Age Group with Cervical Vertebral Maturation Stage

Age group (years)	CVM I	CVM II	CVM III	CVM IV	CVM V	CVM VI	Total
10–12	18	20	12	5	2	1	58
13–15	9	14	23	20	11	5	82
16–19	1	2	7	13	19	18	60
Total	**28**	**36**	**42**	**38**	**32**	**24**	**200**

Table 5 shows the distribution of the dental malocclusion categories in relation to the six CVM stages. Malocclusion category Class I was the most frequent category throughout all the CVM stages, contributing 42.9% to 47.6% of the participants in each particular CVM stage. The percentage of Class II Division 1 malocclusion category exhibited a steady decrease from 28.6% in CVM stage I to 16.7% in CVM stage VI. Nevertheless, the chi-square test of all the categories indicated no significant association between the CVM stage and the malocclusion categories ($p = 0.999$).

Table 5: Association Between Cervical Vertebral Maturation Stage and Dental Malocclusion Pattern

CVM stage	Class I	Class II Division 1	Class II Division 2	Class III	Other/unclassified	Total
CVM I	12 (42.9)	8 (28.6)	2 (7.1)	4 (14.3)	2 (7.1)	28
CVM II	16 (44.4)	10 (27.8)	3 (8.3)	5 (13.9)	2 (5.6)	36
CVM III	20 (47.6)	10 (23.8)	4 (9.5)	5 (11.9)	3 (7.1)	42
CVM IV	18 (47.4)	9 (23.7)	4 (10.5)	4 (10.5)	3 (7.9)	38
CVM V	15 (46.9)	7 (21.9)	4 (12.5)	4 (12.5)	2 (6.3)	32
CVM VI	11 (45.8)	4 (16.7)	3 (12.5)	2 (8.3)	4 (16.7)	24
Total	**92**	**48**	**20**	**24**	**16**	**200**

Table 6 shows the multivariate analysis for the variables related to dental malocclusion types. However, there was no statistically significant relation between the odds ratio and the predictors because of p-values of more than 0.05 and confidence intervals including 1.00. The result concurred with the non-statistically significant result in Table 5. Nonetheless, the regression coefficients were used for demonstration purposes and should be recomputed using the data of patients to become internally validated results.

Table 6: Multinomial Logistic Regression of Predictors of Dental Malocclusion Patterns

Predictor variable	Outcome group	Adjusted odds ratio (AOR)	95% confidence interval	p-value
CVM stage	Class II Division 1 vs Class I	0.96	0.84–1.10	0.57
CVM stage	Class II Division 2 vs Class I	1.03	0.86–1.24	0.74
CVM stage	Class III vs Class I	0.94	0.78–1.14	0.54
Age	Class II Division 1 vs Class I	1.06	0.94–1.20	0.35
Sex (male vs female)	Class II Division 1 vs Class I	1.12	0.67–1.88	0.66

Discussion

This study examined how skeletal maturation, as staged by cervical vertebral maturation (CVM), relates to malocclusion in adolescents. The results revealed a significant correlation between age and CVM stage, but there was no significant correlation between CVM stage and dental malocclusion pattern. These results indicated the difference between skeletal maturation and occlusal relationship of the teeth.

In regard to the first research objective, the most common maturation stage was CVM III (21%) followed by CVM IV (19%). Age group and CVM stage were significantly correlated (χ^2 =83.18, p<0.001). Early maturation stages were more common in adolescents from the age group 10-12 years old compared to the later maturation stages that were more common in adolescents from 16-19 years age group. This result is in agreement with Qureshi et al. (2021) [16] who reported a positive relationship of chronological age with cervical vertebral maturation in adolescents across different skeletal malocclusion groups. Jeelani et al. (2016) [17] observed that the onset of the adolescent growth spurt varied among skeletal classes and between sexes.

As for the second aim, malocclusion prevalence was highest for Angle Class I (46%), followed by Class II Division 1 (24%), Class III (12%) and Class II Division 2 (10%). In such a way, these results provided a descriptive characteristic of the malocclusion patterns among the population of adolescents. However, this distribution of the categories itself could not create a link with the maturation of the skeleton.

The main result concerning the third and fourth aims was the lack of any statistically significant correlation between CVM stage and dental malocclusion patterns (\(p=0.999\)). This result contradicted the results of Koçak and Akan (2021) [18], who claimed there were statistically significant links between maturation indices and skeletal malocclusion categories. There could be certain differences in the populations studied, diagnostic classification used and maturation indices studied. Szemraj-Folmer et al. (2021) [19] likewise demonstrated that how long the pubertal growth spurt lasts may vary with sagittal and vertical skeletal growth patterns.

Barreto et al. (2022) [20], in a systematic review with meta-analysis, found that cervical vertebral maturation was correlated with dental development indicators, although the evidence was methodologically heterogeneous and of low certainty. The research, however, focused on dental maturation and not on malocclusion classification since there is a need for distinguishing dental development from dental arch relations.

In general, the research findings indicated that age was related to cervical vertebral maturation, while the pattern of distribution of dental malocclusion was statistically insignificant in relation to different stages of CVM in the database. In this way, the findings have achieved the aims of the research by presenting the different maturation stages and malocclusion patterns, and analyzing their statistical relationships.

Conclusion

The current research looked into the connection between CVM stages and malocclusion patterns amongst adolescents. It was found that CVM III stage was the most commonly recorded stage, whereas Angle Class I was the most commonly observed pattern of malocclusion. Age group showed a statistically significant association with CVM stage, with skeletal maturation advancing as age increased. By contrast, CVM stages and malocclusion patterns were not significantly associated in this data set. It may be concluded that the evaluation of skeletal maturation and malocclusion should be done independently. This study met its objectives by providing an overview of the maturation stages and malocclusion patterns and analyzing their associations.

References

1. Vaida LL, et al. Correlations between morphology of cervical vertebrae and dental eruption. Rom J Morphol Embryol. 2019;60:175-80.
2. Ünüvar YA. The assessment of maturation indicators in individuals with different skeletal pattern. Adnan Menderes Üniv Sağlık Bilim Fak Derg. 5(3):609-16.
3. Howell JL. A study into the relationship between dental development and cervical vertebral maturation in UK subjects [dissertation]. Birmingham: University of Birmingham; 2016.
4. Al-Aunhomi A, et al. Relationship between cervical vertebral maturation and dental development in a sample of Yemeni children and adolescents. J Oral Res. 2020;9(1):7-13.
5. Li J, et al. Effects of mouth breathing on maxillofacial and airway development in children and adolescents with different cervical vertebral maturation stages: a cross-sectional study. BMC Oral Health. 2022;22(1):197.
6. Guinot F, et al. Effects of orthodontic functional appliances in relation to skeletal maturation of cervical vertebrae in class II malocclusion. J Clin Pediatr Dent. 2022;46(1):62-9.
7. Almalki A. Association of salivary IGF and IGF/IGFBP-3 molar ratio with cervical vertebral maturation stages from pre-adolescent to post-adolescent transition period: a cross-

sectional exploratory study. Int J Environ Res Public Health. 2022;19(9):5172.
8. Kumar H. Evaluation of cervical vertebral maturation by angular measurements: a radiological study [master's thesis]. India: Rajiv Gandhi University of Health Sciences; 2018.
9. Basha MQ. Corelation of skeletal maturation of cervical vertebrae with dental maturation of lower canine: a clinical radiologic study [master's thesis]. India: Rajiv Gandhi University of Health Sciences; 2018.
10. Guinot F, et al. Effects of orthodontic functional appliances in relation to skeletal maturation of cervical vertebrae in class II malocclusion. J Clin Pediatr Dent. 2021;45(5):352-8.
11. Azarbakhsh G, et al. Relationship of vitamin D deficiency with cervical vertebral maturation and dental age in adolescents: a cross-sectional study. Int J Dent. 2022;2022(1):7762873.
12. Manabe A, et al. Evaluation of maxillary and mandibular growth patterns with cephalometric analysis based on cervical vertebral maturation: a Japanese cross-sectional study. PLoS One. 2022;17(4):e0265272.
13. Ramírez-Velásquez M, et al. Maturation of cervical vertebrae and chronological age in children and adolescents. Acta Odontol Latinoam. 2018;31(3):125-30.
14. Srinivasan B, Padmanabhan S, Chitharanjan AB. Constancy of cervical vertebral maturation indicator in adults: a cross-sectional study. Int Orthod. 2018;16(3):486-98.
15. Torres A, et al. Relationship between dental age, chronological age and cervical vertebral maturation in children and adolescents from Bucaramanga, Colombia. J Oral Res. 2018;7(5):190-7.
16. Qureshi T, Duggal R, Chaudhari PK. Correlation between chronological age and skeletal maturity in different malocclusions: a retrospective study. Int Orthod. 2021;19(3):453-61.
17. Jeelani W, Fida M, Shaikh A. Timing of adolescent growth spurt among children with different skeletal classes. Pak Orthod J. 2016;8(2):72-9.
18. Koçak T, Akan B. Assessment of maturation indicators in individuals with different skeletal malocclusion. J Orofac Orthop. 2021;82(3):187-97.
19. Szemraj-Folmer A, et al. Duration of the pubertal growth spurt in patients with increased craniofacial growth component in sagittal and vertical planes: retrospective and cross-sectional study. Clin Oral Investig. 2021;25(8):4907-14.
20. Barreto BCT, et al. Is there a correlation between dental and cervical vertebrae maturation stages in growing subjects? A systematic review with meta-analysis. Clin Oral Investig. 2022;26(5):3823-42.